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Mima Mounds Formation and Their Implications for Climate Change

by
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Figure 2. Typical Mima mounds at their type locality on Mima Prairie southwest of Olympia. Mounds there are commonly 7 to 8 feet high and are composed of an unsorted mixture of black silt with disseminated sand and pebbles. According to Bretz (1913), the black silt contains very little organic material, thereby minimizing the likelihood of plants or animals being involved in their development.

Figure 3. Mima mounds at the Pacific Lutheran University Golf Course are barely discernable from the ground, being only 1 foot or less in height.

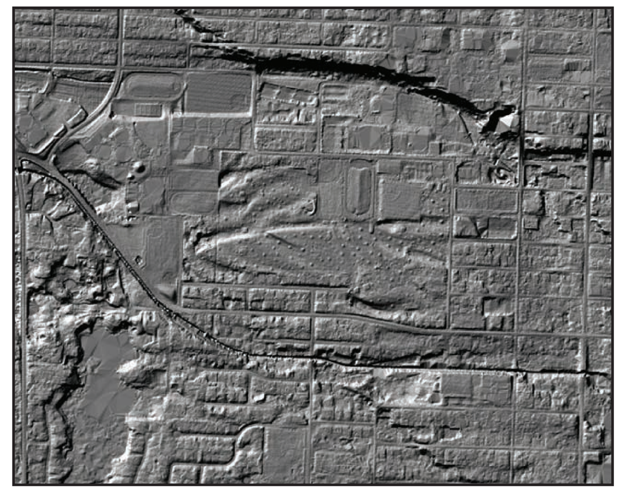

Figure 4. The Pacific Lutheran University Golf Course Mima mounds "floating point" lidar image, using a 6X vertical exaggeration, 315 azimuth illumination. Mounds are generally best viewed at between the scales of 1:6,000 to 1:12,000.

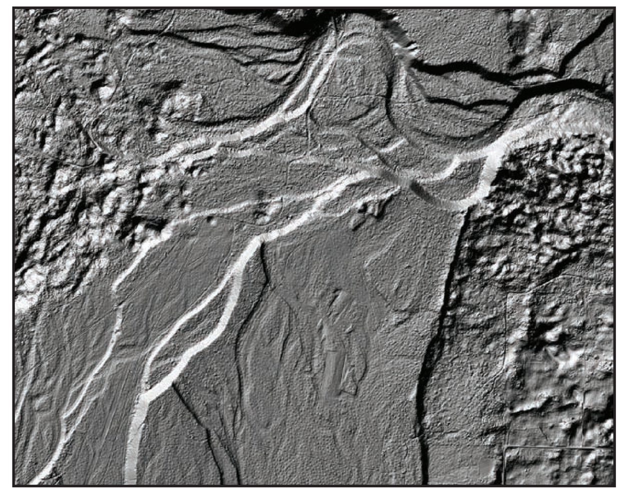

Figure 5. Lidar image of the Tenalquot Prairie area showing the outburst channel emerging from the terminal moraine of the Yelm Lobe and unmatched mound-covered terraces that developed as meltwater flowed along the edge of the ice terminus.

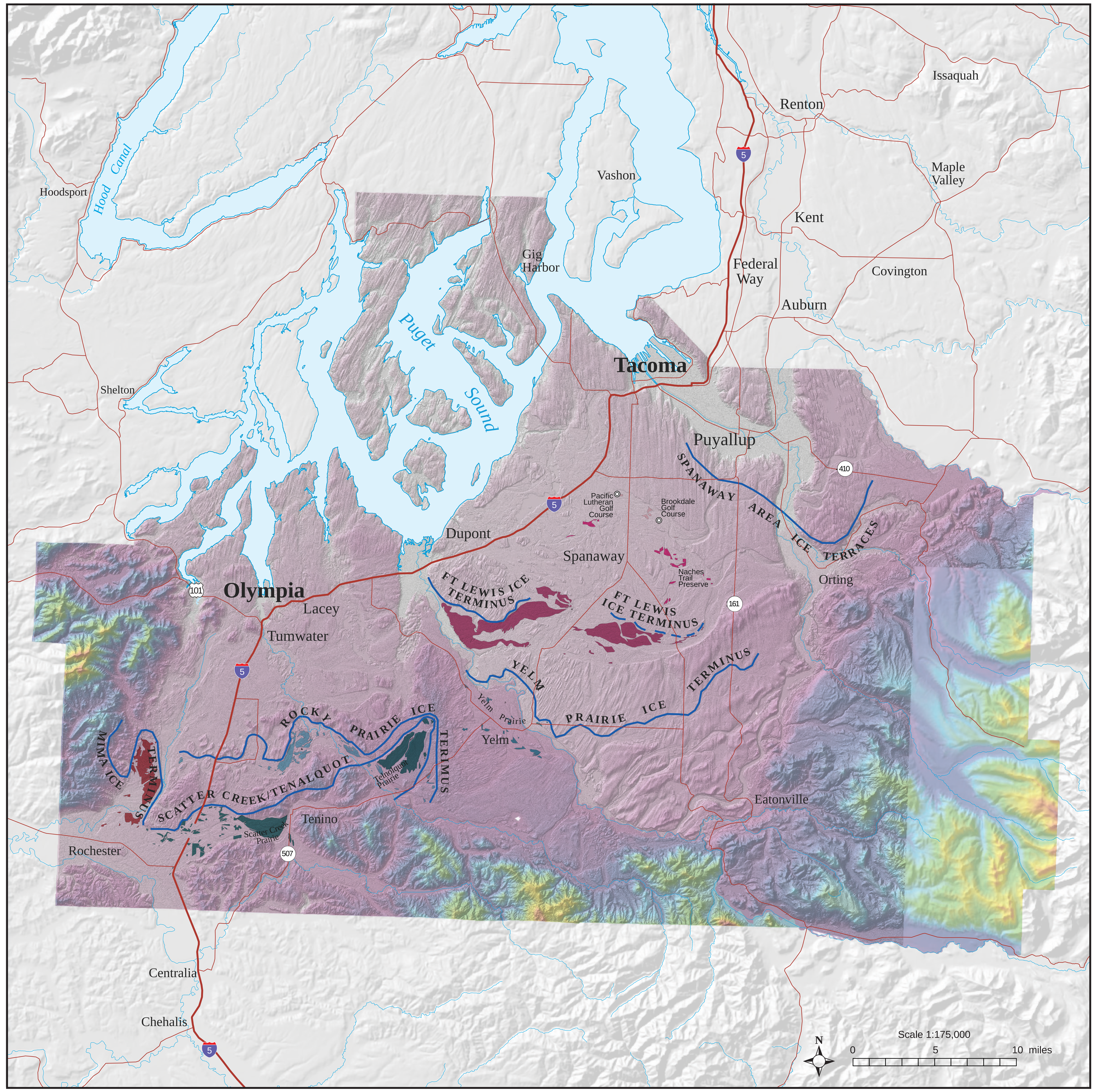

Figure 1. Lidar image of the southern Puget Lowland. Relative ages of the Mima mound sets are shown as numbers 1 through 5. Approximate locations of the adjacent retreating ice front are shown by heavy blue lines, however "islands" of remnant stagnant ice probably remained scattered over much of the area as proglacial and subglacial streams flowed across the area during ice breakup.

Abstract

Geomorphic evidence indicates that Mima mounds in the southern Puget Lowland are spatially and probably temporally related to ice retreat at the end of the Wisconsinan. The mounds occupy proglacial recessional outwash channels that apparently formed as drainage from the east side of the Puget Lowland glacier surged around the glacier's snout periodically during the ice front's retreat. There are at least four or five mound-bearing channels between Tenino and Tacoma. The channels are all sharply cut and the mounds are of similar size, suggesting that the time interval between the episodic formation of both the channels and the mounds are short, possibly seasonal or shorter. If the channels formed seasonally, then the ice front may have retreated about 25 miles in four to five years.

The fine-grained mounds are restricted to the braided coarse-grained outwash channels and are in sharp contact with the channel deposits, suggesting that the mounds were lowered onto the channel surface, perhaps by melting ice. This could have occurred if hydraulically dammed, late stage shallow floodwater or possibly saturated flood gravels froze and subsequent lower-energy drainage introduced the fine-grained mound material on top of the ice. As atmospheric warming occurred, the fine material migrated on the ice surface to sun cups, which, when melting was complete, formed mounds atop the outwash channels.

Introduction

Lidar imagery was used to map Mima mound occurrences in the southern Puget Lowland (Fig. 1) and relate those occurrences to geomorphology left as the Vashon ice sheet waned at the end of the last glaciation in western Washington. A quick field reconnaissance was done to verify the lidar mapping. Field reconnaissance showed that, although the mounds are of similar size horizontally, they diminish in height significantly from several feet high in their type locality on Mima Prairie south of Olympia (Fig. 2) to barely a foot high at the Pacific Lutheran University golf course near Spanaway (Figs. 3 and 4).

All mounds investigated consist mostly of fine-grained, nearly black soil sitting on top of a coarse-grained substrate of outwash gravel (Fig. 2). A fairly detailed synopsis of previous studies of the mounds can be found in Washburn (1988).

Timing and Location

Depending on how they are counted, there appear to be five episodes of mound formation. The oldest and largest (up to about 8 feet high) Mima mounds appear to have formed on Mima Prairie between a terminal moraine on the west bank of the Black River and remnant dead ice on the east edge of the Black Hills to the north and west (Fig. 1). These are the only mounds that formed on outwash from the Olympia lobe. These mounds were likely followed closely by a set of mounds that formed on the outwash train that runs from Tenalquot Prairie (Fig. 5) through the Scatter Creek Prairies (Fig. 1). Another outwash train spawned a set of mounds that were also derived from the Tenalquot area, but followed the upper Deschutes River drainage to Offut Lake and then westward through Rocky Prairie. The above three sets of mounds were all formed on gravel trains that were deposited by high energy streams that issued from the Yelm Lobe.

As the ice front retreated northward, Yelm Prairie was formed by glacial outwash carried by water from the Orting area, east of Puyallup (Fig. 1). The gravel train was deposited by subglacial, proglacial, and ice marginal drainage that flowed southwestward across the present day Nisqually River to emerge a few miles southeast of Yelm. Finally, three relatively rapid-fire outbursts of proglacial meltwater emerged under artesian head from beneath ice occupying the area that later became the Puyallup Valley. These streams deposited the outwash trains on which the Fort Lewis Prairies, the Naches Trail Preserve, and Brookdale/Pacific Lutheran Golf Course mounds formed.

Mound Formation

After each outburst, somehow mound-forming silt with disseminated sand and pebbles was deposited in sharp contact onto the underlying coarse-grained gravel. Rogers (1893) and Bretz (1913) probably were the first to describe the most plausible mode of silt emplacement and mound formation, but Bretz (without the benefit of lidar) discarded the explanation based on "the great range in altitude and the wide distribution of the Mima type mounds". The explanation involved standing water on the gravel freezing and subsequently being covered with mostly silt with some sand and pebble gravel, which migrated to pools as the proglacial ice melted. Upon completion of melting, mounds of silt were left on top of the gravel. Bretz recognized that such an explanation required extraordinary circumstances and that those circumstances needed to be repeated several times to account for the widespread occurrences of the mounds.

It is conceivable that conditions at the ice terminus when the ice front began to retreat were conducive to the Bretz model. First, the gravel trains were deposited by very high energy, high volume streams that were able to carry large quantities of coarse materials. We suggest that these streams emerged from beneath or around the ice front as rapid outbursts when ice floated or gave way to meltwater under artesian head. The artesian head was due to supraglacial or ice-marginal lake or stream water making its way to the base of the ice front. The discharges emerged onto broad, flat, saturated outwash plains where dissipation was difficult, leaving large areas of standing water. Katabatic wind from the glacial ice likely froze the proglacial standing water. Continued, but lower energy, stream flow could have deposited silt on the frozen areas, with lowering of the silt onto the coarser outwash below, thus creating the sharp contact and the mounds. Repetition of the process would have occurred as lakes and streams upstream (and upgradient) from the glacial front would refill and again build up enough pressure to break through or below the ice, and as the ice terminus retreated northward. The Tenalquot Prairie's unmatched terraces (Fig. 4) are a good example of this rapid geologic process. The terraces were formed as the outburst water flowed, with one bank being the ice front and the other an outwash plain. Each terrace is covered with mounds, suggesting that outbursts occurred as fairly closely timed pulses. To enable mound formation to occur, repetition of the process was necessary. The terraces at Tenalquot Prairie and other mound sites support this timing because they are separated by low (about 20 feet or less) scarps, which were probably cut very rapidly in the unconsolidated outburst sediments.

Conclusions

If this set of unique conditions were able to occur numerous times, the conditions had to remain long enough for all of the mounds from Tenino to Spanaway to be formed. It is difficult to imagine that the conditions would exist over many tens or hundreds of years. More likely the mounds were formed in either just a few years or possibly in one season. However, if the outbursts were seasonal, say due to melting in the summer season, freezing proglacial water in the fall, and thawing in the spring to form the mounds, then the ice front may have retreated about 25 miles from Tenino to Spanaway in about 4 to 5 years. Or more than likely the glacial ice could have broken up in just one season. Either way, it would require adjustment of calculated glacial advance and retreat in the Puget Lowland as reported by Booth (1987).

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Figure 1 Explanation

Mound Occurences
- Mima Prairie
- Tenalquot/Scatter Creek Mounds
- Rocky Prairie
- Yelm Prairie
- Fort Lewis Prairies
- Naches Trail Preserve
- Brookdale and Pacific Lutheran University Golf Course

Elevation
- High : 2950 ft
- Low : –49 ft

- Golf Courses
- Glacial Terminus
- Interstate
- U.S. Highway
- Hydrography