9-1-2012

Rock Elm Crater. Pierce County, WI: Stratigraphy of a Recently Exposed Proposed Central Peak Outcrop and Characterization of Soils

Mallery Navis
Winona State University

Christina Slowinski
Winona State University

Candace Kairies-Beatty
Winona State University

WINONA STATE UNIVERSITY | Department of Geoscience
"Forming the bedrock of responsible citizenship and success."

Nancy Peterson
Grants and Sponsored Projects Office

Re: Student Research Reports for
Mallery Navis
Christina Slowinski

May 7, 2013

Dear Ms. Peterson –

Please find attached the undergraduate research report documents for Mallery Navis and Christina Slowinski. These two students worked at the Rock Elm impact crater over this past year with Drs. Candace L. Kairies Beatty, W. Lee Beatty, and Jennifer L. B. Anderson in the Geoscience Department.

These students (along with Melissa Maslowski, James Reed, and Thomas Stromback for a total of $3000) were awarded undergraduate research funds to support their impact-cratering related projects in February 2012. These funds were used to support their field work in August 2013 at their outcrops in Pierce County, WI.

In addition, these two students were awarded a total of $1000 to support their travel to Houston, TX, to present their work at the Lunar & Planetary Science Conference in March 2013.

Please find attached a Research Project Abstract and Summary form for both students along with their co-authored LPSC abstract and the poster they presented at that conference. They also presented their poster at the Ramaley Research Celebration and gave a talk as a part of the Geoscience Department's Earth Talks Series in April 2013.

If you have any further questions, please feel free to contact one of us.

Thank you for your continued support of undergraduate research at WSU!

Sincerely,
Jennifer L. B. Anderson
Candace L. Kairies Beatty
W. Lee Beatty

Appendix C

RESEARCH / CREATIVE PROJECT ABSTRACT / EXECUTIVE SUMMARY
FINAL REPORT FORM

Title of Project
Stratigraphic characterization of the Rock Elm basin fill sedimentary rocks, western WI

Student Name Mallery Navis

Faculty Sponsor W. Lee Beatty, Jennifer L.B. Anderson, and Candace L. Kairies Beatty

Department Geoscience

Abstract
Mallery completed field work at the Rock Elm impact crater in Pierce County, WI, in August 2012. She spent the fall semester creating a stratigraphic column of the new central peak outcrop and looking for planar microstructures in thin section as well as doing additional field work as needed and continuing her background research.

Mallery submitted a co-authored abstract about her work as well as Christina Slowinski's work at the Rock Elm crater to the Lunar & Planetary Science Conference in January 2013. She attended the LPSC in March 2013 and presented as part of that conference as well as the Undergraduate Research conference held the Sunday prior to LPSC.

Mallery and Christina presented their poster at the Ramaley Research Celebration in April 2013. Mallery also gave a talk about her research as part of the Geoscience Department's Earth Talks series in April 2013.

Mallery's Earth Talks slides, LPSC abstract and poster are attached.

Thank you for supporting undergraduate research!

The end product of this project in electronic format has been submitted to the Provost/Vice President for Academic Affairs via the Office of Grants & Sponsored Projects Officer (Maxwell 161, npeterson@winona.edu).

Student Signature ____________________ Date __________

Faculty Sponsor Signature ____________________ Date __________

Appendix C

RESEARCH / CREATIVE PROJECT ABSTRACT / EXECUTIVE SUMMARY FINAL REPORT FORM

Title of Project
Characterization of soils within the Rock Elm meteroite impact structure, Western Wisconsin

- -

Student Name: Christina Slowinski

Faculty Sponsor: Candace L. Kairies Beatty, W. Lee Beatty, and Jennifer L.B. Anderson

Department: Geoscience

- -

Abstract

Christina completed field work at the Rock Elm impact crater in Pierce County, WI, in August 2012. She spent the fall semester processing and analyzing geochemical data that she obtained in WSU labs as well as data that she sent out to an analysis company. In addition, she continued her background research into soil geochemistry.

Christina submitted a co-authored abstract about her work as well as Mallery Navis's work at the Rock Elm crater to the Lunar & Planetary Science Conference in January 2013. She attended the LPSC in March 2013 and presented as part of that conference as well as the Undergraduate Research conference held the Sunday prior to LPSC.

Christina and Mallery presented their poster at the Ramaley Research Celebration in April 2013. Christina also gave a talk about her research as part of the Geoscience Department's Earth Talks series in April 2013.

Christina's Earth Talks slides, LPSC abstract, and poster are attached.

Thank you for supporting undergraduate research!

- -

The end product of this project in electronic format has been submitted to the Provost/Vice President for Academic Affairs via the Office of Grants & Sponsored Projects Officer (Maxwell 161, npeterson@winona.edu).

Student Signature ______________________ Date ____________

Faculty Sponsor Signature ______________________ Date ____________

Rock Elm Crater, Pierce County, WI: Stratigraphy of a Recently Exposed Proposed Central Peak Outcrop and Characterization of Soils.
C.M. Slowinski[1], M.M. Navis[1], C.L. Kairies Beatty[1], W.L. Beatty[1], J.L.B. Anderson[1] and H.A.S. Dolliver[2]. [1]Department of Geoscience, Winona State Univ., Winona, MN. [2]Department of Plant and Earth Science, Univ. of Wisconsin River Falls, River Falls, WI. (corresponding author: JLAnderson@winona.edu)

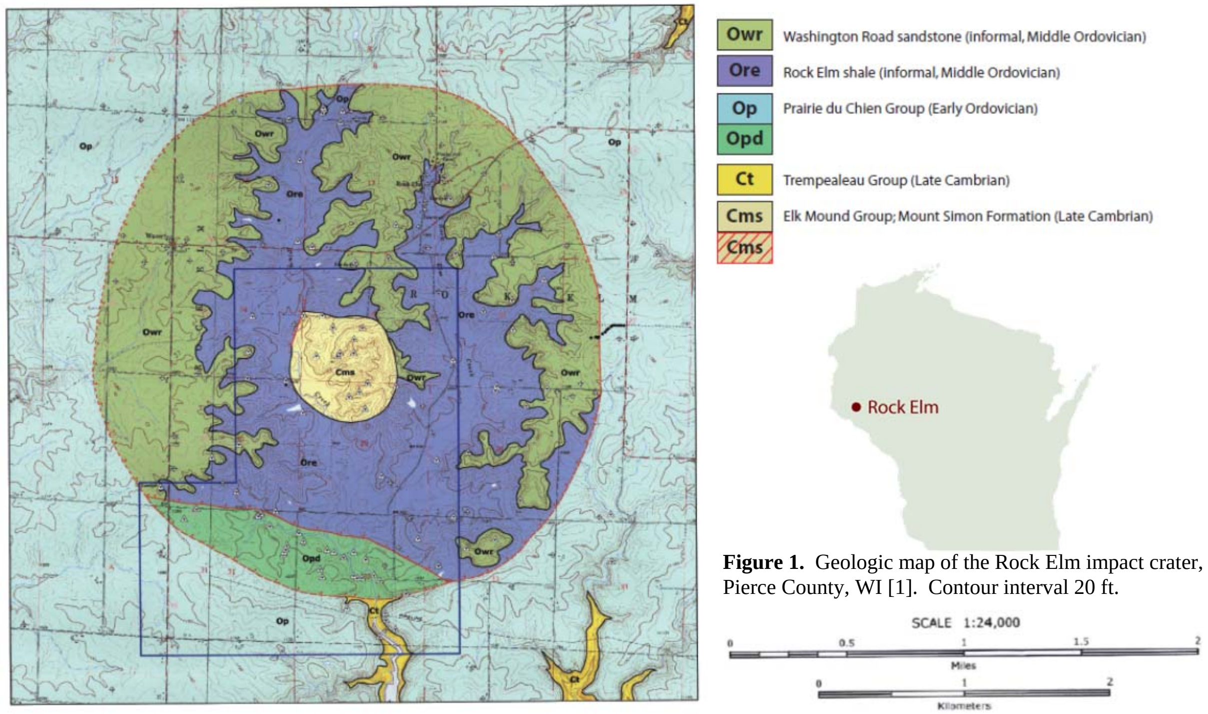


Figure 1. Geologic map of the Rock Elm impact crater, Pierce County, WI [1]. Contour interval 20 ft.

Introduction: The Rock Elm crater (Figure 1), Pierce County, WI, is Ordovician in age[1]. This 6.5 km diameter complex crater has a central peak likely composed of the Mt. Simon Sandstone, lifted 250-300 meters above its normal stratigraphic position[2]. Since the crater's formation, the region has undergone heavy glaciation that has removed the ejecta deposit and the uplifted crater rim. Two sedimentary units fill the crater: the Rock Elm Shale and the Washington Road Sandstone. These units are unique to the crater [2].

Our group is currently working on two lines of research at the Rock Elm crater. First, we are characterizing a sandstone outcrop within the central peak area that was recently uncovered by the landowners. We present here the first stratigraphic analysis of that outcrop and compare it to other sandstones in the region to determine if it is related to the Mt. Simon Sandstone. Second, we are investigating anecdotal information that the soils developed within the crater on the Rock Elm Shale are of poorer agricultural quality than the soils formed outside the crater on the Decorah Shale. We are analyzing the chemical and physical properties of these soils to evaluate this claim.

Methods – Stratigraphy: Four sections of the newly discovered proposed central peak outcrop were selected for in-depth stratigraphic analysis. Multiple sections were chosen so that both vertical and lateral variation within the outcrop could be examined. At each study site, the vertical succession of rocks was carefully measured and described in detail and representative samples from the dominant lithologies were collected. A high-resoution panorama of the outcrop was captured using a GigaPan Epic robotic camera mount. A detailed graphic log of each of the stratigraphic sections was created. Petrographic thin sections of the rock samples are being prepared.

Methods – Soils: Soil cores were collected at six different locations (three inside and three outside the crater) where soils developed either on the Rock Elm Shale (inside the crater) or on the Decorah Shale (outside the crater). At each site, a bucket auger was used to obtain a soil core. Coring stopped once the C horizon (partially altered parent material) was reached (approximately 1.5 m). Each soil core has 3-5 horizons, delineated by major differences in soil forming processes. The color of each horizon within a core sample was determined using the Munsell® Color Chart and each core was photographed. Texture of each sample was evaluated using field techniques (feel/ribboning). Samples from each horizon were placed in separate, labeled Ziploc® bags and returned to the lab. A sample of the Rock Elm Shale was also collected.

The pH of each soil horizon within a core was determined by mixing 10 g of sample with 10 mL of reverse osmosis (RO) water. The pH was then measured using a Hach® pH meter and probe. Percent moisture of each of the soil samples was determined by drying 5 g of sample in an oven at 105 ^{o}C until the weights were constant (about 72 hours).

Preliminary Results – Stratigraphy: Four dominant lithologies were observed at the new outcrop: a bedded mudstone; an iron-stained siltstone; a fine, bedded sandstone; and a friable, poorly sorted massive sandstone. Each of these lithologies is present laterally across the outcrop.

Preliminary Results – Soils: The pH of soils within the crater consistently decrease with core depth (Figure 2). The pH of the soil outside the crater is inconsistent and no trends are evident within the cores or between the three sites (Figure 3).

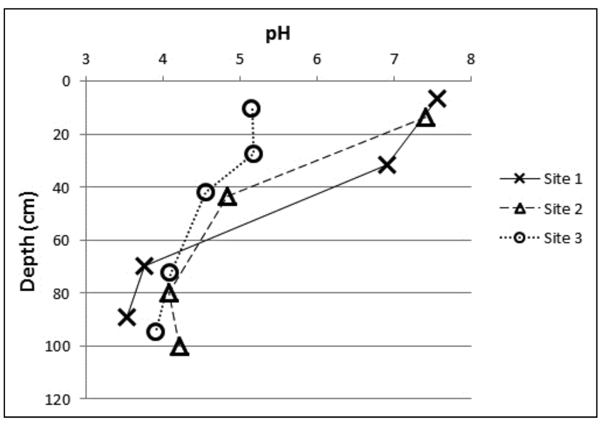


Figure 2. pH of soils within the Rock Elm impact crater.

Future work – Stratigraphy: We plan to analyze the thin sections of samples collected from the proposed central peak area as well as samples collected from known Mt. Simon formation outcrops. We hope to correlate this new sandstone outcrop with one of the three sandstone units in the region (Mt. Simon, Jordan, or St. Peter sandstones). We will also compare it to previous studies of other central peak outcrops at the Rock Elm crater[2]. In particular, we will examine thin sections for evidence of shock metamorphism, such as planar deformation features, that would indicate an impact event.

Future Work – Soils: Additional sample analyses will be completed to fully characterize the chemical and physical properties of the soils that developed in the Rock Elm impact crater. In particular, trace and major elemental composition for the Rock Elm shale sample and each of the soil samples will be determined using a four-acid digestion (hydrochloric, nitric, perchloric, and hydrofluoric acids) followed by analysis using inductively coupled plasma-optical emission spectroscopy (ICP-OES) at Activation Laboratories in Ancaster, Ontario, Canada. The data will be used to compare the geochemistry of soils within the crater to soils in other parts of Pierce County.

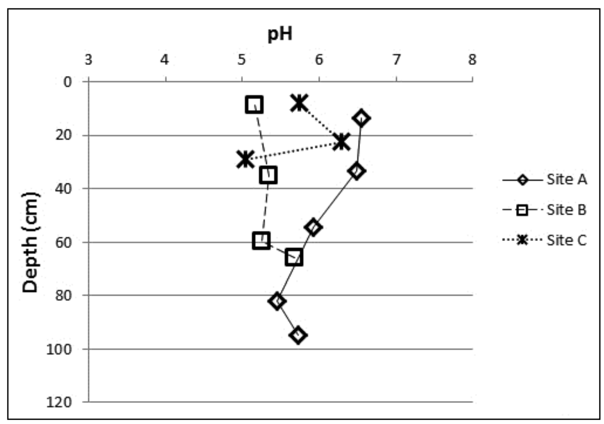


Figure 3. pH of soils outside the Rock Elm impact crater.

Acknowledgements: We would like to thank Dr. William Cordua (UW-River Falls) and Luke Zweifelhofer (WSU) for their assistance. We would also like to thank James Reed, Thomas Stromback, and Melissa Maslowski for their assistance in the field. This project is funded by a WSU Undergraduate Student Research Award and WSU Faculty Professional Improvement Funds.

References: [1] Cordua, W. (1985) *Geology, v13,* 372-374. [2] French, BM et al. (2004) *GSA Bulletin, 116,* 200-218.

Rock Elm Crater, Pierce County, WI: Stratigraphy of a Recently Exposed Proposed Central Peak Outcrop and Characterization of Soils.

C.M. Slowinski, M.M. Navis, C.L. Kairies Beatty, W.L. Beatty, J.L.B. Anderson, and H.A.S. Dolliver
Department of Geoscience, Winona State University, Winona, MN. (corresponding author: JLAnderson@winona.edu)

Introduction

The Rock Elm crater (Figure 1), Pierce County, WI, is Ordovician in age[1]. This 6.5 km diameter complex crater has a central peak proposed to be Mt. Simon Sandstone uplifted 250-300 meters above its normal stratigraphic position[2]. Subsequent heavy glaciation has removed the ejecta deposit and the uplifted crater rim. Two sedimentary units fill the crater: the Rock Elm Shale and the Washington Road Sandstone; neither is found outside of the crater[2]. We present here two lines of research at the Rock Elm crater: (1) stratigraphic characterization of a newly uncovered sandstone outcrop within the central peak area, and (2) geochemical analysis of soils developed within the crater on the Rock Elm shale compared to soils outside of the crater; anecdotal information implies that soils within the crater are of poorer agricultural quality than outside soils.

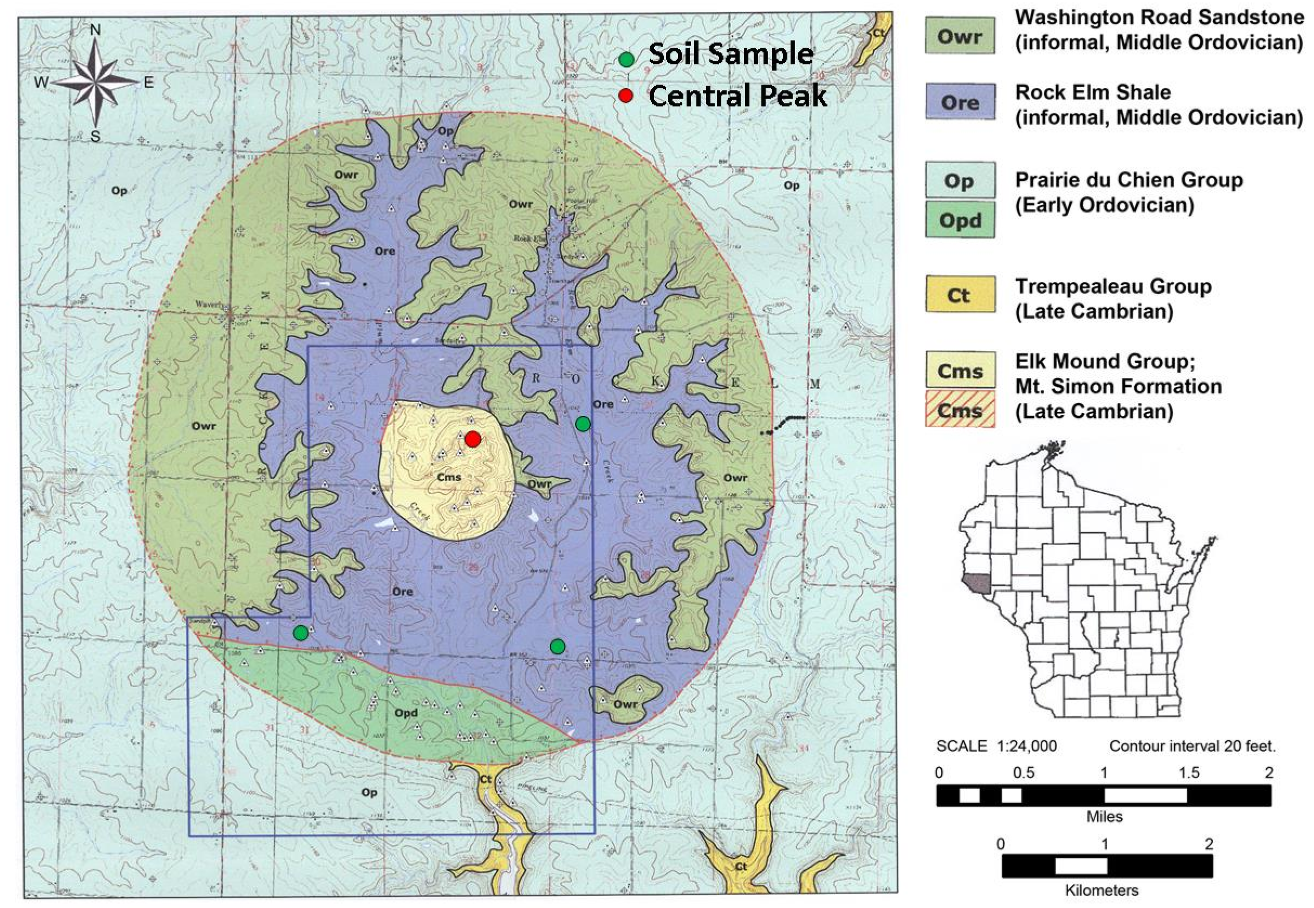
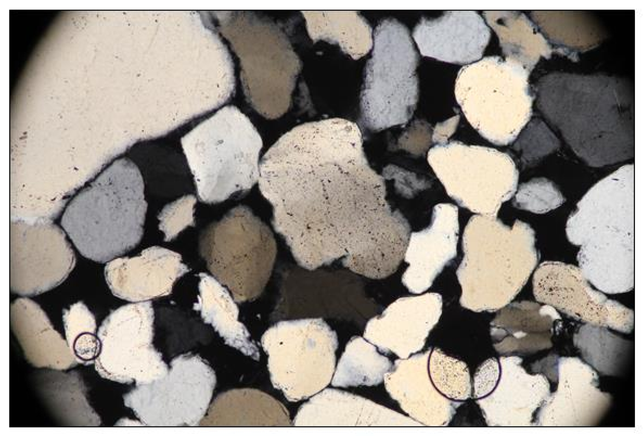


Figure 1. Geologic Map of the Rock Elm impact crater, Pierce County, WI [1].

Unshocked Mt. Simon Sandstone

Figure 2. Mt Simon sandstone is fine to coarse grained, poorly sorted, and quartz rich. Its color is orange to light gray weathered. This sample was collected from a basal unit of Mt Simon Sandstone near Eau Claire, WI. Viewed at 100x, cross-polarized light.

0.5 mm



Proposed Central Peak Outcrop

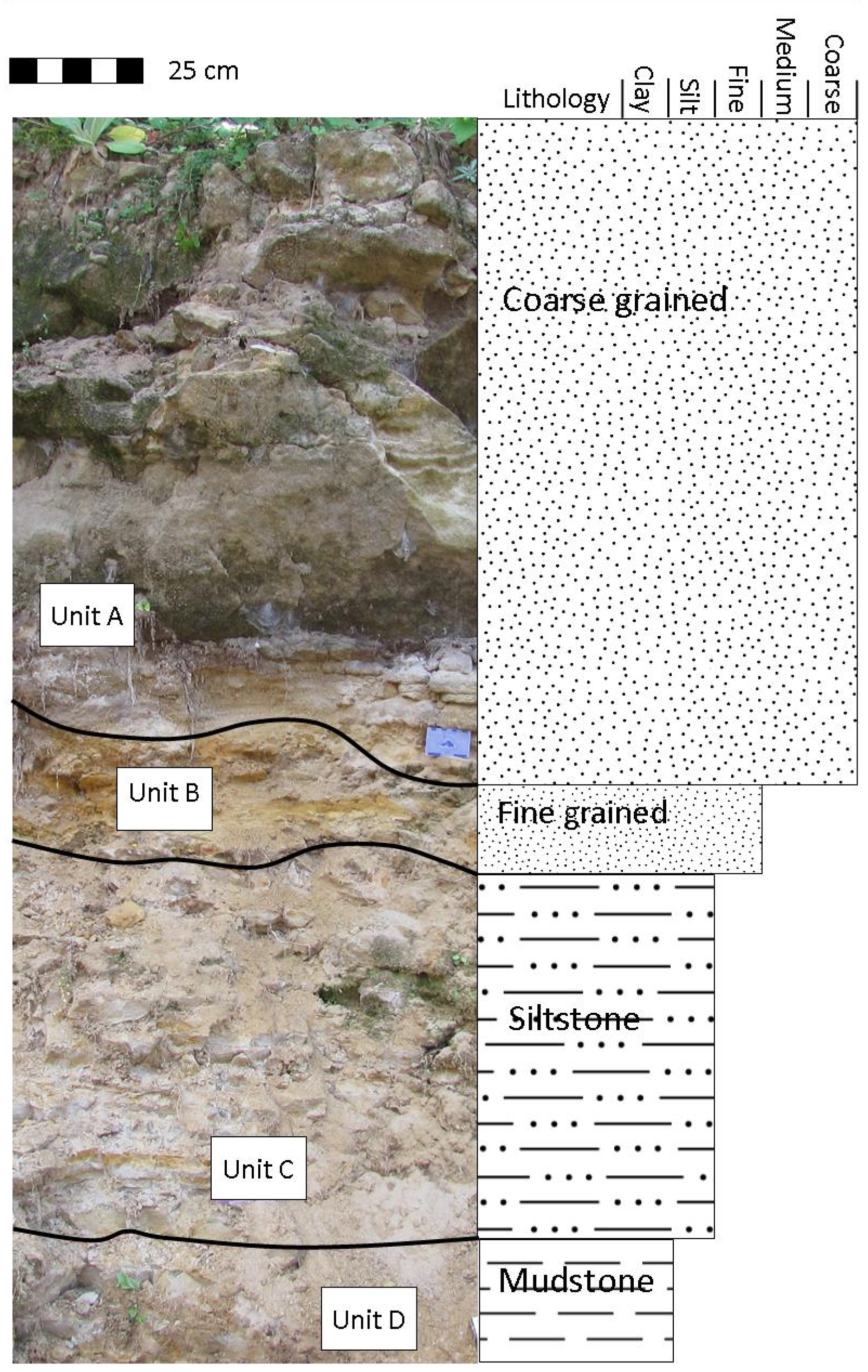


Figure 3. Vertical cross-section from proposed central peak outcrop. Outcrop is 41 m long and maximum of 2.4 m high, facing East. No fossils were apparent in any unit.

- Unit A: Friable, massive, poorly sorted, quartz-rich sandstone. Rounded to very well rounded grains with a few pebbles. Tan-orange in color, weathers to light grey.
- Unit B: Friable, moderately sorted, quartz-rich sandstone interbedded with very well indurated layers. Angular to sub-angular clasts. Orange in color, weathers to light grey or tan. Localized areas of red banding.
- Unit C: Moderately indurated, very well sorted siltstone. Bedding is ~3 cm thick. Light tan to orange in color, weathers to brown.
- Unit D: Very fine grained clay to silt-sized mudstone. Bedding is ~4 cm thick. Light grey to tan on fresh surface.

Central Peak Outcrop Conclusions

The presence of planar fractures, planar deformation features, and "feather feature lamellae" [3] indicate that these rocks underwent shock metamorphism and demonstrates that this newly uncovered outcrop is a part of the central peak of the Rock Elm impact crater. Based on rock descriptions and descriptions of regional sandstones of this age, we conclude that this outcrop is composed of Mt. Simon Sandstone and originally was 250-300 meters below the surface.

Evidence of Shock Metamorphism

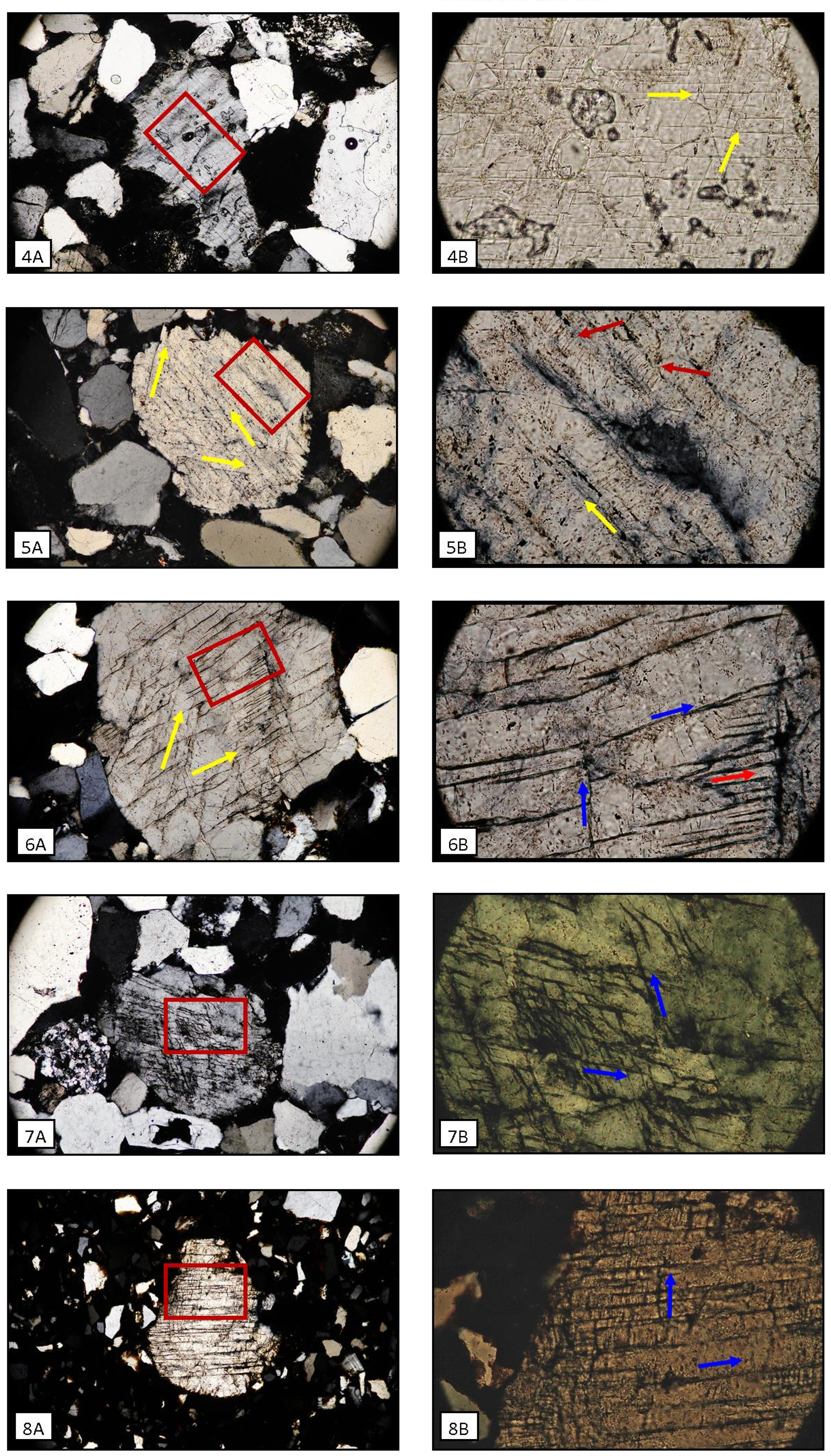
Figures 4-8. Evidence for shock metamorphism was found in grains from Unit A (Fig 4-7) and Unit B (Fig 8) including planar fractures (blue), planar deformation features (yellow), and feather features [3] (red arrows).

Left column: 100x, all cross-polarized.

0.5 mm

Right column: 400x, Plane-polarized (1,2), Cross-polarized (3-5).

Field of View 0.45 mm



Soil Geochemistry Methods

Soil cores were collected at six different locations (three inside and three outside the crater) where soils developed either on the Rock Elm Shale (inside the crater) or on the Decorah Shale (outside the crater). Coring stopped once the C-horizon (partially altered parent material) was reached (approximately 1.5 m). Each soil core has 3-5 horizons, delineated by major differences in soil forming processes (Figure 9). The pH of each soil horizon within a core was determined by mixing 10 g of sample with 10 mL of reverse osmosis (RO) water and measured using a Hach® pH meter and probe. Bulk density was determined using the paraffin clod method. Trace and major elemental composition for each horizon were determined using a four-acid digestion (hydrochloric, nitric, perchloric and hydrofluoric acids) followed by analysis using inductively coupled plasma-optical emission spectroscopy (ICP-OES) at Activation Laboratories in Ancaster, Ontario, Canada.

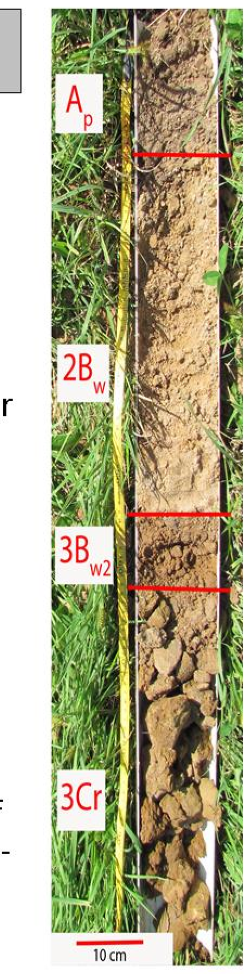


Figure 9. Example soil core collected from the Rock Elm Area. The Ap horizon is the layer of organic rich topsoil, which in this case has been plowed. The B horizons are zones of deposition of minerals and other constituents from above and below. The C horizon is the area of partially altered parent material.

Soils Results

The pH of soils within the crater consistently becomes more acidic with core depth (Figure 10A). The pH of the soil outside the crater is inconsistent and no trends are evident within the cores or between the three sites (Figure 10B), though pH is generally higher in these soils compared to those within the crater.

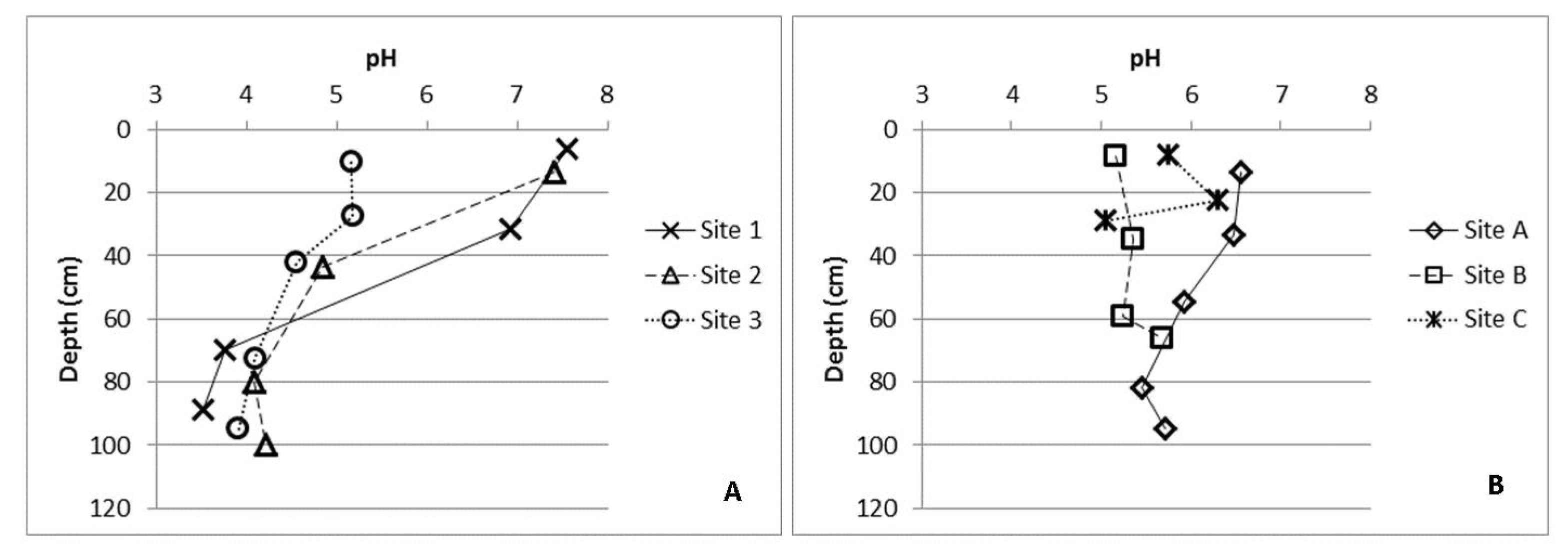
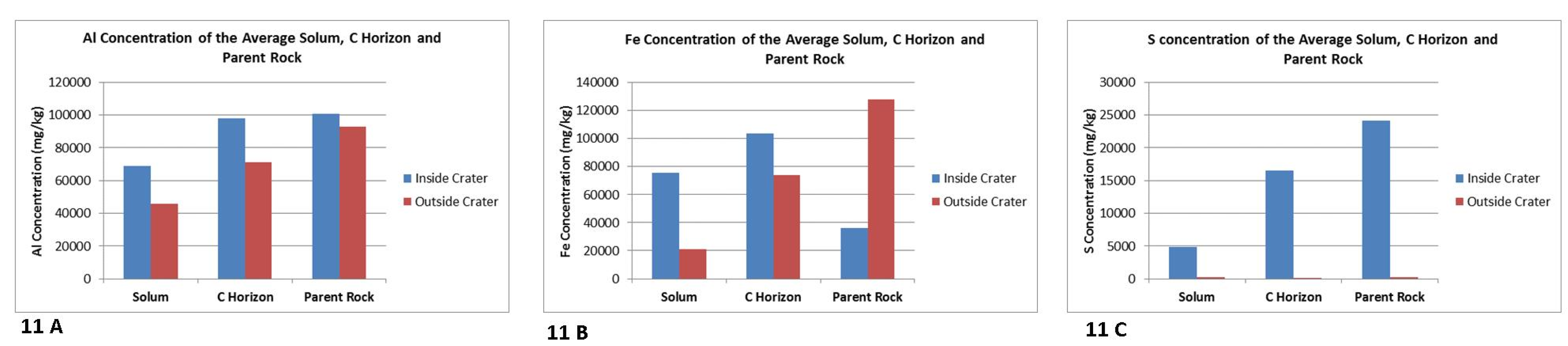


Figure 10. Soil pH inside (A) and outside (B) the crater.

Soil geochemistry was evaluated by averaging individual elemental concentrations of the solum (the A, E and B horizons) and of the parent material (C horizon) for soil cores inside the crater and soil cores outside the crater and comparing the averages to the geochemical data reported by Cordua [4] for the Rock Elm and Decorah shales. The concentrations of Al, Fe, and S are higher in the soils developed on the Rock Elm Shale than those developed on the Decorah Shale (Figure 11) with sulfur exhibiting the greatest difference. Although not shown, a number of trace elements, including Cu, Cr and Zn were also higher for soils inside the crater.

Figure 11. Elemental composition of the average solum, C horizon and parent material for soils inside and outside the crater: (A) Al, (B) Fe and (C) S.



Soils Discussion & Conclusions

The high concentrations of Fe and S in the soils developed within the crater and their associated Rock Elm parent material could indicate the presence of pyrite in the parent rock. The acidity generated through pyrite dissolution would account for the lower pH values observed inside the crater. The high concentration of Fe in the solum indicates the presence of iron oxides and hydroxides, which are highly effective adsorbents of a variety of trace metals and could explain the elevated concentrations of trace elements seen in the solum of the Rock Elm soils. Our results support the anecdotal evidence that implies that soils within the crater are of poorer agricultural quality than soils outside the crater. However, additional work is necessary to confirm the presence of pyrite in this material.

In comparing the mineralogy of other Ordovician shale (including the Decorah Shale) to that of the Rock Elm Shale, Cordua [4] concluded that the Rock Elm shale likely experienced a greater degree of weathering and possibly originated from a different parent rock. These differences would subsequently influence the resulting geochemistry of the associated soil and could account for the differences seen here.

References

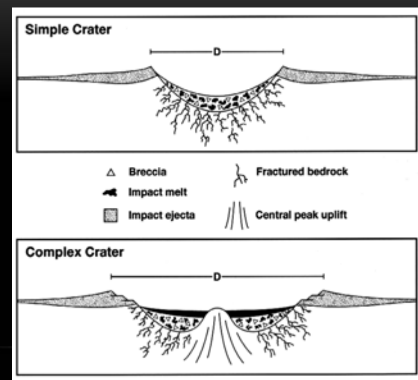
[1] Cordua, W. (1985) *Geology, v13,* 372-374. [2] French, BM et al. (2004) *GSA Bulletin, 116,* 200-218. [3] Poelchau, MH and Kenkmann, T. (2011) *JGR Solid Earth, v116,* B02201. [4] Cordua, W. (2007) Wisconsin Geological and Natural History Survey report.

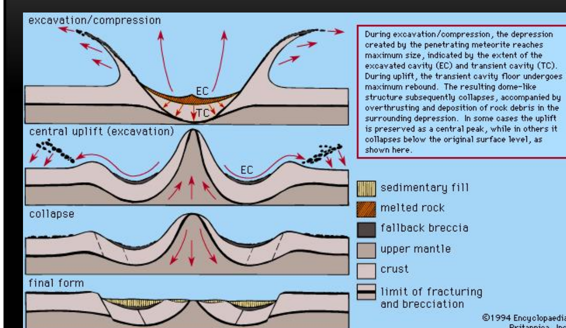
Acknowledgements

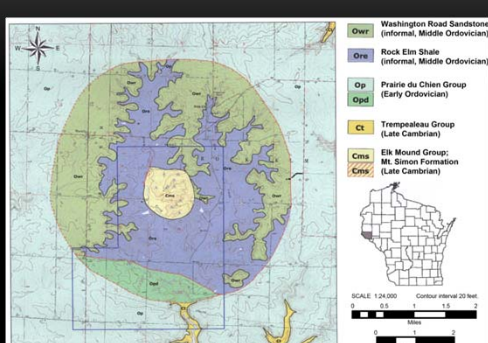
We would like to thank Dr. William Cordua (UW-River Falls) and Luke Zwiefelhofer (WSU) for their assistance. We would also like to thank James Reed, Thomas Stromback, and Melissa Maslowski for their assistance in the field. This project is funded by a WSU Undergraduate Student Research Award, Undergraduate Student Travel Fund, and Faculty Professional Improvement Funds. Partial funding for LPSC was provided by NASA's Science Mission Directorate through the YSS Undergraduate Conference.

STRATIGRAPHY OF A RECENTLY EXPOSED CENTRAL PEAK OUTCROP OF THE ROCK ELM CRATER, PIERCE COUNTY, WI

M.M. Navis, C.L. Kairies Beatty, W.L. Beatty, J.L.B. Anderson







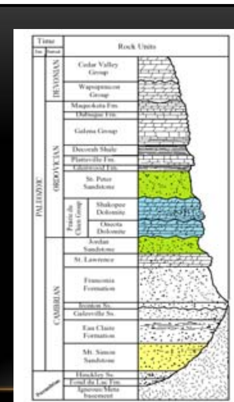
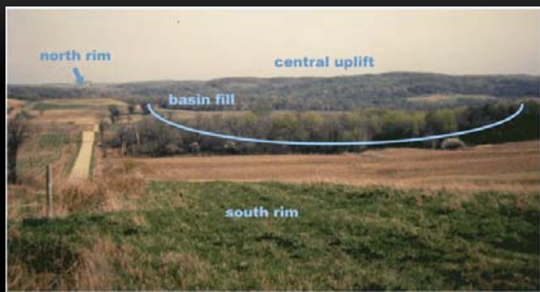


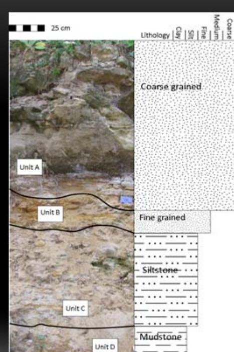
Figure 2. Generalized Paleozoic rock column for southeastern Minnesota.



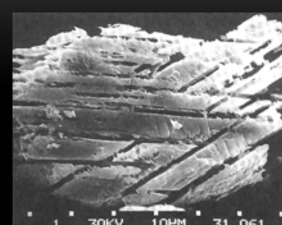
OBJECTIVES

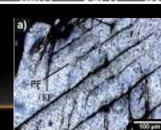
1. Look for evidence of shock metamorphism
2. Compare lithology to regional sediment types specifically Mt. Simon

FIELD/LAB WORK

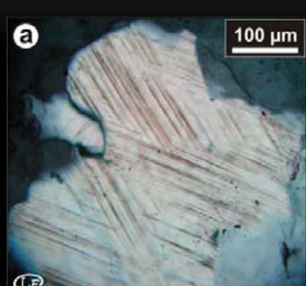


PLANAR FRACTURES





PLANAR DEFORMATION FEATURES



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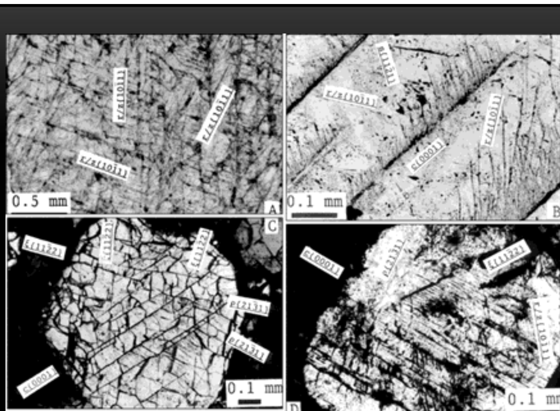
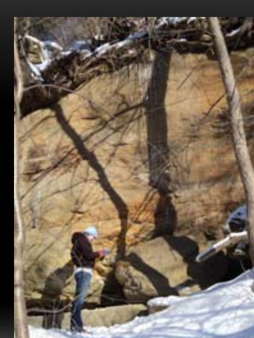
MY SEARCH FOR SHOCK METAMORPHISM



CORRELATION WITH MT SIMON FORMATION



Mt Simon, Chippewa Falls (below)

- Massive to tabular cross bedding
- Quartz (95%) Feldspar(~5%)
- Light gray, tan fresh surface
- Medium to coarse sand size
- Some trace fossils.
- Poorly sorted sandstone

Unit "A" sample (above)

- Massive blocky sandstone
- Mostly Quartz content (~95%)
- Grains are sub-rounded to angular
- Light Gray, tan fresh surface, gray and orange weathered surface
- Grain size: medium to very coarse sand and some pebbles (~1 cm)
- No apparent fossils or bedding
- Moderate to poorly sorted

CONCLUSIONS

ACKNOWLEDGEMENTS

- I would like to thank Luke Zwiefelhofer for all of his assistance.
- I would also like to thank, James Berglund, James Reed, Thomas Stromback, and Melissa Maslowski for their assistance in the field.
- This project is funded by a WSU Undergraduate Student Research Award, Undergraduate Student Travel Fund, and Faculty Professional Improvement Funds. Partial funding for LPSC was provided by NASA's Science Mission Directorate through the YSS Undergraduate Conference.

REFERENCES

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- Illustrations: Wisconsin USGS, www.meteorimpactonearth.com

Rock Elm Crater, Pierce County, WI: Characterization of Soils

C.M. Slowinski, C.L. Kairies Beatty, W.L. Beatty, J.L.B. Anderson, H.A.S. Dolliver

Intro

Rock Elm, WI

Units of Interest:

- Outside Crater: Decorah Shale
- Inside Crater: Rock Elm Shale

Why do we care?

- Soils on top of the Rock Elm shale are claimed to be of poor agricultural quality

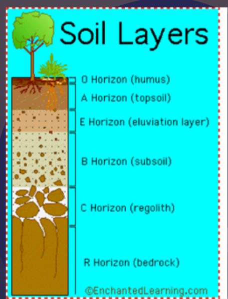
Methods

Field and Lab

Learning about soil horizons. Pictured: Melissa Maslowski, Christina Slowinski, Dr. Dolliver

Sampling a soil core with an auger. Pictured: Christina Slowinski, Thomas Stromback

Field Work



A: layer of organic rich topsoil, which in this case has been plowed

B: zones of deposition of minerals and other constituents from above or below

C: area of partially altered parent material

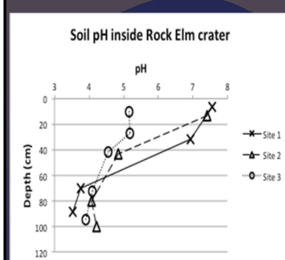
Soil Horizons

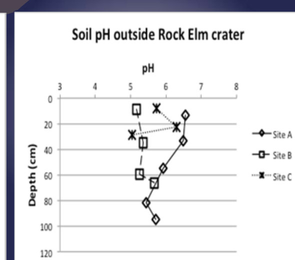
- Determined pH of each soil horizon
- Determined bulk density using the paraffin clod method
- Trace and major elemental composition for each horizon

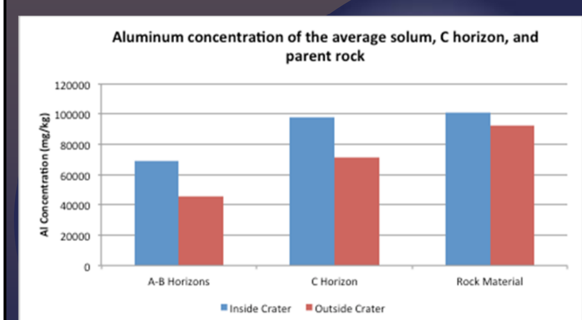
Lab Work

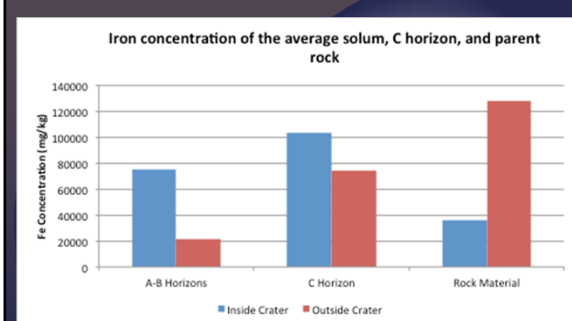
Results

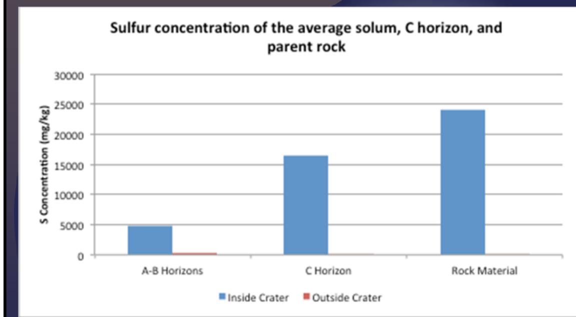
pH and Trace and Elemental composition



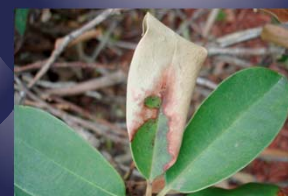








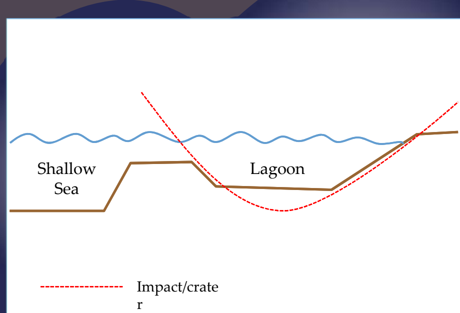
- Plants main nutrients are Nitrogen, Phosphorus, and Potassium
- Only small amounts of Sulfur and Iron are needed
- Aluminum is not needed for plant growth



Discussion/Conclusion

Pyrite?

- High concentrations of Fe in the solum = presence of iron oxides and hydroxides
- Fe + S → Pyrite
- Pyrite dissolution →higher acidity → lower pH



Future Plans

What's next for the project?

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