Spectral Characterization of Holocene Volcanic Ash and Aeolian Deposits in the North American Cordillera, Canada

Author: Chan Chung Sang Morris[1, 2]
Supervisors: Dr. Mitch D'Arcy[2], Henry Crawford[2], Dr. Su-Chin Chang[1]

[1] Department of Earth Sciences, The University of Hong Kong
[2] Department of Earth, Ocean and Atmospheric Sciences, The University of British Columbia

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Poster No.: D1
Name: Chan Chung Sang Morris
Student's Major: Geology (Intensive)

ABSTRACT: **Volcanic ash deposits (tephra) are important paleoenvironmental archives which provide chronological controls, as their eruption times and history are precisely dated and recorded. While pure and massive tephra layers are often distinguishable by the naked eye, some remain mixed and detached in tiny layers which are difficult to identify. This study presents a non-destructive, quick, and continuous approach that uses spectroradiometry to comprehensively detect and characterize Holocene tephra within associated sediments in the North American Cordillera.**

INTRODUCTION

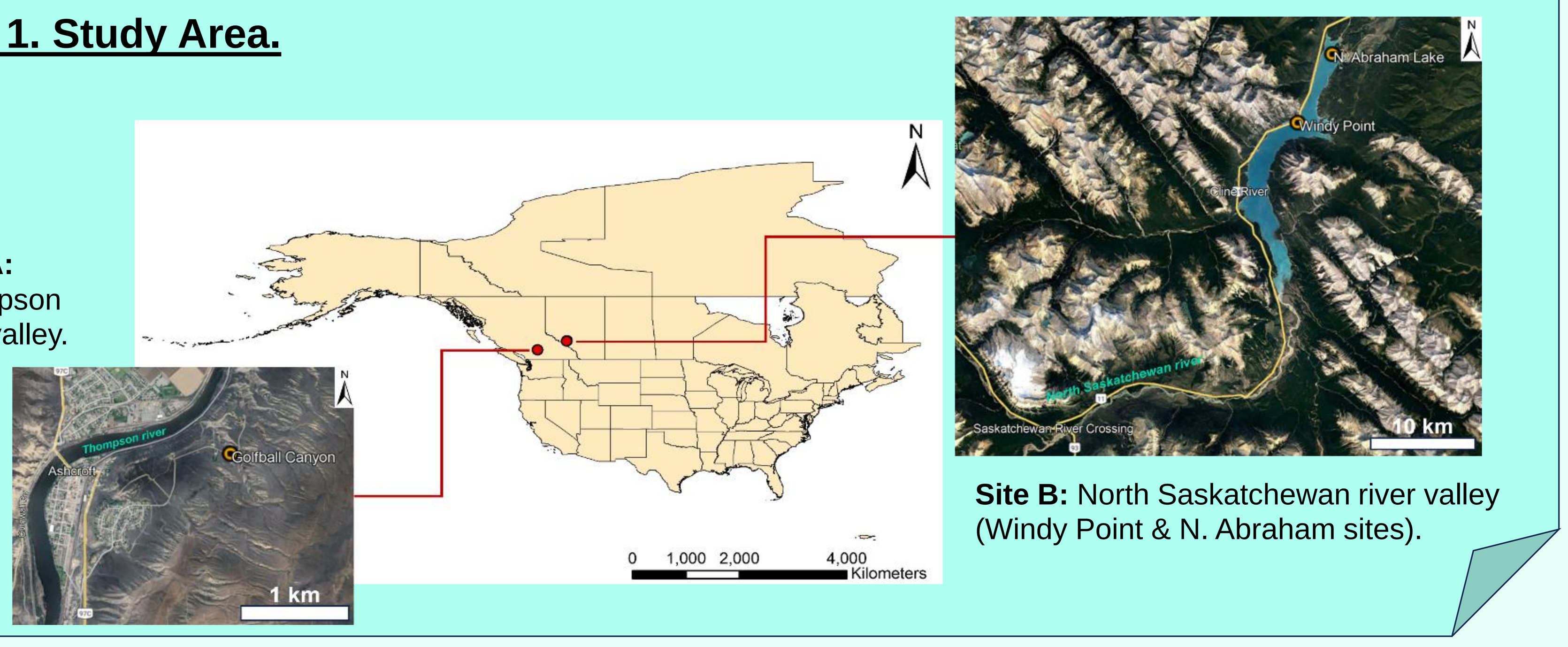
This study combines two approaches to characterize sediments:

1. Tephrochronology: Using dated tephra beds as stratigraphic markers to infer and constrain the time of deposition in sedimentary layers **[1]**.
2. Spectroradiometry: Multi- and hyperspectral remote sensing techniques measuring Earth materials from visible to short-wave infrared wavelengths **[2]**.

☆ The 3 tephra layers to be investigated: Bridge River (**BR**, aged 2360), Mount St Helens Yn (**SHY**, aged 3660), and Mazama (**MAZ**, aged 7630) **[1, 3]**.

☆ Sediments in river valleys of the study area include: Aeolian deposits, Alluvial fan sediments, Paleosols, and Glacial outwash deposits.

Fig. 1. Study Area.



OBJECTIVES

① *To examine the **vis-SWIR spectral characteristics** of Holocene tephra in Canada, and differentiate them from associated sediments*

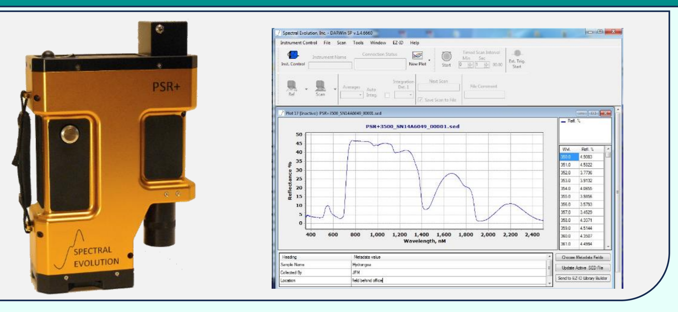
② *To establish a model for detecting **cryptic tephra** in the field, and quantitatively identify its detection limits*

③ *To explore the feasibility of **reconstructing Holocene environments** with spectroradiometry*

METHODOLOGY

Fig. 2. The PSR+ Portable Spectroradiometer.

- Conducts full measurements of wavelengths from 350 to 2500 nm
- Spectra are digitally accessed and managed by the DARWin software



In-situ Analysis

Field sampling and high-resolution stratigraphic logging with spectroradiometer – For every 5 cm increment, 3 triplicate scans were collected and averaged to improve the signal to noise ratio.

Laboratory Analysis

Mixing experiments – Samples dried and sieved to 0.105 mm, artificially spiked with known and incremental tephra concentrations, creating a reflectance-based spectral index, as a function of known tephra concentrations within a sedimentary substrate.

Spectral Library & Tephra Index

A spectral library is created which stores the sample scans for calibration. Building upon absorption feature values of the three ashes, a tephra index is established for predicting tephra contents in other samples.

RESULTS

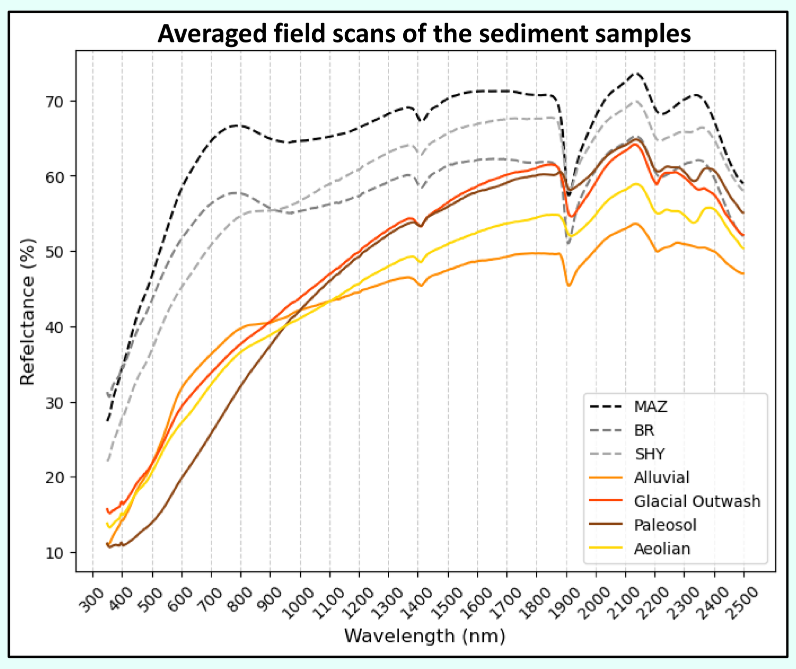


Fig. 3. Vis-SWIR spectra of the samples.
Raw spectra of all sediment materials are shown – Tephra layers (dotted) exhibit distinctive spectral properties when compared to other sediments (solid).

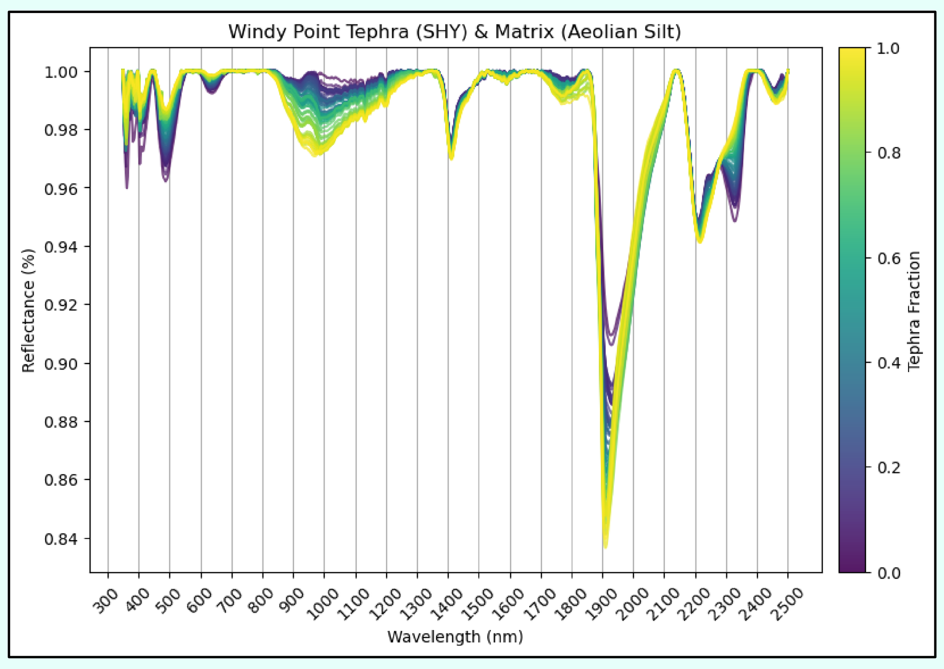


Fig. 4. Continuum removed spectra of a mixture between SHY & Aeolian sediments.
Clear calibration between the end member materials – key spectral features are extracted to build the tephra index and detection model.

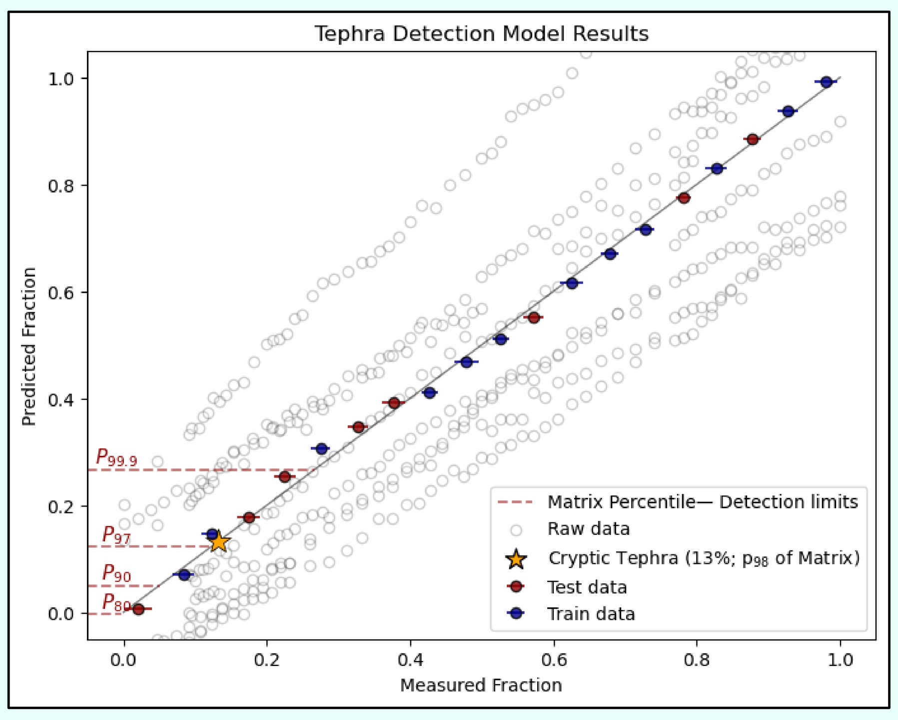


Fig. 5. Tephra detection model for the cryptic SHY tephra.
The detection limits (dashed lines) are determined by the ability of the model to discriminate between tephra and other sediments, which can be quantified using the percentiles shown in the figure.

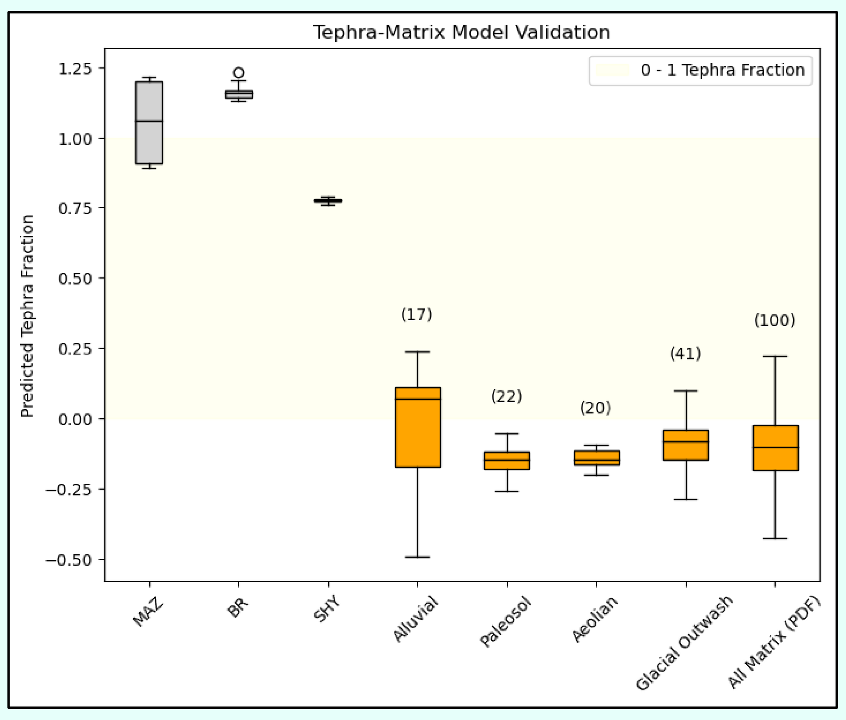


Fig. 6. Validation for the tephra-matrix model and the tephra index.
Box plots represent the prediction results using the tephra index. Brackets show the no. of sample scans for validation. A probability density function is incorporated to make the model more robust.

IMPLICATIONS

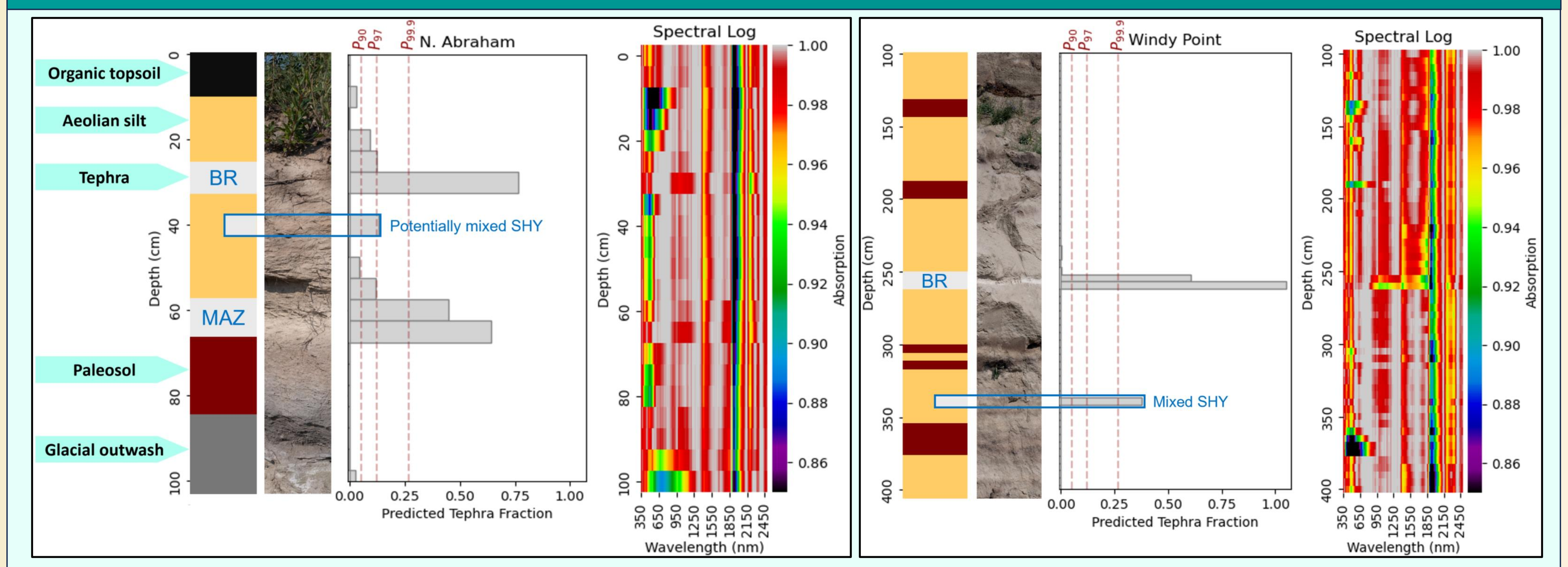


Fig. 7. Spectral stratigraphic logs of soil profiles at North Saskatchewan river valley.
Field stratigraphic logs are correlated to predicted tephra fractions derived from the tephra index.

1. Holocene tephra in Canada can be differentiated against other sediments by strong absorptions near 1900 and 2200 nm, likely due to H_2O stretches and metal-OH bonds – indicative of phillosilicate clay minerals like montmorillonite and smectite, the weathering products derived from dacitic source rocks **[3, 4]**.
2. Mixing between tephra and host sediments during the time of deposition can be anticipated – which explains the similar but not identical spectral features among 3 tephras, and their detected presence in the layers immediately above (Fig. 7).
3. The tephra detection model provided insightful results in detecting Holocene dacitic cryptotephra in Canadian contexts (Fig. 5), enabling additional age controls and reconstructions of past environments. Such method can be extended towards other types of tephra and localities for further studies.

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KEY REFERENCES

[1] Wolfe, S. A., & Lian, O. B. (2021). Timing, rates and geomorphic controls on Holocene loess and aeolian sand deposition using multiple chronometric methods, southeastern Cordillera, Alberta, Canada. *Aeolian Research, 50*, 100687.

[2] Aymerich, I. F., Oliva, M., Giralt, S., & Martín-Herrero, J. (2016). Detection of tephra layers in Antarctic sediment cores with hyperspectral imaging. *PLoS One, 11*(1), e0146578.

[3] Jensen, B. J., Beaudoin, A. B., Clynne, M. A., Harvey, J., & Vallance, J. W. (2019). A re-examination of the three most prominent Holocene tephra deposits in western Canada: Bridge River, Mount St. Helens Yn and Mazama. *Quaternary International, 500*, 83-95.

[4] Henderson, M. J. B., Horgan, B. H. N., Rowe, M. C., Wall, K. T., & Scudder, N. A. (2021). Determining the volcanic eruption style of tephra deposits from infrared spectroscopy. *Earth and Space Science, 8*(2), e2019EA001013.