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Glacier to Bay Sediment Analysis; Identifying Lahar, Interglacial and Glacial Sediment Deposits Along the Puyallup Watershed System

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Introduction

Suspended sediment in river systems is a component of water quality, a geomorphic indicator, and is a major flux of material from the terrestrial to the marine environment. Fully understanding suspended sediment transport requires knowledge of sediment sources. However, tracking these sources using traditional methods is time and labor intensive.

Suspended sediment is a concern in parts of the Puyallup-White River Watershed. The watershed has headwaters at Mt. Rainier and flows to Commencement Bay.

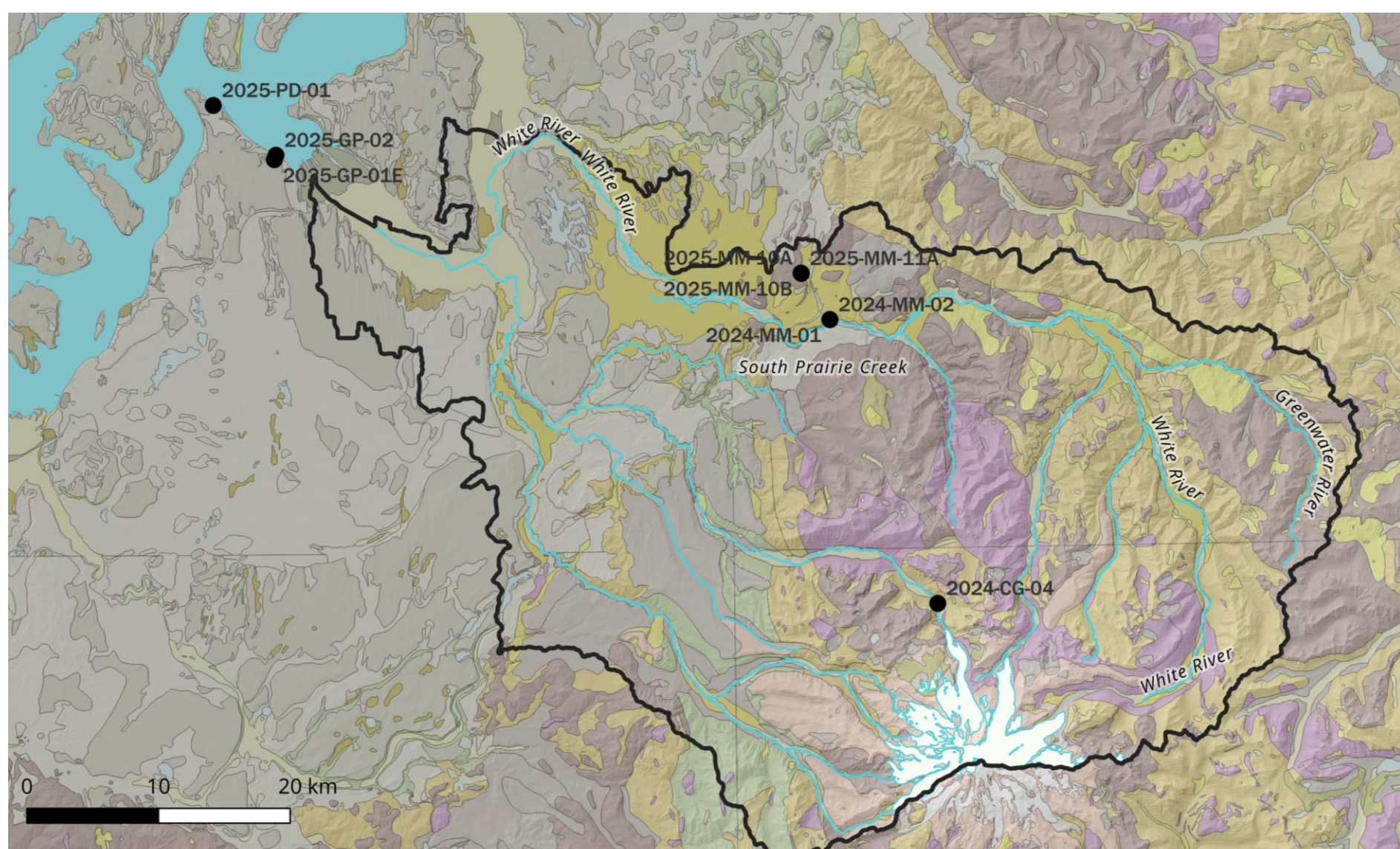
The Pacific Northwest region is highly geologically diverse, having been massively altered by glacial and lahar activity; each of which leave a unique fingerprint in the sediment surrounding the event (USGS, 2026). Pleistocene continental glacial deposits, sourced in the northern Cascades and British Columbia, contain granitic and metamorphic clasts, whereas material from Mt. Rainier is dominated by andesitic rocks.

- The most recent glacial movement occurred 13,000 to 15,000 years ago in the form of the Vashon Stade, covering the region in a thick layer of ice and slowly carving out the Puget Sound basin as it advanced and receded (WADNR, 2026).

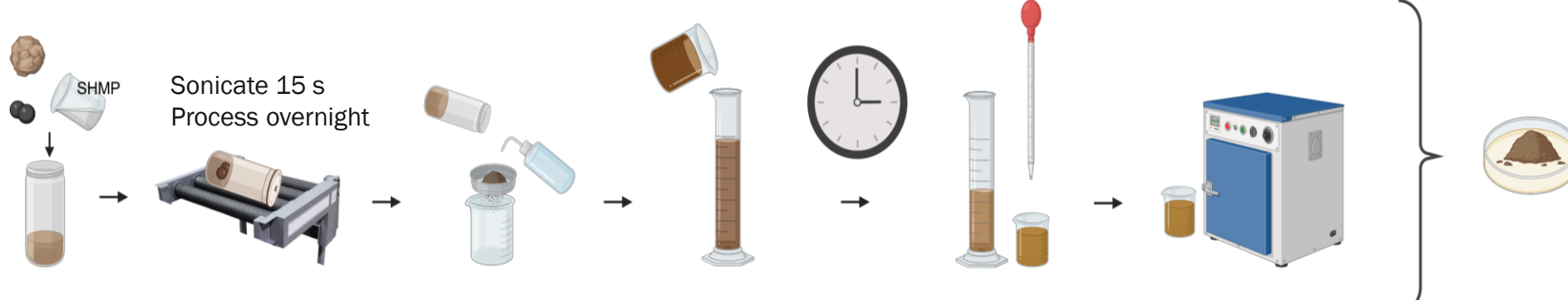
- Lahars, including the Mt. Rainier Osceola Mudflow, occurring ~5600 years ago, are fast moving mudflows that can grow based on the addition of continued sources of debris and water causing massive destruction in its wake (USGS, 2026).

By analyzing fine grained sediment and identifying ferromagnetic iron oxide minerals in these sediments we can better understand the sources of suspended sediment and understand its transport through the Puyallup-White River Watershed system.

Sampling and Methods

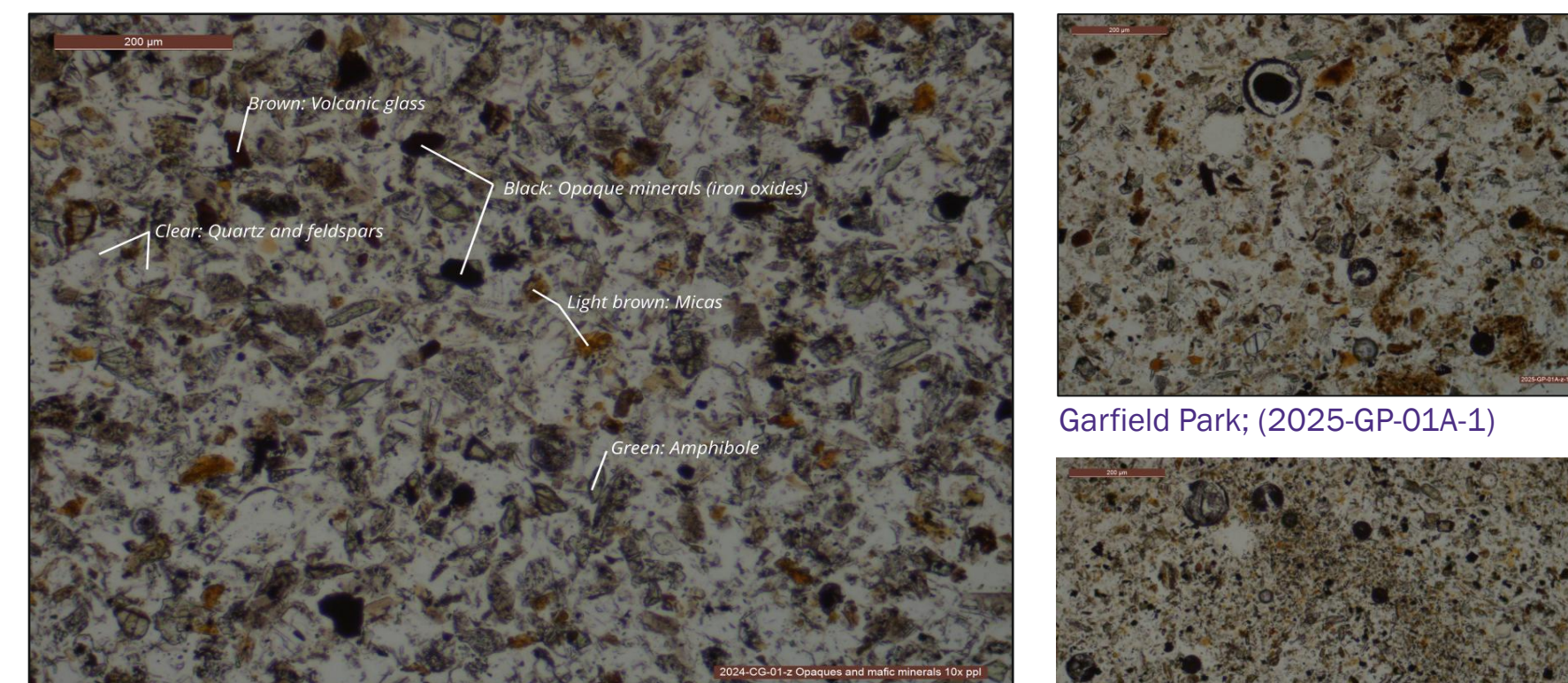


Sampling locations (black dots) in Puyallup watershed (black line) overlaid on Washington 1:100,000 geologic map (WADNR, 2026). Note that Mud Mountain (MM) samples are in the Osceola Mudflow (yellow) region, Garfield Park (GP) and Point Defiance (PD) sites in Pleistocene glacial deposits (tan), and Carbon Glacier (CG) in modern glacial deposits.



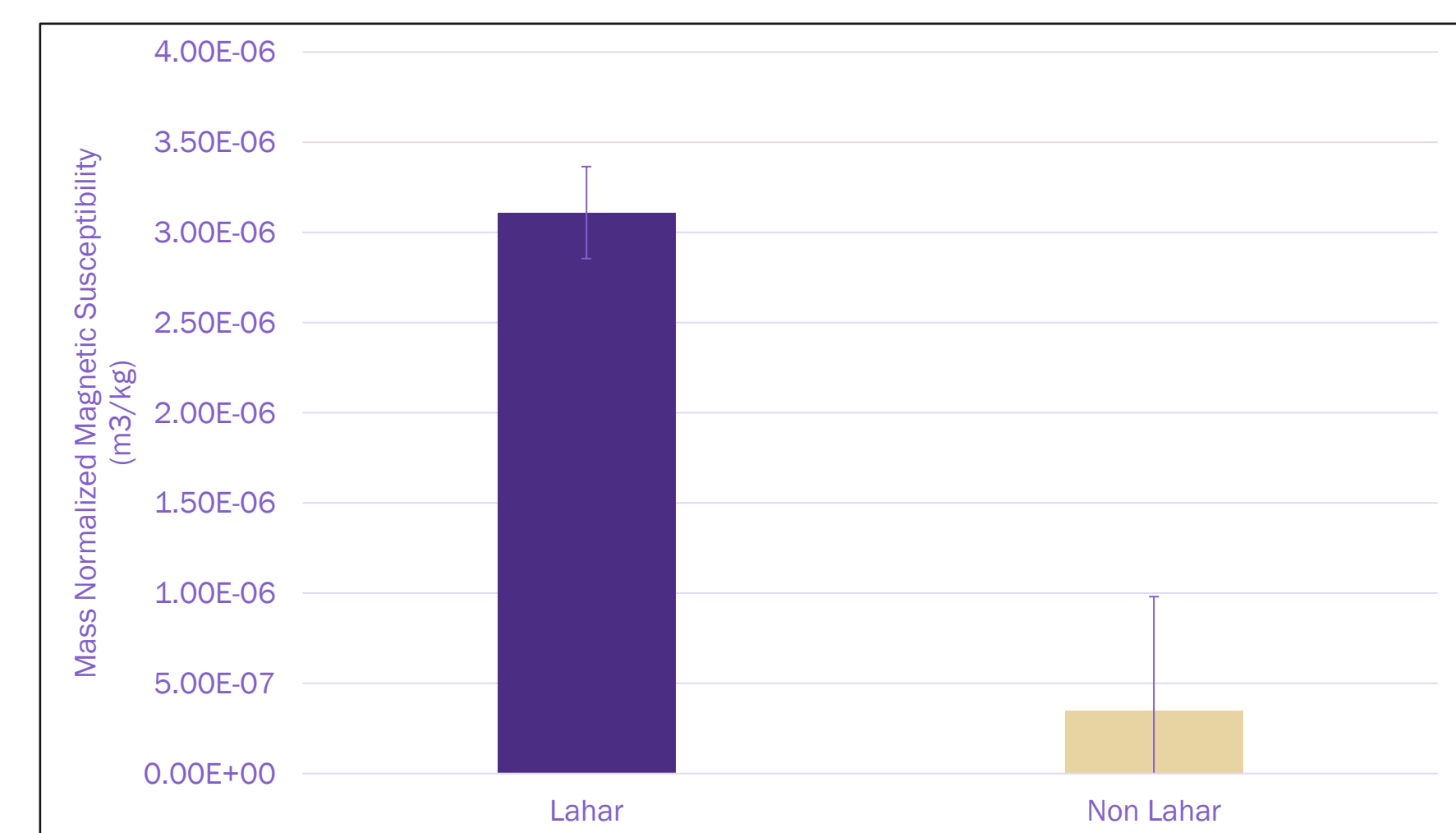
Particle Size Separation: Sediment was disaggregated and separated into grain size classes using Stokes Law settling process. In this study, silt particles were used for all analyses as a common point of comparison.

Optical Petrography



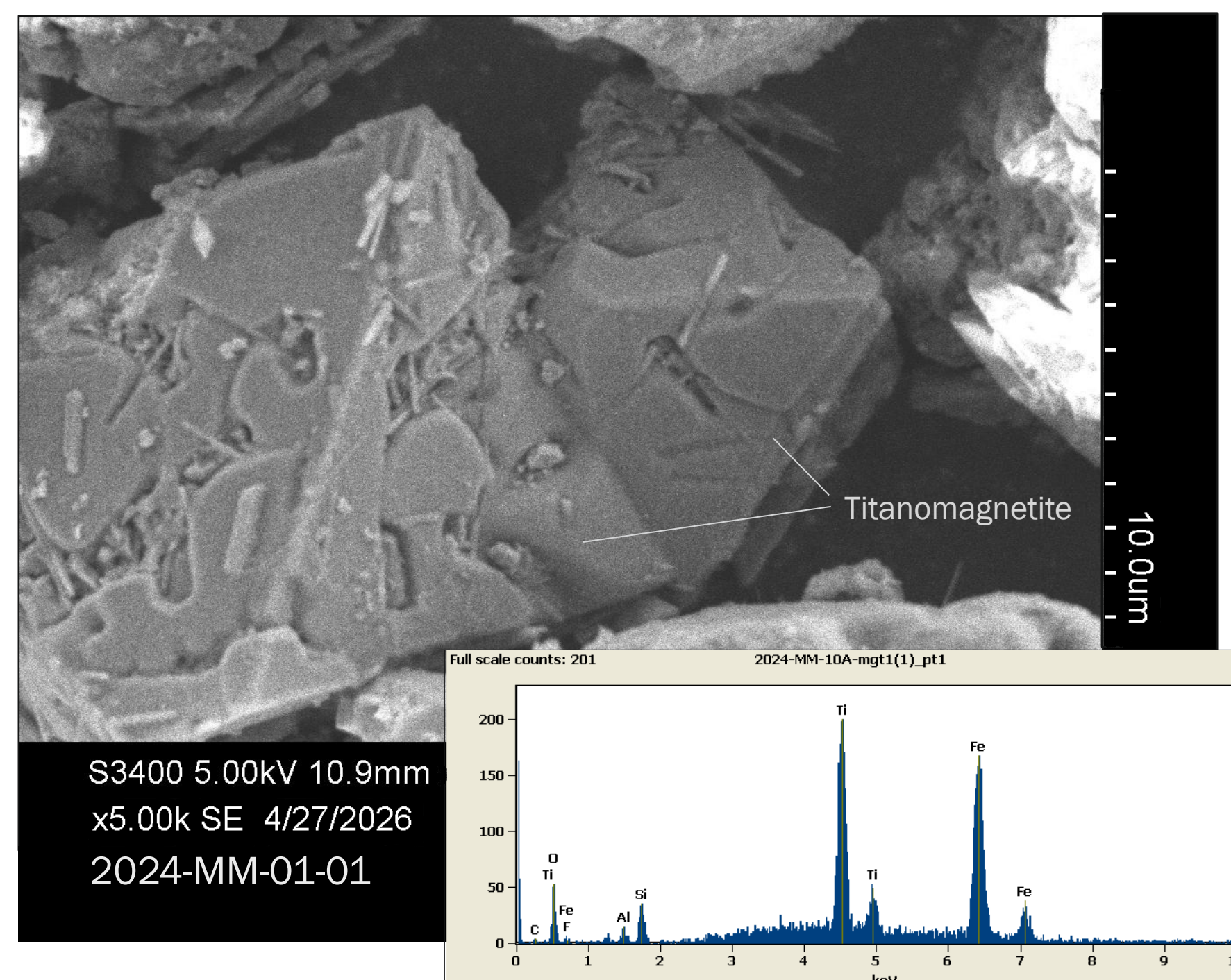
Plane polarized light image of silt components from modern glacial (2024-CG-01), Pleistocene glacial (2025-GP-01A-1) and lahar (2025-MM-10A-1, 2025-MM-11A-1) sediment. Example minerals are indicated on image noting similarities and differences of total composition.

Magnetic Susceptibility (χ)



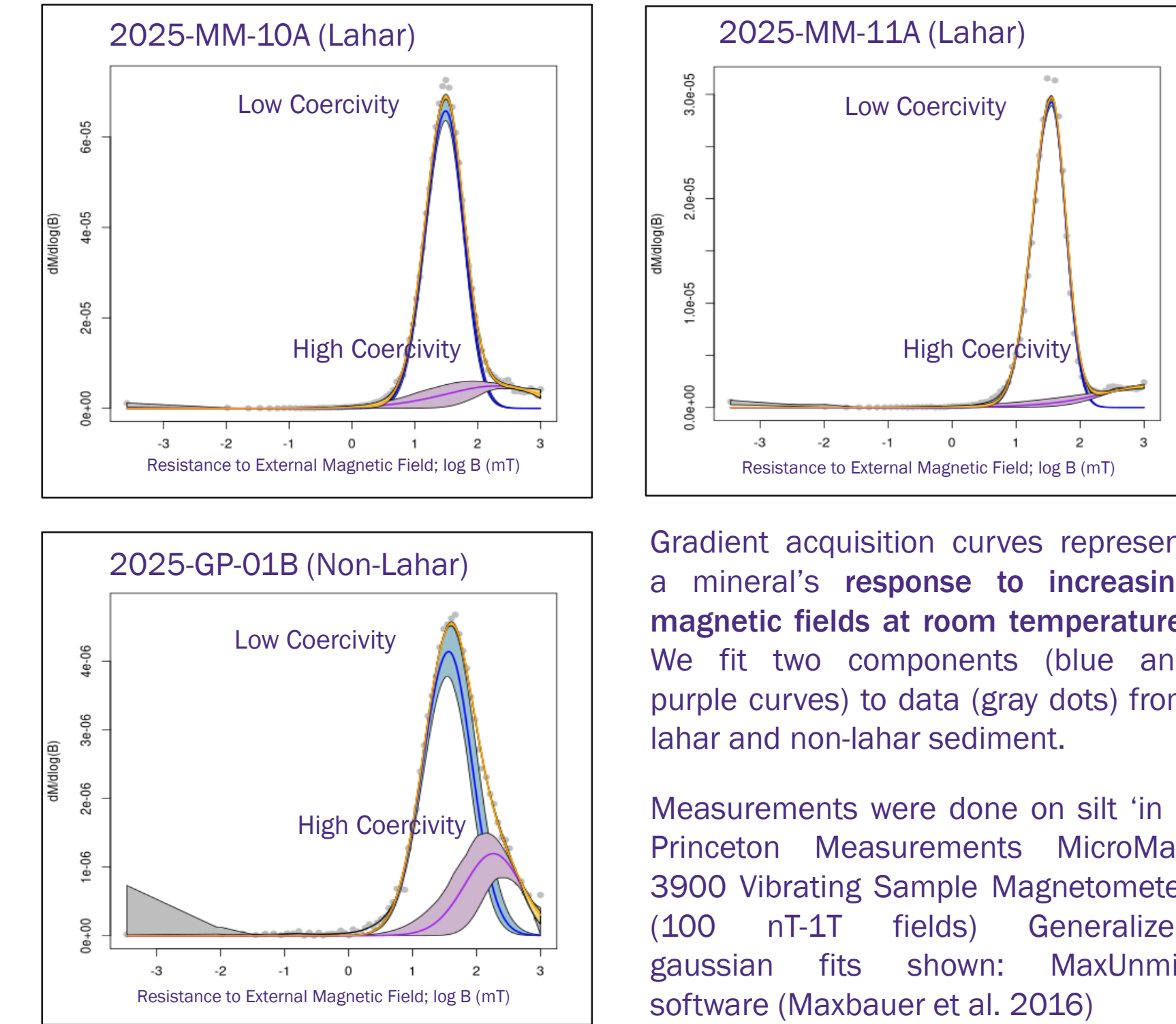
Magnetic susceptibility, a sample's induced response of weak applied magnetic fields, is a measure of the concentration of ferromagnetic, paramagnetic, and diamagnetic material in the sediment. Magnetic susceptibility was measured on capsules of silt in a Bartington MS2B/MS3.

Scanning Electron Microscope (SEM)



Scanning Electron Microscope (SEM) secondary electron image of titanomagnetite grain with octahedral crystal habit (lahar sample 2024-MM-11A-1). Inset: energy dispersive spectrum (EDS) for the same grain indicating presence of Ti and Fe. Analyses on magnetic separates from silt using Hitachi S3400N SEM; EDS spectrum collected using 11.5 kV and 70 μ A probe conditions.

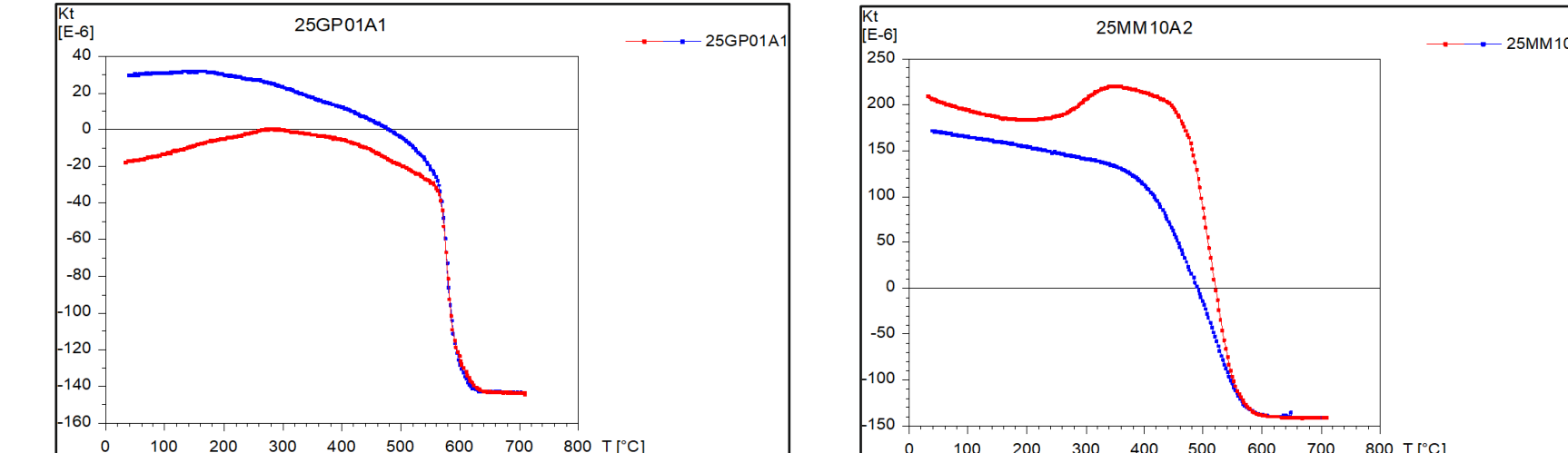
Isothermal Remanent Magnetization (IRM)



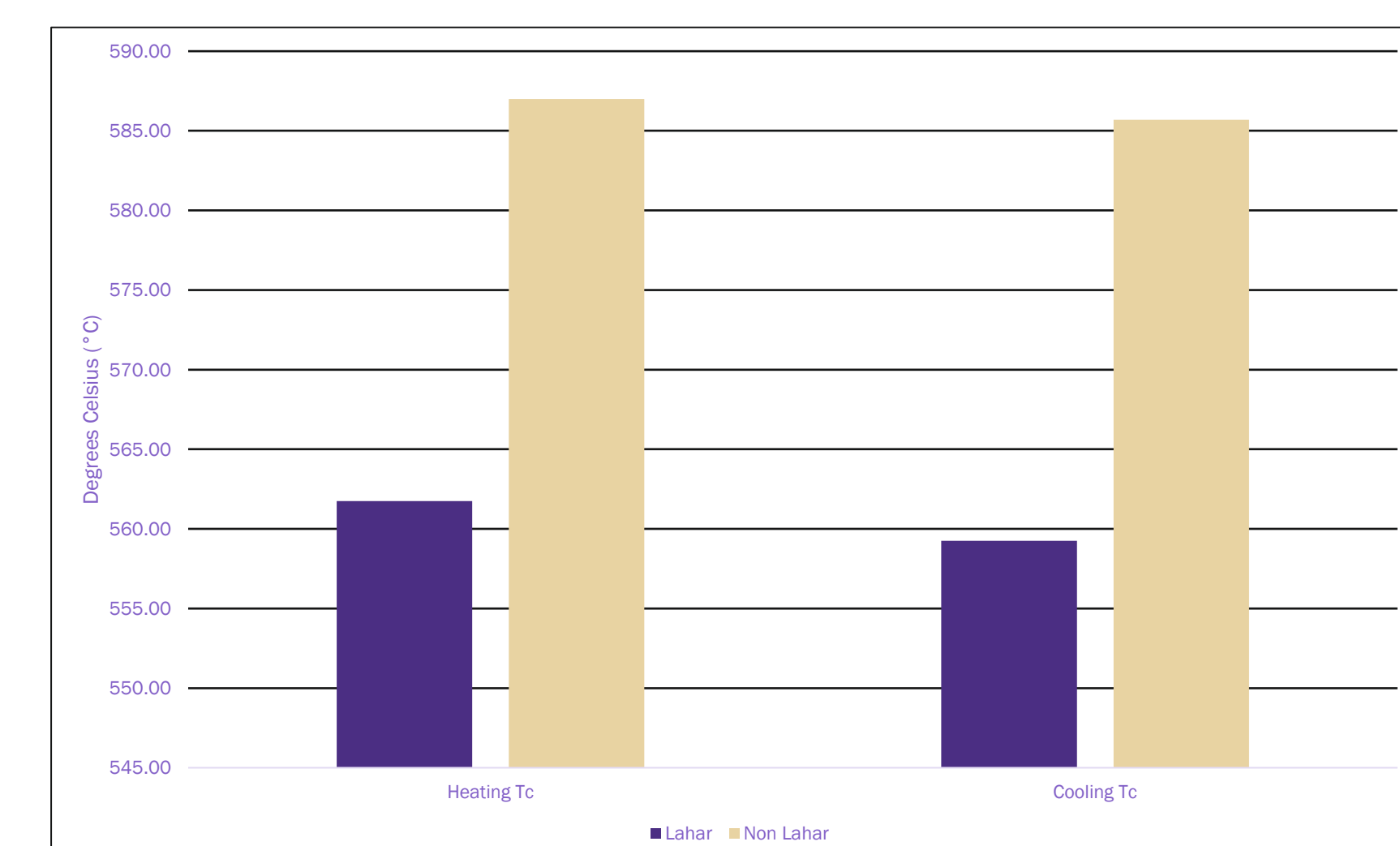
Gradient acquisition curves represent a mineral's response to increasing magnetic fields at room temperature. We fit two components (blue and purple curves) to data (gray dots) from lahar and non-lahar sediment.

Measurements were done on silt in a Princeton Measurements MicroMag 3900 Vibrating Sample Magnetometer (100 nT-1T fields) Generalized gaussian fits shown: MaxUnmix software (Maxbauer et al. 2016)

Curie Temperature Curve (T_c)



Magnetic susceptibility with temperature on heating (red) and cooling (blue) in argon atmosphere in a Kappabridge KLY-2. The heating curve shows the loss of magnetization at the Curie Temperature (T_c) point, followed by cooling where some mineral magnetization is recovered; the differing curve lines show the irreversible nature of other mineral magnetism recovery. Curie temperatures are indicative of different ferromagnetic minerals (Table 1); non lahar sediments have a higher (T_c) than lahar sediments.



Above: Average Curie Temperature of lahar and non-lahar sediment; calculated using peaks in second derivative. **Left:** Average Curie Temperature of lahar and non-lahar sediment; calculated using inverse susceptibility.

Curie Temperatures (T_c) of Common Magnetic Minerals

Magnetic Mineral	Curie Temperature ($^{\circ}$ C)
Hematite (α -Fe ₂ O ₃)	675-680
Magnetite (Fe ₃ O ₄)	578
Titanomagnetite (Fe ₂ -Ti O ₄)	~370-550+
Maghemite (γ -Fe ₂ O ₃)	Unknown

Table 1 (Bilardello, D., 2020; Jackson, M. and J.A. Bowles, 2014)



Top Left: Physical differences of glacial sediment properties; Garfield Park, Tacoma. Top Right: 2025 sample data collection at the WWU Paleomagnetism Laboratory, Bellingham. Bottom Left: UWT Selkin Lab Undergraduate Research Team 2025. Bottom Right: UWT students collecting sediment samples; Mud Mountain, Hwy 410, Enumclaw.

Discussion

Compared to non-lahar sediment, lahars have higher magnetic susceptibility. This is consistent with the greater concentration of opaque particles observed petrographically.

Both lahar and non-lahar sediments have a similar low-coercivity component, but non-lahar sediments have a greater high-coercivity component.

Curie temperatures of lahar sediments are generally lower than those of non-lahar sediments, but both display non-reversible behavior.

Magnetic susceptibility and optical observations suggest that the lahar sediments have a greater concentration of oxide material.

The lower Curie temperatures of lahar sediment suggest that titanomagnetite may be present in lahars. The irreversible behavior of both sediments indicates some oxidation, possibly maghemite. However, only non-lahar sediments have substantial high-coercivity IRM components.

These differences in magnetic properties can aid in tracking river sediment to lahar and glacial sources.

Acknowledgements

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References

