Project Title

Trace-Metal Bearing Sulfides and Oxides in Cambrian Strata of West-Central Wisconsin

Project Directors

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Tentative Field/Laboratory Dates

7/7/25 – 8/8/25

Number of Students

10 Gateway Students and 1 Near-Peer Mentor

Total Project Budget Requested

$100,807

Project Description

Mississippi Valley Type (MVT) mineralization is an epigenetic, stratiform replacement of primary sedimentary features, predominantly in carbonate host rock. In one of its type regions, Upper Mississippi Valley Type mineralization is found throughout southwest Wisconsin and extends into Illinois, Iowa, and Minnesota (Fig. 1; see Heyl and West, 1982; Symons et al., 2010). While the most pervasive MVT mineralization in Wisconsin occurs in Ordovician carbonates, the underlying Cambrian quartz sandstone and dolomite-cemented glauconitic sandstone also contain MVT sulfide minerals, some of which bear exceptionally high levels of trace metals (Zambito et al., 2019, 2022a,b). The occurrence of trace metal-bearing MVT sulfides and sulfide weathering product oxides in these sandstones is significant because these strata serve as a regional groundwater aquifer as well as a source of industrial sand that is mined throughout west-central Wisconsin where these strata are well-exposed in the Driftless Area (Parsen and Zambito, 2014; Zambito et al., 2019). Therefore, redox changes resulting from water table fluctuations due to groundwater pumping and sandstone crushing/washing during industrial sand mining (ISM) processes are both potential sources of groundwater contamination by trace metals in the study area (Fig. 2).

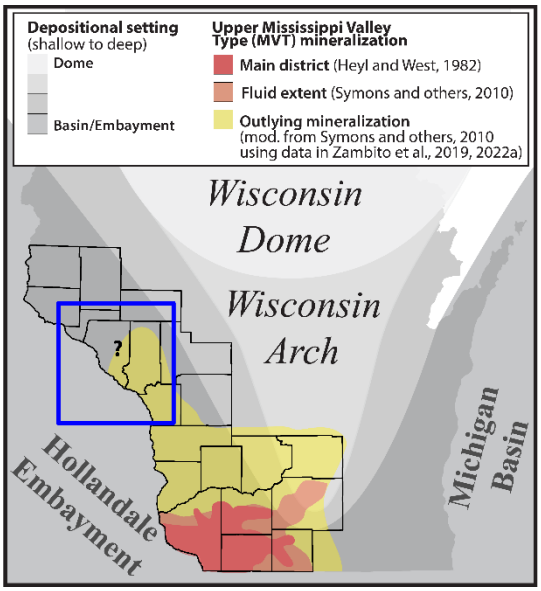

Figure 1: Generalized geologic setting and concentration of Mississippi Valley Type (MVT) ore deposits in the study area. Wisconsin state boundary in darker gray and select county boundaries indicated by black lines. Grayscale gradient represents submarine depositional settings with the shallowest areas (pale gray) over the Wisconsin Dome and Arch in northern and central Wisconsin and becoming progressively deeper to the southwest and southeast into the Hollandale Embayment and Michigan Basin, respectively. During deposition of the Wonewoc Formation and Tunnel City Group rocks, the source of siliciclastic sediment (primarily quartz grains) was from modern north and may have included the Wisconsin Arch and Dome (Dott et al., 1986; Runkel et al., 2007, 2012). The blue box denotes both the area of recent previous work (Zambito et al., 2018, 2019, 2022a,b, in prep.; Haas et al., 2024) and this proposed research with a question mark indicating the area of outlying mineralization that will be refined by this study. Modified from Zambito and others (2019).

In this proposed Gateway Project, 10 rising sophomores and 1 near-peer mentor (rising senior) will learn to map, collect, and analyze Cambrian sandstone samples from outcrop and core in west-central Wisconsin to better understand sulfide and oxide distribution and trace metal composition and improve our understanding of MVT mineralization and potential natural sources of groundwater contamination.

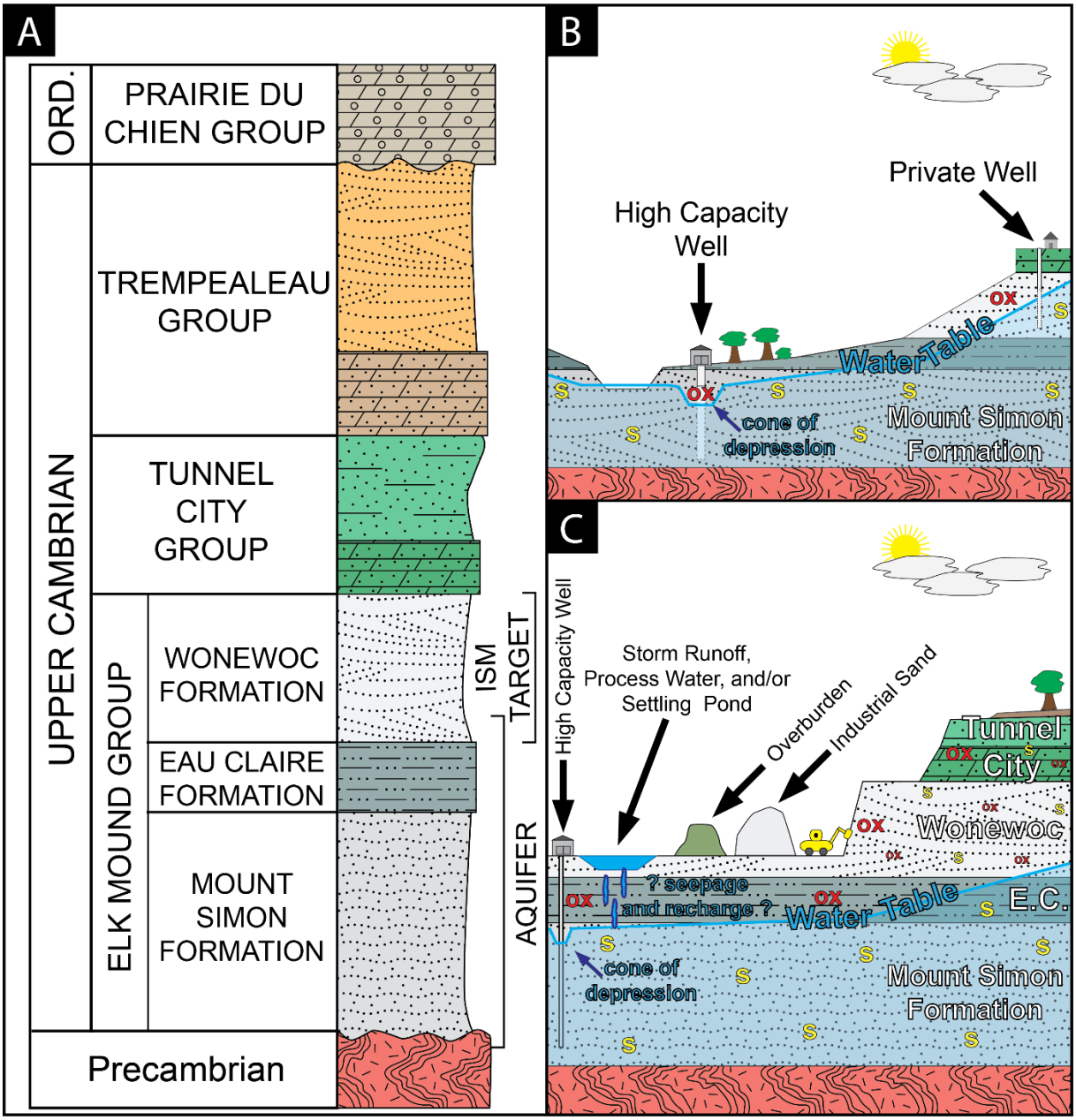

Figure 2: A) Generalized stratigraphy for the study area. ISM stands for industrial sand mining. B) Conceptual model (not to scale) showing the oxidation (red 'ox') of hypothetical sulfide zones (yellow 's') due to water table fluctuations and the formation of a cone of depression in the water table through high-capacity well pumping. Unlabeled stratigraphic units are the same as in parts A, B and C of this figure. C) Conceptual model (not to scale) showing the hypothetical interaction of surface water (unlined storm runoff, process water, and/or settling pond) with groundwater at an industrial mine site through seepage and recharge. Note that strata are oxidized near the exterior of the hill being mined, but sulfides exist further within the hillside. This could be a potential source of groundwater contamination. E.C. stands for Eau Claire Formation. For wells in parts B and C, solid lines of boreholes represent cased portions of wells and dashed lines represent un-lined portions open to the aquitard-aquifer system; in these schematics the borehole in part B is only partially cased, while the borehole in part C is cased to depth. Modified from Zambito et al. (2022a).

Cambrian-Ordovician lithostratigraphy, sequence stratigraphy, and depositional environments have previously been described by Runkel and others (2007, 2012) as part of a regional synthesis of Upper Mississippi River Valley (see also Dott et al., 1986). More recent studies primarily focused in Trempealeau County, west-central Wisconsin (Figs. 3, 4, and 5; Zambito et al., 2018, 2019, 2022a,b; Haas et al., 2024) have identified trace-metal bearing sulfide and oxide minerals throughout the Cambrian sandstone succession, including within the aquifer sandstone and aquitard shale of the Mount Simon and Eau Claire formations, respectively, and the ISM target sandstone and overburden dolomitic glauconitic sandstone of the Wonewoc Formation and Tunnel City Group, respectively. In the proposed project the Project Directors and Students will build off this previous work by collecting a dataset of sulfide and oxide occurrence and trace metal composition in neighboring Buffalo County (located just south of Eau Claire, WI, see Fig. 3). The relative simplicity of the system (sulfides interacting with oxygen to become oxides) and the various techniques used on both outcrop and core samples will emphasize a variety of core concepts and skills in the geosciences for these Gateway Students.

Previous work has demonstrated that trace metal-bearing sulfides and oxides in the study area are a potential source of groundwater contamination (Zambito et al., 2019, 2022, a,b); indeed, water samples from private wells near, and process water ponds at, ISM sites show trace metal concentrations above safe levels (Zambito et al., 2019). The results of this project will therefore refine our understanding of not only the extent of MVT mineralization in west-central Wisconsin (Fig. 1) but provide a crucial dataset that will allow local and state government, industry, environmental groups, and private citizens to make more informed decisions regarding locating and permitting extraction of aggregate, industrial sand, and groundwater resources to minimize groundwater impacts. As part of the professional student learning outcomes of this project, the students will interact directly with researchers, environmental regulators, and policy makers in the study area thereby gaining first-hand experience in sharing their societally relevant research with stakeholders while simultaneously learning about potential career paths.

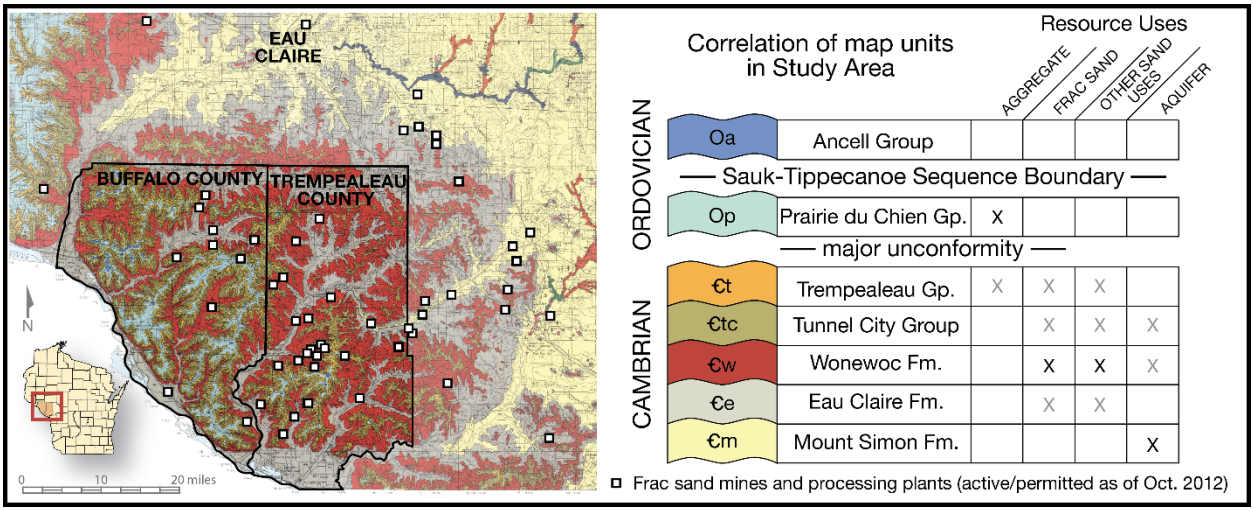

Figure 3: Buffalo County (located just south of Eau Claire, WI) is near the center of large-scale industrial (frac) sand mining (white squares) in west-central Wisconsin, and neighbors Trempealeau County were a large pre-existing data set of sulfide and oxide distribution and trace metal concentration is available from previous studies (Zambito et al., 2018, 2019, 2022a,b; Haas et al., 2024). Black X's indicate (for the study area) common uses and high extraction rates for the designated purposes, gray X's indicate less common uses and lower rates of extraction. Modified from Zambito and others (2018).

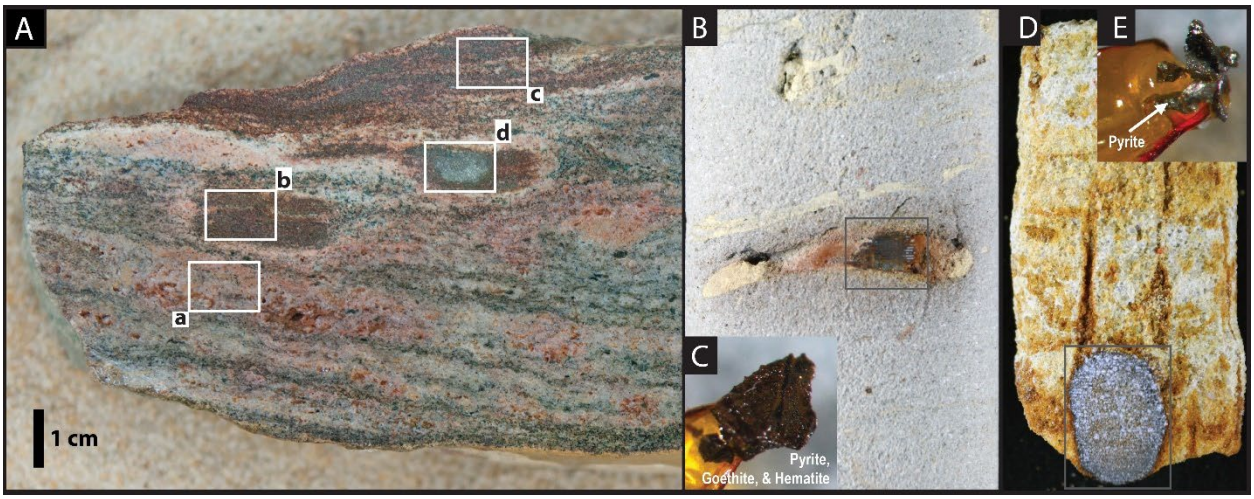

Figure 4: Photographs of select samples analyzed by XRD (modified from Zambito et al. 2019 and 2022a). A) Hand sample from the Tunnel City Group showing variable iron (hydr)oxide (subsamples a, b, c) and pyrite (subsample d) distribution on a slabbed surface. B, C) Core photograph and single 'grain' sample of pyrite, goethite, and hematite from a stratiform, potentially vug-filling rusty sulfide nodule in the Eau Claire Formation. D, E) Core photograph and single 'grain' sample of pyrite (in the form of external molds of sand grains) from a sulfide nodule that appears to be associated with Skolithos burrows in in the Mount Simon Formation. Single 'grain' samples range in size from ~0.1 to 0.3 mm, and are mounted on the slitted end of an amber-colored, <1 mm diameter tube and attached with vacuum glue. Drill core samples shown are approximately 5.0 to 6.0 cm wide.

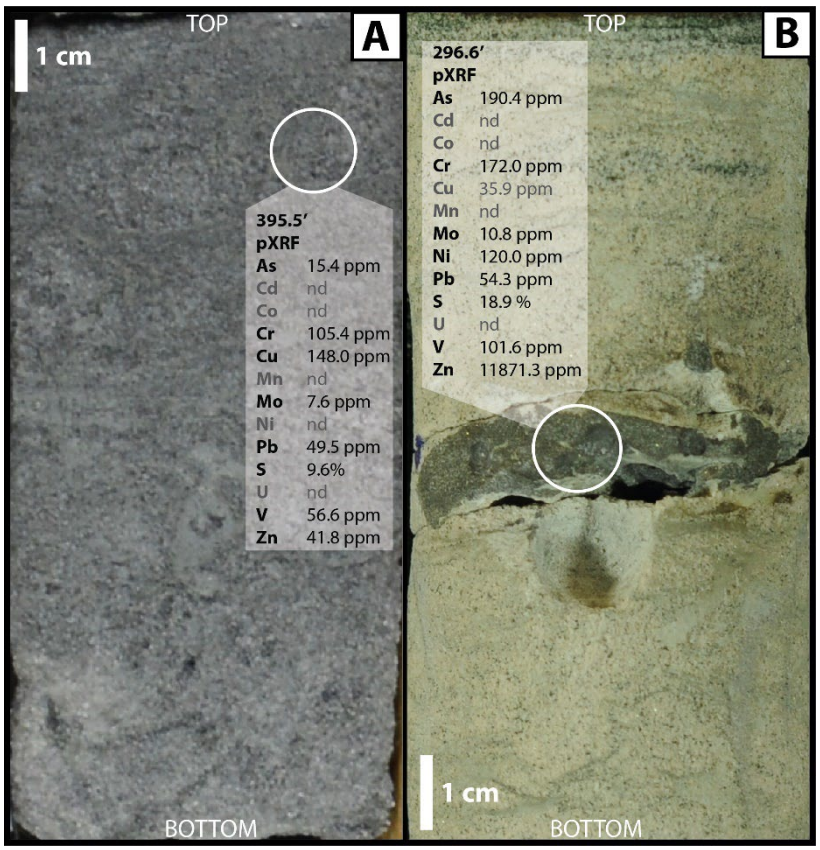

Figure 5: Photographs of select core samples from Trempealeau County analyzed by pXRF showing elevated trace metal concentrations in disseminated sulfide cements in the Wonewoc Formation (A) and a stratiform pyrite nodule in the Tunnel City Group (B). Modified from Zambito and others (2019).

Learning Outcomes

Student learning outcomes for this project are varied and range from practicing general geologic skillsets related to notetaking, sampling (pros and cons of core versus outcrop as well as how to 'read' and sample drill core including best practices for not over-sampling), and construction of stratigraphic columns to utilizing specific analyses (*e.g.*, determining trace metal concentrations using x-ray fluorescence, mineralogy using x-ray diffraction, and scanning electron microscopy). Importantly, students will learn about fundamental redox reactions as sulfide minerals will be more prevalent in the reducing conditions of the subsurface (core samples), while iron oxide minerals will be common in outcrop samples that have been weathering at Earth's surface for potentially millions of years in the Driftless Area (Zambito et al. 2022a). The professional learning outcomes of this project are focused on providing opportunities for the students to interact with geological researchers, environmental regulators, policymakers, and industry professionals (outlined in more detail below). Through these interactions, students will have the opportunity to share their research as well as learn about possible career paths. Personal learning outcomes for all the students include experience as: a productive collaborator through working in a group setting, an effective communicator in both scientific and public mediums, a creative problem solver through integrating data from core and outcrop as well as from previous studies, and professionally and intellectually agile researchers from the experience gained through field work where weather and other factors can result in last minute adjustments. Additionally, the near-peer mentor will gain leadership and mentoring experience through their interactions with the other students and build upon this summer research as part of their senior thesis at Beloit College.

Potential Student Projects

The following potential student projects are both suitable for rising sophomores and will serve the overall project goals by utilizing a variety of methods to develop a better understanding of sulfide and oxide occurrence and trace metal composition in the study area to constrain MVT mineralization.

1) Mineralogy of outlying MVT mineralization (2-3 students)
   MVT deposits in the main mineralization (lead-zinc mining) district consist of galena and sphalerite, yet previous work (Zambito et al., 2019, 2022a) found most of the mineralization in the outlying area of MVT mineralization (Fig. 1) consists of trace metal-bearing pyrite. A compilation of new (Buffalo County) and previously published (Trempealeau County) mineralogical data of sulfides and oxides from the region obtained via XRD and SEM analysis will provide insights into regional MVT mineralization.
2) Trace metal composition of sulfide and oxide minerals (2-3 students)
   Portable X-Ray Fluorescence Analysis (pXRF) offers a relatively cheap and fast tool for collecting large elemental datasets. The relatively small analysis window (8mm) also allows acquisition of data from mineralogically variable subsamples (see Fig. 4A). Students will collect data on trace metal composition across sulfide-oxide phase changes in samples from outcrop and core to document the mineral phases in which trace metals are present and develop a model for trace metal liberation through redox reactions. Subsequent ICP-MS analysis will be used to better constrain trace elemental concentrations.
3) Lithostratigraphy of the Cambrian Succession, Buffalo County (2-3 students)
   To date, there has been no detailed lithostratigraphic work on the succession in Buffalo County. Previous work in neighboring Trempealeau County (Zambito et al., 2018, 2019, 2022, a,b) will serve as a reference for students to recognize stratigraphic units in the study area and interpret environmental changes that may represent a depositional depth gradient from the Wisconsin Arch to Hollandale Embayment (Fig. 1).
4) Magnetic Susceptibility and the Stratigraphic Distribution of Sulfides and Oxides (2-3 students)
   Magnetic Susceptibility (MS) analysis provides information on the presence of magnetic minerals either in the iron-titanium oxygen (FeTiO) group or the iron-sulfur (FeS) group; each mineral or rock has a different average susceptibility value based on its composition. MS data is also a relatively cheap and fast tool for collecting large datasets. Systematic collection of MS data from cores in the study region will provide a stratigraphic dataset from which students can estimate if some sandstone units are more 'mineralized' than others and with which to compare to lithologic observations.

Project Logistics

Student Participants, Locations, and Timeline

This Gateway Project involves 10 rising sophomores and 1 near-peer mentor (rising senior) that will learn to map, collect, and analyze Cambrian sandstone samples from outcrop and core in west-central Wisconsin to better understand sulfide and oxide distribution and trace metal composition and improve our understanding of MVT mineralization and potential natural sources of groundwater contamination through: a project introduction at Beloit College; field work in west-central Wisconsin (Buffalo County); core measuring and sampling at the Wisconsin Geological and Natural History Survey (WGNHS) core repository; laboratory analyses at Beloit College laboratories; and participation and presentation at the Geological Society of America National Meeting in San Antonio, TX. A tentative timeline for core repository/fieldwork, laboratory work, conference travel, and resulting products is outlined in Figure 6 and text below.

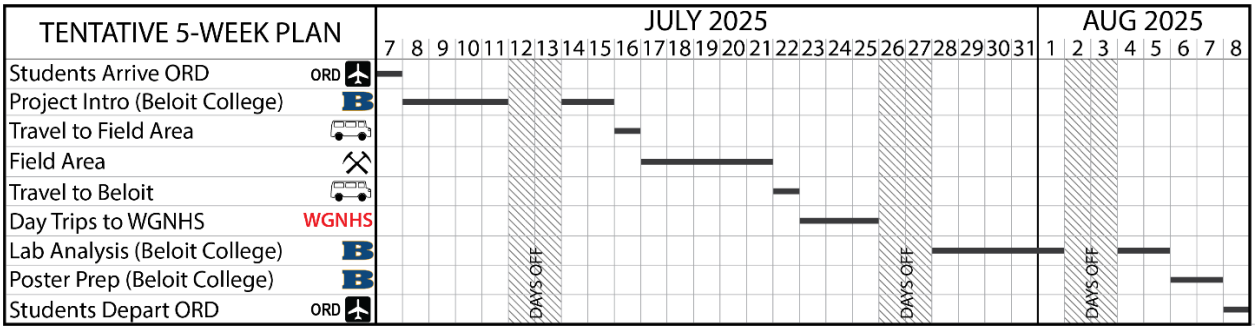

Figure 6: Gantt chart outlining tentative 5-week Keck project plan. See text below for details that include post-summer activities.

Pre-Project Planning

June 2025: At least 2 group Zoom meetings will cover personal introductions as well as travel and project logistics.

4-Week Keck Project

July 7: Students arrive at Chicago O'Hare Airport (ORD), travel by shuttle bus to Beloit College.
July 8-11: Project Intro: safety training and mini-lectures focused on mineralogy, sedimentology, etc.
July 12-13: Days off; students will have access to discount/thrift stores and pharmacies.
July 14-15: Project Intro: Discussion of previous literature and geologic maps.
July 16: Travel to field area in Buffalo County, Wisconsin by van.
July 17-21: Field work (outcrop sampling) and professional development (WI DNR, county officials, industry).
July 22: Travel back to Beloit College by van.
July 23-25: Day trips to WGNHS (core sampling) and professional development (WGNHS)
July 26-27: Days off.
July 28- Aug 1: Laboratory Analysis.
August 2-3: Days off.
August 4-5: Laboratory Analysis.
August 6-7: Prepare Poster for National GSA Meeting.
August 8: Students return home via travel by shuttle bus to Chicago O'Hare Airport (ORD).

Academic-Year Professional Development

August 2025: Students begin fall semester; Project Directors communicate GSA preparations.
October 2025: Students present group poster at National GSA Meeting (San Antonio, TX).
April 2026: Students work with Project Directors by providing feedback on Keck Short Contribution draft.

Logistical and Safety Concerns

Students will receive safety training throughout the project. Field safety training will include proper PPE, tall outcrop and quarry high wall situational awareness, and poison ivy and tick identification. Core repository training will cover warehouse and forklift situational awareness, lifting heavy objects (core

boxes), and how to handle, read, and measure drill core. Laboratory training will include how to safely wear PPE and use a portable X-Ray Fluorescence (pXRF) elemental analyzer, x-ray diffractometer (XRD) mineralogical analyzer, scanning electron microscope (SEM), and MS meter. Students will also have access to video tutorials for the laboratory work involved in this study that Zambito prepared as part of a previous project during COVID. All project participants will follow the COVID policies regarding vaccination, masking, and quarantine/isolation of the institutions and organizations that we will work at and interact with (Beloit College, WGNHS, WI DNR, etc.). If COVID-related developments restrict in-person interactions, student projects will be developed from previously collected samples and data (Figs. 4 and 5; Zambito et al., 2018, 2019, 2022, a,b) and supplemented by the extensive well log data available through WGNHS.

Expectations for Students

There will be no expectation that students have had a prior geology course. In the beginning of the project the Program Directors, drawing on their extensive experience teaching a variety of introductory geology courses, will provide a series of hands-on activities, problem sets, and mini-lectures related to identifying minerals and rocks, basic sedimentology and stratigraphy, and redox geochemistry. We anticipate that all core repository, laboratory, sample preparation/analysis, field trip and research presentation activities will be completely to highly accessible. All nights will be spent on the Beloit College campus or camping in Wisconsin State Parks, flexible food options will be available, and mobility restrictions to participation minimal. We envision that standard gear (closed-toed footwear, hat, sunscreen, rain jacket, hammer, notebook, and water bottle) will be needed and that all outcrops and quarries examined will be within a short walk of parking during fieldwork. Students will have consistent access to a washer/dryer, and we will schedule time to visit discount/thrift stores and pharmacies on days off.

Description of Faculty

Zambito (Ph.D., Associate Professor of Geology, Beloit College) has studied Cambrian stratigraphy, sedimentology, and mineralogy in the Upper Mississippi River Valley for the last decade, starting as a Research Professor at the WGNHS and continuing during his time at Beloit College with a variety of relevant maps and other publications resulting (Zambito et al., 2018, 2019, 2022, a,b; Haas et al., 2024). He is currently a member of the WI DNR Non-Metallic Mining Advisory Committee. His first experience with the Keck Geology Consortium was when supervising an Advanced Keck student as part of project offered in 2018-2019 (Shonnard et al., 2021), and briefly had the opportunity to join the student in the field to learn more about the project and observe how other Directors organized and implemented an Advanced Keck project. He recently (2023-2024) co-led an Advanced Keck Project on the Michigan Basin (Short Contributions available here: https://keckgeology.org/2024/07/36th-keck-proceedings-volume/).

Rougvie (Ph.D., Associate Professor of Geology, Beloit College) has expertise in petrology and geochemistry with a focus on the effects of fluid-rock interaction on crustal rocks and processes. He has served as an undergraduate research mentor and supervisor through the Natural History Research Experience program at Smithsonian's National Museum of Natural History, the Keck Geology Consortium, The U.S. Department of Education's Ronald E. McNair Program at Beloit College, and the Sanger Summer Research Fellowship program at Beloit College. He has advised nearly 60 Beloit College undergraduate geology theses beginning in 2002.

Description of Facilities

For field work, Beloit College has rock hammers, hard hats, high-vis vests, wading boots, and other field gear that the students will have access to. Additionally, the Beloit Geology Department has all the necessary camping gear that students will need, including tents, tarps, cooking stoves and kits, mess

kits, sleeping pads and sleeping bags (though students will be encouraged to bring their own if available), water jugs, and food bins. For the analytical laboratory component of the project (see below), the Beloit Geology Department has core measuring supplies, a core and hand sample photography setup, access to computers with the Adobe Suite for figure drafting, a Thermo Fisher Scientific Niton XL3t GOLDD+ Handheld XRF analyzer, a Rigaku Miniflex II Powder X-Ray Diffractometer, a JEOL JSM-5900LV Scanning Electron Microscope (SEM), a Terraplus KT-10R v2 Magnetic Susceptibility (handheld) Meter, a variety of petrographic and binocular microscopes with cameras, and access to a variety of other analytical tools that may be useful for sample characterization as listed here: https://www.beloit.edu/academics/schools/environment-sustainability/facilities-instrumentation/.

Analytical Component

Sample Preparation

Some samples will need to be slabbed with a rock saw and/or powdered prior to analysis. The Beloit Geology Department maintains a sample preparation laboratory with a Felker Tile Master saw with diamond-embedded blades, SPEX 8510 Shatterbox, SPEX 8000 Mixer/Mill, a drill press and Dremel Tools with tungsten carbide drills bits for sub/microsampling, and a Frantz Magnetic Separator. Related expendable supplies are requested in the budget.

Mineralogical Analysis

Mineralogical analysis will be undertaken using a Rigaku Miniflex II Powder X-Ray Diffractometer (XRD) at Beloit College. This instrument has a newly installed x-ray tube, and a technician is available to assist project participants with analyses. Mineralogical Analysis will be assisted with the use of a JEOL JSM-5900LV Scanning Electron Microscope (SEM), also available in the Beloit Geology Department. Related expendable supplies are requested in the budget.

Elemental (Trace Metal) Analysis

Students will collect elemental data for hand- and core-samples of interest using a Thermo Fisher Scientific Niton XL3t GOLDD+ Handheld X-ray Fluorescence (pXRF) analyzer at the Beloit Geology Department. Related expendable supplies are requested in the budget. Additional elemental analysis for select, high priority samples will be conducted by the more accurate ICP-MS method using a contract laboratory (see budget justification) and incorporated into the project conference poster. For some elements of interest, pXRF is not suitable (specifically, Co, Ni, V, REE; see Zambito et al., 2016, 2022a) and therefore ICP-MS analysis will be utilized to complement the pXRF data collected.

Sedimentology and Stratigraphy

For each outcrop and core of interest, the students will work as a group to record basic rock properties including color, texture (grain size, sorting, shape), mineralogical composition, sedimentary structures, diagenetic features, and fossil occurrence in their notebooks. The group will then draft a master stratigraphic column post-field/core repository work to make sure all observations and samples are accurately recorded.

Magnetic Susceptibility Stratigraphy

For cores of interest at WGNHS, MS data will be collected at a high-sampling resolution directly from drill core using a Terraplus KT-10R v2 Magnetic Susceptibility (handheld) Meter available in the Beloit Geology Department.

Professional Development Component

Professional learning outcomes are interspersed throughout the project (see Fig. 5) as students interact with: geological researchers at the WGNHS while learning about the geology of the region and collecting core samples for analysis; environmental regulators at the Wisconsin Department of Natural Resources (WI DNR) at their regional office in the field area facilitated through Zambito's role on the WI DNR Non-

Metallic Mining Advisory Committee; County Board members in Buffalo County as part of outreach related to this project facilitated through Zambito's contacts from previous work in the area; and, industry professionals at ISM sites within the study area, including a tour that Zambito will arrange at an ISM site with ongoing reclamation efforts. Through these interactions, students will have the opportunity to share their research with stakeholders as well as learn about possible career paths. Professional Development opportunities for the students will culminate with their attendance and poster presentation at the Geological Society of America National Meeting in San Antonio, TX. During the presentation, the Project Directors will encourage students to solicit and embrace constructive criticism that can be used to inform the subsequent Keck Short Contribution. Additionally, students will be encouraged to attend mentor luncheons, resume workshops, and graduate school tables at the GSA meeting through a scavenger hunt activity that the Project Directors have developed.

Budget (Keck Gateway Project Template)

Budget Summary: Trace-Metal Bearing Sulfides and Oxides in Cambrian Strata of West-Central Wisconsin (Beloit College) 2025-26			
Expenses Paid by Beloit College (Reimbursed by Consortium)			
Summer Project			
Faculty Travel & Subsistence (5 days in the field @ $30/day x 2 faculty)			$300
Student Travel ($500/student x 11 students)			$5,500
Student Subsistence[1] (Beloit summer room and board for 33 days @ $65/day x 11 students)			$23,595
Other (Beloit College vehicle 1100 mi @ $0.70/mi x 2 vehicles; $64 in reservation fees)			$1,604
Analytical Program (Summer or academic year; Total ≤ $500 per student)			
Faculty Travel & Subsistence			$0
Student Travel			$0
Student Subsistence			$0
Other (including analyses, supplies)			
WGNHS Core Repository Fees[2] (3 days space use @ $241/days; core box re-shelving @ $4/box x 200 boxes)			$1,523
Analysis Expendables (sample vials, x-ray thin films, and related expendable supplies)			$950
Contract ICP-MS Analysis ($59.75/sample x 50 samples; $37.30 sample administration fee)			$3,025
Sample Shipping			$50
Professional Development Program (Total ≤ $1225 per student)			
Travel, Food and Lodging (flights @ $500/flight x 11 students; food @ $45/day x 5 days x 11 students; lodging @ $50/night x 4 nights x 11 students)			$10,175
Other ($60 abstract fee x 1 abstract; $275 student registration fee x 11 students)			$3,085
		Total Invoicable Amount:	**$49,807**
Expenses Paid by Consortium Office (Macalester)	units	cost	total
Faculty Fellowship	2	$9,000	$18,000
Student Fellowships	10	$3,000	$30,000
Peer Mentor Fellowship	1	$3,000	$3,000
		Total Paid by the Consortium:	**$51,000**
		TOTAL AWARD:	**$100,807**
[1] based on 2024 summer Beloit College housing and meal plans rates and annual increases			
[2] facility usage fees are set by WGNHS			

Budget Justification

Summer Project

- *Faculty Travel & Subsistence:* A total of $300 is requested for faculty members food while performing field work, calculated at $30/day for 5 days for 2 faculty members.
- *Student Travel:* A total of $5,500 is requested for student roundtrip flights to/from their home and Chicago O'Hare and then for shuttle bus tickets round trip from Chicago O'Hare to Beloit College, calculated at $500/student.
- *Student Subsistence:* A total of $23,595 is requested for student subsistence; per day Room and Board ($65/day) costs are calculated for students based on the cost of summer campus meal plans and housing in 2024 plus estimated annual rate increases. This cost includes food supplies that will be provided to students for cooking at the campsite while undertaking field work and boxed lunches while at the WGNHS core repository.
- *Other:* Ground transportation will be undertaken in two 12-passenger Beloit College vans. Beloit College vans are $8 to reserve per trip and cost $0.70/mile; budgeted mileage cost was estimated using an anticipated distance traveled of 450 miles roundtrip between Beloit and the field area, 200 miles in the field area over 5 days of field work, and 450 miles total for travel to/from the WGNHS Core Repository (150 miles roundtrip x 3 trips).

Analytical Program (Total </= $500/student per Keck Guidelines)

- *Faculty Travel & Subsistence:* None requested.
- *Student Travel:* None requested.
- *Student Subsistence:* None requested.
- *Other (WGNHS Core Repository Fees):* The WGNHS charges facility usage fees as outlined here: https://home.wgnhs.wisc.edu/research-data/research-services/. A total of $1,523 is requested to cover these fees, which includes $241/day facility space use fee (3 days requested) and a $4/box reshelving fee (200 boxes requested).
- *Other (Analysis Expendables):* As described in detail above, analyses will include XRD, SEM, pXRF, and MS. An amount of $950 is requested for expendables related to these analyses such as sample vial/bags, markers, x-ray thin films, compressed air, SEM stubs, rock saw blades, and sampling drill bits as needed.
- *Other (Contract ICP-MS Analysis):* A total of $3,025 is requested for contract ICP-MS analysis of select, high-priority samples by ALS USA Inc., calculated at $59.75/sample for 50 samples plus a $37.90 sample administration charge.
- *Other (Sample Shipping):* A total of $50 is requested for shipping sample powders to ALS USA Inc. for ICP-MS Analysis (see above).

Professional Development Program (Total </= $1,225/student per Keck guidelines)

- *Travel, Food, & Lodging:* A total of $10,175 is requested to student travel, food, and lodging associated with 11 students attending the GSA National Meeting in October 2025, calculated at $500 per roundtrip per student, $45 per day for food for 5 days, and $50 per night (3-4 students per room) for lodging for 4 nights.
- *Other:* A total of $3,085 is requested for the abstract submittal fee for the group poster presentation ($60) plus conference registration for 11 students, calculated at $275 per student.

Fellowships

- Fellowships are based on the Keck Project Proposal Guidelines.

References

Dott, R.H., Byers, C.W., Fielder, G.W., Stenzel, S.R., Winfree, K.E., 1986. Aeolian to marine transition in Cambro-Ordovician cratonic sheet sandstones of the northern Mississippi Valley, U.S.A. Sedimentology. 33, 345–367. https://doi.org/10.1111/j.1365-3091.1986.tb00541.x.

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