The Compass: Earth Science Journal of Sigma Gamma Epsilon

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THE COMPASS

Earth Science Journal of Sigma Gamma Epsilon

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THE SOCIETY OF SIGMA GAMMA EPSILON

Editor: Scott R. Beason

https://www.sgeearth.org

On this page...

Collage of activities associated with the Geology program at the University of Tennesse at Martin, clockwise from upper left: (1) University of Tennessee President Randy Boyd talking to the Coon Creek lead docent at the opening of the University of Tennessee at Martin Coon Creek Science Center in 2019; (2) Coon Creek Science Center Director Michael Gibson answering questions by visiting fossil collectors; (3) Eric Perlen, Natural Resources, conducting stream sampling; and (4) The official state fossil of Tennessee—*Pterotrigonia thoracia*—from the Cretaceous Coon Creek Formation.

Photo Credit: University of Tennessee at Martin

On the cover...

The Joseph E. Johnson Engineering and Physical Sciences (EPS) building at the University of Tennessee at Martin, home to the College of Engineering and Natural Sciences.

Photo Credit: University of Tennessee at Martin

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About the Society of Sigma Gamma Epsilon

PURPOSE AND OBJECTIVE

The Society of Sigma Gamma Epsilon (SGE) was founded to recognize scholarship and professionalism in the Earth Sciences. It has for its objectives the scholastic, scientific, and professional advancement of its members and the extension of relations of friendship and assistance among colleges and universities which are devoted to the advancement of the Earth Sciences.

HISTORY AND GOVERNMENT

The Society was established on March 30, 1915, at The University of Kansas. Over 200 chapters throughout the United States have been installed since 1915. Government of the Society is by student members and the ultimate legislative authority is vested in a National Convention held every two years. It is composed of one student delegate from each chapter and the seven national officers who are faculty members. The Constitution and Bylaws of the Society are located at https://www.sgeearth.org/about/.

WHY SHOULD I JOIN?

Membership in Sigma Gamma Epsilon and the listing of it on one's résumé (or the wearing of a member's pin) tells a prospective employer or a colleague that you are at least a "B" average student and that in the eyes of your peers you are professionally motivated. Members serve their departments in a number of ways such as organizing field trips, tutoring, arranging displays, and many others. Many chapters have money-raising activities to obtain funds to use for scholarships and awards or to purchase items needed for student use or to assist the department in other ways.

Members of Sigma Gamma Epsilon are encouraged to submit articles to the Society's professional journal, *The Compass*, as it provides the opportunity to share your research with the Society. *The Compass* contains student papers and articles by practicing earth scientists in addition to news and notes about the Society.

Also, as an associated society of the Geological Society of America, Sigma Gamma Epsilon members are entitled to discounted rates for registration at the annual national meetings.

HOW CAN I JOIN?

Any person in any branch of the Earth Sciences who has completed at least 10 semester hours or 15 quarter hours in Earth Science courses and has maintained a minimum 3.0 G.P.A. (on a 4.0 system) in all Earth Science courses together with an overall G.P.A. of 2.67 in all college courses is qualified for membership. If you qualify and wish to join, you need only inform any officer or the Advisor of your department's chapter and they can propose you for membership. Initiation of new members is typically held both fall and spring semesters.

FEES AND DUES

A one-time fee of $55.00 provides lifetime membership if initiated after August 1, 2021. If initiated before August 1, 2021, an additional fee of $15.00 is required for lifetime membership.

DOES YOUR SCHOOL HAVE A CHAPTER?

A list of chapters can be found at https://sgeearth.org/chapters/. If you do not now have an active chapter of Sigma Gamma Epsilon at your college or university, the National Office will gladly furnish information and give assistance in reactivating an inactive chapter or chartering a new chapter.

FOR MORE INFORMATION

Visit the website for SGE at https://sgeearth.org for updated information about The Society, resources, products, a calendar of important upcoming dates, frequently asked questions, and other information.

SGE Website

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Email: admin@sgeearth.org
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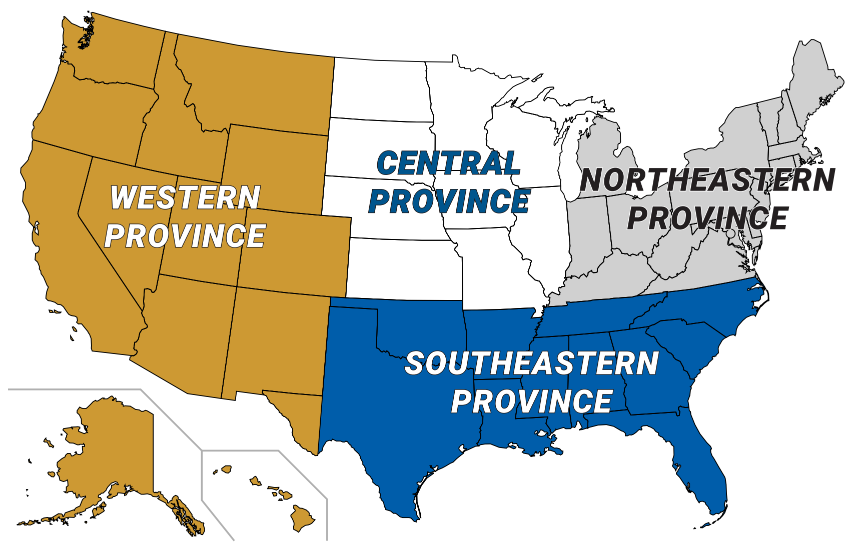

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Eck F. Schramm	1932–1938
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Robert L. Kidd	1940–1942
William A. Staab	1942–1949
Clark B. Carpenter	1949–1953
Fred M. Bullard	1953–1958
Ralph E. Esarey	1958–1960
Edward A. Frederickson	1960–1965
Hubert C. Skinner	1965–1970
Frank D. Holland, Jr.	1970–1975
Hubert C. Skinner	1975–1978
George R. McCormick	1978–1982
Gerald M. Friedman	1982–1986
Austin A. Sartin	1986–1990
Daniel F. Merriam	1990–1995
James C. Walters	1995–2000
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Erika R. Elswick	2010–2015
Aaron W. Johnson	2015–2017
Diane M. Burns	2017–2022
Steven W. Bennett	2022–Present

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Frederick Byron Plummer	1929
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F. Afton Wade	1938
Hugh Densmore Miser	1949
John L. Rich	1953
George Evert Condra	1954
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J Harlen Bretz	1978
Frank D. Holland, Jr.	1978
Charles J. Mankin	1984
Gerald M. Friedman	1986
Kenneth E. Caster	1986
Austin A. Sartin	1990
Daniel F. Merriam	1995
Don C. Steinker	1995
James C. Walters	2007
Larry E. Davis	2022

CALL TO CONVENTION

47th Biennial Convention of Sigma Gamma Epsilon

The Delta Psi chapter of SGE at Western Illinois University will be hosting the 47th biennial convention at its Quad City campus in Moline, Illinois. We hope to see you there!

April 11–13, 2025 — Moline, IL

See Article 1 in this issue (Page 95) for more details and registration information.

Sigma Gamma Epsilon products

Products on this page may be purchased by scanning the QR code to the right or clicking on the following link: https://www.cognitoforms.com/SigmaGammaEpsilon1/OrderForm

Please check your institution's policy regarding the wearing of stoles or cords for graduation before purchasing.

SGE Graduation Honor Stoles

$25.00

The SGE stole displays the gold, blue, and silver colors of the Society in addition to its symbol and Greek letters.

Please allow 3 weeks for delivery and specify date of graduation when ordering.

Graduation Honor Cords

$15.00

These SGE cords display the colors of the Society – gold, blue, and silver.

Please allow 3 weeks for delivery and specify date of graduation when ordering.

Clutch-back Cloisonné Pin

$5.00

Enameled pin 3/4 x 1/2 in tip-to-tip, blue background, white, siler, and gold.

** Each member receives this pin with their certificate and member card at initiation*

Clutch-back Centennial Pin

$5.00

Enameled pin, 1" diameter, white background, gray, blue, and gold.

Pin-back Cloisonné Pin

$5.00

Enameled pin 3/4 x 1/2 in tip-to-tip, blue background, white, siler, and gold.

Centennial Patch

(Limited Availability)

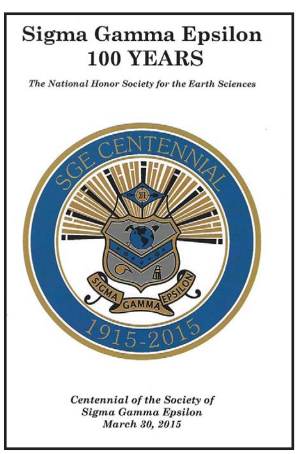
$5.00

The crest of blue, silver, and gold on a light gray background with metallic gold lettering, approximately 3.5" in diameter.

Sigma Gamma Epsilon 100 YEARS

$10.00

Engaging articles highlight the 100 year history of Sigma Gamma Epsilon in this glossy, 58-page book. 2015



All prices include shipping and handling

Please allow 3-4 weeks for delivery

If you would like to mail in your payment, please submit the order at the link above and mail the check or money order made payable to Sigma Gamma Epsilon to:

Sigma Gamma Epsilon
P.O. Box 324
Cedar Falls, IA 50613

Important upcoming dates

ACADEMIC REGALIA FOR GRADUATION

Please submit your orders for Honor Cord sets or Honor Stoles with 10 business days lead time so we may process the order. Regalia orders for more than one graduate will be shipped to the chapter advisor.

NOVEMBER 1, 2024

Deadline for submission of Fall 2024 Chapter Members Form (found at https://sgeearth.org/officer-resources/ > Member Form).

Be sure to include returning Life Members even if you only initiate new members in the Spring. This is a prerequisite for applying for the Quality Chapter Award.

APRIL 11–13, 2025

47th Biennial Convention of SGE

Delta Psi (Western Illinois University) will be hosting the next biennial convention at its Quad City campus in Moline, Illinois. See the call to convention article in this issue for more information!

OCTOBER 19–22, 2025

GSA Annual Meeting & Exposition

San Antonio, Texas, USA

OCTOBER 11–14, 2026

GSA Annual Meeting & Exposition

Denver, Colorado, USA

OCTOBER 17–20, 2027

GSA Annual Meeting & Exposition

Montreal, Quebec, Canada

Contributing your work to *THE COMPASS*

RESEARCH ARTICLES

THE COMPASS is continuously looking for research articles submitted by undergraduate and graduate level students, as well as their advisors, faculty members, and outside researchers. All work submitted to *THE COMPASS* undergoes peer review prior to publication. There are no publication fees for *THE COMPASS* and all final journal articles are Open Access and hosted on the Digital Commons® platform at the College of Saint Benedict and Saint John's University.

All work submitted for consideration should be original research. Articles should contain appropriate sections such as introduction, background, study area, results, dicussion, and/or conclusions. Articles generally contain figures, tables, and/or appendicies.

ON THE OUTCROP

Beginning with Volume 84, *THE COMPASS* will feature a series titled "On the Outcrop." The purpose of this feature is to highlight an outcrop of geological significance with photos and a brief article. More information about this format can be found here: https://digitalcommons.csbsju.edu/compass/ontheoutcrop.html

CHAPTER NEWS AND NEWS UPDATES

Chapter news and news updates for the society should be sent to the National Editor no later than the dates noted below. Letters to the society may also be submitted in this format.

PUBLICATION SCHEDULE

- Issue 1: January 1 (materials due October 31)
- Issue 2: April 1 (materials due January 31)
- Issue 3: July 1 (materials due April 30)
- Issue 4: October 1 (materials due July 31)

SUBMITTING A MANUSCRIPT

A Manuscript Template (Microsoft Word document) and Digital Repository Material Contribution Form can be found at https://digitalcommons.csbsju.edu/compass/instructions.html. Submit all necessary materials and refer any questions to the National Editor at editor@sgeearth.org. Please utilize the Manuscript Template when submitting articles.

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News Update

Sigma Gamma Epsilon – Call to Convention: First Notice

The National Council has accepted an invitation from the Delta Psi Chapter (Western Illinois University) to host the Society's 47th Biennial Convention on WIU's Quad Cities Campus – located in Moline, Illinois, on the east bank of the Mississippi River. The convention is scheduled for April 11–13, 2025, and planning is underway. The Friday afternoon through Sunday noon schedule is designed to minimize the number of class days that delegates would need to miss. The Quad Cities International Airport (MLI) serves the area. At this time, we encourage chapters to "save the date" and to start making plans for a delegate to attend. We welcome chapters to send more than one member if possible; chapter advisors are also welcome and encouraged to attend.

In addition to being a lot of fun and a chance to expand networking—there will be field trip to explore the local geology on Saturday—the biennial conventions serve an important function in that the delegates set policy for SGE as a student-run organization. Your national officers advise and carry out the policies established at the national conventions. For this convention, the National Office will provide a $500 stipend for one official delegate from each active chapter. Alternates will receive stipends of $50. Chapter advisors participating in this meeting will receive $250 stipends. Stipends can be combined if your chapter would like to bring a group (e.g. – rent a van and travel together). Meals and lodging during the meeting will be provided.

Complete details, including registration instructions, will be provided to chapters at a later date.

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Left: Wildcat Den State Park; Left center: Black Hawk State Historic Site; Right center: Western Illinois University–Quad Cities Riverfont Campus; Right: Fryxell Geology Museum, Augustana College.

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Available at: https://digitalcommons.csbsju.edu/compass/vol93/iss2/1

LETTER

Introduction to the issue: University of Tennessee at Martin Eta Alpha Chapter volume

Michael A. Gibson*

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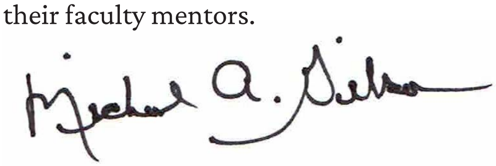
Welcome to the Eta Alpha Chapter volume of The Compass. The geosciences degree program at The University of Tennessee at Martin celebrated its 50th anniversary in 2022, just in time for the 46th Biennial Convention of Sigma Gamma Epsilon. The cover photo for this volume depicts the Joseph E. Johnson EPS (Engineering and Physical Sciences) Building that has been the home of the geosciences program since its construction in 1960. This volume is a series of papers that were initially compiled to be part of the 46th biennial convention volume that was to occur in 2019; however, the COVID-19 pandemic, along with additional scheduling difficulties, forced a hiatus of that meeting and consequently this volume. The papers in this volume present the history of the geology program at the University of Tennessee at Martin, along with the history of the student organizations central to its geology mission. UT Martin has a long history of geoscience education service. This volume also presents the history of the Tennessee Earth Science Teachers (TEST) organization. We present the result of several projects undertaken by Eta Alpha SGE members and their faculty mentors.



Michael A. Gibson

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RESEARCH ARTICLE

A history of the geology program at the University of Tennessee at Martin

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ABSTRACT

The teaching of geology has as long a history as The University of Tennessee at Martin has itself, extending back to 1901 when the first geology class was offered at the campus's original institution, Hall-Moody Institute, a small Baptist college. Geology, usually with geography, was offered as a service course to the primary programs of agriculture, education and, later, engineering. Faculty turnover during these formative years was frequent. When the school was acquired by the University of Tennessee in 1927 and became UT Junior College, geology remained a service course. Geology offerings had been expanding since 1947 and, in 1951, the school became the UT Martin Branch. Geology continued to expand and, in 1967, UTMB became the University of Tennessee at Martin (UT Martin). The groundwork was laid for geology, and geography, to expand, so that in 1972, geology established a B.S. degree granting program with three geology faculty members and a full curriculum. In 1975, geology and geography split from the Department of Physical Science to become the Department of Geology, Geography, and Physics. The subsequent evolution of the geosciences department and geology program through periods of expansion, contraction, and reorganization is presented.

KEYWORDS

University of Tennessee at Martin, Hall Moody Institute, department history, geosciences

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INTRODUCTION

The geology program at what is now the University of Tennessee at Martin (hereafter, UT Martin) was established 52 years ago in 1972; however, the first geology course taught occurred in 1901 when the school was called the Hall-Moody Institute. Although college education in Martin dates from 1927, UT Martin was not the first educational institution that used the current site and geology education was deemed essential from the beginning. To understand the establishment and evolution of the geology program at the UT Martin, we first must know the evolution of UT Martin from its inception as Hall-Moody Institute and how it arrived within the University of Tennessee system. In celebration of 2022 Sigma Gamma Epsilon 46th National Convention, hosted by the UT Martin Eta Alpha Chapter, this paper is a synopsis that celebrates the history of teaching geology and the geology degree program at UT Martin, with some inclusion of the geography, travel and tourism, physics, and meteorology concentrations where appropriate to understanding departmental history.

RESOURCES

University catalogs, journals, announcements, annuals, newspaper stories, historical documents (e.g., correspondences, annual reports, self-studies, external reviews, town histories), and personal testimonies were analyzed to chronicle the history of geology at UT Martin. The publications cited in this summary, including recorded interviews of surviving faculty members recorded in 2016, and additional historical photographs and documents that

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were consulted but not cited, are housed at Paul Meek Library on the campus of the UT Martin in the Office of Special Collections, in University Relations, and in the departmental files of the geology program housed in the Joseph E. Johnson EPS building. These documents and testimonies span over 124 years. The University's online database of *Addenda* articles, yearbooks, archival photographs, the department's faculty newsletter were used to gather information that served to highlight of the chronology of changes at UT Martin. Some source language and grammar may contain variations of spelling no longer in practice. Furthermore, personal testimonies and informal records should be taken with an appropriate air of subjectivity. Efforts were always taken to fact check subjective information. Over the years, what most colleges would refer to as their "catalog" has been referred to as "announcement," "journal," or catalog. Hereafter, any of the annual documents will be referred to as the catalog and cited by institution name and year (e.g., UTM, 2024); however, to save space and avoid excessive repetition, all citations are grouped within the same citation reference in the references cited. Due to space constraints, the history of student organizations will be treated elsewhere (Gibson and Hudson, 2024, this volume). Where the dates for a geology faculty member's birth and death are known, they are indicated.

HISTORY OF THE UNIVERESITY OF TENNESSEE AT MARTIN

The town of Martin, originally called Green Briar Glade, was named after William Martin in 1873 and began as a train stop on the intersection of the Nashville and Northwestern Railroad and the Mississippi Central Railroad (Vaughan, 1997; Melton, 2018). The importance of the construction and operations of railroads throughout rural West Tennessee cannot be overestimated. Many West Tennessee towns owe their founding and subsequent prosperity to the arrival of rail lines during the latter half of the 19th century.

In 1900, Ava Gardner Brooks, who lived a few miles west of present-day Martin in the Gardner Community, donated land on the outskirts of Martin to the Tennessee Baptist Convention for the purposes of opening a school to provide religious training (Hall-Moody Institute, 1901; Inman, 1960; Vaughn, 1997; Carroll, 2000; Dennis, 2009). The school opened as the Hall-Moody Institute (1900–1917), named for two locally prominent Baptist ministers. Hall-Moody Institute originally offered students curricula that spanned elementary grades to the equivalent of the first years of collegiate work. In 1917, Hall-Moody Institute changed its name to Hall-Moody Normal School reflecting a focus shift to teacher training as its primary focus. By 1923, Hall-Moody again changed its name, to Hall-Moody Junior College, reflecting curriculum expansion after World War I. However, declining enrollment and financial difficulties in the mid-1920s nearly resulted in the school's closing. So, in 1927, the Tennessee Baptist Convention made the decision to consolidate Hall-Moody with a similar institution, Union University, in nearby Jackson, Tennessee (Inman, 1960; Vaughn, 1997; Carroll, 2000).

This decision was not popular and motivated civic and political leaders in Martin to ask the State of Tennessee to allow the Hall-Moody facilities to be acquired by the University of Tennessee. University of Tennessee president Harcourt Morgan agreed to accept the proposition on the condition that the Martin community would acquire the existing property as well as additional land for future expansion. On February 10, 1927, Senate Bill Number 301, approved by Governor Austin Peay, established the University of Tennessee Junior College (UTJC). UTJC began operations with 120 students on September 2, 1927 (Inman, 1960).

UTJC nearly closed twice during its first quarter-century, first during the hard times of the Great Depression and again in the early 1940s when nearly all male students enlisted in the various branches of the U.S. Military (Inman, 1960; Carroll, 2000). Mirroring developments nationally, an influx of returning servicemen to UTJC in the post-World War II years, largely under the influence of the G.I. Bill of Rights, ushered in rapid growth both in enrollment and educational offerings. From 1934 to 1967, the school was led by Paul Meek providing stability in leadership.

In 1951, with the addition of four-year fields of study leading to a bachelor's degree, UTJC was redesignated the University of Tennessee Martin Branch (UTMB). In 1961, it was the first campus in the University of Tennessee system to begin racial desegregation of undergraduates (graduate schools at other campuses had begun desegregation in 1952). Until 1967, the academic units at the UTJC-UTMB campus were treated as offsite departments of their counterparts on the main campus in Knoxville, meaning that program governance was controlled by the flagship institution in Knoxville. For example, geology at UTJC was under administrative control of the geology program in Knoxville and faculty had to routinely travel across the entire state to attend faculty meetings. In 1967, UTMB was granted equal status with the main campus in Knoxville and its presiding officer was granted the title of chancellor. The school's name was officially changed to The University of Tennessee at Martin (UT Martin or UTM) (Carroll, 2000). For a short time during a reorganization of science programs, geology was housed in a Department of Natural and Physical Sciences, but by the end of 1972 the Department of Geology, Geography, and Physics (GGP) was established. Regardless, the geology program had its roots in courses from the turn of the 20th century as geology was offered at each of the predecessor colleges to UT Martin.

TEACHING GEOLOGY

The Hall-Moody Years (1901–1927)

Geology was an integral part of the curriculum at Hall-Moody Institute, "a school for the masses" (Dennis, 2009) from the establishment of the school. Hall-Moody Institute was the first college-level school in Martin. According to the 1901–02 Hall-Moody Announcement (HMI, 1901 and succeeding catalogs) students could follow one of two curriculum pathways: "Classical College Course" or "Scientific College Course." The classical course was a four-year pathway in which geology (or political economy) was taken as the junior-level science course, but most of the curriculum was centered on the classics related to religious studies and public education (history, languages, religion). The scientific pathway, essentially a "junior college tract" with focus on sciences and nature, was a three-year program in which geology or physics satisfied the second-year science requirement. Geology was not listed for teacher preparation at this point. These first catalogs, called announcements or journals, were rudimentary, listing titles of courses only. They did not usually contain course descriptions, textbooks, or necessarily indicate which faculty were teaching specific courses (although some did). These early announcements published the names of individual students and the programs that they were pursuing. Geography was not listed in the first catalog, but a senior could take astronomy for their science requirement.

Attracting qualified teachers for courses was difficult in the early years of HMI, as indicated by the high turn-over rate of faculty. The requirement of a terminal degree (M.S. or Ph.D.) was not uniform for faculty. Often the expertise of the faculty member hired to teach geology was shallow as most faculty held specialties in other allied fields (e.g., geography, chemistry, etc.) and not specifically in geology. Many of the science faculty were part-time or shared with other programs; their day jobs often were at high schools. Undoubtedly, the rural nature of Martin during these early years was a hindrance to attracting and keeping candidates. The religious nature of HMI may well have also been a factor who taught the geology course, as well as its content. Geology was included as a service course to agriculture at HMI. This geologic content would have focused on minerals, rocks, weathering processes, and landforms (i.e., physical geology). Historical geology aspects (e.g., geologic time, evolution, age of the Earth, etc.) would probably have been considered too "controversial" and contradictory to HMI's religious nature. Finding qualified experts would have been difficult.

Early records are sparse as to who taught the first course to contain geology (or geography) at Hall-Moody Institute, but there is some indirect evidence that the most likely person was Ms. Frances Copass in the Fall of 1901, who headed HMI's Expression Department (Dennis, 2009). Ms. Copass' time at the school was a short five months (Carroll, 2000) as she was dismissed for not adhering to demands made by the school trustees for her to cease her frequent dating (perhaps as many as sixteen dates within a four-month period) and to better serve her duties as a study hall monitor (which she would evidently do coincident with the time that she would be teaching a 45-minute class in a different room). Expectations of female behavior were quite strict and draconian at this point in American history, especially in the rural deep South. The terms of Ms. Copass' termination eventually were taken to Weakley County Court (she lost that case) and later were appealed on her behalf in the Tennessee Supreme Court. That Court ruled that Hall-Moody Institute owed her $275, the amount she first sued for, which was worth about half of her annual salary (Carroll, 2000). It appears that the institute received both positive and negative publicity over the incident, especially considering the rise of feminism at this time in history. One local farmer declared that the monetary loss was the greatest investment made by Hall-Moody history because it publicized the high moral standards of the institute and its board of trustees (Carroll, 2000).

Despite the scandals associated with Frances Copass, science education quickly gained more support and prominence at Hall-Moody. In 1908, the campus opened its second instructional facility, the new Science Building (Figure 1; Dennis 2009). Furthermore, by 1909, HMI was conferring

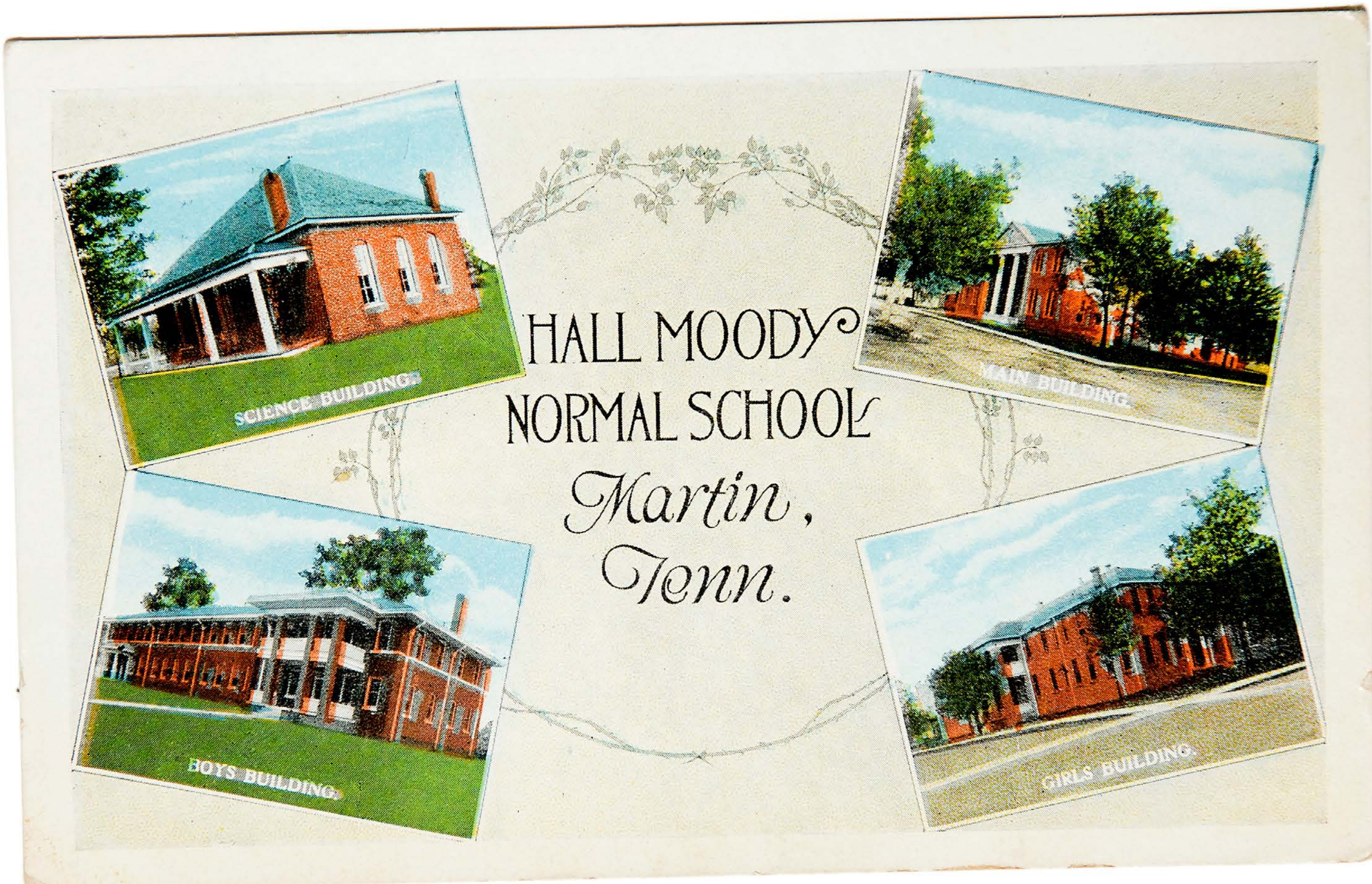

Figure 1: Postcard of Hall Moody Institute showing the Science Building (upper left), constructed in 1907 where geology and geography classes were taught (University of Tennessee at Martin Archives).

both A.B. and B.S. degrees and stressed mathematics and science (Dennis, 2009). By the 1911–12 academic year, the two curriculum pathways remained as they were in 1901 but, in the Classic Curriculum, General Geology was offered in the junior year. A textbook by geology icon James Dwight Dana (1813–1895) was used in this course. There is no information on the precise title, date, or edition, but the course emphasized "Earth composition and structure," and so the most likely book was probably one of the editions of Dana's "*Manual of Geology*" or "*A Text-book* (sic) *of Mineralogy*." The course description also indicated that Hall-Moody Institute had acquired collections of minerals and rocks for laboratory use. There was no indication from where the collections were obtained. Physical Geography was taught as a second-year course and geology was required for a secondary education teaching endorsement certification. The faculty member listed for teaching geology in that year was W.W. Dunn (B.A., A.B. in "modern languages and science"), who had been at HMI since 1904.

There were no changes in the trackways, teaching endorsement requirement s, courses offered, or textbooks used from the 1912–13 through 1914–16 academic years (HMI, 1912; HMI 1914); however, there was a high turn-over in instructors for geology. According to Dennis (2009), a new science lab that was completed in 1908, the second building on the campus, that was 24 feet by 30 feet in size and stocked with newly purchased equipment (specifically mentioned was a $17 barometer and an 18-inch globe). W.W. Dunn was not listed as the instructor in 1912–13. Instead, Nolan M. Stigler (B.S. Assistant in Science and English) and Jas. T. Warren (B.S., A.B., V.P. Science, Mathematics, and English) were listed as faculty. By the 1913–14 academic year, Nolan M. Stigler had departed leaving Jas. T. Warren to teach geology (HMI, 1913). In the 1914–15 academic year, H.E. Watters (A.M., D.D.) was a new hire to serve as HMI President and had a background in science, literature, mathematics, the Bible, and teacher training. It is unclear whether Watters taught geology (HMI, 1914). The available faculty in sciences changed again for the 1915–16 academic year with the departure of Watters and Warren (HMI, 1915). L.D. Rutledge (A.B. from Valparaiso University) was hired to teach courses in science, math, English, Latin and H.C. Witherington (B.S., A.B.) to teach science, Latin, French, and German, but there was no indication as to exactly who taught the geology classes. There is little information available on what prompted the high turn-over rate of faculty during this decade, except for the fact that the school was still relatively new and was establishing itself.

1916 saw the first significant change in the geology offerings at Hall-Moody. Geology of Tennessee was listed as an available course curriculum pathway in the Announcement (HMI, 1916), but was not included in the list of courses being offered in either semester. Additionally, geology was listed within the Department of Natural and Physical Sciences, not under the Department of Science. "Professor Wooldridge" was listed as teaching Physiography as a junior-level course for the "monor" (sic), as well as General Geology and Economic Geology (junior standing) for the major. This catalog (called a journal) marked the first time that specific instructors were listed individually for the courses that they taught. Wooldridge also served as co-president, professor of biology, philosophy, and education. He held a B.S. and A.B. from Bethel College (Jackson, Tennessee) and an A.M. from Potomac University (Washington, D.C.). L.D. Rutledge and H.C. Witherington were not listed in the faculty for 2016.

Geology at Hall-Moody began an unexplained hiatus with the 1917–18 academic year (HMI, 1917). The courses remained on the books, but not on the semester offering lists. Presumably, Wooldridge left the school unexpectedly as he was not listed as faculty anymore. Only one person, N.M. Stigler, was listed as science faculty. Physical geology remained missing from the 1918–19 course (HMI, 1918) offerings (although Geology of Tennessee was listed with biology and physical geology in the course listing). No faculty member was specified for geology. Stigler was still on-staff along with J.W. McKay, a new hire in science subject to "military duty." Presumably the hiatus of geology and geography offerings can be explained by America's involvement in World War I. McKay earned his B.S. and A.M. from Mississippi College in 1918. 1919 saw the beginning of summer catalogs at Hall-Moody. Neither geology nor geography were offered during the summer of 1919 or the summer of 1920 (HMI, 1919; 1920).

No catalog is available for the 1919–20 academic year, but the post-war 1920–21 catalog reflected several changes (HMI, 1920). Geology was then listed along with physiology as a second-year science class in the "Academic or High School" curriculum pathway. Within the Department of Science section, geology was listed as a Fall Term course, with "physiography, general geology, and geology of Tennessee" offered. Within the faculty listing section of the catalog, there was no one listed as teaching any geology courses specifically. Instead, one faculty member, Henry Carl Witherington, was listed as teaching all science and Latin courses.

Things became even more confusing in the 1921–22 catalog with geology being listed under "Grammar School" as a second-year course, but not included in the Junior College listing (HMI, 1921). As with the year before, the catalog listed "Fall Term – Physiography and including general geology and geology of Tennessee" as being offered. The general geology course was listed as being taught by Albert Tennyson Barrett, who was also the Dean of Education, with degrees from the University of Rochester, Mary Sharp College, and Union University. Interestingly, Barrett also served as the superintendent of schools for Chattanooga, Tennessee. The chair of the science department at this time was H.C. Witherington and both men were also listed as co-chairing the philosophy department. This same arrangement remained for the 1922–23 academic year (HMI, 1922); however, Oscar Lee Rives, who was a teacher in nearby Obion County, with his A.B. degree in science and history from Union University, joined the staff at Hall-Moody. For the first time, the room where the courses were to be taught was listed in the catalog (Room 11). There was no geology offered in the summer of 1923, but geography was listed with Mrs. James T. Warren as the geography faculty teaching it (HMI, 1923). The course descriptions and offering s remained the same for the 1923–24 academic year, but with a change in faculty. Barrett and Witherington were still listed as science faculty, but Oscar Rives was now gone. In his place was Ira Dance, who was listed as "science and coach." Dance was a Hall-Moody alumnus, the first one to return to teach science at Hall-Moody, with a B.S. from Carson-Newman College in East Tennessee in 1923. He was also listed as a "rural pastor." No geology course was offered for the summer of 1924, but Witherington taught physical geography in Room 3 and Miss Lois Bowden taught geography in Room 16 (HMI, 1924). She was a Hall-Moody graduate candidate in the "Demonstration School" at Peabody School for Teachers in Nashville.

Geology was listed in the 1924–25 catalog; however, it appears that no courses were offered, and no instructor was listed as teaching geology (HMI, 1924). One new science faculty, W.E. Wilson, was listed as "science and coach." Wilson was a West Tennessee Normal School graduate with an A.B. from Union University and served as the Crockett County High School principal. Although still listed in the catalog, geology was not offered in the summer of 1925 (HMI, 1925).

The 1925–26 catalog is reflective of a fiscal storm brewing for Hall-Moody for 1926. The official catalog in the UT Martin archives actually is a 1924–25 catalog with numerous handwritten strikeouts and corrections. For example, the listing of the campus president was changed from J.T. Warren to William Hall Preston, reflecting the turnover in administrative leadership in 1926. Geology was not listed anywhere in the catalog, nor was there any faculty identified as teaching any geology course. Witherington (now promoted to dean) and Bowden were still the listed science faculty. W.E. Wilson was gone, but coach H.K. Grantham (A.B. from Union University and a teacher at Millington High School and at Newbern High School) was listed as "science and physical education." Geology was not offered in the summer of 1926. A new science faculty member was listed in the faculty section for the summer term. H.G. McCorkel, also a Hall-Moody alumnus, was listed as "science and mathematics." McCorkel was an Obion High School science and math teacher with some training at Union University and one semester from Peabody Teacher College. Although no records were located to indicate any direction connection, one wonders what impact the 1926 "Scopes Monkey Trial" would have had on the teaching of geology and the faculty teaching sciences at HMI. This trial was a major legal event in Tennessee and nationally. Many of the religious organizations in Tennessee were participants.

In the Spring 1926 catalog, geology was not listed in the catalog as a full course (HMI, 1926). Under the "science" section, the catalog indicated that one year could be devoted to "physiography" with one-half unit being physiography and one-half unit being geology, but no instructor was named. A.T. Barrett was listed as "emeritus," Miss Lois Bowen was absent from the listing altogether, leaving only H.K. Grantham as the faculty member that could have been responsible for this course. He was also listed as teaching chemistry, which was probably his primary training field.

1926 was Hall-Moody Institute's final academic year before being absorbed into the University of Tennessee. The instability of faculty, along with a continually growing debt without new sources of income (e.g., failed efforts at fundraising, etc.) resulted in the decision to either close the doors to HMI or merge it with another institution (Carroll, 2000; Dennis, 2009). While there was a valiant effort to raise funds for HMI, the Baptist State Convention decided that the best option was to merge HMI with Union University (Carroll, 2000). HMI ceased operations at the end of that year and the property was transferred to The University of Tennessee (Inman, 1960; Dennis, 2009).

The University of Tennessee Junior College Years (1927–1952)

Departments of Instruction

The campus began classes on Sept. 2, 1927, as The University of Tennessee Junior College (UTJC, 1927). Much of what was Hall-Moody Institute was assimilated by Union University in Jackson, Tennessee (Inman, 1960; Dennis, 2009). Construction at UTJC on a new science building, Science Hall, began immediately and was completed in 1929. That building, which became known as the "Sociology Building" also housed the anthropology program and still stands today. UTJC started without a science department per se and geology courses were listed as in "departments of instruction" for a few years (UTJC, 1927).

Partly because of the transition to UT and partly in response to the Great Depression, UTJC, and the geosciences at UTJC in particular, entered a period of stagnation that would go on for 14 years during which no geology or geography courses were taught. The Depression caused reductions in operating budgets and a 10% reduction in faculty salaries that did not bottom-out until 1933, when the operating budget at UTJC fell from $90,000 to $36,000, the number of faculty was reduced to seven, and enrollment plunged to 92 students (Carroll, 2000). It would take the rest of the decade for UTJC to fully recover from the effects of the Depression. Undoubtedly, geology offerings suffered during this period of time.

Finally, in Fall 1941, Geography 171 and 172 – Elements of Geography were offered as 8 a.m. lectures in Room A-7 of Science Hall (UTJC, 1941) and were taught by Jannie Miller. Miss Miller had a B.S. in education and was an instructor of elementary education primarily. She taught these courses until 1942 when Marion Preston Laster (B.S, M.A. in education), the principal of Dresden, Tennessee High School, was hired as instructor of geography and took over the classes for the Spring 1943 semester only (UTJC, 1942). For the 1943–1944 academic year, only geography was taught by Miss Lavella Mae Corley, who also taught mathematics (UTJC, 1943). Miss Corley was now listed as a part-time faculty and the catalog listing for geography did not have her name listed as instructor (the instructor was listed as "Mr. -----"). Mrs. Corley, she evidently had married, was listed as the instructor for the 1944–1946 academic years (UTJC, 1944). Catalogs for the period of 1942–1945 indicated that there were many professors teaching classes related to "war training" (e.g., UTJC, 1945).

Physical Sciences Department

After an absence of nearly two decades, geology returned to the campus shortly after World War II and it did so in a big way. At this point in time, the college began to hire highly trained experts with specific disciplines who were allowed to devote their full-time efforts to their respective fields of study. It also began to offer more sophisticated, college-level geology and geography courses. In Fall 1947, UTJC hired Allington Paul Wishart, Sr. (1921–1996); A.B. geology, B.S. and M.S. in education from UT Knoxville, Ph.D. in education from University of Texas—the first graduate from UT Science Education Center—as instructor of geology and geography (Wishart, 1981; UTJC, 1947). Wishart became the first full-time geology instructor (specifically trained in geology) in the school's history and proved instrumental in laying the groudwork for establishing the geology major later in time. Wishart's first course was Geology for Engineering Students (Geology 121), along with General Geology for Students of Agriculture (Geology 131), demonstrating the service support role that geology played to the more established programs at the school (UTJC, 1947). At this time, geology was housed in the School of Liberal Arts within the Physical Sciences Department. Geology was not offered during the summer of 1947; however, Wishart did teach geography that summer, which included a listed field trip as part of the course (UTJC, 1948). 1948 is the first year that geology was specifically listed as a faculty position within the catalog. Wishart was listed as "instructor of geology and geography." Additionally, 1948 was the first year that geology was specifically listed as a required course in a curriculum and not an elective (UTJC, 1948). Agriculture students were required to take Geology 131 (General Geology for Agriculture Students) during their sophomore year and civil engineering students were required to take Geology 121 (General Geology for Engineering Students) in their sophomore year. The civil engineering geology requirement was dropped in 1951 (UTJC, 1951).

Wishart, who preferred to go by A. Paul Wishart, was the first trained geologist to be hired and provided stability and growth to geology during the 1950s and stewarded geology during the shift from UTJC to University of Tennessee, Martin Branch. Even though the geology degree program was still years into the future, he could be considered the "founding father" of the program due to the groundwork he laid. He clearly intended to expand geology into a major (see more below) as there was a general geology curriculum listed in the 1949 and 1950 catalogs (UTJC, 1949; 1950). The geology course sequence expanded to include Geology 111, 112, and 113 (in a quarter system) with Geology 113 a "historical geology" course. This numbering sequence remained in place until 1988. Interesting, this sequence did not satisfy requirements for a "liberal arts degree" at this time; however, Wishart got it accepted for the 1951 catalog (UTJC, 1951). Beginning with the 1950 catalog, Geology 131 (General Geology for Agriculture Students) became a prerequisite course to the first soils course, Soils 213 for agriculture majors (UTMB, 1950). For most of the next decade, there were no changes in geology course offerings and Paul Wishart remained the sole geology and geography instructor until 1952 (UTMB, 1952).

In 1959, Wishart was promoted from instructor to assistant professor of geology and geography. After laying the foundation for what would become a geology program at UTMB, Wishart left UTMB and returned to UTK in 1961 to become professor of education in the Department of Curriculum and Instruction, where he remained until his retirement in 1986. Also in 1986, Wishart received the National Science Teachers Association award for science education and a University of Tennessee National Alumni Association Public Service Award. Wishart passed away in 1996. The College of Education at UT Knoxville established the Dr. A. Paul Wishart, Sr. Scholarship in his honor.

The author (MAG) had the honor of meeting Paul Wishart during his graduate school days at UT Knoxville working toward his Ph.D. in geology. Wishart, who had obtained his A.B. in geology from UTK and had briefly been a petroleum geologist in Colorado early in his career, would occasionally visit the UTK geology department, especially to listen to some of the speakers in the weekly colloquium. As my dissertation topic was focused on the paleontology of West Tennessee, we occasionally conversed about the geology of the region (or perceived lack of geology as the region is "flat" compared to East Tennessee) and he shared his UT Martin history with me, including his time at UTMB. He highlighted West Tennessee geology in his courses. Wishart felt that students, and especially his beloved science teachers, should know that West Tennessee was home to interesting and important geology (e.g., Reelfoot Lake, fossil deposits, glacial deposits, and the unusual course of the Tennessee River). He shared with me that he was the "first geology professor" on the campus and that he "helped to organize" the department at UT Martin with that goal in mind. When the Department of Geology, Geography, and Physics (GGP) was proposed to be established in the late 1960s (see below), Wishart was one of its early supporters. He was proud enough of this achievement that he highlighted it in his Tennessee Academy of Science presidential address (Wishart, 1981).

The University of Tennessee Martin Branch Years (1952–1967)

Physical Science Department

In 1952, the state legislature passed House Bill 264 which changed the UTJC name to the University of Tennessee Martin Branch (UTMB), and a massive program and facilities expansion effort began. UTMB was empowered to offer bachelor of science degrees (Carroll, 2000). The UTMB 1952 catalog marked the first year that pictures of geology and geography classes and faculty were included in the catalog (UTMB, 1952, p. 21); however, no geology pictures were included in the next two catalogs. Summer 1953 became the first year that General Geology 131 was offered as a summer school course (UTMB, 1953), aimed at agriculture majors.

1953 saw another faculty change with the addition of Gilbert H. Boyd (1935–2019), who was hired to teach both geology and geography as Paul Wishart was listed as being on a leave of absence. Boyd earned his B.S. and M.S. in geology from UTK where he worked under UTK geologist James G. Walls from 1952–1956. In 1955, he completed his master's thesis "A geologic study of the Chickamauga formations or Raccoon Valley, Roane County, Tennessee" (Boyd, 1955). While teaching geology at UTMB, he was an offensive line assistant football coach. Boyd later became successful in the petroleum industry working for Texaco, Hunt, and Tatham oil companies. According to his daughter, when he started his own petroleum company in 1971, he called it United Texas (UT) to honor is alma mater and his time at UTMB (Sarah Boyd Jimenez, personal communication, 2024). In 1994, Boyd and his wife Jo Ann, now living in Houston, Texas, established an endowment in the Department of Geology (now Earth and Planetary Sciences) to honor Walls. The author met Gill Boyd in 1989 and the discussed the geology program. Boyd was in Tennessee for a UTK football game and visited GGP as part of the trip. Boyd participated in a field trip lead by the author to the Devonian fossil beds near Parsons, Tennessee. Like Wishart, Boyd was proud of his time at UT Martin and how the program had grown. In 2016, Boyd donated numerous specimens from his geology collection to UT Martin geology.

In 1954, geology was still housed within the Department of Physical Sciences at UTMB, which was under the chairmanship of A. Norman Campbell (UTMB, 1954). Geology was listed as satisfying requirements for a liberal arts degree from UTMB and geology was now listed within the education curriculum to satisfy requirements for endorsement in secondary education (UTMB, 1954).

For 1955, Wishart was again listed as "on leave" and Boyd remained the sole geology and geography instructor until the 1956 academic year when he was replaced by George F. Beatty for one academic year. Beatty received his B.S. from Ball State University (1949) and his M.S. from the University of Illinois (1951). The catalog (UTMB, 1955) listed Boyd as "resigned." Beatty had returned to Ball State to obtain his Ph.D. (1958), where he remained as a geography professor until his retirement in 1983 (American Association of Geographers (AAG), 2004).

Geology, and geography, was then taught by Assistant Professor Horace Greely McDowell, Jr. (1922–1997: B.S., M.A. University of Nebraska) for the 1957 academic year. Inexplicably, a Max S. King (B.S.) was listed in the faculty listing as being a geology and geography faculty, but all the courses were listed as being taught by McDowell (UTMB, 1957) and by 1958, King was listed only under the chemistry faculty (it is not clear if his listing as a geology faculty was a catalog error). For the 1958 academic year, McDowell taught all the geography courses, including the new Geography of Tennessee, but he was listed as co-teaching the geology course with John T. Neece (M.A.) who was identified in the catalog as a professor of chemistry (UTMB, 1958). Neece was listed as teaching geology for the one year and resigned by the 1962 academic year (UTMB, 1961). McDowell left UTMB and moved to the University of Chattanooga , which became the University of Tennessee at Chattanooga in 1969. For 1959, no geology or geography instructor was listed (e.g., "Mr. ----"), as McDowell had resigned (UTMB, 1959).

The early 1960s was a time of expansion for UTMB as the student population had risen significantly. This was a direct result of a 1956 committee report to the UT Board of Trustees that recommended that UTMB should expand its liberal arts programs, including physical and biological sciences, primarily in support of the anticipated move to become a degree-granting four-years institution (Inman, 1960). Senate Bill 31 by the Tennessee legislature in 1957, signed by Governor Frank G. Clement, provided the funds to expand UTMB significantly and placed control of future new degree programs under the UT Board of Trustees (Inman, 1960).

In 1960, the Department of Physical Sciences had new co-chairmen in Lloyd A. King and Henry C. Allison as Campbell had returned to the chemistry faculty (UTMB, 1960); however, he returned as chairman in 1961 (UTMB, 1961). 1960 began with William Wayne Chester (1932–2023; M.A., St. Louis University) being hired to replace McDowell. In the 1960 catalog, Chester was listed as the instructor for all geology (Chester was a geographer by training and claimed to have been a "self-taught geologist") and geography courses; however, he was not listed as part of the departmental faculty on the same pages, suggesting that his hire was considered temporary at first (UTMB, 1960). According to Chester (Chester, recorded interview, 2016), he was hired by Dr. Harry Houff from a pool of six other candidates. Chester had been a cartographer for the U.S. Navy with his most notable contribution having been to produce one of the first physical models for Antarctica. Chester's hire came after the catalog revision deadline as geology and geography courses listed the instructor as "Mr. ----" (UTMB, 1960), but listed Chester as instructor for the next year (UTMB, 1961). Geology was not required for engineering or education students, but Geology 131 was still required for agriculture students.

As noted by Carroll (2000), the late 1950s and early 1960s were a period of extensive growth for UTMB. In 1957, UTMB had over 800 students and by 1960, the student population was risen to 1,123 students. As a result of the Soviet Union's 1957 Sputnik achievement and the perception of the U.S. was falling behind the Soviets in science, the U.S. launched an expansive national endeavor to expand science education and research (e.g., Geiger, 2004). To accommodate this growth of science and engineering programs, as well as the influx of students to UTMB, new building construction began. In 1960, the three-story Engineering and Physical Sciences (EPS) building (Figure 2A) opened on the site of the old Mechanical Arts Building. The 1962 catalog highlighted the opening of the "EPS Building," which was depicted on the cover of the catalog (Figure 2; Issue Cover; UTMB, 1962). Chester moved all of the geoscience courses and materials onto the 2nd floor of the new EPS Building which then housed all "non-biological" sciences. In 1969, EPS was expanded by adding a T-shaped extension to the west side of the building (Figure 2B). Chemistry occupied the third floor and engineering occupied the first floor. EPS has remained the home of geology even after the construction of the Latimer-Smith Science Building in 2022.

The 1963, and 1964, UTMB catalogs reflected the expansive changes in science at the higher education level as it was a significantly longer catalog (UTMB, 1963). Several changes occurred in the catalog, including the omission of student names within majors that had been so common in earlier catalogs. The EPS building was featured in the 1963 catalog, especially the fact that it was "air-conditioned" (including a photograph). Faculty listings moved to the back of the catalog, where they remain to this day. For the first time, geology was listed as a high school entrance requirement satisfier. Oddly, within the endorsements for secondary education, geology topics (but not any specific geology course) were listed to satisfy "physical science or Natural (sic) science" requirements. There was still no geology required in the engineering program this academic year. Coincident with the above change in the 1963 catalog was that there was a "physical science" sequence entitled "Elements of Physical Science 101, 102, 103" which had geology and meteorology content within it. Several faculty were listed as teaching the course sequence including Henry C. Allison and Charles R. Graham (physics), Glen Bremer (chemistry), and Wayne Chester (geosciences). That year Chester was listed as teaching all geology and geography courses, eight courses in total (UTMB, 1963).

The 1964–65 academic year was a banner year for geology at UTMB, and changed the direction of geology for the years that come. Chester, having been promoted to assistant professor, had a heavy teaching load (nine courses) and enrollments were up. It was time for another trained geologist to handle the geology program and enable its growth. It is also notable that the long-running Geology 131: General Geology for agriculture students was dropped from the course offerings and a geology course was no longer required for the Agronomy 131 soils course in the agriculture curriculum.

In 1964, the first of "three founding fathers" of the geology degree program, William Thomas "Tom" McCutchen (1939–), was hired as an instructor of geology to relieve

Chester's heavy teaching load by taking over the introductory geology sequence (Geology 111, 112, 113), which was one of the sequences that satisfied science requirements for a liberal arts degree (Figure 3A). McCutchen earned his B.S. in geology from Berea College in Kentucky (1957) and his M.S. in geology from Florida State University (1959), after which he completed one year toward his Ph.D. at the University of Texas at Austin (1959–60). McCutchen was an instructor at Miami Dade Junior College from 1961 to 1964, before coming to UTMB. His geologic specialty was mineralogy, thus making him the first "hard rock" geologist in the program. By summer 1965, McCutchen had been promoted to assistant professor and taught the first summer geology offering in over a decade (UTMB, 1965). Almost immediately, McCutchen's introductory classes rose to over 150 students, and his first teaching class included future UT Martin Chancellor Nick Dunagan (McCutchen, recorded interview, 2016). McCutchen would remain on the faculty until his retirement in 2000 after 39 years of teaching in higher education (Ogg, 2012; Shaw, 2016). McCutchen had the distinction of being the first "published" geology faculty member having published an article on glacial moraines in models in the 1959 Bulletin of the Geological Society of America (McCutchen and Tanner, 1959). He also had the distinction of being the first geology faculty at UTMB to publish a paper while on the faculty. In 1966, he published an article on using set theory to better teach rock classifications in the Journal of Geological Education (McCutchen, 1966). He also completed mapping of some crystalline rocks in Edgefield County, South Carolina in 1965 (McCutchen, 1970). In 2017, McCutchen was honored by the endowment of the Tom McCutchen Geology Scholarship, spearheaded by 1971 UT Martin geology graduate Walter Parrish (Shaw, 2016).

University of Tennessee at Martin Years (1967–)

Department of Physical Sciences

In 1967, the University of Tennessee Martin Branch was

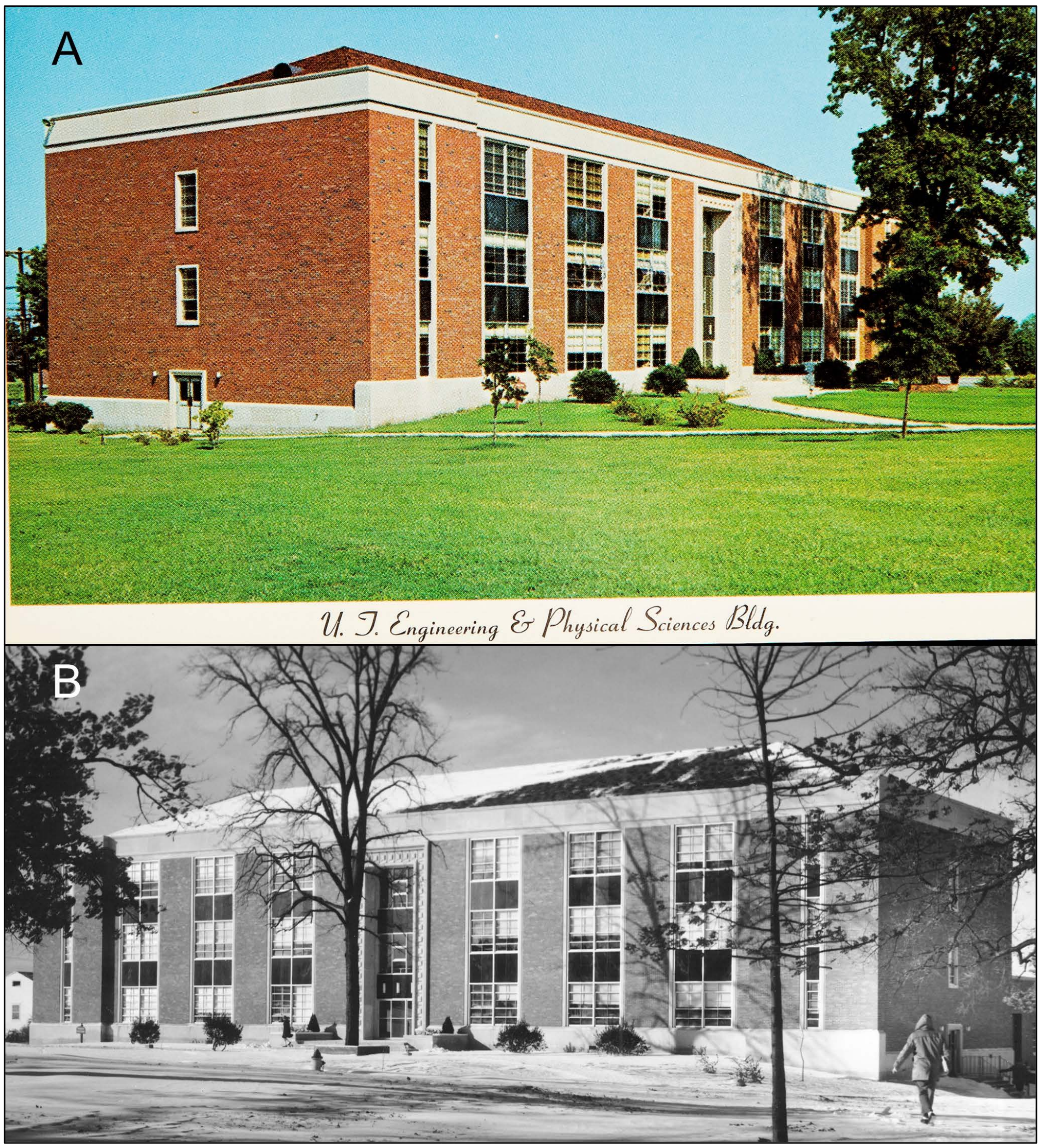

Figure 2: Photographs of the Engineering and Physical Sciences (EPS) Building. (A) EPS soon after it was constructed in 1960. (B) 1970s photograph of EPS after an addition was added (just visible to the right side of the photograph). Geosciences occupied the second floor. In 1991, EPS was rededicated as the Joseph E. Johnson EPS Building. EPS has been home to the geosciences since it opened in 1960 and is scheduled for a second renovation in 2025 (Photographs supplied by University of Tennessee at Martin Archives).

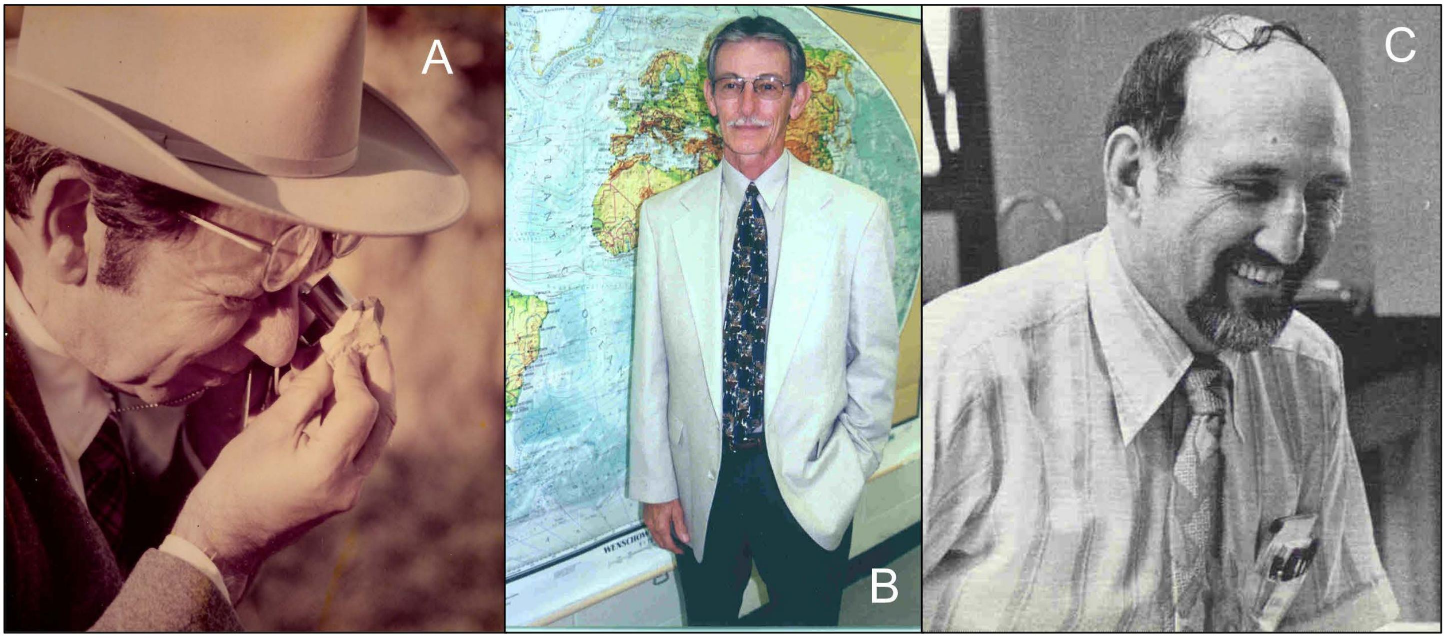

Figure 3: The "founding fathers" and "first generation faculty" of the geology degree in the Department of Geology, Geography, and Physics program at UT Martin. (A) William T. McCutchen, (B) Kenneth V. Bordeau, and (C) Ernest Blythe, Jr. (Photos supplied by University of Tennessee at Martin Archives).

renamed The University of Tennessee at Martin (UTM, UT Martin) with passage of Senate Bill 488 by Governor Buford Ellington (Carroll, 2000). Longtime chancellor Paul Meek, chancellor from 1934–1967, was replaced by Archie Dykes. Geology and geography remained within the Department of Physical Sciences, but changes were looming. Beginning that year, UT Martin catalogs no longer listed which faculty member was teaching a specific course. In the summer of 1967, the course numbering system changed and the quarter system geology courses became Physical Processes 1110, Geomorphology 1120, and Historical Geology 1130 (UTM, 1967).

Figure 3B depicts Kenneth V. Bordeau (1923–2011), regarded as the "second founding father" of the geology program at UTMB, who was hired in 1967 (after finalization of the 1967 UTMB catalog, which included the 1968 academic year as well), thus expanding the geology program to two full-time faculty members (Gibson, 2022). Bordeau was a World War II veteran stationed in the European Theater and married his wife "Elvi," who was an Allied translator during the Nuremburg trials, while overseas. The G.I. Bill funded Bordeau's higher education and he received his B.S. from the University of New Hampshire and M.S. and Ph.D. from the University of Oklahoma. He was a micropaleontologist trained under the influential R.W. Harris. Before he came to UT Martin, Bordeau worked for Union Producing Company and then spent three years in Libya, North Africa working for American Overseas Petroleum Company. He was the first Ph.D. level geologist to be hired at the school and the first "soft rock" geologist. Upon his arrival to UT Martin in 1967, Bordeau expanded the paleontology offerings by adding several micropaleontology courses normally only found in graduate programs, including biostratigraphy, which became known as the "scourge of the geology program" because of the amount of memorization of the scientific names and geologic ranges of important biostratigraphic fossils. He was also well-feared for his grading system on exams. In his system, it was possible to get a negative exam score! While at UT Martin, he continued his research on conodonts from the Ordovician Fernvale Formation, which had been his dissertation topic. The geology department still houses his vast micropaleontology fossil collection (with tens of thousands of specimens) within the Bordeau Micropaleontology Collection. With his passing in 2011, and that of his wife in 2013, his estate was donated to UT Martin and the Kenneth V. Bordeau Paleontology Endowment was established as their legacy. It remains the largest donation to the geology program in the history of the school (Gibson, 2022).

The 1969 academic catalog for UT Martin noted that geography had an A.B. major as well as a B.S. major in geography, with sixteen courses in the program; however, geology offered no major or degree at this time (UTM, 1969). Geology was expanding, however, as McCutchen had added Geology 3170: Crystallography and Methods of Mineralogy and Bordeau added a two-quarter sequence, Geology 3210–3220: Invertebrate Paleontology (UTM, 1969).

In Fall of 1969, the third "founding father" of the geology program (Figure 3C) was hired, Ernest W. Blythe, Jr (1930–2005; B.S., in Industrial Management, Tennessee Technological University, M.S. Geology, UT Knoxville). At the time, Blythe was also working toward his Ph.D. in geology from the University of Tennessee Knoxville coincident with his first few years of teaching at UT Martin, which he completed in 1974, working under Kenneth R. Walker (see Gibson [2007] for Blythe's GSA memorial). Blythe's dissertation research centered on the Ordovician stratigraphy of the Carters and Hermitage formations exposed in Sequatchie Valley of Tennessee. Blythe would expand his research interests while at UT Martin to include the stratigraphy of the Reelfoot Lake region and earthquake hazards associated with the New Madrid Seismic Zone. Much of this research was in collaboration with Richard Stearns of Vanderbilt, and resulted in the publication of several guidebooks to the region, including the popular Tennessee Geology Survey, Reports of Investigations 36 (Gibson, 2007).

Also in 1969, the geology program, still without a degree pathway (although it did offer a minor in geology), expanded even more with the addition of a second historical geology course at the sophomore level (Geology 2130: Historical Geology), Mineralogy 3180, Lithology 3310, Geology of Central and West Tennessee 3340, Structural Geology 3370, Biostratigraphy 4210, and Principles of Geomorphology 4510 (UTM, 1969). The addition of these courses laid the foundation for the formal approval of a B.S. degree program in geology, which was accomplished by the beginning of the 1972 academic year. Oddly, for the 1971 year, the department was listed as the Department of Natural and Physical Sciences in the yearbook (Figure 4A). It was listed as the Department of Physical Sciences and Chemistry in the 1972 catalog (UTM, 1972). The first student club, the GeoClub, was established during this transition. See Gibson and Hudson (2024, this volume) for the history of clubs and student professional organizations in the geology program at UT Martin.

Several new courses were developed in 1971 and added to the 1972 geology curriculum catalogs (UTM, 1972) including Micropaleontology 3250, Special Problems in Geology 4000, Sedimentation-Stratigraphy 4110, Principles of Economic Geology 4410, and Field Geology 4440, all of which were listed as awaiting final approval by the Faculty Senate for the 1972 catalog. Also listed as waiting for final Faculty Senate approval was the removal of Historical Geology 2130 with the replacement course being Advanced Historical Geology 3120, a junior level course (UTM, 1972). Moving historical geology to an upper division level was innovative for its day as nearly all other schools used historical geology as the second half of their introductory sequence and as groundwork for most upper division geology courses. The first night course in geology was offered by Blythe in 1971 (UTM, 1972). It is an interesting event as the course was Structural Geology 3370, which was a major's course listed in the UT Martin graduate catalog (see below for a discussion of graduate courses).

The first complete degree granting geology class of students matriculated in 1972. Majors were required to complete the introductory sequence (Geology 1110, 1120, and 1130), Crystallography and Methods in Mineralogy 3170, Minerology 3180, Invertebrate Paleontology 3210 and 3220, Lithology 3310, Structural Geology 3370, Sedimentology-Stratigraphy 4110, Biostratigraphy 4220 with an additional eight hours of upper division geology electives (UTMB, 1972). This curriculum was typical to the curriculum for most undergraduate geology programs across the country at that time, and mirrored what was being offered at UTK (and had been subject to the approval of the UTK geology faculty). By the 1973 academic year, Bordeau had been promoted to associate professor (UTM, 1973).

Additionally, geology hired its first laboratory assistants for the introductory course sequence to help relive the increased teaching loads of the faculty (UTM, 1972). Mrs. Gloria C. Mansfield (1945–2009; B.S. and M.S., UT Martin), a 1973 alumna of the expanded geology program at UTMB, who later earned her M.S. in education, was hired as the first laboratory instructor in the program. Also serving as laboratory instructors were Fred Davis (M.S., UT Knoxville), who later became a science teacher in Gibson County, and Walter C. Parrish (1952–; another UTMB geology alumnus). All three returned for the 1973 academic year. Mansfield, the longest running geology lab instructor (35 years), oversaw the laboratory sequences until 2007 when she was forced to retire due to declining health.

Department of Geosciences and Physics

1974 and 1975 would prove to be years of transition for both geology and geography. Individually and separately, the

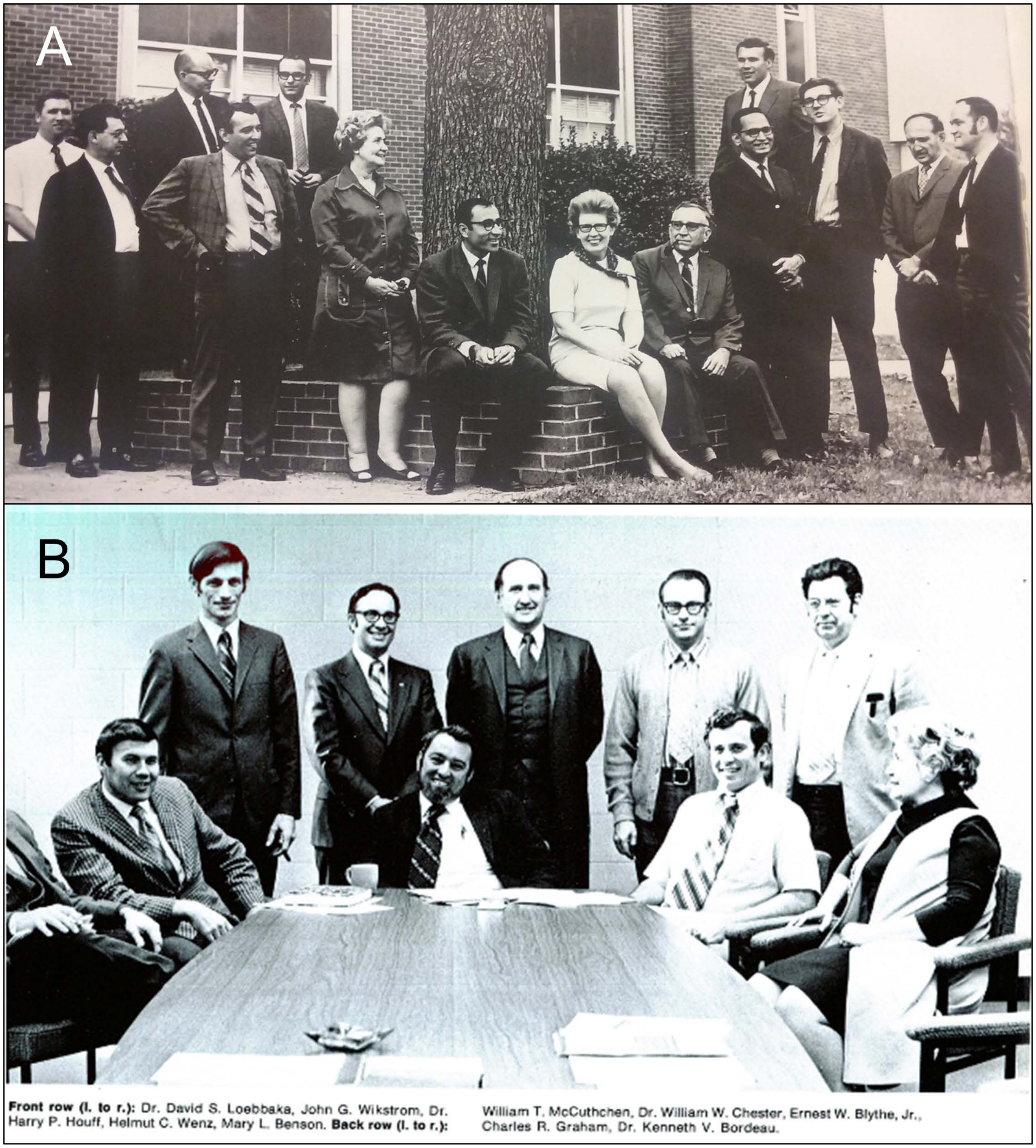

Figure 4: Photographs of the earliest iterations of the geosciences. (A) Department of 1970 interim taken in front of the EPS Building (1971 Spirit Yearbook). Geologists Ernie Blythe is second from the right and Ken Bordeau is second from the left on the front row. William McCutchen is not pictured. The other members were geography and physics faculty. (B) 1974 GGP faculty meeting in EPS conference room (1975 The Spirit Yearbook). Standing (left to right) are William McCutchen (geology), Wayne Chester (geography), Ernie Blythe Jr. (geology), Charles Graham (physics), Ken Bordeau (geology). Seated (left to right) are John Wikstrom (geography), Harry Houff (physics, chair), Helmut Wenz (geography), and Mary Benson (physics). David Loebbaka (physics) is seated to far left partially pictured (Photos supplied by University of Tennessee at Martin Archives).

fledgling geology and geography programs had low numbers of majors and graduates, and was falling under scrutiny. The geography and geology faculty (Figure 4B) determined that a combined degree "umbrella" would be prudent and submitted a proposal in May of 1975 to merge the two degrees into a single geoscience degree program, still within the Department of Physical Sciences (UTM, 1975). The report noted that, if successful, the UTM geoscience program would be the first such merger of geology and geography within Tennessee. There was little change to each discipline's degree curriculum requirements.

The proposal was accepted and approved; however, with modification. Geology and geography were effectively removed from the Department of Physical Sciences (which underwent other changes) and geology and geography were elevated to being a new department (UTM, 1976). There was no change in the physical location of geology or geography (still located on the second floor of the EPS building). The department office was established in Room 222 of the EPS building, which was also the outer office suite for the physics faculty, as it was determined that the physics faculty, including astronomy, would be included in the newly formulated department. It should be noted that there was no major in physics at this time, nor has a major in physics ever been established. Physicist Harry Houff became the first chairman of the department.

The 1976 academic year catalog listed, for the first time, the Department of Geosciences and Physics (UTM, 1976). By 1978, Bordeau had been promoted to full professor and Blythe and McCutchen to associate professor. Also in the new umbrella geosciences department were department chairman Harry P. Houff (physics), Davis S. Loebbaka, Henry C. Allison, Mary Benson (physics), Wayne Chester (geography), Charles R. Graham (physics), Helmut Wenz (geography), and John G. Wikstrom (geography) (UTM, 1978).

The major changed to a B.S. in Geoscience, with four concentrations. Option A – Earth science concentration required a variety of geology, geography, and astronomy courses with upper division electives. The Option B – Individualized are a of concentration was subject to the approval of the geoscience faculty and the Dean and designed to provide maximum flexibility in curriculum design for a student. Option C – Geography Concentration was the primary geography major's option and Option D – Geology Concentration was the primary geology major's pathway. For Option D, aspiring geology students were required to complete the Geology 1110-1120-1130 introductory sequence followed by the original B.S. geology curriculum. No minor was offered in the geology concentration within the geoscience degree. Geology added several courses including the return of a course for engineering students (1210 Engineering Geology), Survey of Petroleum Occurrence and Development 2990, and Earth History and the Fossil Record 3110 (UTM, 1976).

The rest of the 1970s and early 1980s were a period of relative stability in the geology program. However, in 1979, a reorganization of the University resulted in the Department of Geoscience and Physics being reassigned from the College of Liberal Arts to the newly named College of Arts and Sciences. In 1987, geographer Helmut Wenz received funding for a travel study trip to Venezuela that would be the precursor to the very successful travel-study program in the department for the next several decades (see below). Geologists McCutchen and Blythe participated in the trip to study (their first international travel for the program). McCutchen assumed the role of acting department chair from 1988–1989.

The next major change in faculty occurred in 1988 when Bordeau unexpectedly retired at the end of the academic year after 21 years of teaching. Michael A. Gibson (1957–) was hired becoming the first of the "second generation" geology faculty (the last geology faculty had been hired in 1969). He earned his B.S. in geology from the College of William and Mary, an M.S. in geology from Auburn University, where he taught for one year, and his Ph.D. University of Tennessee Knoxville. Gibson's Ph.D. research centered on the paleoecology of the Lower Devonian Ross Formation in West Tennessee. With the hire of Gibson, geologic research production increased significantly, and he was considered the program's "first research hire" (McCutchen, personal communication). Over the years, his research interests expanded to include the geology of Belize, Central America and Quintana Roo, Mexico, the Reelfoot Lake region, and ultimately the Cretaceous Coon Creek Formation (Gibson, 2024A). He was also active at the national level in the Paleontological Society and National Association of Geoscience Teachers, winning the Neil Minor Award in 2007 (Byerly, 2008). He was one of the founders of the Tennessee Earth Science Teachers association (Gibson, 2024B, this volume) and helped establish Tennessee's state fossil (Gibson, 2024A). He also served as president of the Tennessee Academy of Science (Gibson, 2010). Gibson remained at UT Martin for 35 years, making him the second-longest running geology faculty member in the history of the department.

Gibson added additional paleontology offerings to the program by adding Paleobiology 351 in 1989 and Paleoecology 471 in 1990. After teaching it once, Gibson dropped Bordeau's Biostratigraphy in 1990. Geology of Tennessee 334 returned to the curriculum as an elective in 1996 (UTM, 1996), along with Geodynamics 371, which was a course that focused on geophysics applications in geology, Geohydrology 440, Special Topics in Geology 481, and Senior Research 490 (UTM, 1996).

Blythe had become the founding director of the UT Martin Honors and Scholars programs in 1981, where he would remain until his retirement in 1997, although he continued to teach sedimentology and stratigraphy until 1990. As the Honors and Scholars programs grew, his time commitment to those programs grew as well. In 1990, Blythe moved to the Honors and Scholars programs full-time. Gibson took over teach structural geology and a new sedimentologist was sought. Blythe passed away in 2005 (See Gibson, 2007 for his GSA memorial).

The middle 1990s was a time of faculty turnover in the department. Geographers John Wikstrom (who taught geography from 1970–1995) and Wayne Chester (who taught geology and geography from 1960–1995) both retired. Cultural geographer Jefferson Rogers was hired in 1995 and meteorologist Mark Simpson was hired in 1996, both originally in temporary positions, as their replacements. Geology needed need of another faculty member to cover its expansion and Blythe's move out of the department.

Changes in department leadership transpired as well. For the 1988 academic year, McCutchen served as acting chair and for the 1990 academic year, physicist David Loebbaka served as interim chair and oversaw the hiring of a new department chair, Robert P. Self, who became the first geologist to chair the department. Self also filled the faculty position vacated by Blythe and the second person in the "second generation" of geology faculty.

Robert P. Self (1940–2019; A.A. Pasadena City College, B.S. and M.S. University of Oklahoma, Ph.D. Rice University) assumed the mantle of Department Chair in 1990 (see Gibson [2020] for Self's GSA memorial). Self, a sedimentologist, had retired from Nicholls State University in Thibodaux, LA, after nineteen years of service, which included serving as their department chair from 1980 until the Nichols State geology department closed down in 1990. For his master's degree at Oklahoma, Self studied under Charles J. Mankin, doing his dissertation on the Permian Duncan Sandstone. After one year at Florida State University working toward a Ph.D., he transferred to Rice University in Houston, TX to study under Robert Lankford. For his dissertation, Self studied the petrology of Holocene age carbonates on the modern beaches of Veracruz, Mexico. While at Nichols State, he developed an interest in gravel deposits of the Citronelle Formation along the Gulf Coast. When he moved to UT Martin, he expanded that research to include the Paleogene and Neogene gravels of West Tennessee, publishing several papers, including one paper that postulated a new explanation for how the Tennessee River changed its course to flow northward (Self, 2000). In addition to teaching sedimentology and stratigraphy, Self added Environmental Geology 341 in 1990 and Oceanography 310 to the UTM curriculum in 1991 (UTM, 1990; 1991). Self served as the chair of the department until 1994 when he stepped down to assume full-time teaching responsibilities; he remained part of the geology faculty until his retirement in 2007 (Gibson, 2020). After his retirement, Self relocated to central Florida, where he continued to teach geology for Ocala Community College until his passing in 2019.

Department of Geology, Geography, and Physics

In 1992, the department underwent a name change to become the Department of Geology, Geography, and Physics (GGP) to give greater name exposure to the individual disciplines (UTM, 1992). Physicist Harry Houff was elected as chair of the department from 1991–1996. Physicist David S. Loebbaka became chair of the department in 1995 and served until Harry Houff returned as interim chair for the 1999 academic year (UTM, 1990–1996). Houff retired in 2000.

During this time the geography program added a concentration in Travel and Tourism under the leadership of geographer Helmut Wenz. The popularity of this program grew rapidly and many of the international trips were cooperative ventures with faculty in geology and with cross-listed course numbers. These travel-study courses included trips to Europe, Africa, Central America, South America, as well as Japan, Mexico, and Canada. The Travel and Tourism Club was established in 1997 (see Gibson and Hudson, 2024, this volume). The Belize, Central America trip became a yearly offering through the late 1990s and early 2000s.

In 1991, Gibson traveled to Japan as part of the UT

Martin – Hirosaki University sister school relationship. This resulted in sedimentologist Kotaro Kamada of Hirosaki University coming to GGP as a visiting professor for the 1993 academic year. He taught courses on the geology of Japan and seismology.

As noted above, in 2007, Bob Self retired. Following the tradition of informally renaming rooms in the EPS building to honor retiring faculty, the geology field equipment storage room that is outside of EPS 204 was renamed "Self Storage" in his honor.

Stan P. Dunagan (1970–) was lured away from Austin Peay State University to become UT Martin's third sedimentologist. Dunagan was the first tenure-track faculty member who was also an alumnus of the same UT Martin geology program. Dunagan graduated from UTM in 1993 and entered the Ph.D. program at UT Knoxville under Kenneth R. Walker, the same professor who mentored Ernie Blythe, graduating in 1998. His research focused on lacustrine and palustrine carbonates from the Morrison Formation (Upper Jurassic) in Colorado. Dunagan assumed most of Self's courses (except Oceanography which went to Gibson). Over the years, Dunagan's research focus continued in sedimentology, often collaborating with Gibson, and geohydrology. Dunagan enhanced the travel opportunities for students in the program by routinely running field trips within the U.S. and internationally, including Central America, Iceland and Africa, as part of the UT Martin Travel Studies program.

Geology underwent a major revision of its curriculum in 1996 including the introductory geology sequence (UTM, 1996). The introductory geology sequence used to satisfy entrance into the geology major, and to satisfy general education (the GenEd) requirements in science, would now consist of Physical Geology 111 and Applied Geology 112. This was a direct response to many students telling the faculty that if they had only known about the geology major earlier, they would have majored in it. Most students taking the introductory sequence to satisfy GenEd science requirements waited until their junior and senior year to take geology. Another issue facing the geology program was the rotation schedule of classes. Most upper division course were only offered on a every-other-year basis, which created difficulties for students scheduling require classes.

Applied Geology 112 was designed to be a modified version of environmental geology that would provide students with exposure to geology topics most relevant to their lives as citizens. It was felt that this change, away from a traditional geology sequence to one that introduced environmental topics (e.g., global change, medical geology, engineering geology, etc.), would increase recruitment of new geology majors by exposing them to these topics earlier in the academic progression. Geology majors could not use the Applied Geology 112 course to satisfy their degree requirements. Historical Geology 113 remained at the introductory level for the time being, but was targeted toward geology and education majors.

The geology degree required Physical Geology 111, History of the Earth 113, Mineralogy 318, Igneous and Metamorphic Geology 331, Structural Geology 337, Principles of Paleontology 351, Sedimentology 441, Principles of Stratigraphy 412, and Methods in Field Geology 462–463, along with an additional 6–9 hours of geology electives. This sequencing was standard for most geology programs nationally. This curriculum would remain steady until 2000, when one addition to the required geology curriculum was made. Career Exploration and Development 200, for one credit hour, is added as a vehicle to help geology majors work on skills such as writing mechanics and career portfolio development (UTM, 2000).

The UT Martin celebrated its 100th anniversary beginning in 2000, with Chancellor Phillip Conn at the helm (Conn had replaced Margaret Perry as chancellor, who retired in 1997.) Also in this year, UT Martin reorganized its colleges within the University. The School of Arts and Sciences was reorganized such that GGP was now moved into the newly formed College of Engineering and Natural Sciences (CENS) with engineer Doug Sterrett as the Dean. The GGP office moved out of the "physics suite" to the newly remodeled Room 215, a more centralized location within the department with more space.

Due to Harry Houff's stepping down as department chair (1998), and having an interim chair for two years, and followed by geologist Tom McCutchen's retirement in 2000, the GGP was in need of both a new chair and a "hard rock" geologist. At that time, McCutchen was the longest running member of the geology program, 36 years, and the last of the "founding fathers" to retire. Upon his retirement, the faculty wanted to provide him with a memorable sendoff, so the Outstanding Senior Geology Major Award was renamed the William T. McCutchen Geology Award in his honor. As noted earlier, this award was later endowed by alumnus Water Parrish and remains the largest geology award given annually to a geology major. A favorite of the students, McCutchen was known for his great sense of humor. When initially asked if he would like EPS 204, the introductory classroom, named in his honor, he jokingly said to rename the faculty men's room for him instead... and that is just what happened, beginning a tradition in the department to that survives to this day.

In 1997, the University hired geologist Christopher I. Chalokwu (1952–) as Vice Chancellor for Academic Affairs, becoming the first geologist to serve in the upper administration at UT Martin. Chalokwu earned his B.S. and M.S. in geology from Northeastern Illinois University and his Ph.D. from Miami University. Chalokwu did not carry regularly scheduled teaching duties in the geology program at UT Martin; however, he participated in numerous geology events. The geology program had now grown to five faculty; however, this is short lived as Chalokwu left UT Martin in 2000 to accept a position at St. Xavier University, Chicago.

The early 2000s was another time of turnover in GGP. Geologist Aley K. El-Shazly (1962–) joined the department in 2000 becoming the program's third chair. Egyptian-born El-Shazly earned his B.S. in geology from the University of Alexandria, Egypt and his M.S. and Ph.D. in geology from Stanford University. El-Shazly was a geochemist and metamorphic petrologist by training, so he assumed the "hard rock" position vacated by the retirement of Tom McCutchen in addition to his duties as a department chair. El-Shazly served as chair until 2002 when he is resigned from the chair's position and assumed full-time teaching responsibilities. Geographer Jefferson S. Rogers (1962–) became interim chair in 2002. In 2007, Rogers became the chair of GGP, the first geographer to chair the department (UTM, 2007). Rogers remained the chair of the department until 2009 when the program is removed from the CENS to be a program within the College of Agriculture and Natural Sciences (see below).

In 2005, El-Shazly left UT Martin to accept a position at Marshall University in West Virginia. The "hard rock" position was again vacant. Gibson and Dunagan covered the hard rock classes for one year. Structural geologist Elizabeth A. McClellan (1953–) joined the faculty for the 2007 academic year as the third "hard rock" geologist. McClellan earned her a B.S. from the University of South Alabama, a B.S. and M.S. in geology from the University of Alabama, Birmingham, and had just finished her Ph.D. from the University of Tennessee Knoxville, where she worked under the iconic structural geologist Robert Hatcher. While at UT Martin, McClellan continued much of her research on the structural relationships and tectonics of the Appalachians. McClellan was the first female faculty geologist in the program's history.

In 2006 (UTM, 2006), geology restructured its course offerings by moving the historical geology course to become History of the Earth 340 and added a new paleontology course entitled Fossils: History of Life 325 to capitalize on the very large fossil collection the University had just obtained from Vanderbilt University.

Beginning in 2005, GGP faculty Gibson and Lionel Crews (astronomy) became the natural science experts tasked with helping to design the natural history exhibits for a new museum-park to be constructed in Union City, the Discovery Park of America (DPA). Their natural history committee worked with design firms and the Kirkland foundation to obtain over $2-million worth of fossils, mineral, and rocks for indoor and outdoor exhibits (e.g., Discovery Park of America (DPA), 2019). The DPA, which opened in 2008, features many of UT Martin's collection of minerals, rocks, and fossils on loan to the park and includes a mosasaur skeleton discovered by a UT Martin student on an expedition to Kansas to obtain specimens for the DPA. The relationship between the DPA and UTM resulted in geosciences having a dedicated, funded, natural history internship at the DPA that has served as a career pipeline for geoscience students upon graduation. Gibson continued to serve as a consultant to the staff at the DPA into his retirement.

The 2007 academic year saw the next major change in the geology curriculum with a total restructuring of the course numbering system (UTM, 2007). Numerous revisions over the years, compounded with a Registrar's stipulation that no course number that was removed could be reused for ten years, had resulted in a disjointed system of course numbers that students found confusing for advising. A new numbering system was devised in which all required geology core courses would end in "0" (e.g., 110, 120, 130, etc.) and all geology elective courses would end in "5" (e.g., 315, 345, etc.). Non-major's courses like Engineering geology retained course numbers ending in a "1" (e.g., 121). Honors sections were added to the introductory sequence for the Honors Program students (e.g., Geology 110H, Geology 120H). This numbering system is still in effect.

Geology 200: Career Exploration was removed from the geology curriculum and replaced with Geology 210: Methods in Geoscience. This course had a mirror section in the geography curriculum and was team-taught by Gibson and Rogers. The course was primarily a course in how to conduct scientific research, write scientifically, and included other skills needed by professional geoscientists (e.g., photography, oral speaking, etc.). Geology of Tennessee was renamed Tennessee's Geologic and Culture Landscape 365, cross-listed with the geography program to replace their Geography of Tennessee course, and became the second team-taught course by Drs. Gibson and Rogers. The entire state of Tennessee was traversed as part of the course, which demonstrated the role that geology and landforms played in the history and culture of Tennessee (Gibson and Rogers, 2010).

In 2008, the geology program expanded again with the hire of Thomas A. "Lan" DePriest (1974–) as the new lab instructor. Gloria Mansfield (1945–2009) had served as the geology lab instructor until her health declined and forced her to unexpectedly retire in 2008. DePriest earned a B.A. in environment geography from the University of Memphis (1997), a B.S. in geology from UT Martin (1999), a M.A. in curriculum and instruction from the University of Mississippi (2005), followed by a Ed.D. in educational from Union University (2009) and a Ph.D. in Earth science from the University of Memphis (2018).

The Department of Agriculture, Geoscience, and Natural Resources (2008–Current)

Beginning in 2007 and culminating in 2009, the largest global financial crisis since the Depression—The Great Recession—gripped economies around the world (e.g., Weinberg, 2013). The impact on higher education was far reaching. Faced with a financial crisis, the University of Tennessee System looked to save money by downsizing and by removing or restructuring "low producing" programs to survive the financial crisis. In Fall of 2008, the UT Martin administration created a committee, Academic Program Discontinuance Committee (APDC), to address this issue on the UT Martin campus. This committee, along with Dean of the College of Engineering and Physical Sciences Doug Sterrett, identified the GGP as program to cut and unceremoniously informed the GGP faculty and staff in November of 2008, just days before their Thanksgiving recess. Some changes were immediate, and others were to take effect at the end of the academic year. Immediately, GGP chair Rogers worked with the faculty to produce a document in defense of the department that highlighted the accomplishments of the department and its importance to the mission of UT Martin, in particular noting how the discontinuance of the program would likely cost UT Martin more money than it would save (APDC minutes, February 3, 2009; February 13, 2009; March 5, 2009).

The same day of the announcement to the GGP faculty by Dean Sterrett , the Dean of the College of Agriculture and Applied Sciences (CAAS), James Byford, contacted the geology faculty with a hopeful proposition. Byford recognized the utility of geology, and the meteorology courses in geography, to the CAAS Department of Agriculture and Natural Resources program. Byford presented a proposal to the chair of that department, Jerry Gresham, who took the proposal to his faculty a few days later, to merge geology and geography with agriculture and natural resources. The agriculture and natural resources faculty were enthusiastically receptive to the proposal. By spring 2009, the University administration had also signed off on the merger. In his last e-mail to the GGP faculty on June 16, 2009, Rogers explained the changes that were now coming: Effective Wednesday July 1, 2009, the Department of Geology, Geography, and Physics (GGP) on the UT Martin campus was dissolved and its units reassigned to other departments. The geology and geography programs, and their faculty, were to be absorbed into the newly renamed Department of Agriculture, Geosciences, and Natural Resources (AGN) under agriculture faculty Jerry Gresham as chair. The "P" of GGP, physics, was briefly stated to move into engineering, but ultimately was combined with chemistry into a new Department of Chemistry and Physics. GGP chair Rogers (chair from 2002–2009) resumed his duties as a full-time faculty member in geography and GGP's administrative assistant, Janice Lee, left UT Martin. GGP's department office in 215 EPS was closed-down and administrative duties moved to the AGN office in 256 Brehm Hall under the AGN administrative staff. All EPS spaces occupied by geology and geography remained under their control.

In 2011, the leadership for AGN underwent its first change since the arrival of geosciences into the department two years earlier. Jerry Gresham became the dean of the college (CAAS) and the Department of AGN faculty selected AGN faculty member Tim Burchum as interim chair. Burchum took a position at Arkansas State University in 2013. AGN faculty member Wes Totten became the chair of AGN in 2014 and has remained in that role. During this span of time, Dean Gresham retired (2013) and was succeeded by Todd Winters, who remains the college dean to this day. Dean Gresham passed away in 2017.

The move to AGN proved to be beneficial for both the geology and geography programs in terms of resources and budget, both of which increased significantly in the years after the merger. Agriculture was the largest program on the UT Martin campus, which is a land grant school. Geosciences were traditionally STEM, and usually was housed in science colleges elsewhere, so there was a period after the transition that the geosciences at UT Martin struggled to maintain its STEM status and image. Regardless, the move to AGN provided more money, space, and other resources that could not have been achieved otherwise. Additionally, AGN benefitted from the addition of a meteorology concentration in 2011 (UT Martin had collected climate and weather data since 1939 (UTM, 2011; Grimes, 2014). As geology was part of the GenEd science core in the liberal arts degree in the College of Engineering and Natural Sciences (CENS), AGN, in a different college, now had access to the money generated by these courses.

In the spring of 2009, McClellan announced that she would be taking a position at Radford University in Virginia. Gibson once again taught minerology and structural geology and Dunagan taught igneous and metamorphic petrology. For Fall of 2011, Benjamin P Hooks (1978–) joined the geology program as its fourth "hard rock" geologist. Hooks earned his B.S. in geology from Allegheny College and his M.S. and Ph.D. in geology from the University of Maine. His dissertation topic revolved around the geodynamics of exotic terrane accretion in southeastern Alaska. Hooks remained at UT Martin until 2016, when he left UT Martin to work in the private sector.

Angela Van Boening (1980–) became the fifth "hard rock" geology faculty member in 2017. She had a dual geology and geography B.S. from Northwest Missouri State University, a M.S. in geology from the University of Missouri, and was finishing her Ph.D. from the Texas A & M University at College Station when hired (completed in 2020). She was originally hired as a three-year instructor, but became tenure track in 2020. Along with her expertise as a structural geologist, Van Boening had developed research in geoscience education involving geologic learning and cognitive science principles. Her dissertation focused on how geology undergraduates used gestures to convey information and illustrate ideas when they were describing and explaining geologic features.

Rapid turnover of the laboratory instructor position became an ongoing issue for geosciences. By 2010, Lan DePriest had shifted roles in the program and was now responsible for the growing online and extended campus offerings of the geology introductory sequence. Geology the first dual enrollment and online science courses at UT Martin. Also, UT Martin had satellite centers in Selmer, Parsons, Bolivar, and later Sommerville and Jackson State Community College. DePriest became the program's traveling educator.

Mary Varnell Jubb, (1982–) joined the department in 2010 becoming the program's third laboratory instructor. She earned her B.S. in geology from UT Chattanooga and her M.S. in geology from UT Knoxville having studied structural geology under Robert Hatcher. Jubb left the program after just one year and Eleanor Gardner (1985–) became the program's fifth lab instructor in 2011. Gardner received her B.S. from St. Agnes Scott and a M.S. in geology from the University of Georgia where studied the evolution of birds under the mentorship of Sally Horn. She left the program in 2016 and was succeeded by Claire Landis. Landis (1986–) earned her B.S. in geology from the Tennessee Tech University and a M.S. from the University of Wyoming, where she worked in the planetary geology field. She left UT Martin in 2017, and was replaced by Audrey Pattat. Pattat (1992–) had earned her B.S. from Tennessee Tech University and her master's from Texas Tech University in Lubbock, TX.

Even though the geology program saw several changes in faculty, 2009–2018 were relatively stable years in terms of the courses offered in the geology program, with a few notable exceptions. In 2010, Marine Geology 415 was added to the geology curriculum, capitalizing on Gibson's teaching as an adjunct summer faculty for the Dauphin Island Sea Lab, Alabama (2004–2018).

In 2018, the geoscience faculty began a major overhaul of the entire geosciences program in response to declining student recruitment for the major, and as an attempt to modernize the course offerings, adapt to changing learning styles of students, alleviate scheduling problems for students due to "every other year" course rotations for required courses, and to take advantage of the unique position that geoscience held within the AGN. This revision was the most extensive program change in the history of the geosciences program. It included the move to a three-semester rotation to the required core courses for the geology major as one step towards solving the problem of new majors having to wait so long for a required class to be offered. Another major shift was to more-fully integrate the geology and geography curricula at the introductory level, which could help recruit more majors, by including a 100-level meteorology laboratory course. The revision also readdressed issues related to the scientific writing, speaking, and mathematics skills of students seen as becoming increasingly more deficient. Geography was removed as a concentration to make room for the new meteorology program, although courses in physical and cultural geography were still offered as service courses to other programs. The new program went into effect Fall 2019, several months prior to the breakout of the COVID-19 pandemic (see below), and underwent a few minor tweaks for the next several years (UTM, 2019–2023).

The result was an innovative and modern curriculum focused on the student's needs and proclivity to be mobile in their career paths and with more flexibility in course timing and offerings. Greater emphasis was placed on experiential learning and broader global issues. The current (2024) geosciences program consists of a major in Geoscience with three possible concentrations: geology, geosystems, and meteorology (UTM, 2024). Within the geosystems concentration, students can follow a geographic information systems (GIS) option or a more general Earth sciences option.

For the Geology Concentration, students need a minimum of 42 credit hours in of upper division geology courses. The courses are organized into four content areas designed to ensure a common core based in classical geology while allowing the students some flexibility in their upper division courses and electives (UTM, 2024) for specialization. "Geology Foundations" is a sequence of 100–200 level introductory courses required of all geology majors: GEOS 120 – Earth Materials and Processes; GEOS 130 – Global Change and Earth History; GEOL 210 – Geoscience Literacy; GEOL 220 – Methods in Field Geology; and GEOL 230 – Geoanalytics. Geoscience literacy, methods in field geology and geoanalytics were designed to provide majors with the writing, speaking, field, and mathematical skills commonly used in the geosciences and whose mastery is expected for the upper division geology courses.

The "Geology Core" consists of the specialty areas typical in geology (any four of the six courses listed can be used to satisfy this requirement): GEOL 320 – Mineralogy; GEOL 330 – Igneous and Metamorphic Petrology; GEOL 350 – Principles of Paleontology; GEOL 360 – Sedimentology and Stratigraphy; GEOL 400 – Structural Geology; and GEOL 445 – Geohydrology.

The third content area is "Geology Electives," mostly three-hour non-laboratory courses, and requires at least eight hours to be taken from: GEOL 285 – Topics in Geology; GEOL 315 – Principles of Oceanography; GEOL 355 – Principles of Geomorphology; GEOL 385 – Plate Tectonics; GEOL 395 – Economic Geology; GEOL 485 – Special Topics in Geology: (Title); and SOIL 321 – Soil Genesis, Morphology and Classification.

Finally, geology majors are required to have at least six hours of coursework of an applied, experiential, travel, or work-study nature ("Experiential Courses") drawn from: GEOG 410 – Geographic Information Systems: Modeling and Applications; GEOL 275 – Travel Studies in Geology; GEOL 365 – Tennessee's Geologic and Cultural Landscapes; either GEOL 401 – Research Participation or GEOL 402 – Research Participation; GEOL 415 – Marine Geology; GEOL 465 – Geology Internship; GEOL 475 – Travel Studies in Geology: (Title); GEOL 495 – Senior Research Project; and GEOL 499 – Senior Seminar.

COVID-19 Pandemic

In December 2019, a new respiratory coronavirus, COVID-19, originated in Wuhan City, in the Hubei Province, China (e.g., Centers for Disease Control (CDC), 2023). By March of 2020, the campuses in the UT System, and nationwide, were sending their students home for safety. The pandemic quickly spread worldwide. University faculty were forced to shift classes from "face-to-face" to online deliver, including labs and field trip experiences. Most faculty were told to work remotely from home and travel was severely restricted. Geology responded by shifting ongoing courses to the new format, using Zoom technology and filming resources, and prepared take-home laboratory kits for student to use in laboratories. Nearly all public events were cancelled, including the Eta Alpha Chapter of Sigma Gamma Epsilons plans to host the 2019, and then rescheduled, 2020 biennial convention (Gibson and Hudson, 2024, this volume). The "lockdown" and online programming remained in effect until Fall, 2020 when the campus reopened for classes under rigid COVID-19 safety protocols that included wearing masks to class, limited class enrollments and distances between students, continuous cleaning of classrooms, and limited travel. University budgets were severely impacted, but the geology program managed to weather the pandemic reasonably well and benefitted from having all courses converted to online delivery formats that could be used whenever needed. Additionally, faculty had been receiving pedagogical training in online course delivery. By 2021, several vaccines had been developed. Despite a public controversy about the vaccinations and face mask-wearing, including a UT System policy that vaccinations could not be required, by Fall of 2021 the pandemic seemed to be under control and the University again offered in-person classes and things began to get back to normal.

The most recent faculty changes in geosciences began with the arrival of Allison Bohanon (1998–) in 2022 to take over as the laboratory instructor from the departed Audrey Pattat. Bohannon had a B.S. from Tennessee Technological University and a M.S. GIT from Mississippi State University. In 2023, Gibson retired after thirty-five years in the geology program. In 2024, Gibson's paleontology position was filled by his son, Brandt M. Gibson (1992–). Brandt Gibson is an UT Martin geology alumnus, having earned his B.S. in geology and a B.S. in biology in 2015. He completed his M.S. and Ph.D. at Vanderbilt University, working under paleontologist Simon Darroch. He was also a post-doc for both Vanderbilt University and University of Toronto, Canada. Gibson's research interests are focused on the early evolution of life and taphonomy. This also represents the first "father–son" legacy in the geology program at UT Martin.

Graduate Courses and the GEDU Program

Throughout its history, the geology program has always been primarily undergraduate, offering a B.S. in geology and a minor in geology. Graduate level geography courses were added to the course listing beginning in 1968 (UTM, 1968), soon after the name change from UTMB to UT Martin. Geology began offering graduate level courses in 1971 when their major was approved (UTM, 1971). Most upper division geology course carried 500 and 600 (graduate) level numbers. These courses were targeted primarily toward teachers and students in the education program working on advanced degree requirements. Additionally, the GGP faculty, and later AGN geoscience faculty, were active in grant-funded summer professional development programs for educators that were seeking advanced course work at the master's level. These courses could only be taught by faculty who had earned graduate faculty status as approved by the UT Martin graduate school.

In the 2000s, a need for qualified teachers to teach geology and Earth science at the secondary level was identified by the Science Consultant to the Tennessee Department of Education (see Gibson, 2024B, this volume). At that time, there was no graduate-level program in Tennessee for geoscience education. Additionally, online courses and programs were becoming popular avenues for teacher development. At the urging of the Tennessee State Science Consultant, a cooperative program between geology program and education department at UT Martin devised an innovative way to offer graduate level geoscience training that could lead to a geoscience education endorsement for teachers. The program was housed within the graduate program in the School of Education, but primarily ran by M. A. Gibson in geology. The only other graduate geoscience education program in the southeast was the Teachers in Geoscience (TIG) program at Mississippi State University (e.g., Binkley and Johnston, 2007).

The Master of Science in Education with Major in Teaching and Concentration in Interdisciplinary: Geoscience Education (GEDU) supported teachers seeking advanced training in geoscience disciplines of geology, astronomy, meteorology, or general Earth science. The GEDU was offered as professional development for teachers moving into geoscience education from another science content area, adding Earth science or geology courses, or seeking to teach AP or dual enrollment (DE) courses. The GEDU courses could be taken for the degree or as professional development (UTM, 2024).

In 2008, the first teachers matriculated into the GEDU program (UTM, 2008). All coursework was online except for a field course experience, which was usually offered in the summer and could be satisfied by a travel-study program transferred from any institution. Education faculty included courses in advanced topics of and geology faculty provided the geoscience content. The GEDU curriculum consisted of: GEDU 700 Advanced Earth Systems Science; GEDU 705 Earth/Space Science and STEM Integration for Middle Grades 5–9 Teachers; GEDU 710 Advanced Physical Geology for Educators; GEDU 720 Oceanology for Educators; Geoscience Education 730 Understanding Evolution; GEDU 740 Field Experience in Geoscience: [Topic Title]; GEDU 750 Global Climate Change; and GEDU 760 Astrophysics for Educators. Geoscience instructors in the program included UT Martin geologists and geographers, as well as geologists from UT Chattanooga and UT Knoxville. The program was marginally successful resulting in eight graduates.

Coon Creek Science Center

The geology program at UT Martin administers a unique asset, the UT Martin Coon Creek Science Center (UTMCCSC). The UTMCCSC is an internationally recognized fossil lagerstätte deposit from the Upper Cretaceous. It is the type locality and type section for the Coon Creek Formation, which is a marine clastic deposit that preserved unaltered invertebrates (including the State Fossil of Tennessee, *Pterotrigonia thoracica* (later renamed *Tennessiella thoracica*), vertebrates, plants, and trace fossils. The site, located in rural McNairy County, Tennessee, was preserved for research and education in 1988 by the Memphis Pink Palace Museum (MPPM). UT Martin geologist Michael Gibson began serving as Associate Curator to the MPPM and oversaw the scientific research at the site, along with geoscience education for teacher professional development. In 2019, UT Martin acquired control of the site and rededicated the facility after upgrades that included a new paleontology laboratory. M. Gibson served as the director of the UTMCCSC until his retirement in 2023. Alan Youngerman, director of the Selmer Center, assumed the directorship of the UTMCCSC with UT Martin geology alumnus Joshua Ratliff becoming the head of instruction. Josh Ratliff is a lecturer in geosciences in AGN with a B.S. in geology from UT Martin and a M.S. in paleontology from the South Dakota School of Mines.

Currently, the 232-acre UTMCCSC is the only geoscience education facility of its kind in the southeast and is visited by over 5000 students, researchers, and the public per-year. The reader is referred to Gibson (2024A) for a complete history of the site, including a description of geoscience programing.

SUMMARY

The subject of geology has been taught at this institution for more than 124 years and has been an integral part of higher education in West Tennessee dating back to the original days of Hall-Moody Institute. It began as a service course to support agriculture, engineering, and education programs and continues its strong service mission. There was high faculty turn-over during these earliest years, along with a hiatus in offering geology from the Great Depression until after World War II. By 1947, Hall-Moody Institute had been acquired by the University of Tennessee system as the UT Junior College. A. Paul Wishart, the first trained geologist to be hired, championed the development of a broader geology course curriculum that laid the foundation for later expansion. The sequence established by Wishart remained largely unchanged through the transition of UT Junior College to UT Martin Branch, and then through most of the earliest part of the UT Martin years. The geology program remained predominantly service oriented during this time.

High college enrollments of the late 1950s and early 1960s, along with a revolution of science education (K–16) prompted by national and political events, paved the way for a greater demand for geology and created a need for more geology faculty Nationwide. In 1962, the Engineering and Physical Sciences (EPS) building was constructed, and geology moved into the second floor of EPS and remains in that building to this day. There was strong support within the Department of Physical Sciences to expand geology. In 1964, the first "founding father" of what will become a degree-granting program in geology in 1971, William T. McCutchen, was hired. Kenneth Bordeau and Ernest Blythe, Jr. were the next "founding fathers," hired in 1967 and 1969 respectively. The Geology, Geography, and Physics department was established in 1972 when geology became a degree program. In 1975, geography and geology combined degree programs to become geosciences (UTM, 1975).

For the next half century, the geology program continued to be a mostly undergraduate program providing service to many of the other programs at UT Martin. It went through periods of stability punctuated by periods of reorganization, some prompted by external crises. Currently, the geology program is housed in the same college as agriculture and natural resources. The faculty has enlarged to five full-time faculty that maintain active research programs with strong publication records. Over the years, geosciences graduated dozens of geology majors. Many of the UT Martin geology graduates have gone on to earn Ph.D.'s and have become leaders in their fields of study, with three returning to UT Martin as geology professors. The geology program has a vibrant online clientele, and the faculty are highly active at the state, national, and international levels. The program expanded to develop a master's program in geoscience education and is steward of the UT Martin Coon Creek Science Center, a unique fossil site for geoscience education. As this paper is coming to publication, the geology program is approaching its 52nd anniversary and geology, as a course, has now been taught on this campus for 123 years. Geosciences has remained in the EPS building since the building was opened in 1960 (it was renamed the Joseph E. Johnson EPS building in 1991), even when chemistry and engineering were relocated to the new Latimer-Smith Engineering and Science building in 2022. As of this writing, EPS is slated for a renovation that will significantly expand the classroom and lab space allocated to geosciences to two floors of the building, thus heralding a new age for geosciences at UT Martin.

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RESEARCH ARTICLE

Geoscience student organizations at the University of Tennessee at Martin

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ABSTRACT

In celebration of 2022 Sigma Gamma Epsilon 46th National Convention being hosted by the University of Tennessee at Martin (UT Martin), Eta Alpha Chapter, this paper serves a synopsis that celebrates the history of student clubs and professional organizations in the geosciences program at UT Martin. The first geoscience student organization officially recognized by the University was devoted to geology, the GeoClub, and established in 1970 and still serves as the primary student organization for all of the geosciences. UT Martin established the Eta Alpha Chapter of Sigma Gamma Epsilon honor society in 1997. A Travel and Tourism club was in existence from 1994-1999, although it was not officially noted by the University until 1997. A student chapter of the American Meteorological Society was established in 2014, along with the establishment of that degree concentration. The most recent student organization to be established is the local chapter of the Association of Women Geoscientists in 2016.

KEYWORDS

University of Tennessee at Martin, geosciences, SGE Eta Alpha, GeoClub, student organizations, AMS, AWG

THE SOCIETY OF SIGMA GAMMA EPSILON

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INTRODUCTION

Although geology and geography courses were taught at UT Martin from its early days as Hall Moody Institute, continuing through its evolution as UT Martin Junior College and then UT Martin Branch, it is not until 1969 that the first geoscience degree program will be established (Gibson, 2024A, this volume). Geology continued to expand and in 1967 UT Martin Branch becomes the University of Tennessee at Martin (UT Martin). With the groundwork laid for geology and geography, the program became degree granting in 1972 with three geology faculty members, three geography members, and a full curriculum. This occurred just two years after UT Martin established its first student organization devoted to geology, established in 1970. For the past 54 years, the student clubs, honor societies, and student chapters of professional societies have enhanced the collegiate experience for UT Martin geoscience majors and contributed to the mission of the University. In celebration of 2022 Sigma Gamma Epsilon 46th National Convention, hosted by the UT Martin Eta Alpha Chapter, this paper serves a synopsis that celebrates the history student clubs and professional organizations in the geosciences program at UT Martin. For an overall history of the geology program, the reader is referred to Gibson (2024A, this volume), and this paper is intended as a companion history to that paper.

RESOURCES

University catalogs, journals, announcements, annuals, newspaper stories, historical documents (e.g., correspondences, annual reports, self-studies, external reviews, town histories), and personal testimonies were analyzed to chronicle the history of geology at UT Martin. The publications cited in this summary, including recorded interviews of surviving faculty members in 2016, and additional historical documents consulted but not cited,

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are housed in the Office of Special Collections at Paul Meek Library on the campus of UT Martin. Departmental files of the geology program and club historical records are housed with the GeoClub in the Joseph E. Johnson EPS building. The Universities online database of Addenda articles, Spirit yearbooks, archival photographs, and the department's faculty newsletter were used to gather information on student activities.

GEOCLUB

History of GeoClub

The students in the geology program established its first student club in 1970, called the GeoClub (Cavaness and Houstrup, 1988). The GeoClub was established just after geography began to matriculate students for a degree in geography in 1969. The club's name will change over time (e.g., Geo Club, Geoclub, GeoClub), ultimately settling on GeoClub by the 1990s (Figure 1). The GeoClub had been organized by geology professor Ernest Blythe, who served as its first official advisor. The GeoClub's first appearance in the school yearbook, *The Spirit*, was 1970. The club members are pictured with geology faculty member Kenneth V. Bordeau in a candid photo. It was not until 1972 that the GeoClub is officially listed within clubs in the UT Martin Catalog (UTM, 1972).

The original stated mission of the GeoClub was for students and professors at UT Martin drawn to the physical sciences, specifically geography and geology, to have more interaction with other peers in the scientific field. This role has since broadened to become an organization of students interested in all aspects of the Earth. Although membership in the GeoClub are mostly geology, geography, and meteorology majors, the club welcomes anyone interested in Earth science, travel, and fellowship. The GeoClub's first faculty advisor was Ernest Blythe. Blythe remained the faculty advisor until 1987 when William T. McCutchen joined Blythe as co-advisor. In 1992, Michael Gibson became the advisor (Figure 1) and in 1993, geologist Robert Self became a second advisor to GeoClub. In 1993, McCutchen returned to co-advise with Gibson. Gibson was the sole advisor in 1994 and 1995.

By 1994, UT Martin was asserting more control over organizations at UT Martin and their activities. The University began requiring organizations to develop and file a constitution with the Office of Student Life, so the GeoClub, which had been a more informally run organization up to this point, developed a constitution and a logo (Figure 2A). The constitution would undergo revisions in 2005 and again in 2021.

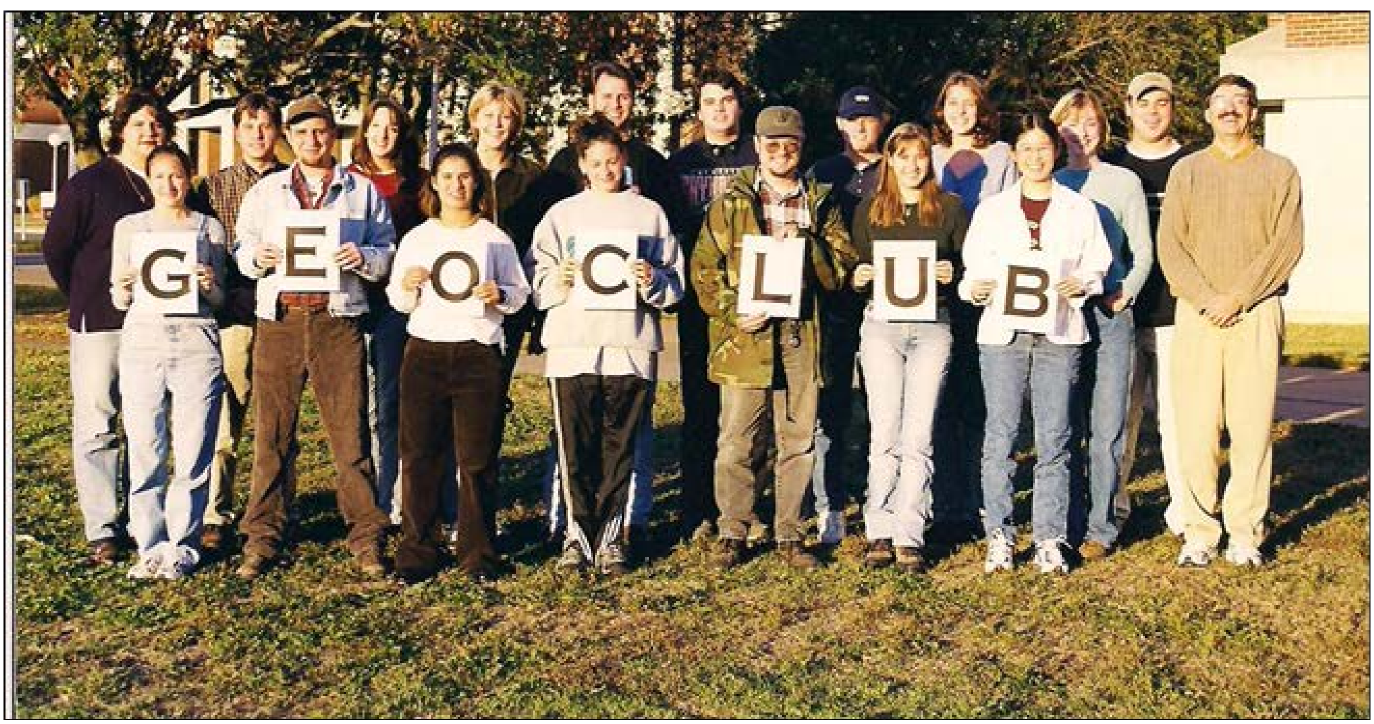

Figure 1: The 1992 GeoClub photograph taken outside of the EPS building. Advisor Michael Gibson is far right and future geology professor Thomas DePriest is standing behind the woman holding the letter C (photographer unknown).

Figure 2: Logos developed by the GeoClub (A) and student chapter of AMS (B).

By the early 1990s, geography students and geology students had begun to drift apart in terms of their interests, reflecting evolving differences in the two concentrations within geosciences. Helmut Wenz had developed a travel and tourism (T&T) program within the geography concentration in 1990 which was drawing a lot of interest (UTM, 1990). He also organized the T&T students into a loose organization similar to the GeoClub. By the mid-1990s, the GeoClub was dominated by geology majors, so their activities became more geology oriented. Geography students were voicing displeasure that GeoClub activities had become geology oriented and were not participating in GeoClub activities, nor were they seeking positions as officers in the club. This schism concerned the faculty, so in an effort to develop a shared atmosphere that may again reunify the GeoClub, the advisorship for GeoClub shifted such that two advisors would be elected by the club membership annually, one advisor would be a geologist and one would be a geographer. In spite of this, the schism continued.

By 1996, geographer Helmut Wenz had become the co-advisor with Gibson. Gibson and Wenz, along with biologist Wintfred Smith, began co-running international travel and tourism courses, primarily focusing on annual trips to Belize Central America and Quintana Roo, Mexico (Gibson and Wenz, 2003). The academic content of the trip was designed to blend the geosciences and these trips partially accomplished the goal of reuniting the geology and geography students; however, this did not manifest in geographers returning to the GeoClub, rather the geographers remained active in T&T. In 1997, the first year that the T&T club was listed in the catalog (UTM, 1997), Wenz folded the T&T club into the GeoClub (although it remained a catalog listing until 1999) as one more effort to reunify the students (UTM, 1999). Wenz and Gibson would remain co-advisors until 2005 when Gibson becomes the sole advisor again for one year. Wenz retired in 2008. Geographer Jefferson Rogers joined Gibson in 2006 through 2008, at which time UT Martin's new meteorology faculty, Todd Albert, joins Gibson as co-advisor for two years until he leaves the University. Gibson's last year as a GeoClub advisor was 2010 with geographer Albert.

Geologist Ben Hooks became the geology advisor from 2011–2017, but there was no geographer co-advisor until 2016 when meteorologist Chris Karmosky comes on-board. Karmosky was the co-advisor for only one semester, however, as he left the University in 2016, followed by Hooks' departure in 2017. Jefferson Rogers returned to be the geographer advisor in 2016, and remained through 2018.

Geologist Stan Dunagan became an advisor in 2017. Dunagan was a UT Martin geology graduate and had served as GeoClub president for two years (1991 and 1992) as a student. He became the first student alumni to return as a tenure-track faculty (Gibson, 2024A, this volume) and the first GeoClub member to return to UT Martin as a GeoClub advisor. Dunagan and Rogers remain co-advisors until 2021 when newly hired geology laboratory instructor Audrey Pattat became the sole advisor. From this point forward, there will be no geographers as co-advisors. Geologist Angie Van Boening served as the geology advisor for the 2022 academic year. In 2023, the next newly hired geology laboratory instructor, Allison Bohanon took over the as GeoClub advisor. By this time, meteorology and geography students were again participating in the club.

GeoClub Activities

The GeoClub is both a service and social organization for the geosciences (https://runway.utm.edu/organization/geoclub). As a service club, the GeoClub is often the "workhorse" of the department supplying manpower for numerous activities and projects (e.g., Coon Creek Science Center clean-up days). GeoClub members are often called upon to help with faculty visiting area schools for geology programing, meteorological demonstrations, and general department maintenance.

In 1996, the GeoClub took the lead in identifying an Official State Fossil for Tennessee. In 1997, the Eta Alpha Chapter of SGE was established (see below) and participated in the endeavor. Their activities included researching viable fossil candidates, traveling to schools across Tennessee, primarily by collaborating with the Tennessee Earth Science Teachers (TEST), to make presentations to teachers and students (see Gibson [2024B], this volume for information on TEST). In 1997 (Figure 3), they organized a state-wide voting campaign to allow students and educators to determine which fossil would be proposed to the Tennessee State Legislature. The winning fossil was the extinct Cretaceous bivalve *Pterotrigonia (Scabrotriginia) thoracica*. In 1998, their efforts were realized and Tennessee became the 38th state to adopt a state fossil (see Gibson [2024B; 2024C] for more information about the state fossil). The GeoClub won the Tennessee Earth Science Teachers association Ptero Award for their efforts in 1999.

GeoClub is the primary group of geology majors that train and participate in the annual GeoConclave competitions. GeoConclave is an annual event where geology degree-granting institutions across Tennessee (and occasionally from nearby states) meet for fellowship and competition. The member school rotate responsibility for each year and organize field trips. The competition consists of fun activities (e.g., hammer toss, geogolf, etc.) and academic competitions (e.g., mineral, rock, fossil identification, structural geology interpretation, field mapping skills, etc.), culminating in the Rock Bowl. The Rock Bowl is an academic competition that tests each school's knowledge of geology in a series

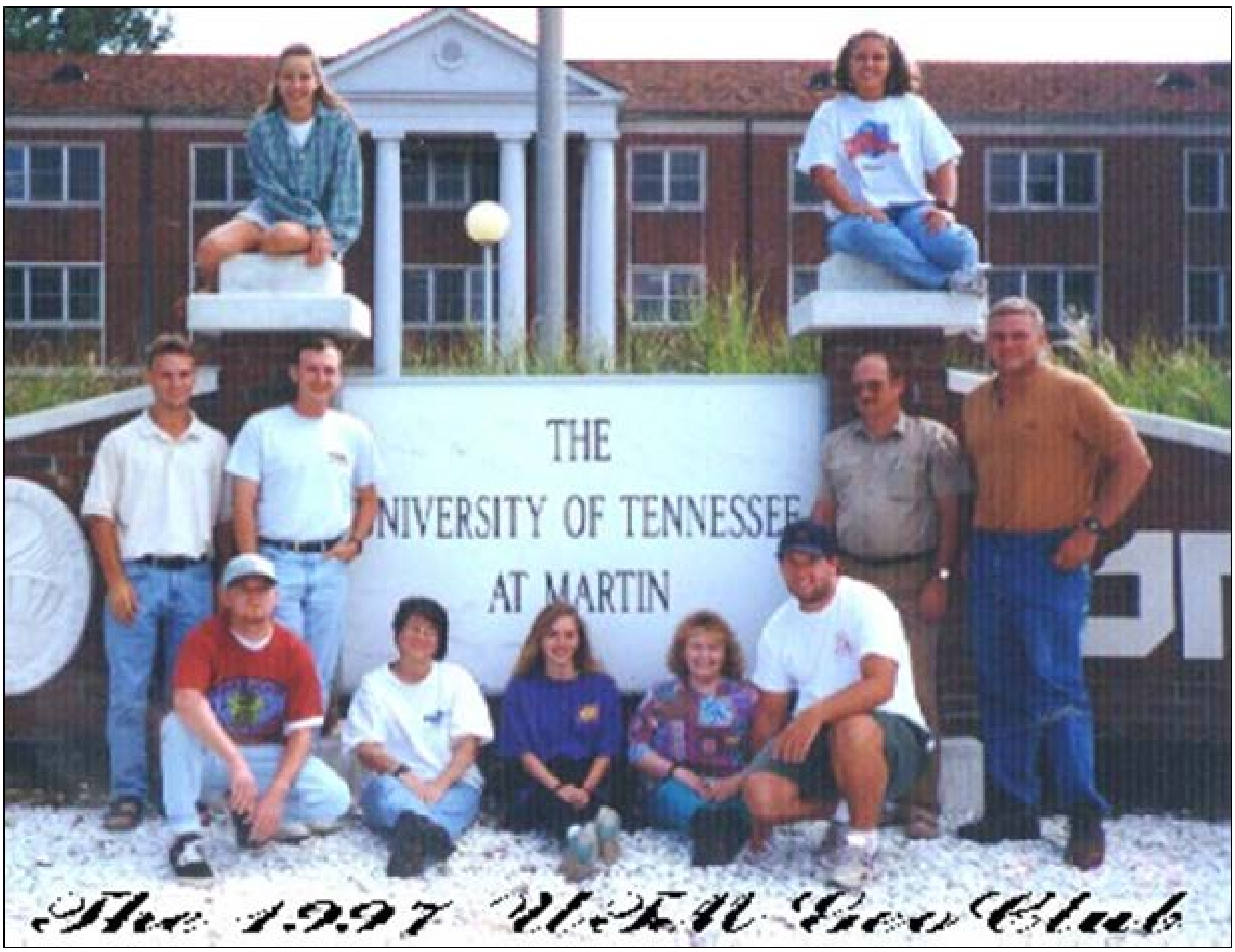

Figure 3: The 1997 GeoClub photograph taken in front of the school monument and University administration building. This is the GeoClub group that spearheaded the drive to establish a state fossil for Tennessee (photographer unknown).

of elimination rounds patterned after the College Bowl television series of the 1960s (see Haroldson and others [2020] and Gibson and others [2021] for an explanation of GeoConclave). GeoConclave is the GeoClub's primary annual event.

The GeoClub, along with the Eta Alpha Chapter of SGE (see below), presents programs and merit badge courses for various scouting groups. GeoClub members also usually man a give-away table at the Prime Student event aimed at sharing information about the geosciences major with the UT Martin student population. This is one of the club's primary recruiting events.

Lastly, the GeoClub is the primary student social organization in the geosciences. Members organize a variety of get-togethers (e.g., pizza parties, movie nights, tee-shirt tie dye events, rock and mineral sales, Valentine's Day giveaway, etc.). "Cheezy movie" nights have been popular over the years where movies with a geology theme, especially "B" movies, are shown and playfully critiqued.

ETA ALPHA CHAPTER OF SGE

Eta Alpha Chapter History

While the GeoClub does participate in academic enrichment events it remains a student club. By the mid-1990s, geoscience students were interested in establishing or finding a geoscience-oriented honor society that would add to their career development and that could be listed on resumes. Geologist faculty member Michael Gibson had been inducted into the Delta Beta Chapter of Sigma Gamma Epsilon: The Earth Science Honor Society (SGE) in 1982 as a graduate student at Auburn University, serving as the chapter president. He continued in the Gamma Gamma Chapter of SGE at the University of Tennessee, Knoxville. Gibson proposed to the geoscience students that they should consider petitioning SGE to establish a chapter at UT Martin and contacted the national council on their behalf. After a successful department visitation and evaluation by SGE by James Walters, the Eta Alpha Chapter of SGE was installed on April 3, 1997, as the 166th SGE chapter in the nation. Eta Alpha authored a chapter constitution by 1998 and filed it with the University, becoming officially recognized as a campus honor society. The Eta Alpha constitution was later revised in 2013. Gibson became the first faculty advisor and served until his retirement in 2023, when geologist Angie Van Boeing became the faculty advisor. The Eta Alpha chapter has always sought the broadest membership in Earth sciences. Membership in the chapter not only draws from the geosciences program, but includes soils science students, astronomy students, and meteorology students. In 2018, Gibson received the Sigma Gamma Epsilon Earth Science Honor Society, UTM Eta Alpha Chapter, 30-Year Certificate of Appreciation for Service to SGE Eta Alpha Chapter. For the years 2006–2023, Gibson served as the SGE National Vice President of the Southeastern Region.

At the 2017 SGE national convention at Eastern Illinois University, the Eta Alpha Chapter proposed to host the 2019 convention on the UT Martin campus. The chapter immediately began the preparation process, which was to include a field trip to the Coon Creek fossil lagerstätte deposit. Unfortunately, the COVID-19 pandemic struck that spring forcing universities nationwide to enter into a lockdown. The 2019 meeting was rescheduled for 2020. Unfortunately, the pandemic prohibited a face-to-face 2020 meeting from occurring as rescheduled, although there was a virtual meeting, so the chapter again deferred to host the biennial convention for one more round. At the 2021 national officer meeting, held in conjunction with the 2021 GSA annual meeting in Portland Oregon, still under COVID-19 masking and distancing protocols, it was determined that UT Martin would move forward to host the 2022 biennial convention. By that time, UTM would have acquired and refurbished the fossil site, which would have been rededicated as the University of Tennessee at Martin Coon Creek Science Center (UTMCCSC). Subsequently, the 46th biennial meeting of SGE was held at UT Martin's Selmer Center and the UTMCCSC. At the convention, Gibson was presented with the Sigma Gamma Epsilon Earth Science Honor Society – Service & Dedication Award (2020), the presentation of which had been postponed by the pandemic. The reader is referred to Gibson (2024C, this volume) for highlights of that meeting field trip and to Ford and Potter (2024) for a summary of the meeting.

TRAVEL AND TOURISM CLUB

The Travel and Tourism club was formed in 1997 by geographer Helmut Wenz. It is the shortest existing of the student organizations in the geosciences program. Wenz was a cultural geographer with a strong interest in travel and history. He was also an amateur archaeologist by interest. In 1990, Wenz began a new Travel and Tourism concentration within the Geosciences Program at UT Martin. That same year he received a grant, with yearly funding thereafter, from American Airlines to expand the program. The program worked extensively with International Programs at UT Martin with many of the international students coming to study at UT Martin choosing this concentration. In 1997, Wenz formalized these students into the Travel and Tourism Club, which was listed in the UT Martin catalog (UTM, 1997). The concentration was abandoned in favor of adding a meteorology program in 2009 and Wenz retired in 2008. Without at T&T advisor or concentration, the club was disbanded.

AMERICAN METEOROLOGICAL SOCIETY STUDENT CHAPTER

As noted above, the T&T concentration was discontinued in 2009 after Wenz retired in 2008. Geography was shifting emphasis to becoming a meteorology-oriented program since UT Martin hired meteorological geographer Mark Simpson in the 1990s. In 2011, a meteorology concentration, the only meteorology program in Tennessee, was added to the geosciences program (UTM, 2011) and a second meteorologist, Christopher Karmosky, trained as a glaciologist, was hired. A student chapter of the American Meteorological Society (AMS) was started in 2014 to complement the new program. Karmosky left the University in 2015 and the vacancy remained open until 2017 when Tim Wallace was hired as a lecturer in geosciences to help Simpson with the meteorology program. Wallace has specialties in severe weather, storm chasing, and winter weather. He earned his B.A. at the University of Memphis and a M.S. from Mississippi State University. The chapter developed a logo in 2022 (Figure 2B). Simpson retired in 2022. By 2021, meteorology graduate Shaley Dawson, who had been working at WBBJ-TV in Jackson, Tennessee as a broadcast meteorologist, returns to help expand the meteorology program by co-teaching a broadcast meteorology class with Wallace (UTM, 2024). Wallace left the program in July of 2024 and Aaron Scott was hired as a tenure-track replacement of Dr. Simpson and he takes over as the AMS advisor.

The UT Martin AMS student chapter is very active, and the program is growing, reflecting the interest in extreme weather held by the public as global climate change continues. The chapter annually attends the national AMS meeting and Wallace organized summer "storm chasing" excursions. AMS students are frequently invited to local classroom and civic groups for talks and weather demonstrations. AMS teams-up with the GeoClub and SGE for some events, especially annual Earth Science Week events held at the Discovery Park of America. The chapter maintains a Facebook page that highlights Martin weather.

ASSOCIATION OF WOMEN GEOSCIENTISTS

Historically, there has always been a high percentage of female geoscience graduates at UT Martin, often over 50%. In 2016, under the encouragement of lab instructor Eleanor Gardner, the women geologists petitioned to have a chapter of the Association of Women Geoscientists (AWG) established at UT Martin; however, the chapter went inactive soon after. In 2018, Angie Van Boening was hired at UT Martin and began efforts to reactive the chapter, which was reinstated in 2019 with Van Boening as the advisor (https://www.awg.org/general/?type=chaptersutmartin). AWG is the smallest of the student professional societies in the geoscience program at UT Martin. As most of the members, male and female, are also members of the other societies and groups, AWG nearly always cosponsors with them in activities (Figure 4).

SUMMARY

Although the UT Martin geoscience program is relatively small, there is a strong legacy of student involvement in professional societies and clubs. The largest and oldest is the GeoClub, established in 1970 prior to the geology program being given degree-granting status. The program also has a strong chapter of the Sigma Gamma Epsilon, the Eta Alpha Chapter, in which all of the various societies and clubs within the geosciences program come together. Additional active programs in include highly active student chapters of the American Meteorological Society and Association of Women Geoscientists.

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FIGURE 4: UT Martin student chapter of the Association of Women Geoscientists (AWG) advertising poster.

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RESEARCH ARTICLE

Isolating microbes from the surface of an introductory laboratory halite hand sample

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THE SOCIETY OF SIGMA GAMMA EPSILON

ABSTRACT

Introductory geology labs stress simple physical testing (luster, hardness, etc.) to identify common minerals, using mineral charts to eliminate minerals not exhibiting a particular property. Special properties (magnetism, specific gravity, taste, etc.) for specific minerals narrows mineral identity. Students often express safety concerns about licking minerals, especially when they realize others have previously licked the specimen. As an exercise in medical geology, we cultured microbes from a halite sample used for nearly 25 years and licked by numerous students over that time span (Sample 1), a commercially purchased unused and freshly exposed surface of halite licked by one person (Sample 2), and a disinfected sample repeatedly licked by only one person (Sample 3), to determine microbial presence, especially those potentially harmful to students applying the taste test. From the new crystal licked by one person (Sample 2), we identified sixteen different phenotypic groups of microorganisms after incubation of the crystal in growth medium. 16S ribosomal RNA sequence analysis was performed on one representative from nine of the sixteen groups. From this analysis, we obtained one species of *Bacillus*, four of *Paenibacillus*, and four of *Staphylococcus*, including *Staphylococcus epidermidis*. Comparing our results to published studies of the human tongue biome, we find that all of our cultured microbes occur naturally within a typical person's mouth and do not pose significant health risk as used in lab. Saliva with microbes can be transmitted as the halite is reused, especially if the test is administered quickly after a previous licking, so caution is warranted, but the process is essentially safe under normal conditions.

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Halite, Medical geology, Microbes, Mineral testing safety, COVID-19

INTRODUCTION

Halite (NaCl) is one of the primary minerals students are taught to identify in introductory geology laboratories. Halite exhibits perfect cubic crystal growth form and cleavage, easily recognized by students struggling with the concepts of cleavage and symmetry, and halite is familiar to students due to its commonplace occurrence in their homes as a seasoning. It is often pointed out that "salting" is used as a preservative that alters the composition of the microbial community present in food to one that is considered "harmless" to humans (Ingram and Kitchell, 1967, but see Kim et al., 2017, for an alternative view), with the expectation that salt surfaces are relatively free of harmful microbes. Hand-samples are passed from student to student for the "taste test," the definitive technique used for identifying halite.

Some studies have been conducted on inclusions in halite, reporting the presence of ancient microorganisms

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(McGenity et al., 2000; Vítek et al., 2010; Lowenstein et al., 2011). *Haloarchaea* have been recovered within microscopic droplets of brine within the laboratory-grown halite crystal and can be viable for several decades, providing the basis for the hypothesis that ancient microorganisms can be isolated from ancient halite samples (Fish et al., 2002). Adamski and others (2006) reported finding *Pseudomonas aeruginosa* in fluid inclusions in laboratory-grown halite. Using 16S rRNA gene sequence analysis, isolates from the surface of ancient evaporates from different geological formations failed to demonstrate consistent differences in gene sequences despite the potential fracturing and recrystallization events these evaporates may undergo throughout time (McGenity et al., 2000; Fish et al., 2002). Few studies have been conducted on microbes on the surface of halite (see DasSharma, 2007 for a discussion of the potential of *Haloarchaea* for teaching basic microbiology), and none have been conducted to determine bacteria on a halite geology lab hand-sample.

The question arises: is the taste test used in introductory geology lab safe for the students to use? Our goals were to evaluate the safety of the "lick test" used in typical introductory geology laboratory activities by: (1) investigating the diversity of microbes that potentially can be transferred to halite during typical geologic mineral testing; (2) determining if any of these microbes belong to potentially harmful taxa; and (3) investigating the length of time that microbes remain viable on typical lab specimens. Additionally, this study provides a personally relevant model for students of the relatively new geologic field of "medical geology" as an application of basic principles of geology and a possible career path (e.g., Finkelman et al., 2001; Berger, 2003; Bunnell, 2004).

Oral Microbiome

Over 600 taxa inhabit the human mouth, with overall species estimates being closer to ~1200 (Dewhirst et al., 2010; Jenkinson, 2011). The human microbiome varies by individual, no one having the same microbes as another, and varies within the same individual over time depending upon diet, health, and environmental exposure. There is no universal pattern; however, diet, environment, host genetics, and early microbial exposure have all been implicated (Human Microbiome Project Consortium, 2012). This diverse microbiome includes viruses, fungi, protozoa, archaea, and bacteria (Wade, 2013). About half of the bacteria are uncultured in laboratory settings, but the ones that have been cultured have been identified and described through culture-independent methods directly from samples of saliva or oral biofilms (Paster and Dewhirst, 2009; Wade, 2013). As noted above, it is possible to identify cultured microbes through the use of molecular techniques, such as analyzing the 16S rRNA gene, which can then be compared to the human oral microbiome database (HOMD, www.homd.org) (Dewhirst et al., 2010; Wade, 2013).

Bisset and Davis (1960) identified 19 genera within the mouth microbiome belonging to seven families: *Bacillaceae*, *Coccaceae*, *Lactobacteriaceae*, *Mycobacteriaceae*, *Nocardiaceae*, *Streptomycetaceae*, and *Actinomycetaceae*. Genera identified within the mouth included *Bacillus*, *Clostridium*, *Staphylococcus*, *Streptococcus*, *Lactobacillus*, *Mycobacterium*, *Streptomyces*, *Actinomyces*, and *Bacteriodes*. Studies of microbial communities on the tongue reported diverse microbiota with high cell density (Riggo et al., 2008; Papaioannou et al., 2009; Zaura et al., 2009). Zaura and others (2009) reported that the most common bacterial classes found on the tongue are *Actinobacteria*, *Firmicutes*, and *Proteobacteria*. *Bacillaceae* and *Staphylococcaceae* were classified as "exclusive" families, meaning that they were not found in each of the host individuals, but were found in at least one. The highest mean count of bacteria is found in suprangingival plaque and on the tongue, producing very similar bacterial profiles containing high concentrations of *Prevotella malaninogenica* and *Streptococcus salicarius* (Papaioannou et al., 2009). Aerobic, catalase positive, gram-positive cocci, such as *Staphylococci*, are commonly found in oral swabs but usually do not occur in high numbers and inhabit the surface of the tongue (Hardie and Bowden, 1973).

METHODS

Most geology labs provide bulk samples containing many specimens of each mineral for student identification or provide each student, or student group, with their own sample sets. Individual halite samples can be handled by multiple students during a lab session with varying amounts of time between handling. After mineral identification labs are over, these samples may sit for weeks with no human contact. There is no procedure for cleaning halite once it has been used. To simplify the initial procedure and establish a baseline for later studies involving previously used samples, our sampling method in this study was limited to microbial contribution from a single individual using previously unused halite samples. Halite samples used in this study were obtained from new student packs purchased from Ward's Science along with one large (> 5 cm) "cleavage" specimen that had been used by the class instructor repeatedly for nearly 25 years as a classroom demonstration specimen. As only mineral specimens were sampled, no IRB approval was necessary.

Sample Exposure

Sampling took place within a biological laboratory without the use of a vent hood to simulate typical introductory geology lab conditions in which halite samples are not disinfected before or after use. The 25-year-old halite sample (Sample 1) was swabbed after licking and streaked out onto a TSA plate to determine if growth occurs after licking. To characterize the diversity of microbes that can be transferred to a typical halite sample during the lick test, an unused halite sample from the student pack was broken to expose new surface believed to be uncontaminated by human microbiota; however, it was not disinfected in any other way (Sample 2). Although this control sample was expected to be microbe-free, it was swabbed before licking and tested for microbial presence. Standard microbial sampling procedures used in hospitals and laboratories were used (Madigan and Martinko, 2009; Johnson and Case, 2010). Students lick halite samples within minutes of another student licking the same hand-sample, then move on to other minerals to identify, therefore the licked sample was swabbed every minute for 11 minutes after exposure. Swabs were streaked onto Tryptic Soy Agar (TSA) (Fisher Scientific) plates and incubated at 37 °C for four days. TSA is a general, nonselective, complex medium suitable for growth of most microbial taxa (Johnson and Case, 2010). Colony phenotype was recorded for each swab sample (TABLE 1). To eliminate potential microbe contamination due to handling the halite that would affect microbe identification, a second unused hand-sample (Sample 3) was subjected to ultraviolet light to disinfect the outside surfaces before conducting any tests. Once disinfected, the halite hand-sample was licked by the same student and stored inside a sterile petri dish.

Microbe Identification

For microbe identification, the sample was crushed within a disinfected bag and pieces of similar size and weight placed in Luria broth (LB) (Fisher Scientific) and Tryptic Soy broth (TSB) (Fisher Scientific) and placed in a New Brunswick Scientific I 24 Incubator Shaker Series at 30 °C for 48 h (TABLE 2). To ensure microbial growth, media with four salt concentrations were used: no increased salt concentration, slightly increased (5 g/L NaCl) salt concentration, moderately increased (10 g/L NaCl) salt concentration, and highly increased salt concentration (50 g/L NaCl). A sample from each broth culture was streaked out onto two types of media plates, Luria broth agar (LB plates) and TSA plates, and placed in aerobic conditions in an upright incubator and anaerobic conditions using an anaerobic jar (McIntosh and Fildes, 1916). After 48 h of incubation at 30 °C, individual colonies were streaked for isolation resulting in a pure culture (one type of microbe per plate). To ensure no colonies were missed during isolation procedures, samples from LB broth were streaked onto TSA and LB plates, and samples from TSB were streaked onto TSA and LB plates. Each strain was tested

TABLE 1: List of phenotypes cultured from 'sample exposure' halite sample.

Timed Swabs (min)	Phenotypic description
0	Single large white colony with a yellow center
1	Single large white colony, multiple fibrous looking yellow colonies
2	Tiny brown and yellow colonies overtaken by white colonies
3	Single large white colony covering entire section
4	Small white and clear colonies
5	Few white isolated colonies
6	Small white colonies with a single off-white colony
7	White colonies covering section
8	White colonies with orange center dot covered section with a few small all white colonies mixed in
9	Single yellow colony
10	Large white, matte colony covered section
11	Few white colonies

TABLE 2: List of crystal weights and broth types.

Broth	Sample crystal weight
TSB	0.2061 g
TSB	0.1343 g
TSB	0.0705 g
LB	0.2163 g
LB	0.1408 g
LB	0.0645 g

for its ability to grow in all four salt concentrations on LB and TSA plates.

Genomic DNA was extracted from each pure culture sample using the MasterPure Gram Positive DNA Purification Kit (Epicentre). The 16S ribosomal RNA gene in each sample was then amplified by Polymerase Chain Reactions (PCR) using primers 5'-AGAGTTTGATCMTGGCTCAG-3' and 5'-ACGGYTACCTTGTTACGAYT-3' and analyzed by gel electrophoresis. PCR products were gel purified using the QIAquick Gel Extraction kit (QIAGEN) and sent to the Molecular Resource Center at the University of Tennessee Health Science Center in Memphis, TN for sequencing using the same primers used for amplification. Sequence comparisons were performed using BLAST (http://blast.ncbi.nlm.nih.gov/Blast.cgi) to identify each isolate.

RESULTS

Sample Exposure and Growth Comparison

Growth to varying degrees occurred on all samples. However, the control (Sample 2; which was swabbed before licking) had a single colony present. For the timed sampling, no single minute had greatly increased growth. Minute 5, minute 8, minute 9, minute 10, and minute 11 all had few or only one colony present after the four day incubation period. Majority of colonies present were small and white or yellow. Few minutes had larger white colonies. Minute 10 had one larger white colony. Minute 11 had five small white colonies.

Microbe Identification

For each of the nine isolates sequenced from the samples, the top five matches in the forward and reverse direction are displayed because full-length sequence for the 16S ribosomal RNA gene was not obtained (Table 3). Microbes identified belong to the genera *Bacillus* (KJG4), *Paenibacillus* (KJG15, KJG28, KJG35, KJG63), or *Staphylococcus* (KJG29, KJG31, KJG36). Isolates KJG15 and KJG63 were the cultured in anaerobic conditions.

The BLAST results for isolate KJG4 indicate that is it most similar to *Bacillus circulans*. KJG15 and KJG 28 are most similar to *Paenibacillus provencensis* and *Paenibacillus urinalis*. KJG29, KJG31, and KJG36 are most similar to *Staphylococcus epidermidis*. KJG35 and KJG63 are similar to *Paenibacillus* sp.

DISCUSSION

All of these identifications are considered "likely" but not "conclusive." Regardless of this, enough information exists to determine if the microbes belong to taxa harmful to humans.

Sample Exposure

Growth was more than expected on the 25 year old licked halite sample (Sample 1). The microbial colony present in the control section (Sample 2) could suggest that there are microbes present on the halite sample before licking despite not having been disinfected. However, since only one colony was present, and it did not look phenotypically like other colonies that were found after licking, there are a few viable explanations. First, the colony could be a contaminant from a few different sources (e.g., air borne or breath). Second, the colony could have already been present on the halite surface and unable to grow in the presence of other microbes present after licking. Third, some bacterica have a strong tolerance to high salt stress and cannot be completely eradicated from environments of increased salt concentrations (Feng et al., 2022). Without further testing to determine if this is a recurring phenomenon or a one-time phenomenon, a conclusive explanation as to the origin of this colony or how it got in the specimens is not possible at this point.

The time of 11 minutes was used to simulate the passing of the hand-samples from student to student. Based on the growth that was present during the time frame, the idea that "salt could kill all the microbes present or transferred when licked" is unfounded. In fact, microbes have been found to be able to live for prolonged periods in ancient salt inclusions (Lowenstein et al., 2011).

Bacillus

The genus *Bacillus*, present in one of our isolates, is found in a wide array of environments, including freshwater, saltwater, soil, air, in and on plant and animal tissue, and can survive extreme conditions, such as high temperatures, extreme ranges of salinity, and acidic geochemistry, as well as oxygen poor (anaerobic) environments. These microbes survive extreme environments through the formation of endospores, or dormant cellular structure, which has been recognized as the hardest known form of life on Earth and are characteristic of some halophiles (Nicholson et al., 2000). *Bacillus* is found in the immune systems of animals (Maughan and Van der Auwara, 2011). The *Bacillus* species

TABLE 3: List of top five possible identifications for each isolate in each direction.

Isolate	Direction	Possible Identification	Sequenced Portion Match
KJG4	Forward	*Bacillus* sp. IMT13	Partial
		Uncultured bacterium clone NS 65	Partial
		Uncultured bacterium clone S 379	Partial
		Bacillus circulans Strain OH3057	Partial
		Bacillus circulans Strain 18.1 KSS	Partial
	Reverse	*Bacillus circulans* Strain 18.1 KSS	Partial
		Bacillus sp. IMT13	Partial
		Bacillus circulans Strain Q11	Partial
		Bacillus circulans	Partial
		Bacillus circulans Strain OH3057	Partial
KJG15	Forward	*Paenibacillus* sp. J16-10	Partial
		Uncultured bacterium clone nbw312e05c1	Partial
		Paenibacillus sp. Cu2	Complete
		Paenibacillus provencensis Strain W03	Partial
		Uncultured bacterium clone nby264d03c1	Partial
	Reverse	*Bacillales* bacterium Cul 0294	Partial
		Paenibacillus urinalis Strain 5402403	Partial
		Paenibacillus sp. J16-10	Partial
		Paenibacillus sp. 7-5	Partial
		Paenibacillus provencensis Strain W03	Partial
KJG28	Forward	*Paenibacillus* sp. J16-10	Partial
		Uncultured bacterium clone nbw312e05c1	Partial
		Paenibacillus sp. Cu2	Complete
		Paenibacillus provencensis Strain W03	Partial
		Uncultured bacterium clone nbw312e05c1	Partial
	Reverse	*Bacillales* bacterium Cul 0294	Partial
		Paenibacillus urinalis Strain 5402403	Partial
		Paenibacillus sp. 7-5	Partial
		Paenibacillus sp. J16-10	Partial
		Paenibacillus provencensis Strain W03	Partial
KJG29	Forward	*Staphylococcus* sp. Isolate O-10	Partial
		Staphylococcus epidermidis Strain APP-10	Partial
		Staphylococcus epidermidis Strain P8	Partial
		Bacterium 7-II	Partial
		Staphylococcus sp. HKG 170	Partial
	Reverse	*Staphylococcus epidermidis* Strain JPR-05	Partial
		Staphylococcus sp. QD53	Partial
		Staphylococcus epidermidis Strain B7 3CO2	Partial
		Staphylococcus epidermidis Isolate OCOB9	Partial
		Staphylococcus epidermidis Isolate OCAT33	Partial

Continued...

Table 3 (*Continued*): List of top five possible identifications for each isolate in each direction.

Isolate	Direction	Possible Identification	Sequenced Portion Match
KJG31	Forward	*Staphylococcus epidermidis* Isolate PN58	Partial
		Staphylococcus epidermidis Isolate PN51	Partial
		Staphylococcus epidermidis Isolate N26	Partial
		Staphylococcus epidermidis Strain MJMG8.1	Partial
		Staphylococcus epidermidis Strain E4.Cd3	Partial
	Reverse	*Staphylococcus epidermidis* Strain JPR-05	Partial
		Staphylococcus sp. QD53	Partial
		Staphylococcus epidermidis Strain B7 3CO2	Partial
		Staphylococcus epidermidis Isolate OCOB9	Partial
		Staphylococcus epidermidis Isolate OCAT33	Partial
KJG35	Forward	*Paenibacillus* sp. J16-10	Partial
		Uncultured bacterium clone nbw312e05c1	Partial
		Paenibacillus sp. Cu2	Complete
		Uncultured bacterium clone nby264d03c1	Partial
		Uncultured bacterium clone nby568g10c1	Partial
	Reverse	*Bacillales* bacterium Cul 0294	Partial
		Paenibacillus urinalis Strain 5402403	Partial
		Paenibacillus sp. J16-10	Partial
		Paenibacillus sp. 7-5	Partial
		Paenibacillus sp. 1	Partial
KJG36	Forward	*Staphylococcus* sp. Isolate O-10	Partial
		Staphylococcus epidermidis Strain APP-10	Partial
		Staphylococcus epidermidis Strain P8	Partial
		Bacterium 7-II	Partial
		Staphylococcus sp. HKG 170	Partial
	Reverse	*Staphylococcus epidermidis* Strain JPR-05	Partial
		Staphylococcus sp. QD53	Partial
		Staphylococcus epidermidis Strain B7	Partial
		Staphylococcus epidermidis Isolate OCOB9	Partial
		Staphylococcus epidermidis Isolate OCAT33	Partial
KJG61	Forward	*Staphylococcus* sp. Isolate O-10	Partial
		Staphylococcus epidermidis Strain I167	Partial
		Staphylococcus epidermidis Strain EH-7	Partial
		Staphylococcus epidermidis Strain EH-6	Partial
		Staphylococcus epidermidis Strain EH-5	Partial
	Reverse	*Staphylococcus epidermidis* Strain JPR-05	Partial
		Staphylococcus sp. QD53	Partial
		Staphylococcus epidermidis B7	Partial
		Staphylococcus epidermidis Isolate OCOB9	Partial
		Staphylococcus epidermidis Isolate OCAT33	Partial

Continued...

TABLE 3 (*Continued*): List of top five possible identifications for each isolate in each direction.

Isolate	Direction	Possible Identification	Sequenced Portion Match
KJG63	Forward	*Paenibacillus* sp. J16-10	Partial
		Uncultured bacterium clone nbw312e05c1	Partial
		Paenibacillus sp. Cu2	Complete
		Uncultured bacterium clone nby264d03c1	Partial
		Uncultured bacterium clone nby568g10c1	Partial
	Reverse	*Bacillales* bacterium Cul 0294	Partial
		Paenibacillus urinalis Strain 5402403	Partial
		Paenibacillus sp. J16-10	Partial
		Paenibacillus sp. 7-5	Partial
		Paenibacillus provencensis Strain W03	Partial

likely found on the halite hand-sample, *B. circulans*, has been found in even more saline environments and has grown on agar with a 7% NaCl concentration (Nakamura and Swezey, 1983). Two species of the *Bacillus* commonly cause infections in humans, *Bacillus cereus* (food-borne illness) and *Bacillus anthracis* (anthrax); the remaining species are perceived as of little clinical significance (Rowan et al., 2001; Maughan and Van der Auwara, 2011) suggesting that the "lick test" is essentially safe with respect to *Bacillus*. However, Griffiths (1990) and Beattie and Williams (1999) reported that *B. circulans* produced toxins to a detectable level when isolated from dairy products, meaning this species may pose a potential hazard, at least in the presence of dairy product. Rowan and others (2001) also reported that when *B. circulans* was isolated from human blood samples, it was associated with diseases such as Sepsis and Lymphoma. Although most published studies were focused on toxins that were detected only when isolated from food products or human blood and not mineral testing, geology students are not likely to transmit blood onto halite samples by licking except under unusual circumstances, so we conclude that the likelihood of B. circulans causing any adverse effect during mineral testing is unlikely, although not impossible.

Paenibacillus

Paenibacillus, meaning "almost Bacillus," became a separate genus in 1993 (Ash et al., 1993) and has over 30 species of facultative anaerobes (Lal and Tabacchioni, 2009). *Paenibacillus* species are commonly found as saprophytes in many environments including soil, water, plant tissue, food, feces and diseased insect larvae and can produce endospores, but are not considered pathogenic to humans (Roux et al., 2008). The two possible matches to our four isolates (KJG15, KJG28, KJG35, KJG36) were *Paenibacillus urinalis*, which was originally isolated from a human urine sample, and *Paenibacillus provencensis*, originally isolated from human cerebrospinal fluid (Roux et al., 2008). Both of these species grow in the presence of 5% NaCl, higher than salt concentrations used in this study. While urine and cerebral fluid contamination of laboratory halite samples is considered unlikely, except under the most extreme of circumstances, there may be some other means of contamination of *Paenibacillus* that has yet to be recognized and documented.

Staphylococcus

The genus *Staphylococcus* currently has 30 species identified within it, and are halotolerant (Komaratat and Kates, 1975; Gill et al., 2005). Only two species are of clinical concern for our study, *Staphylococcus aureus*, an aggressive pathogen, and *Staphylococcus epidermidis*, commonly found on the skin surface (Gill et al., 2005). *Staphylococcus epidermidis*, is now considered to be one of the top five causes of hospital acquired infections, but the virulence differs greatly by strain (Zhang et al., 2003; Gill et al., 2005) and is only of concern with contaminated implanted medical devices, such as indwelling catheters, or a skin puncture (Vuong and Otto, 2002; Von Eiff et al., 2002; Zhang et al., 2003; Gill et al., 2005). Some strains can be found on hospital equipment, such as catheters, and can produce a slime coat that protects the bacterium from antibiotics, thus increasing its virulence (Christensen et al., 1982).

Although we identified *S. epidermidis* on our halite sample, the particular strain of the species remains unknown without more analysis. The lick test for halite did result in the transfer of a strain that produces a slime layer onto the surface of the halite; however, it is unlikely to pose any danger of infection under normal laboratory exposure to healthy students. For *S. epidermidis* to change from the normal state found on the surface of the skin to an infectious agent, the host must be predisposed or have a compromised immune system (e.g., patients under immunosuppressive therapy, AIDS patients, and premature newborns) (Caputo et al., 1987; Tacconelli et al., 1997; Domingo and Fontanet, 2001; Vuong and Otto, 2002). Caution is warranted because this organism can be viable for extended time due to its resistance to drying and temperature change (Lowy and Hammer, 1983). So, unless the halite is being implanted in a student, the risk of infection is unlikely.

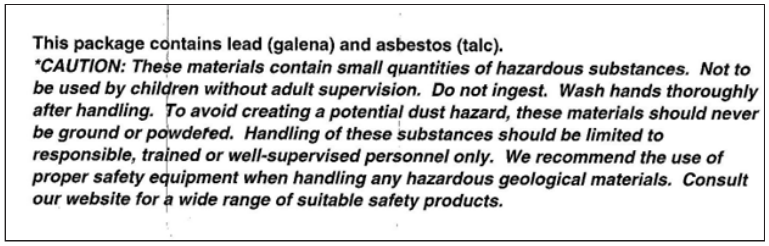
This package contains lead (galena) and asbestos (talc).
CAUTION: These materials contain small quantities of hazardous substances. Not to be used by children without adult supervision. Do not ingest. Wash hands thoroughly after handling. To avoid creating a potential dust hazard, these materials should never be ground or powdered. Handling of these substances should be limited to responsible, trained or well-supervised personnel only. We recommend the use of proper safety equipment when handling any hazardous geological materials. Consult our website for a wide range of suitable safety products.

Figure 1: Warning label included in Ward's student mineral kits. Hazardous materials such as galena, which contains lead, and talc, which contains asbestos, are clearly labeled with instructions on intended use, proper handling, and suggested supervsion; however, halite is not included by name as the substance itself is not considered hazardous.

Classroom Application & Implication

Tasting is used primarily to identify halite (NaCl), but also works for borax (sweet alkaline taste), epsomite (bitter), melanterite (sweet, astringent and metallic), and sylvite (bitter). As the special property test of tasting is quick and easy to do, and because salt is a common household item, students readily employ this sense to identify minerals, yet many will feel uncomfortable about the safety of the testing. There is also the potential problem of students contaminating specimens with HCl residue (which also produces a salty taste) by misapplying the taste test to calcite or applying HCl to halite during testing, thus exposing them to low concentrations of that salty acid. We checked over ten currently sold physical geology lab manuals for warnings regarding the use of the taste test for halite, or any other mineral, and found that none contained cautionary statements of any type within either the explanatory text of taste as a physical test or within the mineral identification charts. Ward's mineral kits do come with printed warning labels (Figure 1) in the boxes that warn the students that the boxes may contain "small quantities of hazardous substances", specifically lead (galena) and asbestos (talc), but do not list halite as a potentially hazardous mineral. It should be noted that same label also warns against ingesting; however, this warning refers to the listed minerals only.

Medical Geology and COVID-19

This study is an example of the type of investigations typical of the relatively young field of medical geology (e.g., Bunnell, 2004), only the study was "turned inward" to evaluate the geological community pedagogy itself. Prior to the COVID-19 pandemic, we incorporated the results of our study in the labs when teaching mineral testing to (1) alleviate student concerns over the safety of the taste test itself and (2) provide the students with an example of how geology functions as a truly interdisciplinary science with direct medical applications. This experiment was conducted prior to the COVID-19 pandemic. We now know that the COVID-19 virus can, indeed, be spread via saliva (e.g., Fini, 2020). Although our studies did not include testing for the COVID-19 virus, clearly, the halite taste test is more problematic than we realized from our initial study. We informally polled students in the same courses post-COVID (N = 66) to see if their opinions or concerns had changed. Considering that most students are leery of the taste test in the first place, it is not surprising that there was near unanimous response that the taste test should either never be used, or only by geologists in safe situations.

Medical geology is a topic area within several sections of the introductory level geoscience course that serves to fulfill part of the University's Biological and Physical Systems general education requirement. Inclusion of this study into that course serves as a "personally relatable" experience (experiential learning) for the students laying groundwork for broadening topics to include other medical geology issues such as geophagy (ingestion of loess or clay) and dose-dependent toxicity of minerals (e.g., lead, selenium, arsenic, etc.), and medicinal Earth materials (e.g., Kaopectate®) depending upon exposure and use (Limpitlaw, 2010).

While we have chosen halite to begin a medical geology investigation into our own laboratory exposures and procedures, other minerals could just as easily be tested for the actual interactions with the students during exposures, with the goal of providing scientific evidence as to the degree of hazard testing these minerals pose within the typical geology laboratory setting. We suggest similar testing of lead transfer from galena samples to student hands and other samples can be studies using standard lead testing kits as class projects in medical geology. Asbestos transfer can be studied by using the same air and surface sampling techniques used in professional remediation studies. Obviously, upper division mineralogy courses would have additional mineral species to consider. Such studies can help alleviate student anxiety of these issues and provide experiential learning opportunities.

CONCLUSION

Introductory geology labs have traditionally stressed the taste test as a routine and viable method to identify the common mineral halite. However, specimens tested in a lab setting are generally "group" specimens used repeated by many students for many classes, thus there is the concern of germ transfer. In this pre-COVID-19 study, cultured microbes from one halite sample that had been used for nearly 25 years in a classroom setting by hundreds of students, a sample repeatedly licked by only one person, and a commercially purchased unused and freshly exposed surface of halite licked by one person resulted in positive identification of microbes on these specimens. The new crystal licked by one person produced sixteen phenotypic groups of microorganisms. 16S ribosomal RNA gene sequence analysis of nine of those groups identified one *Bacillus* sp., four *Paenibacillus* sp., and four *Staphylococcus* sp. (probably *Staphylococcus epidermidis*). When compared to published studies of the human tongue biome, we find that all of our cultured microbes occur naturally within a typical person's mouth. Under normal conditions, they would not pose significant health risk as used in lab. The primary concern should be on the number of people handling the specimens and the time between testing. In a lab setting, microbes in saliva are transmitted as the halite is reused, especially if the test is administered quickly after a previous licking, so caution is warranted. For the geologist working in the field, where samples are not handled by others, the process is essentially safe as the sample is reasonably "isolated." Halite is geologically and chemically stable and is characterized by a low water permeability, suggesting that microbes isolated from the inside of the the mineral are likely to have syndepositional orgins as the mineral (Jaakkola et al., 2016). Microbe species isolated from deposited halite range in the dozens, suggesting a lack of diversity in species that can survive this harsh environment (Kim et al., 2012).

So, what can be done in a geology laboratory setting when teaching the taste test? The simplest solution to reduce this possibility, and further alleviate student apprehension over the test, is for students to be provided new specimens with each lab, which they break before tasting (which will reinforce the recognition of cubic cleavage), or require students to have "personal kits" of minerals. Only very small samples are actually needed for the taste test and these can be discarded. The cost would be minimal. Furthermore, we advocate textbook authors consider adding discussions of the safety of the taste test to their manuals along with suggested procedures for taste testing and that laboratories provide and strongly encourage hand sanitizing immediately after the halite testing. We would generalize these practices to other potentially hazardous geologic materials (e.g., galena, etc.). Additionally, preservation of infectious disease microbes is of interest to agricultural communities using salt blocks and in situations where livestock mix with wildlife (see Kaneene et al., 2017, for examples).

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RESEARCH ARTICLE

Examining the relationship between land-use cover change and sociodemographic characteristics: A case study of Madison County, Tennessee

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ABSTRACT

This study sought to holistically examine urbanization in Jackson, Madison County, TN. In order to accomplish this objective, a study of land-use and land cover (LULC) change in Madison County, TN from 1992–2011 was conducted. Once completed, noted changes in LULC were then compared to certain socio-demographic factors; these included, population, population density, point distance, central business district, and distance to roads. To determine if any significant relationships existed between socio-demographic factors and quantified LULC changes Spearman's Correlations were utilized. Relationships between socio-demographic factors and land-use indicators were established as urban areas grew, agricultural and forested areas declined, and population density near the city center decreased.

KEYWORDS

Land-use land cover change, Socio-demographic factors, urban sprawl

INTRODUCTION

The ability to accurately catalogue changes in the environment in a timely manner has become increasingly important (Yuan et al., 2005). Therefore, understanding what land-change science is and by noting the difference between land-use and land-cover is essential. These two terms are different, but are inexorably linked as one term describes the landscape or structures while the other describes activities that may occur on a land-cover (Fonji and Taff, 2014). For example, forested areas, agricultural lands, and urban areas all denote specific types of land-cover. Land-use might indicate that a specific forested area is part of a national park or state park or even how some urban areas can be separated between residential spaces and business or retail areas. The ability to map spatial and temporal changes in the land-use and land-cover (LULC) of an area is crucial to realizing the dynamics between subjects such as urban sprawl and environmental change (Banai and DePriest, 2014).

Changes over time in population growth, urban sprawl, and LULC in the Jackson-Madison County area will be derived and compared. Once completed, the objectives of this paper are: 1) quantify LULC changes and composition for Madison County, Tennessee between 1992–2011 and 2) to determine if any significant relationships exist between socio-demographic factors and the quantified LULC changes found in the study area.

LITERATURE REVIEW

The process of decentralization, or urban sprawl

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(Stone et al., 2010; Wassmer and Edwards, 2005) in the United States is said to follow a logical progression related to population, income, and the value of agricultural lands (Brueckner and Fansler, 1983). The authors state that urban sprawl is affected by the economic market process by which high yield in-demand agricultural land (agricultural rent) has a negative or limiting effect on urban growth. However, a case in which population increase followed the reduction of prime farmland can also be cited (Hasse and Lathrop, 2003). Part of Hasse and Lathrops's (2003) study describes a process in which an increase in population and the simultaneous widespread movement and relocation of inhabitants from a New Jersey city center to the outer suburbs both contributed to sprawl. Large tracts of land that were formerly either agricultural or forested in surrounding rural municipalities were lost to urban growth. In their report, the authors state that at the beginning of the 10-year study period over half of all land being used for growing crops was considered prime farmland, and by the end of the study period 60 percent of farmland lost to development was prime farmland. However, the largest land-cover lost to urban sprawl was forested lands with some 27,000 hectares lost to development.

Impacts of sprawl can be seen all throughout the country, especially the southeastern region of the United States. The Southeastern region experienced an increase in developed area of around 58 percent between 1982 and 1997; this was the highest increase in developed area within the U.S. (White et al., 2009). It is predicted that between 2003–2030, the southeast will experience a 51 percent increase in developed area; this means that the south is expected to develop at rates higher than the national average. Specifically, Tennessee is among southern states expected to develop at the some of the highest rates, over the 28-year time span, with an increase in developed land of some 90 percent. In general, the authors predict that the long term trend for the south is one of continued rise in population and development between 2003–2030 (White et al., 2009).

Urban growth in the southeast is being driven by a multitude of factors including availability of agricultural lands, current land use policies, and economic factors (Lopez and Hynes, 2003). According to Nagy and Lockaby (2011), there are many socioeconomic drivers influencing settlement in this particular region of the United States. For instance, the authors mention that more/better roads, increased accessibility, rising cost of land, and rising costs of maintaining undeveloped lands have contributed to sprawl in the southeast.

The case of increased population and the pervasiveness of urban sprawl has been made (Brueckner and Fansler, 1983; Hasse and Lathrop, 2003; Meyer and Turner, 1992) with the understanding that urban sprawl brings changes to LULC (Hamidi and Ewing, 2014). With the availability of population data from the United States Census Bureau, the technology available to map changes in LULC, and population over time, we may better understand the cause and effects of continued growth and anthropogenic changes (Banai and DePriest, 2014).

STUDY AREA

Madison County, Tennessee is located in Western Tennessee roughly half-way between Memphis and Nashville along Interstate 40 (FIGURE 1). The study area is approximately 1,443.14 km^2 (557.2 mi^2) with an estimated 2010 population of just over 98,000 (United States Census Bureau, 2017). The largest city in Madison County is Jackson, Tennessee, where nearly two-thirds of the county's population reside (FIGURE 2). Madison County has an elevation of nearly 120 m (400 ft) above sea level, is somewhat hilly but still has a significant agricultural presence (Bailey, 1993). Though agriculture played a much more important role in the area's past, the local economy is now more dependent upon businesses and industry (Madison County, TN, 2017).

METHODS AND DATA

This study makes use of National Land Cover Data (NLCD) sets from 1992 (retrofit), 2001, and 2011. NLCD maps are produced by the combined efforts of multiple federal agencies referred to as the Multi-Resolution Land Characteristics (MRLC) consortium (Multi-Resolution Land Characteristics Consortium (MRLC), 2017). The first land cover map produced in late 2000 was derived by Landsat Thematic Mapper™ satellite imagery at a 30-meter scale from the early 1990's. The LULC map developed for the conterminous United States made enquiry into many types of environmental investigations that required land-use data, such as wildlife biology, land management, and water quality possible (Vogelmann et al., 2001).

Due to advances in technology, the processes used in the development of the 2001 NLCD made comparisons between 1992 and 2001 not ideal (Fry et al., 2009; Graham and Congalton, 2017; Homer et al., 2007). Advanced

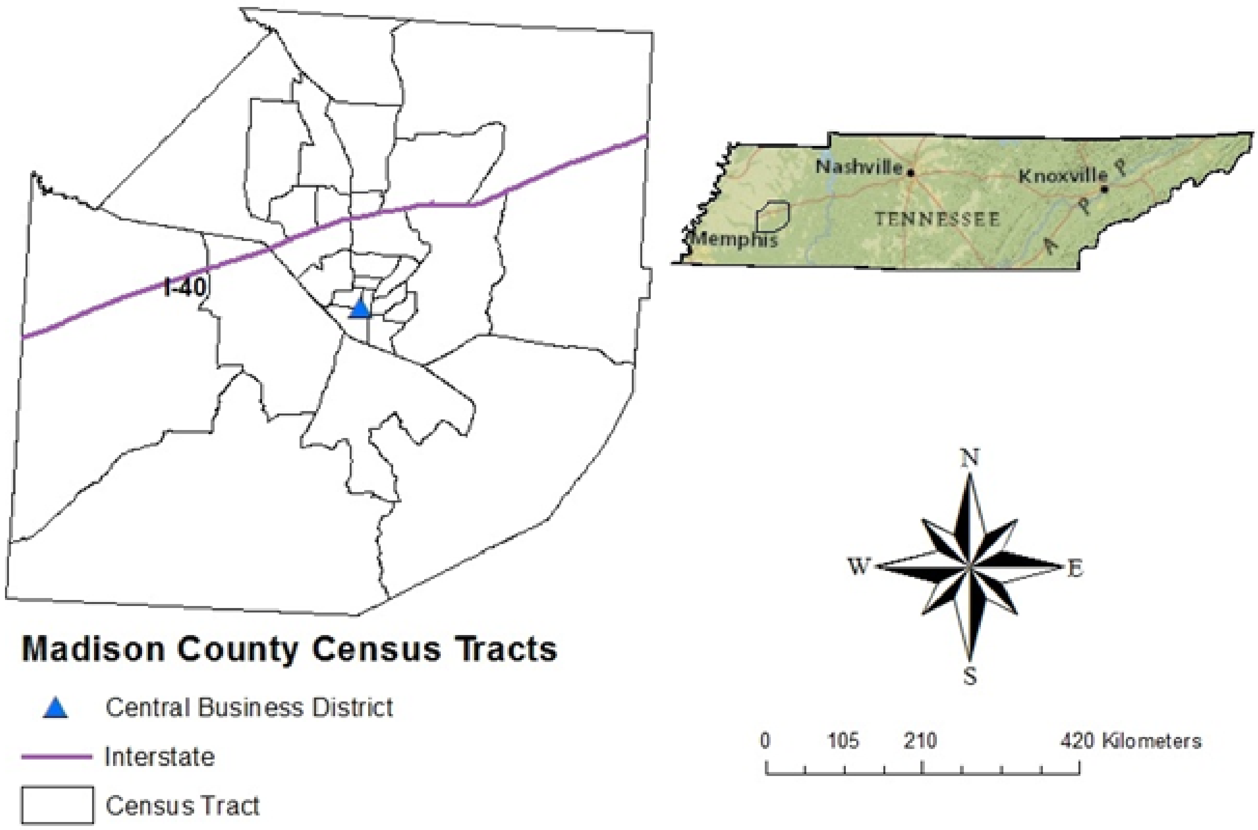

FIGURE 1: Location of Madison County, Tennessee; interstate and census tract boundaries (Map data from ESRI, Inc.).

techniques used in the classification process of the 2001 NLCD led to the production of two distinctly different data sets when comparing 2001 to 1992 NLCD maps. Because one of the ideas behind NLCD maps was to enable land change comparisons over time, the MRLC designed what Homer and others (2007) termed a "bridge product" that makes the comparison of 1992–2001 maps easier. The result was the completion of the NLCD 1992–2001 retrofit that makes use of a "hybrid" class I Anderson Classification technique (Anderson et al., 1976) developed from the more advanced 2001 NLCD map. Comparisons between the 2001 and 2011 NLCD maps are more straightforward because they both employ the same modified 16 class Anderson Land Cover Classification System (ALCCS). In addition, the specifications for the 2001–2011 maps also include 30 meter spatial resolution from Landsat 5 Thematic Mapper™ (Homer et al., 2007; 2015).

As previously mentioned, classification methods and coding of different land classes are not consistent between 1992–2001 NLCD maps. The addition of the 1992 retrofit map allows for a more direct comparison between 1992 and 2001 NLCD maps. The 1992 retrofit's classification is based on a Modified Anderson Level 1 class code in which similar classes are grouped together which reduced the overall number of class units when compared to 2001 or 2011 modified 16 class ALCCS. However, additional modifications to map classification were still needed. NLCD maps were loaded into GIS software ArcMap version 10.4 for the purpose of map reclassification.

Application of an "adapted" Anderson code to the 1992 retrofit map reduced the number of classes in the study area from seven to five class codes (TABLE 1). Specifically, "Open

TABLE 1: Reclassification of 1992 retro NLCD to "adapted" Anderson code.

Retrofit classification description	Modified Anderson level 1 class code	Adapted Anderson code
Open Water	1	1 Water
Urban	2	2 Urban
Barren	3	5 Agriculture
Forest	4	3 Forest
Grassland/Shrub	5	4 Grassland/Shrub
Agriculture	6	5 Agriculture
Wetlands	7	1 Water

Water" and "Wetlands" were combined and listed as "Water" and "Barren" was combined with "Agriculture" and listed as "Agriculture." The 2001 and 2011 NLCD classifications were also modified using the same "Adapted" Anderson classification code with the following results: "Open Water," "Woody Wetlands," and "Herbaceous Wetlands"

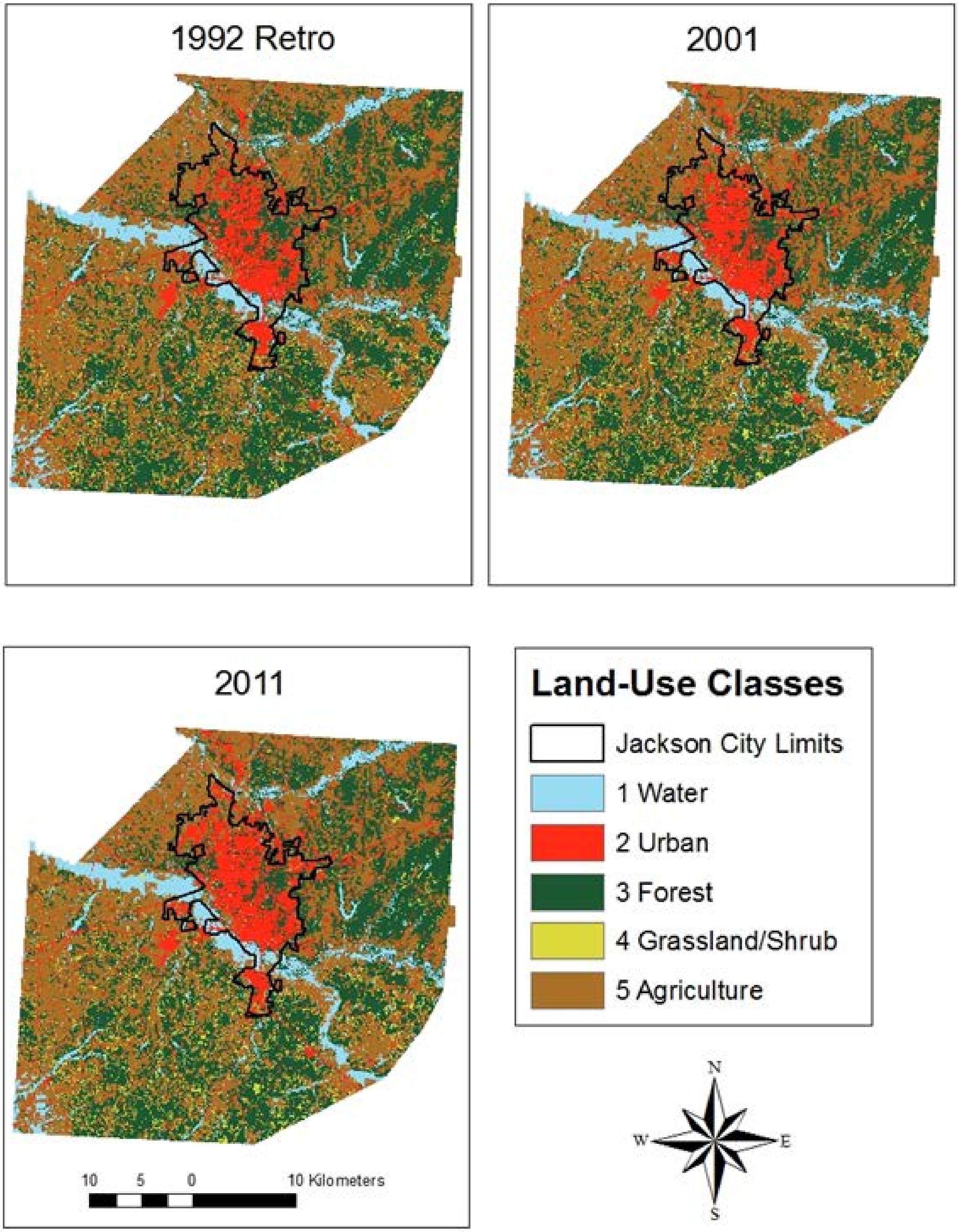

Figure 2: Reclassification land-use maps for 1992 retro, 2001, and 2011 (Multi-Resolution Land Charactertistics Consortium (MRLC), 2017).

were combined and listed as "Water;" "Developed Open Space," and "Low," "Medium," and "High Intensity" were combined and listed as "Urban;" "Barren Land," "Hay/Pasture," and "Cultivated Crops" were combined and listed as "Agriculture;" "Deciduous," "Evergreen," and "Mixed Forest" were combined and listed as "Forest;" and "Shrub/Scrub" and "Grassland/Herbaceous" were combined and listed as "Grassland/Shrub." The "collapsing" technique is utilized by previous land-use studies such as by (Antipova et al., 2011); when outside urban areas including low-density residential lands, agricultural and forested areas were consolidated into a single category of agricultural/rural due to sparse population and similar low-intense economic activity (Antipova et al., 2011). Results from recoding the 2001 and 2011 NLCD maps employing the "adapted" Anderson code are displayed in TABLE 2. In addition, percent changes in land use derived from the application of the "adapted" Anderson code to 1992 Retrofit, 2001, and 2011 NLCD maps are presented in TABLE 3.

TABLE 2: Reclassification of 2001 and 2002 NLCD to "adapted" Anderson code.

2001 and 2011 classification description	NLCD 2001 and 2011 class code	Adapted Anderson code
Open water	11	1 Water
Developed, open space	21	2 Urban
Developed, low intensity	22	2 Urban
Developed, medium intensity	23	2 Urban
Developed, high intensity	24	2 Urban
Barren land	31	5 Agriculture
Deciduous forest	41	3 Forest
Evergreen forest	42	3 Forest
Mixed forest	43	3 Forest
Shrub/Scrub	52	4 Grassland/Shrub
Grassland/Herbaceous	71	4 Grassland/Shrub
Hay/Pasture	81	5 Agriculture
Cultivated crops	82	5 Agriculture
Woody wetlands	90	1 Water
Emergent herbaceous wetlands	95	1 Water

Once reclassification of NLCD maps was completed (FIGURE 2), LULC changes for individual census tracts over the twenty-year study period were sought. To accomplish this, the tabulate area function in zonal statistics under the spatial analyst tools in ArcMap version 10.4 was employed. Each NLCD map (1992 retro, 2001, and 2011) was individually overlain with the 2010 census tract shapefile (TIGER/Line shapefiles) of Madison County. This procedure allowed for the calculation of all five of the "adapted" Anderson codes for each census tract for the 1992–2011 time of study. In addition to LULC changes over time, differences in population and population density during the same twenty-year time span were also sought. Because the dates of the LULC change maps coordinate well with the national census (1990–2010) the only consideration was the level of population data that could be reliably used throughout the study period.

For the purpose of data consistency, population and population density derived from the Longitudinal Tract Database (LTDB) were employed (Logan et al., 2014). In essence, the LTDB uses the 2010 census tract positions and employs techniques that allow population estimates to be tracked backwards and applied to census records back to 1970. Since the census tract boundaries are constant, researchers have the ability to make direct population comparisons over a 40-year time span (Logan et al., 2016). Census tracts generally have a population ranging between 1,200 and 8,000 inhabitants (1,000 to 3,000 housing units). Besides the ease of use, statistical comparisons from each decennial census to census enabled by constant tract boundaries mentioned above, we used this geographic hierarchy of the U.S. Census as an appropriate geographical unit representative of

TABLE 3: Statistical summary of land-use and population changes in Madison County from 1992-2011.

Land cover class and population change	1992 (retro) area (km^2)	% of total	2001 area (km^2)	% of total	2011 area (km^2)	% of total	% Change 1992–2011
Water	114.14	7.89	119.12	8.23	118.61	8.20	3.92
Urban	141.50	9.78	156.07	10.79	167.80	11.60	18.58
Forest	552.49	38.19	530.56	36.67	526.07	36.36	−4.78
Grass/Shrub	69.12	4.78	77.09	5.33	81.69	5.65	18.18
Agriculture	568.45	39.29	562.86	38.90	551.53	38.12	−2.98
Population	77,982	NA	91,836.00	NA	98,294.00	NA	26.05

neighborhoods with relatively homogenous population attributes, as well as similar housing, and socio-economic characteristics (United States Census Bureau, 2017).

RESULTS AND DISCUSSION

As previously stated, classification maps of Madison County, Tennessee were produced from recoding of 1992 (retro), 2001, and 2011 NLCD maps using an "adapted" Anderson Code; statistical output derived from these maps are shown in Table 3. Land-use classes that increased in total area, over the study period, were Urban (18.5 percent) and Grass/Shrub (18.18 percent) while Forest and Agriculture both displayed decreases in total area (-4.78 percent and -2.98 percent respectively). Though Grass/Shrub class indicates a large percent increase from 1992–2011, it only accounts for a small portion of Madison County. In fact, the 81.69 km^2 (5.65 percent) was the smallest total area of all derived classes. Increases in the Urban class was more significant with an expansion of 26.3 km^2 over the study period; this accounted for 167.80 km^2 or 11.60 percent of the total study area. By far, the two largest land-use classes were Forest and Agriculture. These two classes accounted for nearly 75 percent of the total land make-up of Madison County in 2011. Between 1992–2011, Agriculture lost 16.92 km^2 (about 3 percent) and Forest lost 26.42 km^2 (5 percent) of land, while the Urban class had gained 19 percent by 2011, the largest growth among all land uses. The most insignificant change was observed for the water class which in absolute terms changed slightly over time with 4.5 km^2 of area; however, the class consistently accounted for about 8.00 percent of the total area. Changes in total water area could have been caused by fluctuations in actual area that was water, but were probably due to classification errors that will be further discussed in the limitations of study regarding this report.

Numerous variables for the study area were developed for the purpose of statistical assessment. Population and population density variables are straightforward and correspond to the total population amounts displayed in Table 3; however, procedures used to produce other variables within ArcMap 10.4 are given. For example, point distance (PT_DIST) was created by establishing a location to represent the central business district (CBD) of Madison County. This position was the historic downtown area of Jackson, Tennessee and represents places where the Madison County Courthouse and City Hall are located. Once established, ArcMap determined the distances from the CBD to the centroid of each census tract (Figure 3). In a similar fashion, the distance to roads (DIST_ROADS) was computed as the shortest distance between a census tract's centroid and a major or primary road (defined in the study as interstates, highways, or major four-lane roads).

As previously mentioned, each census tract's LULC was cataloged for 1992, 2001, and 2011. This information allowed us to determine the percent change in all land-use categories between 1992–2001, 2001–2011, and 1992–2011 in each census tract. Land-use data was then loaded into IBM's Statistical Package for the Social Sciences (SPSS) version 22. Due to the data not having a normal distribution, we employed nonparametric statistical analysis. Since the second objective of our study was to establish if any significant relationships between socio-demographic factors and LULC changes within Madison County exist, we employed Spearman's rho, a nonparametric correlation analysis (Helsel, 1987). For the purpose of data consistency and statistical analysis, LULC data was coded into SPSS to correspond with census data. LULC data from 1992 was entered as LULC data 1990; the same format was applied to LULC data from 2001 (entered as 2000) and 2011 (entered as 2010). All P values <0.05 are considered to be significant.

As explained above, the land data were matched with the closest Census data available for the time period. To illustrate, we used time series data including Census data for 1990, 2000, and 2010 while using 1992 LULC, 2001 LULC, and 2011 LULC, respectively, to examine changes in land-use and population as a function of distance to the city center between 1990 and 2010 in Jackson, Tennessee. Spearman's correlation coefficient was used to describe an association between the two variables and to test the hypothesis that no relationship exists between population density per square kilometer (PD) and distance to the city center (PT_DIST). Population decentralization manifests itself in the pattern represented by changes in the slope of the density gradient. In agreement with previous studies documenting decentralization of cities (Hasse and Lathrop, 2003; Luo et al., 2008; Nagy and Lockaby, 2011), we find this function downward sloping with distance and population density gradient flattening over a period of time. A steady decline in the steepness of the slope of the density gradient was observed and reflected in the correlation coefficient decreasing from –0.86 to –0.79 to –0.75 (each at the $p<0.01$ level of significance) indicating urban sprawl with low-density housing and fragmented residential development on semirural tracts (Table 4). In

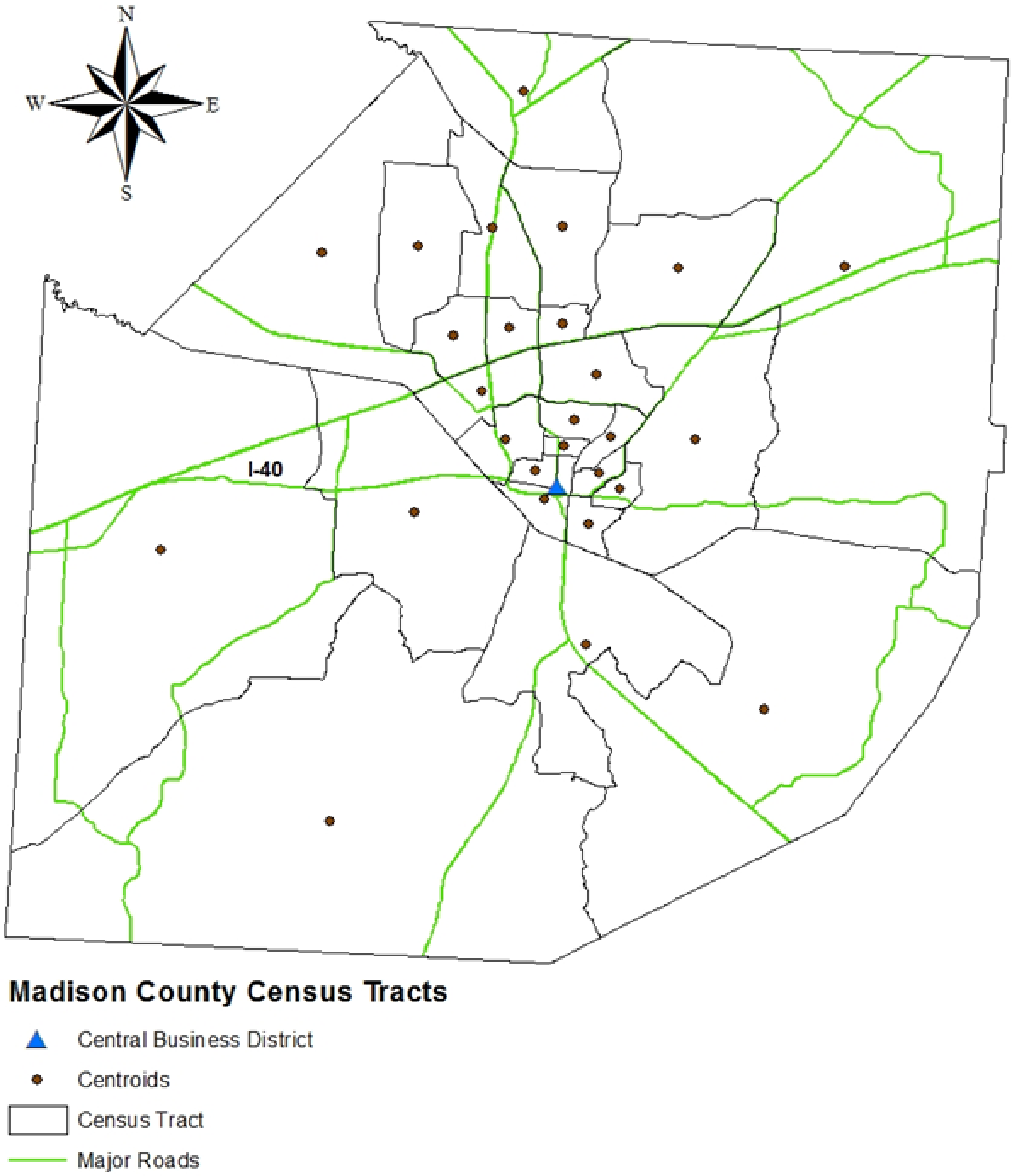

FIGURE 3: Census tract, centroid, central business district, and major roads in Madison County, Tennessee (Map data from ESRI, Inc.).

other words, this finding exemplifies the theory of urban sprawl in which land-use in less urbanized areas are more typically converted and developed into residential and/or urban areas (Luo et al., 2008).

Population density, in the study area, was less at the center as people are moving away from central areas to settle at the outskirts and in the suburban parts of urban areas. This process follows a pattern referred to as exurbanization, where low density housing in rurally located subdivisions allow people to live in the country (Brown et al., 2005; Hansen et al., 2005). Gated communities are a prime example of exurbanization and occur when the affluent locate outside of the city on large lots which enable separation or protection from the public (Le Goix, 2005). Madison County seems to be following the same pattern established by Brown and others (2005) who explain that exurbanization experienced rapid expansion in the U.S. from 1950–2000.

No relationship was found between distance to the city center (PT_DIST) and the percent change of land that was urban between 1990–2000, 2000–2010, and 1990–2010; nor did we observe that proximity to a major road (DIST_ROAD) was related to any land-use changes (TABLE 4). These findings disagree with Luo and others (2008) study in which a negative relationship between the distance to major roads and distance to urban centers and a change from non-urban to urban land was established. However, the relationship between population density (PD) and proximity to major roads (DIST_ROAD) was negative at −0.058 and significant ($p<.01$ level) indicating that people are deterred by the closeness of heavily trafficked roads. This association remained stable for each of the three-time periods in our study.

A minor increase in the relationship between the percent change of land that was forest (PC_Forest) and the distance to city center (PT_DIST) was detected. The coefficient from 1990–2000 (rho = 0.436) presented a slight increase to 0.446 during the study period (1990–2010). It seems that an increase in forest cover would be counter to expectations if sprawl is occurring outside of the city center. This situation might be explained by circumstances in which growth of extensive tree canopies may cause some urban areas to be incorrectly classified as forested (Yuan et al., 2005). A slight decrease in the percent change of land that was agricultural was also observed for the overall period 1990–2010 (PCAg): a modest but significant relationship between PCAg1990_2000 was observed with proximity to urban center (PT_DIST), rho = 0.40, $p<0.05$ indicating that more rural land is found farther away from urban areas. The coefficient decreased to 0.394 for the period of 1990–2010. This result is not surprising as Madison County has historically relied upon agriculture as a major economic driver. Though agriculture is not as prominent as it once was, in the study area, it is still an important factor in the local economy (Madison County, TN, 2017).

TABLE 4: Spearman's correlation output for LULC percent change, socio-demographic, point distance, and distance to major raods.

Socio demographic and LULC	Year(s)	Point distance	Road distance
Pop Density	1990	−0.862	−0.58
P-Values		**0.000**	**0.002**
Pop Density	2000	−0.794	−0.582
P-Values		**0.000**	**0.001**
Pop Density	2010	−0.748	−0.578
P-Values		**0.000**	**0.002**
PDPC	1990-2000	0.225	0.090
P-Values		0.259	0.654
PDPC	2000-2010	0.498	0.093
P-Values		**0.008**	0.645
PDPC	1990-2010	0.455	0.152
P-Values		**0.017**	0.449
PC Urban	1990-2000	0.314	−0.016
P-Values		0.110	0.935
PC Urban	2000-2010	0.272	0.068
P-Values		0.169	0.736
PC Urban	1990-2010	0.313	0.015
P-Values		0.112	0.940
PC Forest	1990-2000	0.436	0.331
P-Values		**0.023**	0.092
PC Forest	2000-2010	−0.013	−0.060
P-Values		0.948	0.767
PC Forest	1990-2010	0.446	0.297
P-Values		**0.020**	0.133
PC Grass	1990-2000	0.261	0.342
P-Values		0.188	0.081
PC Grass	2000-2010	0.293	0.258
P-Values		0.138	0.194
PC Grass	1990-2010	0.289	0.231
P-Values		0.143	0.246
PC Ag	1990-2000	0.399	0.224
P-Values		**0.039**	0.262
PC Ag	2000-2010	−0.135	0.095
P-Values		0.501	0.639
PC Ag	1990-2010	0.394	0.243
P-Values		**0.042**	0.222

Bold = $p < 0.05$ Significant

Finally, we investigated how population changes were reflected in percent change in population density over 10-year intervals across the urban area. Spearman's correlation values were used to describe population change trends. The population density percent change (PDPC) was correlated with distance to city center (PT_DIST) for 1990–2000, 2000–2010, and 1990–2010. Spearman's correlation index is positive indicating that more changes in population are occurring farther away from central high-density areas. The highly dynamic urban-rural fringe area has been described as a peri-metropolitan bow wave where the metropolitan growth occurs with the outward expansion of urban land increasing the value of the adjacent land and excessively decreasing the amount of high-quality agricultural land (Greene and Pick, 2012; Hart, 1991). The strongest correlation was percent change between 2000 and 2010 (0.498 at 0.01 level) supporting the previous finding that the fastest growing locations are places with relatively few people (Table 5). There was also a strong relationship between changes in urban land-use and population (increasing rho = 0.631, 0.652, 0.739) with more population changes taking place on land which is urban at 0.01 level of significance for each of the study periods of 1990–2000, 2000–2010, and 1990–2010, respectively (Table 5). Taken together, these last statements demonstrate that urban sprawl is occurring in the study area as more land is converted to urban and areas that previously had the fewest people are now being developed.

CONCLUSION

In this study we explored the relationship between urban sprawl and important drivers of urban change in the southeast US, which compared to other regions of the US, experienced high rates of urban development. For this purpose, we quantified land-use changes in Madison County, Tennessee over a twenty-year period. Additionally, we established relationships between socio-demographic factors and land-use indicators which suggests that sprawl is occurring in the study area. In general, population density near the city center is decreasing as the growing population (increase of 26 percent over the time of study) settles in areas that were once non-urban. The summation of land-use and population changes (Table 3) for Madison County indicates that population and urban areas are increasing as forested and agricultural areas are decreasing. Several studies are cited (Hasse and Lathrop 2003; Wolter et al., 2006; Yuan et al., 2005) in which a decrease in land that was forest or agriculture was accompanied by an increase in urbanized lands and is described as urban sprawl.

Table 5: Spearman's correlation output for population density percent change and LULC percent change.

LULC	1990-2010 PDPC	2000-2010 PDPC	1990-2010 PDPC
PC Urban	0.631	0.652	0.739
P-Value	0.000	**0.000**	**0.000**
PC Forest	−0.286	−0.357	−0.195
P-Value	0.148	0.067	0.329
PC Grass	−0.038	0.399	−0.111
P-Value	0.849	**0.039**	0.583
PC Ag	0.044	−0.268	-0.098
P-Value	0.828	0.177	0.626

Bold = p < 0.05 Significant

Alig and others (2004) explain the association of population growth and development in their study detailing urban expansion in different regions of the United States. The authors report that the south (southeast United States) had more land developed between 1982–1997 than any other area of the country. In addition, several southern states also had one-third of their development to occur during the same 1982–1997 time span. As a region, the south has typically experienced a large increase in population while its developed area per additional person is higher than average. Based on a 35 percent increase in population and considering historical data on urbanization and socio-economic changes, the authors derived 25-year projections for future urban development. Results from regression analysis for the next 25-years estimate the south will increase in population by about 20 percent but will experience an increase in development or urbanization at substantially higher rates (Alig et al., 2004).

Essentially, what is happening in the Jackson-Madison County focus area is a very close representation of what Alig and others (2004) reported in their study. Why is this important or what are the implications? A study by the U.S. Geological survey on the future of urban sprawl in the southeastern United States predict some of the negative ramifications and potential outcomes of sprawl (Terando et al., 2014). The authors state that some projections describe an increase in urbanization from 100 percent to nearly 200 percent over the next 50 years. If these projections are true, it would have a negative impact on water quality, air quality, and wildlife, just to name a few (Terando et al., 2014). These are examples of the same types of negative impacts that could affect the Jackson-Madison County area in the near future.

Limitations

The results of our study should be viewed with caution as there are limitations that must be considered. First, according to the MRLC, the NLCD maps were produced with the intentions of making regional comparisons. However, there are examples of land-use studies in which NLCD maps were used at a smaller than regional scale (Crowther, 2015). As previously stated, direct comparisons between 1992 data and 2001 NLCD data are not recommended (Fry et al., 2009; Homer et al., 2007) however, the MRLC does not declare that comparisons cannot be made (Crowther, 2015). In his thesis, Crowther (2015) uses 1992, 2001, and 2011 NLCD maps to quantify land-use changes in Pasadena and Inglewood, CA. Crowther stated that comparisons between the different NLCD maps were difficult and the reclassification of maps may have decreased the accuracy of the data. However, this study made use of the 1992 retrofit data and not the original 1992 NLCD data which should have increased the accuracy of derived analysis.

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Research Article

Impact of urbanization on estimated surface runoff and resulting issuance of flash flood warnings in Jackson, Tennessee

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ABSTRACT

Land-use and land cover (LULC) changes for the Jackson, TN area from 1992–2011 were evaluated based on data from the National Landcover Database. During the time of study, this area underwent noted changes in LULC with an increase in the area defined as urban and decreases in forested and agricultural areas. This study also makes note of the increase in the number of days flash flood warnings were issued during the 1990's as compared to the 2000's. During the same time period, high intensity rainfall events during 1990's (n=198) did not appreciably increase when compared to the 2000's (n=208); therefore, increases in flash flood warnings were not influenced by changes in rainfall events. The purpose of this work was to determine if changes in LULC and increases in flash flood warnings were statistically significance. Overall, an increase in runoff of 25% for the study area between 1990-2011 was determined. The majority of correlation analyses between runoff/urban and runoff/agriculture were also found to be significant.

KEYWORDS

Land use-land cover, SCS Curve number, Rainfall runoff, CN Number, Flash flood warnings

INTRODUCTION

Flash flood warnings are issued by the National Weather Service when flash flooding is observed or is imminent (National Weather Service, 2024). An increase in the number of flash flood warnings over Jackson, Tennessee, was observed from the 1990s into the 2000s. In fact, from 1990 to 1999, there were nine different days in which flash flood warnings were issued; contrasted with forty-four days of warnings issued from 2000–2009 (Iowa State University, 2024). These small-scale frequent flood events are of prime concern to Madison County and the city of Jackson, Tennessee (Whetstone, 2016). Whetstone reports that flooding in the area is such a concern that Madison County was awarded funds to develop flood control projects benefiting the county as well as the city of Jackson. Part of the funds will focus on infrastructure improvements to storm water sewer systems. Other monies are earmarked for the construction of artificial wetland areas that will offer recreation as well as flood control for the northern portion of the city and county (Tennessee.gov, 2017; Thomas, 2016).

Causes of Flood Events

Noticeable changes in the land-use and land cover (LULC) have occurred in Jackson, Tennessee from 1992–2011 (Figure 1). For example, areas recognized as urban have increased, while areas identified as agriculture and forest

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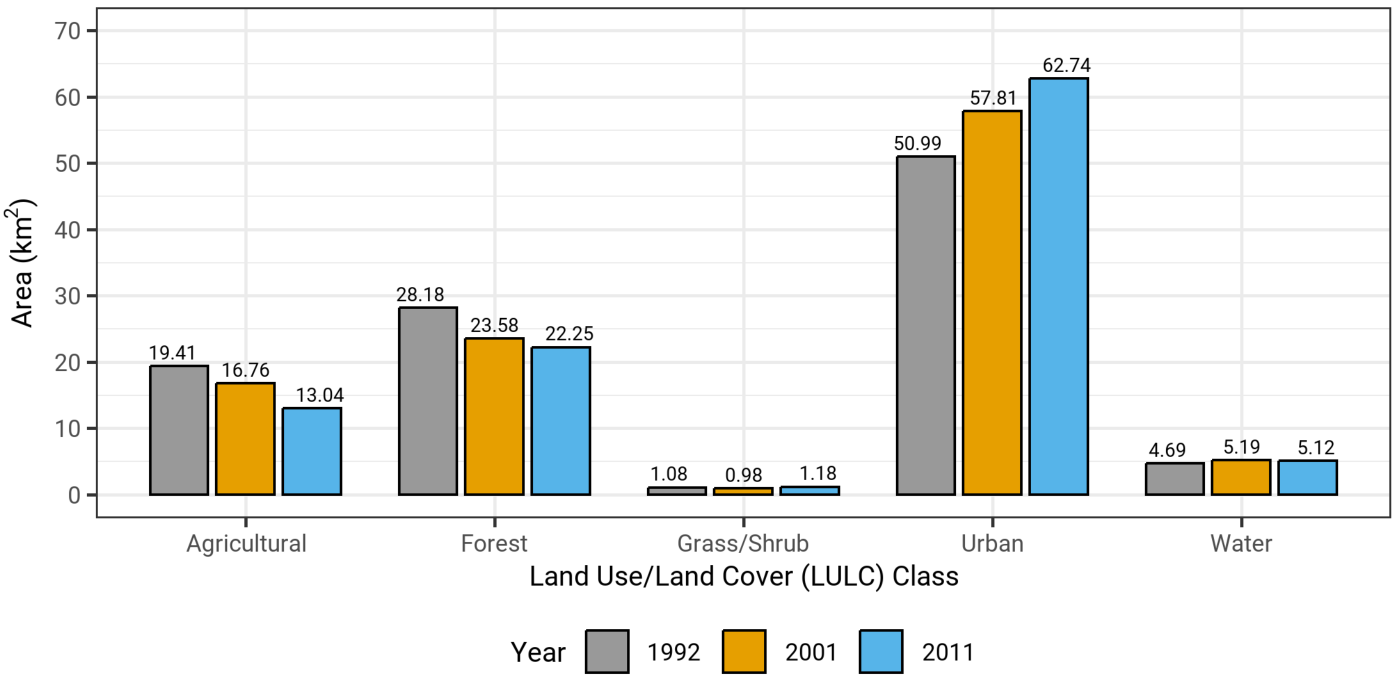

Figure 1: Extent of LULC of the study area in square kilometers from 1992, 2001, and 2011. Data for LULC is from the National Landcover Database (Multi-Resolution Land Characteristics Consortium, 2016).

have decreased. When previously rural areas experience changes in land-use due to urbanization, these man-made changes to the natural drainage systems can have dramatic effects on a basins ability to move and/or store water (Booth, 1991). In areas where overland flow is the dominant path for storm water runoff, the addition of impervious surfaces causes the overland flow velocity to increase. In general, the process of rainfall runoff has not changed (Booth, 1991); however, the speed and therefore, amount of water that enters a stream channel can change or increase. With the addition of an established storm water sewer system, an urban area can effectively drain a region of storm water at a much faster rate (Hollis, 1988). This may be due to a shorter distance as well as a smoother and/or straighter path water travels to the stream channel. The problem with this scenario is the possibility of continued rainfall and the effect additional storm drainage may have on the stream channel. Changes due to additional storm water runoff may include increased stream velocity, higher rates of erosion, and more frequent flood events.

The main objective of this case study was to determine if changes in LULC may be a contributing to the increase in flash flood warnings issued from 1990–2009. First, the increase in flash flood warnings were assessed relative to the number of heavy rainfall episodes defined as an event breaching the 95th percentile. Second, runoff was estimated and assessed for statistical significance during the time of study. Finally, the estimated runoff was compared to changes in LULC and assessed for statistical significance.

STUDY AREA

Jackson, Tennessee, is situated about halfway in between Memphis and Nashville, Tennessee, (Figure 2) within the West Tennessee Coastal Plain physiographic province (Bailey, 1993). This area is located in the Southeastern Plains and Hills Ecoregion (Tennessee Department of Environment and Conservation (TDEC), 2002) and is underlain by several different geologic and sedimentary units; some of the geologic units include Porters Creek Clay, Memphis Sand, and Fort Pillow Sand (Bailey, 1993) and sediments include clays, silts, silty-clays, and fine-grained sands, to name a few (TDEC, 2002). The 2010 census estimated Jackson's population at 67,685 (United States Census Bureau, 2024). Interstate 40 also provides a rough division of precipitation runoff between North Jackson with the Middle Fork of the Forked Deer River and South Jackson with the South Fork of the Forked Deer River. Jackson has an average elevation of ~125 meters (410 feet) above sea-level. One of the area's highest elevation points is just over ~198 meters (650 feet), with a low elevation of ~97 meters (320 feet), the area relief of just over 100.6 meters (330 feet) (TDEC, 2002). Precipitation for the area has an average of nearly 127 centimeters (50 inches) per year (Bailey, 1993).

DATA AND METHODS

95th Percentile Rainfall Events

Precipitation data for 95TH percentile rainfall events was supplied by local weather stations; specifically, Jackson McKellar-Sipes Airport and the Jackson Experimental Station. These daily data were retrieved from the Global Historical Climatology Network (Menne et al., 2012). Extreme precipitation events were found by ranking all available days of precipitation totals for each month during the study period (1992–2011) and computing the 95th percentile. The 95th percentile for each month was then treated as a threshold for an extreme precipitation day. Frequencies of extreme precipitation were then computed monthly.

Surface Runoff Model

Runoff estimations were based on the United States Soil Conservation Service's procedure known as the SCS curve number method (Cronshey, 1986). This method was chosen since it is a well-established procedure employed by engineers and hydrologists (Ponce and Hawkins, 1996). A simplified variation of the SCS equation can be expressed as follows:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{1}$$

where: Q is the runoff; P is the precipitation; and S is the potential maximum storage represented as $(1000/CN) - 10$; with CN representing the curve number. The CN is derived from a combination of land-use, land cover and hydrologic soil group information. Therefore, the two input variables needed to solve this equation are rainfall value(s) and a derived curve number.

Rainfall Amount for SCS CN Method

With an understanding that long-term impacts of land-use change on surface water runoff is more than likely influenced by the collective results of typical precipitation events rather than infrequent large-scale storms (Li and Wang, 2009; McClintock et al., 1995), a representative storm amount for the study area was sought. The NOAA's Precipitation Frequency Atlas was, therefore, employed (Bonnin et al., 2006). Rainfall frequency estimates for the different geographic regions of the United States are provided by NOAA. Atlas 14 Volume 2 Version 3 represents the most current rainfall estimates for the Ohio River basin,

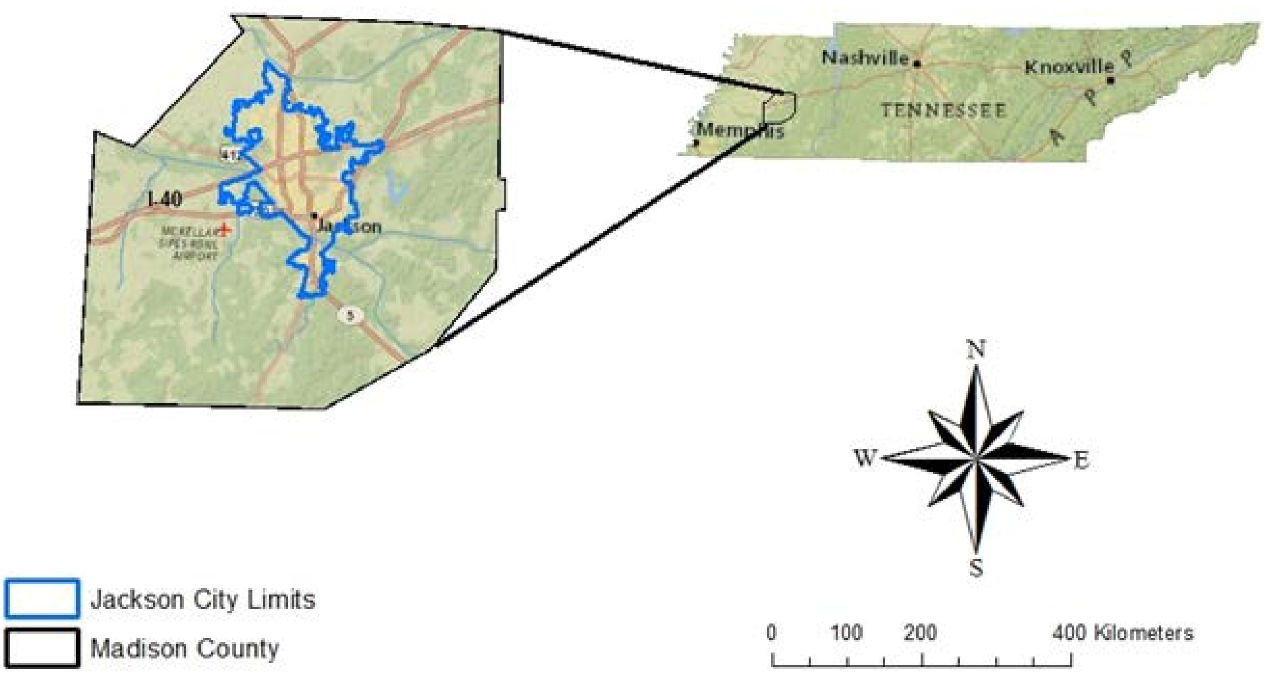

FIGURE 2: Basemap showing the location of Jackson, Tennessee, in Madison County, and the location of major roads. GIS data is derived from ESRI, Inc.

which includes Tennessee. The NOAA employs an interactive webpage that allows one to select an area of interest. Once selected, a range of frequency estimates for storms with recurrence intervals ranging from 1 year to 1000 years and storm durations from five minutes to 60 days are displayed (National Weather Service, 2017). Cronshey (1986) states when consistent rainfall amounts are applied in successive sub-basins, it is sometimes desirable to employ synthetic storms of which 24-hour rainfall durations are commonly used. According to Atlas 14 values found on NOAA's webpage, a one-year recurrence interval rainfall event of a 24-hour duration is 8.18 centimeters (3.22 inches) for the study area.

Curve Number Grid

The relationship between precipitation and runoff, when employing the SCS curve number method, is greatly influenced by potential maximum storage (Weng, 2001). Since the CN is an integral part of potential maximum storage, it is important to obtain the correct value for the CN. Calculation of a curve number grid is the first step in generating a representative CN for a watershed, basin, or sub-basin (Merwade, 2012a). Merwade's (2012a) procedures for the derivation of a curve number grid employing ArcGIS and the HEC-GeoHMS extension were followed. Requirements for curve number grids are a digital elevation model (DEM), soils data, and LULC data. The digital elevation model was retrieved from the United States Geological Survey (USGS) (USGS, 2017), soil data was retrieved from the National Resource Conservation Service (NRCS) (NRCS, 2017b), and land-use data was retrieved from the National Landcover Database (NLCD) (Multi-Resolution Land Characteristics Consortium (MRLC), 2016). Once obtained, DEM, soils data, and LULC data all exhibited 30x30-meter resolution and were clipped to the city limits of Jackson.

Specific land-use data downloaded from the NLCD included 1992, 2001, and 2011 maps of conterminous United States; 1992 data was the land cover change retrofit data. By using 1992–2001 retrofit data, one is able to make more accurate comparisons of land-use change compared to the original 1992 NLCD data (Fry et al., 2009). Land cover classes were reclassified into five classes; these included water (open water and wetland areas), urban, forest, grassland/shrubland, and agriculture (combined with barren lands). One issue with combining classes, such as open water and wetland areas into a single class, is the possibility of exaggerating the CN value. In the instance of the merged water class, initial runoff estimates could be inflated because CN values of "water" are treated as nearly impermeable. 2001 and 2011 NLCD maps were reclassified using the same classification scheme as 1992 retrofit. Classes for 2001 and 2011 were combined as follows: water (open water and all wetland areas), urban (all types of urban areas), forest (all types of forest areas), grassland/shrubland (shrub and grassland/herbaceous areas), and agriculture (hay/pasture and cultivated crop lands). The National Engineering Handbook of Hydrology was referenced in order to assign hydrologic soil values for soil groups A, B, C, and D to the various land covers (Natural Resource Conservation Service, 2017a). Within ArcGIS, the HEC-GeoHMS extension was then used to combine soil and land-use data in order to create a curve number grid of the study area (Shahid et al., 2017). These procedures were then repeated to produce a separate curve number grid for each of the NLCD maps.

Delineation of the Study Area and CN

The next step in deriving a CN was the development of a stream network for the study area. This was accomplished by following accepted procedures employed through HEC-GeoHMS called terrain preprocessing (Knebl et al., 2005; Merwade, 2012c). Merwade's (2012c) tutorial for terrain preprocessing includes completion of a RawDEM, HydroDEM, flow direction grid, flow accumulation grid, stream grid, stream link grid, catchment grid, catchment polygons, drainage line polygons, and adjoint catchment polygons. Following completion of these procedures the study area was divided into 20 sub-basins representing 81% of Jackson's city limits (Figure 3). The number of sub-basins derived through the implementation of these procedures is reliant upon the overall size of the watershed (Kingston III, 2012). A simple default for stream network size determination, i.e. basin size, is 1% of the watershed area. The final steps needed to produce representative CN values for the study area's time periods were to define a project point and a project area (Merwade, 2012b).

Upon completion of these steps only the addition of the previously generated curve number grids was needed for an average CN for each individual sub-basin representing 1992, 2001, and 2011. Once determined, we were able to insert the CN value for each sub-basin with the previously retrieved synthetic rainfall amount into the surface runoff model and generate an estimated runoff amount for each sub-basin over the time of study (Table 1). There are many other steps that

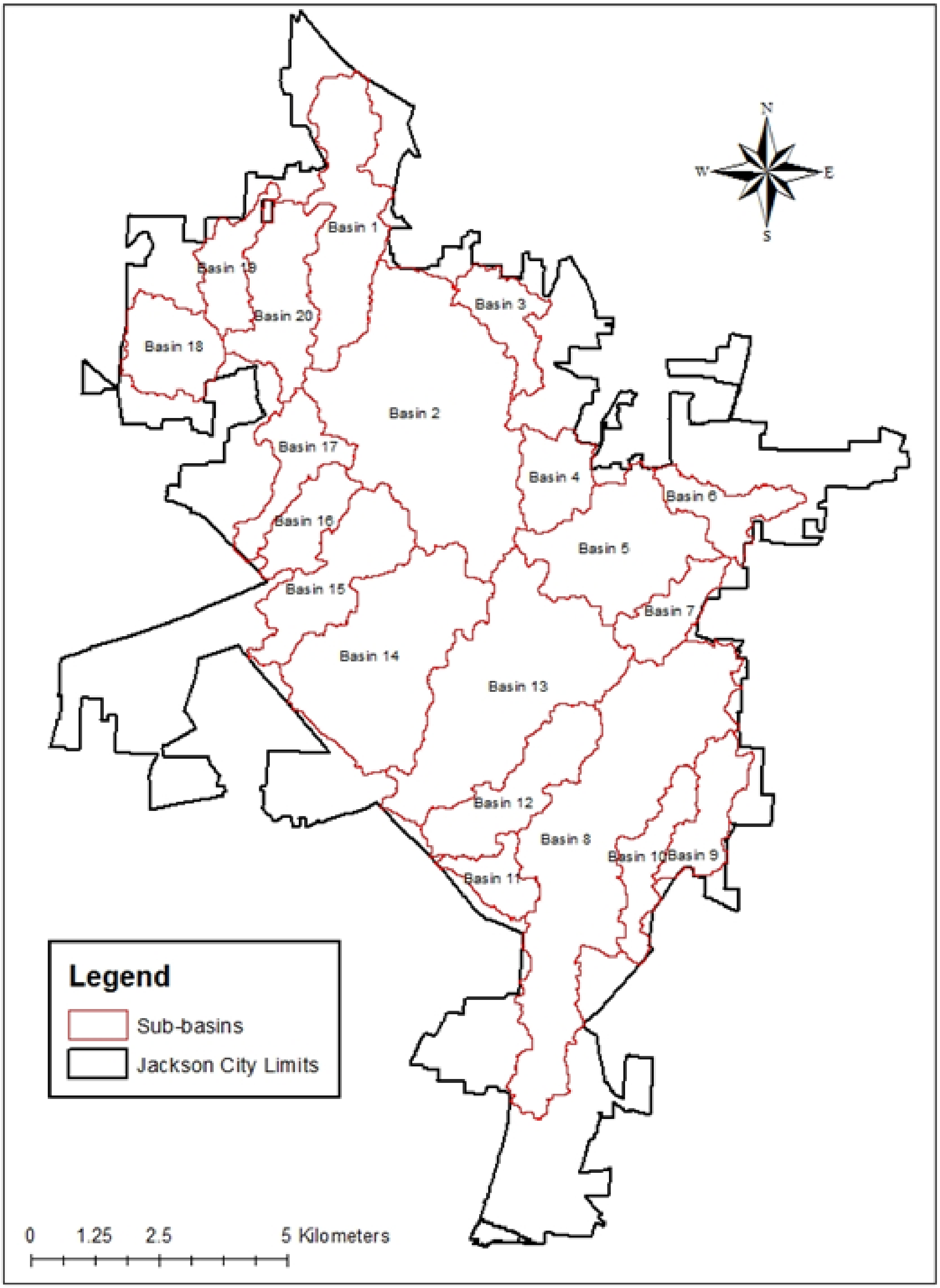

FIGURE 3: Details the shape and location of the 20 sub-basins derived using procedures established by Merwade (2012a; 2012b; 2012c) and their location within Jackson's city limits.

both precede and follow the inclusion of curve number grids when following Merwade's (2012b) instructions. However, these steps are implemented when the purpose is to develop a model that can be downloaded directly into the U.S. Army Corps of Engineers hydrology program (HEC-HMS), but this was not the case in this study. Only the derivation of a representative CN for each sub-basin originating from the different NLCD maps was sought.

Table 1: Derived CN#'s and resulting estimated runff for 1992, 2001, and 2011.

Sub-basin	1992 CN#	1992 Runoff (in)	2001 CN#	2001 Runoff (in)	2011 CN#	2011 Runoff (in)	Area (km^2)
1	72.17	0.95	77.82	1.28	77.81	1.28	6.32
2	71.66	0.92	74.40	1.07	75.19	1.12	15.74
3	70.97	0.89	74.27	1.07	75.05	1.11	2.26
4	61.29	0.46	65.67	0.64	66.88	0.69	2.44
5	60.76	0.44	62.36	0.50	63.04	0.53	6.37
6	62.27	0.50	65.79	0.64	66.20	0.66	2.21
7	68.31	0.76	71.32	0.91	71.81	0.93	2.14
8	72.05	0.94	74.50	1.08	75.20	1.12	15.56
9	67.29	0.71	70.28	0.85	70.90	0.89	2.55
10	75.53	1.14	77.55	1.26	78.18	1.30	2.33
11	91.82	2.35	94.37	2.60	94.48	2.61	1.56
12	71.02	0.89	73.16	1.00	73.52	1.02	4.24
13	65.16	0.62	67.26	0.71	67.91	0.74	11.55
14	68.69	0.78	72.06	0.95	72.51	0.97	10.12
15	68.68	0.78	73.28	1.01	73.90	1.05	4.63
16	64.86	0.60	68.89	0.79	69.52	0.82	2.26
17	62.09	0.49	64.76	0.60	65.27	0.62	2.68
18	70.55	0.87	77.58	1.26	77.24	1.24	3.06
19	69.14	0.80	75.41	1.13	75.39	1.13	2.13
20	70.34	0.86	75.83	1.16	75.92	1.16	4.24

Statistical Procedures

Runoff data derived from the SCS curve number method was entered into the Statistical Package for the Social Sciences (SPSS) version 24. Through SPSS, it was determined that runoff data was not normally distributed and would require the implementation of nonparametric statistical procedures (Helsel, 1987). For the purpose of this paper, p values <0.05 were considered to be statistically significant. In order to determine if the amount of rainfall runoff in the study area had changed significantly over the study time (1992, 2001, and 2011), Friedman's ANOVA (the nonparametric equivalent to repeated measures ANOVA) was employed. In instances where Friedman results were significant, the post-hoc Wilcoxon signed-rank test was utilized to determine significance between years of study (1992, etc.). In addition, several Spearman's correlations were performed to test for relationships between percent change in precipitation runoff (1992–2011) and percent changes in urban growth, forest, and agriculture (1992–2011).

RESULTS

No appreciable change in the number of heavy rainfall events from the 1990s (n=198) into the 2000s (n=208) was detected. Thus, the large increase in the number of flash flood warnings does not seem to be entirely related to changes in the number of heavy rainfall events. Next, relationships between estimated runoff and changes in LULC were assessed.

Estimated Runoff

Figures 4a and 4b show changes in estimated runoff over time. The null hypothesis for Freidman's ANOVA was that the mean rank of estimated runoff was consistent over the study period. Results from statistical procedures indicated there was a significant difference in estimated runoff over time, χ^2 (2) = 37.013, $p < 0.05$. The Wilcoxon signed-rank test was then employed to determine if statistical significance was for the entire study period or if significance only occurred between certain years of the study. All post-hoc comparisons were found to be significant; specifically, 1992–2001 $p < 0.05$, 2001–2011 $p = 0.001$, and 1992–2011 $p < 0.05$. Therefore, we reject the null hypothesis of no difference and can state that

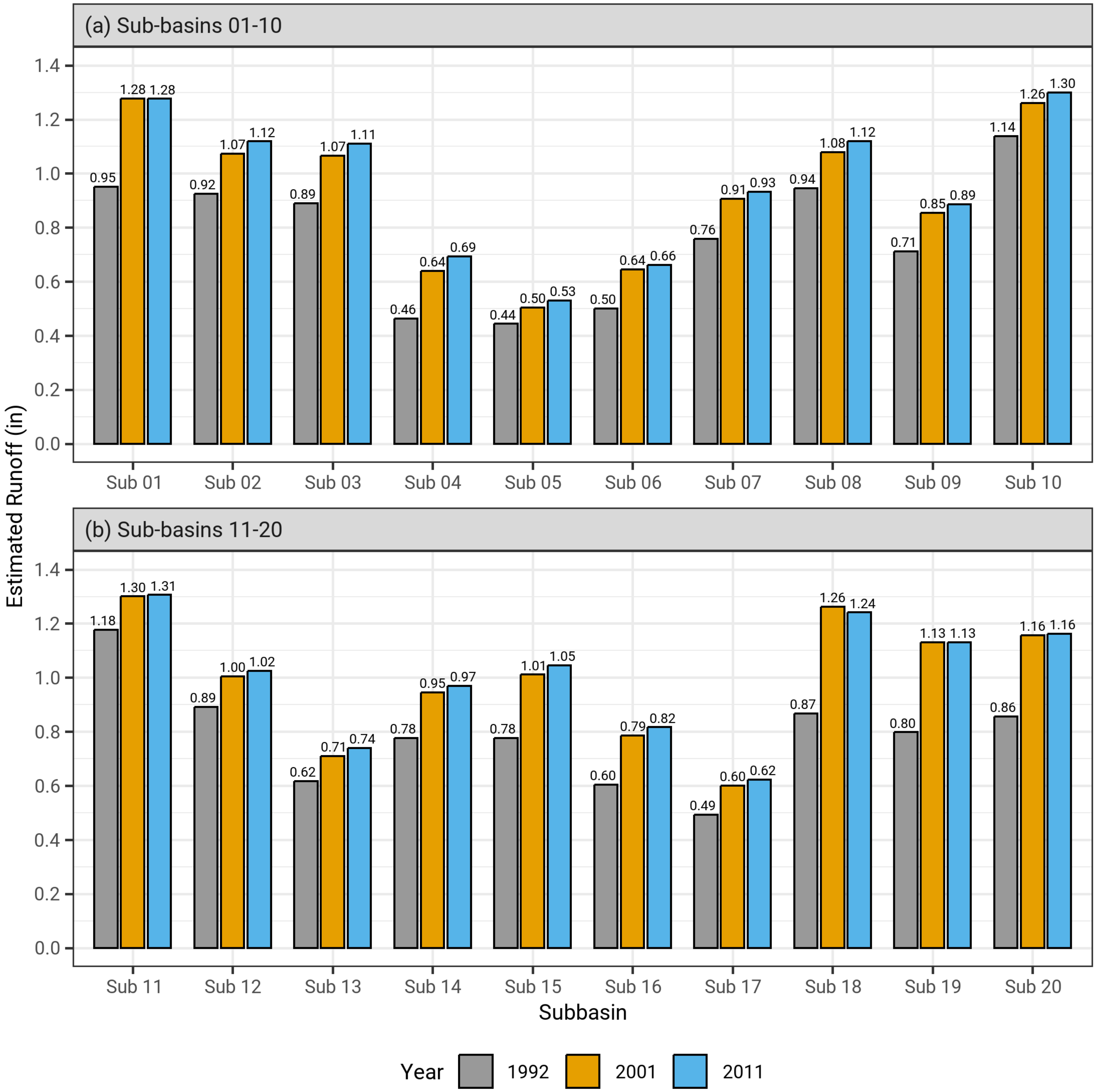

FIGURE 4: (a; top) Details of estimated runoff values for sub-basins 1-10; (b; bottom) Details of estimated runoff values for sub-basins 11-20. The estimated runoff values for sub-basin 11 were normalized.

statistically significant differences between estimated runoff occurred throughout the time of study.

Land-use and Land Cover

Changes in LULC included little to no variations in water and grassland/shrub areas, however, a steady decrease in forested and agricultural areas and a steady increase in urban areas was noted (FIGURE 1). Correlation analysis was performed based on percent changes in estimated rainfall runoff and percent change in LULC that occurred between 1992–2011, 1992–2001, and 2001–2011. Results from correlation analysis indicated that a very strong, positive correlation (r = 0.808) existed between percent change in runoff (PCR) and percent change in urban areas (PCU) from 1992–2011. A moderate, positive correlation (r = 0.399) existed between PCR and percent change in agricultural areas (PCA) during the same span of time. Statistical analysis for PCR and PCU correlation was significant at $p < 0.05$ while PCR and PCA correlation was weakly significant at $p = 0.04$ (one tailed). No significant relationship between PCR and percent change in forest areas (PCF) was observed between 1992–2011. A strong, positive relationship (r = 0.704) existed between PCR and PCU and a moderate, positive correlation between PCR and PCA (r = 0.544) was noted for 1992–2001. Significance between PCR and PCU was $p = 0.001$ and significance between PCR and PCA was $p = 0.013$. Again, no significant relationship was indicated between PCR and PCF between 1992–2001. A weak, negative, relationship that was weakly significant was noted between PCR and PCU ($r = -0.385$, $p = 0.04$, one tailed), while a moderate, positive, and significant correlation between PCR and PCA ($r = 0.507$, $p = 0.023$) was noted for 2001–2011. However, no significant relationship between PCR and PCF existed during the same span of time.

DISCUSSION

Changes in Estimated Runoff

Statistical analyses demonstrated runoff changes were significant for the study interval (1992–2011; Figures 4a and 4b). However, estimated runoff in some sub-basins, between 2001 and 2011, exhibited little to no change or even a decrease in estimated runoff. For example, sub-basins one and 20 revealed no appreciable change in runoff estimates, while sub-basins 18 and 19 displayed a decrease in estimated runoff. These outcomes may be attributed to the type of urbanization taking place in these sub-basins. It is possible that the little to no change in estimated runoff and decrease in runoff estimates reflects a change between agriculture and urbanization. A case has been made where a decrease in estimated runoff was explained by conversion of agricultural lands to suburban lands (Grove et al., 2001). The authors explained that in some instances a low-density or suburban area may have a lower CN value when compared to certain types of agricultural areas, thereby impacting runoff estimates. Comparisons of derived CN values (Table 1) offer possible confirmation of outcomes alluded to by Grove and others (2001). For example, differences in CN values between 2001–2011 in sub-basins 1 and 20 were minimal, while slight decreases in CN values in sub-basins 18 and 19 between the same years were also noted.

Changes in Land-use and Land Cover

As previously stated, changes in LULC included an increase in urban areas and decreases in agricultural and forested areas. With the noted increases in estimated runoff, correlations between percent changes in runoff and percent changes in urban and agricultural areas were, for the most part, expected. Statistical outcomes from 1992–2001 and 1992–2011 describe positive relationships indicative of areas experiencing urban growth with noted decreases in agricultural areas (Li and Wang, 2009). As previously mentioned, the amount of land classified as agriculture decreased over the study period; this is indicated by negative increases in percent change. Therefore, the positive relationship between PCR and PCA signifies an increase in runoff as the amount of agricultural area decreases. Graphs illustrating the percent of land that was urban (Figures 5a and 5b) and the percent of land that was agriculture (Figures 6a and 6b) illustrate changes experienced in each sub-basin. However, the one exception was the negative correlation between PCR and PCU, which is contrary to outcomes of similar studies (Li and Wang, 2009; Weng, 2001). Again, this might be explained by the conversion of agricultural lands to low-density urban lands, lowering the CN value and reducing estimated runoff (Grove et al., 2001). A reduction in the estimated runoff and an increase in percent of land that was categorized as urban might produce the negative correlation observed in this study between PCR and PCU.

CONCLUSIONS

This study investigated whether increased urbanization may impact surface runoff measured by issued flash flood warnings in Jackson, Tennessee. We utilized the SCS curve number method in order to produce estimated runoff over a 20-year period for the Jackson, Tennessee, area. Derivation of a CN is an important component of the surface runoff model. Therefore, based on procedures established by Merwade (2012a; 2012b; 2012c) and beginning with LULC data from 1992, representative CNs for each sub-basin were determined. These procedures were then repeated with the inclusion of LULC data representing 2001 and 2011. The SCS curve number method was then employed in order to produce estimated runoff amounts for each sub-basin during the time of study. Once obtained, statistical procedures were

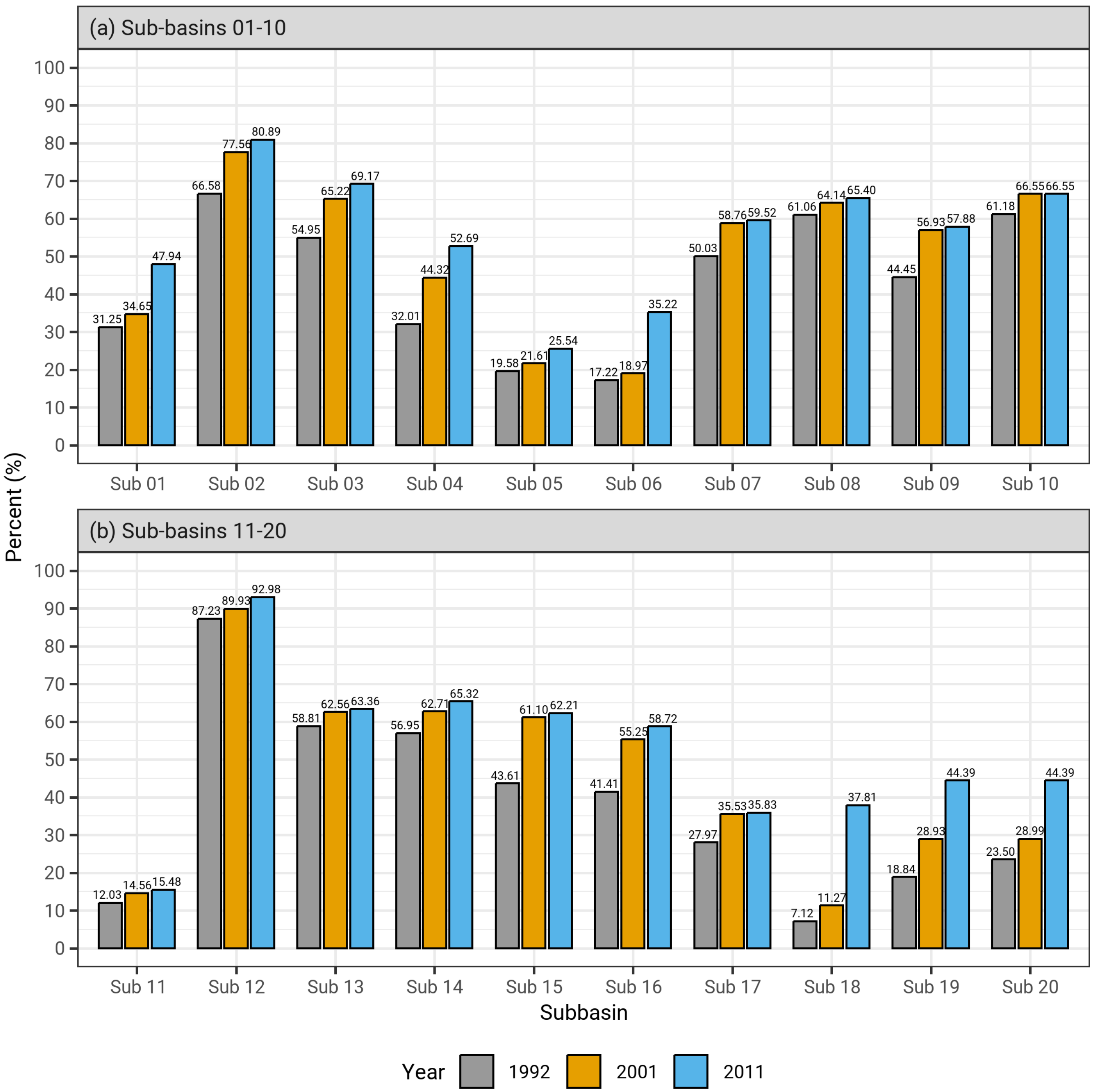

FIGURE 5: (a; top) Details of the percent of land categorized as urban in sub-basins 1-10 for 1992, 2001, and 2011; (b; bottom): Details of the percent of land categorized as urban in sub-basins 11-20 for 1992, 2001, and 2011.

applied to determine if estimated runoff amounts might be a factor in the increased number of flash flood warnings issued in the study area.

Statistical analysis of estimated runoff and LULC changes were, statistically significant. Changes in runoff estimates were significant between 1992–2001, 2001–2011, and 1992–2011. The majority of correlation analyses between PCR and PCU and PCR and PCA, during the study interval, were also significant. Outcomes of correlation analyses included an increase in estimated runoff as urban areas increased and agricultural areas decreased. Calculated runoff, in the study area, increased by 25% from 1992–2011. The majority of the

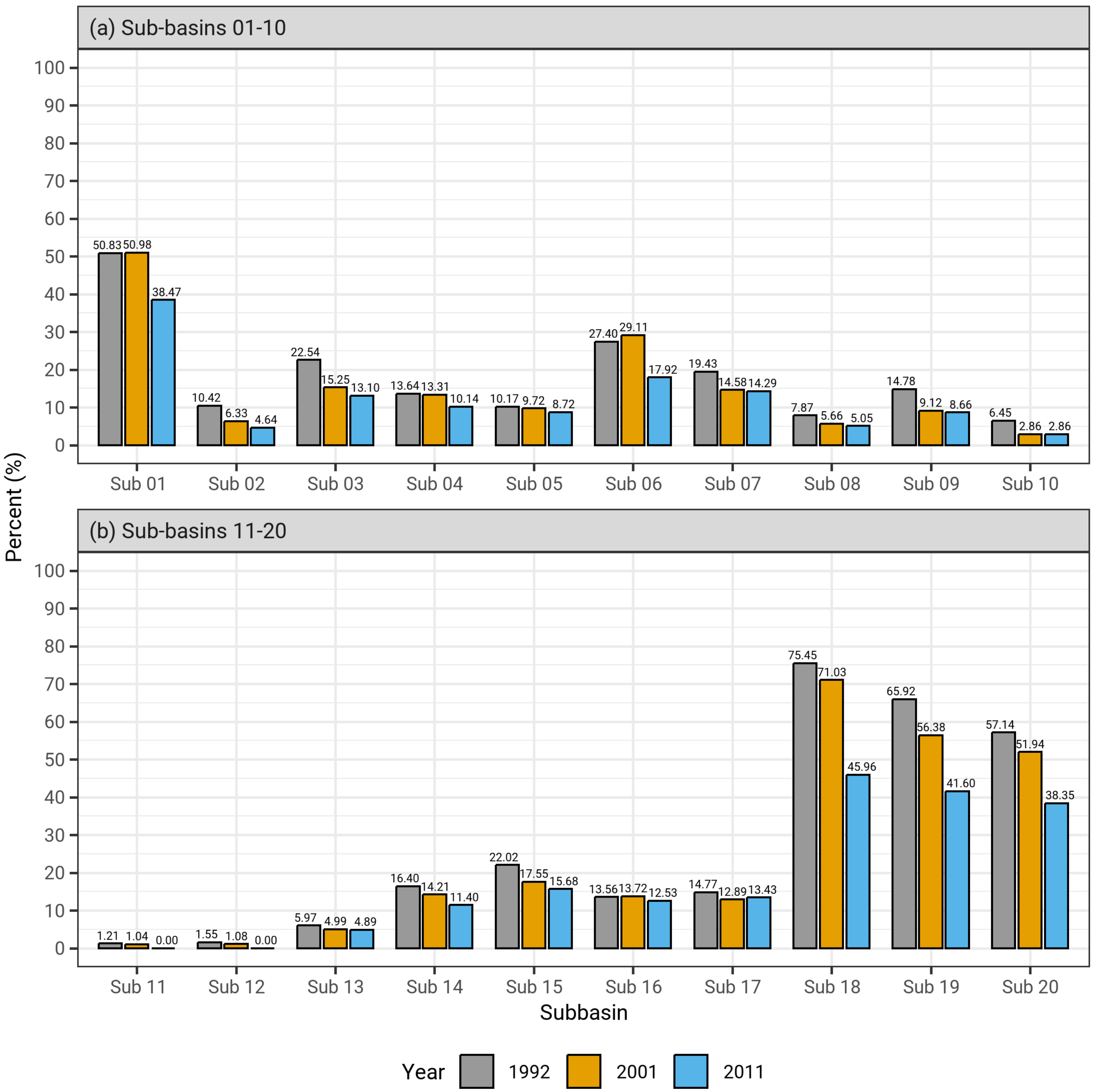

FIGURE 6: (a; top) Details of the percent of land categorized as agriculture in sub-basins 1-10 for 1992, 2001, and 2011; (b; bottom) Details of the percent of land categorized as agriculture in sub-basins 11-20 for 1992, 2001, and 2011.

stated increase in estimated runoff occurred from 1992–2001 (22%), while estimated changes in runoff from 2001–2011 were only about 3%. Therefore, changes in LULC might be a factor in the increase in flash flood warnings issued from the 1990s to the 2000s.

However, there are limitations that must be considered. First, the more detailed a LULC change map is the more representative a CN value can be produced. This study employed NLCD maps that are primarily used for regional studies instead of comparisons made at a smaller than regional scale (Crowther, 2015). In addition, the use of the 1992 retrofit data may have limited the number of land-use classes available for comparison. Use of more detailed classes, such as specific types of agricultural lands or distinctions between low, medium, and high intensity urban development, might have a significant impact on the derivation of CN's. For example, because the water land-use class and wetlands land-use class were combined and labeled as water, initial runoff estimates in sub-basin 11 were likely exaggerated. This is because standing water has a high CN value and treats runoff water similar to that of impervious surfaces. If more detailed land-use classes had been used when deriving CN values, normalization of estimated runoff results for sub-basin 11 would have been unnecessary. Second, the inclusion of satellite imagery for the purpose of completing a LULC study of the area would allow for more detailed classes, while covering a significantly longer period of time. A LULC change study and a longer time period might produce estimated runoff outcomes that differ from these results.

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RESEARCH ARTICLE

The history of the Tennessee Earth Science Teachers (TEST)

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ABSTRACT

Tennessee Earth Science Teachers (TEST) was founded in 1990 to promote awareness of the need to integrate Earth science and geology education into the secondary school curricula of Tennessee and to ensure that Tennessee students received the curricular and instructional benefits of Earth Systems education. That mission expanded to include all K-12 grades and to infusing Earth science into other disciplines. A legacy of the participants from a 1991 Tittle II geology workshop for Tennessee teachers, TEST was instrumental in designing and providing academic and pedagogical training, disseminating educational materials, and with networking K-12 teachers with higher education geoscience educators across Tennessee for over 34 years.

KEYWORDS

TEST, Tennessee Earth Science Teachers, Geoscience education, Standards, Professional Development

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WHY IS THE NUMBER OF GEOLOGY MAJORS DECLINING IN TENNESSEE?

This was the question being asked by Tennessee geology professors around the state, including when they met for the annual GeoConclave competitions (see Haroldson and others, 2020, and Gibson and others, 2021, for an explanation of GeoConclave). Geology programs had been seeing declining enrollments in classes and a reduction in the number of majors in the late 1980s, partly as a result of the oil boom and bust earlier in the decade. Many departments resorted to offering courses like "dinosaurs" or "planetary geology" to attract new students. While a number of causes for lowered enrollments were recognized (e.g., declines in departmental funding, oil and gas boom and bust, neglect by administration, retiring faculty, etc.), a common cause identified by all was that geology (and Earth science in general) in Tennessee was an "unknown" to most college students, primarily because they were not exposed to a course during their high school years. To satisfy college science distribution requirements, most students tended to take the sciences that they had been exposed to in high school—biology, chemistry, and sometimes physics—and avoided geology as an unknown entity. The result was that college-level geology courses, and the potential to major and to have a career in the geosciences, was being missed by most college students. A corollary observation to this was that many of the students who wandered into geology courses did so in their junior or senior year when they were already too far along into a degree program to warrant changing majors without staying on longer to graduate, spending more (if their student loan agencies would even grant them the extended time). The lament "if I had only known about geology earlier" was commonplace with the students who discovered geology too late in their academic careers.

WHY ISN'T GEOLOGY AND EARTH SCIENCE STANDARD IN PUBLIC EDUCATION IN TENNESSEE?

This was the question that was being asked by geology professors and many Tennessee teachers during the late 1980s and early 1990s, even as the news was filled with stories

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about "our failing schools," and at the same time as natural disasters were headlining. Tennessee was consistently ranking in the bottom half of student testing nationally (e.g., OERI, 1997). Data supplied by the Tennessee Department of Education indicated that fewer than 20 schools in Tennessee taught either Earth science or geology courses at the high school level in the middle to late 1990s, most of these in urban areas of East or Middle Tennessee. Why was geology and Earth science not prevalent in high schools was a question being asked nationally as well (e.g., Holbrook, 1997).

WHAT TENNESSEE TEACHERS TOLD US

The author, and Don Byerly, a colleague from the University of Tennessee, Knoxville used a series of grant-funded "GeoCamps" to solicit information directly from Tennessee teachers regarding the status of K-12 Earth science and geology education as well as provide professional development opportunities. As part of these professional development opportunities, teacher discussions concerning Earth science and geology curricula in Tennessee were frequent. Early on, the authors detected strong frustration among the participants regarding the status of Earth science in Tennessee. A few illustrative examples demonstrate some of the issues that the teachers faced.

"Greene County no longer offers Earth science. I am the only high school out of four in [the] county that offers geology. Technical path students will now take environmental science as this course has some standards that are the same as biology – for example "diversity" (Virginia Cooter, Greene County teacher, personal communication, 1990). "Earth science has been dropped from the entire Clarksville-Montgomery County School System curriculum. It has been decided that since Algebra I, Language Arts I, and Biology I have Gateway tests that must be passed, why should we spend any more time on other subjects. It is no longer important in Tennessee for a person to know about tornadoes, lightning, minerals, rocks, soils, earthquakes, volcanoes, topographic maps, etc. As long as you live in Montgomery County, I guess you will be protected from these things if you can dissect a frog, conjugate a verb, and find figure X. I have been fighting this for seven years, but it has done no good. I even had a job interview for an Earth science [teaching] position. When I go there, the guy said that he didn't know why he bothered to have me come in – he wasn't going to offer the subject at his school. (Clarksville teacher Mary Ann Stephens, personal communication, 1990)." "Earth science was dropped from Campbell County's high school curriculum at least 10 years ago. As far as I know, the only Earth science taught is as part of the general science curriculum at the middle school level. My Geology class is frequently not offered because we don't have enough science teachers and the administration gives me reasons like: 'Earth science … is too low-level of a course' or 'we don't have enough labs' or, my favorite, 'it doesn't count as a science credit.' Luckily, this year I am teaching chemistry and am threatening, cajoling, pleading, browbeating, etc. my students to sign up for geology as their 3rd science credit. So maybe next year!" (Campbell County teacher Jo Stout, personal communication, 1990).

WHAT WERE THE IDENTIFIED PROBLEMS WITH GETTING EARTH SCIENCE OR GEOLOGY IN HIGH SCHOOL

Again, using teacher workshops to get access to teachers, several issues were identified as hurdles to initiating Earth science courses in Tennessee. First, biology had historically held the influential "lead" science position within K-12 curricula. Often more than one year of biology is offered (e.g., Biology I and Biology II), so it had become the primary pathway for most students to navigate satisfying their science requirements for graduation. Chemistry and physics courses were more analytical, required a more mathematical mind, usually had prerequisites, and were considered more difficult, thus had fewer students enrolled in them; however, there were more certified/endorsed chemistry and physics teachers available to hire than Earth science teachers. These three courses, the "PCBs" (physics, chemistry, biology), held the monopoly on what could be offered in most school systems across the state, especially rural systems. Importantly, this had been the case for a long time, possibly dating back to the education reforms of the 1960s and 1970s and the Earth Science Curriculum Project (ESCP) programs, when Earth science became a "freshman" level offering nationally (Byerly and Gibson, 1999).

This historical inertia resulted in tight curricula that were well-ingrained. Teachers wanting to add an Earth science or geology course at the secondary level were told that there was enough time (in teacher scheduling or in the student's academic plan) for more science in high school (3–4 courses are the maximum usually), and there were not enough students to populate new courses. There also appeared to be a bias towards physics, chemistry, and biology as being better recognized, hence were more strongly promoted in high school (the "PCB Syndrome"). Many teachers reported their administrators, or even parents, as saying that Earth science or geology was not relevant, or worse, a remedial science (e.g., "rocks for jocks"). Our teachers also confirmed that their students were more likely to take the same science in college that they had in high school.

It also appeared that poor guidance-counseling was part of the problem as there was a general perception that there was greater job potential and more employment opportunities available in other science disciplines. In many cases, echoing a national trend, Tennessee teachers said that their counselors just did not have an awareness of what the Earth sciences and geology entailed (e.g., Holbrook, 1997; Van Norden, 2002). Another "catch-22" hurdle was that most existing Tennessee teachers were not certified or endorsed to teach Earth science or geology, so even when the opportunity arose in a school, there was no one qualified or endorsed who could teach the course, and resources were not available to hire new teachers for just one or two classes.

HOW TO COUNTERACT THE HURDLES

Higher education, specifically universities with geology departments, needed to be part of the solution, as it was to their benefit from a recruiting standpoint to help solve the issues. This was during the time, nationally, that geoscience education, and geoscience education research, was "coming of age," but was still not considered valuable science research to the level that basic geologic research was, especially at Tier 1 research institutions. Many of our university colleagues said that geoscience education work and research was admirable service to do, and necessary, but that they did not have the time to undertake this task, nor did most feel that this type of work would be regarded as highly to their administrators, who were evaluating them for promotions and tenure decisions.

Based upon the discussions with Tennessee K-12 teachers, we concluded that the most efficient way to get Earth science or geology courses into an already full Tennessee school curricula was to find an existing teacher, usually a biology or chemistry teacher, willing to offer a single geology or Earth science class as a special section in their school (often without remuneration, perhaps as an advanced class for science club students or honor students) and then allow popularity of the topics to win over the students, parents, and administrators, to ensure the course continued.

One avenue for achieving this could be the Dual Credit (DC), or Dual Enrollment (DE), programs being offered; however, there were virtually no Earth science or geology DC or DE courses in Tennessee at this time (nor was there an exit exam for the DC courses). These pathways had other unique stumbling blocks and our goal was to get Earth science to be a regular curriculum for all high school students, not just advanced students. Additionally, who would teach the DC or DE course? DC and DE teachers had to be trained and certified or endorsed to teach Earth science, and few were. Finally, there were concerns that end of course assessment scores earned would not be high enough to allow students to use a high school geology course for college credit. Additionally, DC and DE could only be applied to colleges that had geology as a science, which not all colleges do.

Getting more Earth science or geology classes into Tennessee schools seemed, to us, and to the teachers with which we were working, to be our best avenue for success. We recognized that there were several potential impediments to our proposed approach including (1) finding teachers interested in adding Earth science or geology to their curriculum, (2) identifying school systems whose administration would be receptive to the new course, at least on an experimental basis, (3) guaranteeing that the teachers had the necessary content knowledge to teach Earth science or geology, and (4) ensuring that these courses were using the most current pedagogical methods, which at this time was inquiry (Gibson and Byerly, 2024, this volume). Our solution to these impediments was first to network existing Earth science teachers in Tennessee, and to then establish a dedicated communication and interaction with this population. We felt that this could be accomplished through a regular long-term content-rich professional development program.

TENNESSEE EARTH SCIENCE TEACHERS (TEST)

In 1990, Don Byerly from the University of Tennessee, Knoxville obtained Eisenhower Title II funding from the state of Tennessee to run a professional development workshop entitled "Field-Oriented Geology Workshop for Secondary School Science Teachers." Twelve teachers, primarily from East Tennessee, participated in two weeks of travel across the state of Tennessee studying the geology of each physiographic province, collecting mineral, rock, and fossil specimens for classroom use, and developing lesson plans for their students. The workshop was repeated in 1991.

As part of the workshop, the teachers were tasked with finding ways to promote Earth science teaching in Tennessee and to continue their personal investment in teaching Earth science. Publicity and communication were recognized as essential, so one of the requirements of the teachers in these workshops was to attend the annual meeting of the Tennessee Science Teachers Association (TSTA), which originally had been established in 1975 as the Science Association of Tennessee, and is the primary state-level science teacher agency sponsored by the Tennessee State Department of Education (TSTA, 2024). The members organized an Earth science session for the 1991 TSTA meeting and each teacher presented their lessons. Programming expanded for 1992 with both the 1991 and 1992 workshop teachers presenting. This is an annual tradition that continues and has expanded to full day workshops in addition to the multiple days of individual teacher sessions. For a few years in the late 1990s, TEST dominated the TSTA meeting with the largest number of sessions.

After the 1991 TSTA meeting held in Nashville, Tennessee, the workshop members held their next meeting as an organization at Cedars of Lebanon State Park, where they designed a quarterly newsletter, The Test Tube: Communication for Tennessee Earth Science Teachers, to be printed on a regular schedule. The first issue was mailed in December of 1991. In that newsletter, as a way to achieve some degree of official recognition within the state, Byerly asked for the group to develop a suitable name for their fledgling grassroots organization and proposed a June retreat for Tech Aqua, a research farm operated by Tennessee Technological University near Cookeville, Tennessee. In short order the Tennessee Earth Science Teachers (TEST) was adopted as the official name. Elections for officers (President, Vice President, Secretary, Treasurer, and Historian) ensued with officer duties subdivided geographically between the three Grand Divisions of Tennessee. It was determined that field trips that alternated across the state would be a primary recruiting activity of the TEST and that the TEST would have meetings twice per-year at a centralized areas in Tennessee (usually at the annual TSTA meeting held in either Nashville or Murfreesboro and a "floating meeting" held alternately in east or west Tennessee). The TEST initiated affiliation with other Tennessee teacher organizations (e.g., Tennessee Educators of Aquatic and Marine Science (TEAMS) and Tennessee Environmental Education Association (TEEA)). Soon after, Valerie Hunt, the artistically talented wife of a TEST officer, designed "Peck," a cartoon geologist named for his constant use of a geologic rock hammer to peck on rocks, as the mascot of the TEST (Figure 1). The TEST also created a logo (Figure 2).

Figure 1: "Peck" is the official mascot of the TEST. Peck was designed by Valerie Hunt.

Figure 2: The TEST logo. The TEST logo consists of a background field made of two rock hammers facing one another and rounded at the bottom to produce a central sphere, representing the Earth, and ES for Earth Science. The upper left shows a brown starburst representing the process of impacting to include planetary geology. The upper right contains a star.

Since 1991, the TEST has held its annual meeting in conjunction with that of TSTA with additional fieldtrip meetings (sometimes as many as five) throughout the year and spread across the state. These fieldtrip meetings were seen as a way for teachers to experience more of the geology of Tennessee and gather specimens for their classrooms. TEST held numerous organizational meetings during this formative period (1991–1993), mostly in East Tennessee, at which they developed a mission statement and goals statement. The mission of the TEST was, and still is to promote an appreciation and understanding of the interrelatedness of the physical, geological, chemical, and biological components of the Earth's environment. The stated goals of the TEST were, and still are:

1. To promote collaborative efforts between the business and educational communities with the primary focus on the enrichment of Earth science education.
2. Integrate Earth science across the curriculum and through the grade levels K-12.
3. Provide, encourage, and promote professional growth opportunities for all levels of Earth science teaching.
4. Increase awareness of social responsibility as related to Earth science issues.

Don Byerly was given the role of higher-education advisor to provide a communication and association with a major geology program in Tennessee. In 1992, Dr. Michael Gibson from The University of Tennessee at Martin, who had participated in the first two workshops as a field guide for their West Tennessee studies, became the second permanent higher education advisor. In 2002, The TEST's higher education advising expanded to four advisors from across Tennessee, adding geologist Dr. Anne Holmes (University of Tennessee at Chattanooga) and astronomer Dr. Lionel Crews (University of Tennessee at Martin). Later, in 2014, Dr. Peter Lemiszki (Tennessee Division of Geology) became an advisor for a few years and in 2017, Dr. Wayne Leimer (Tennessee Technological University) was added as an advisor until his retirement in 2021.

The primary responsibilities of the higher education advisors included the following: to help organize field trips, define curricula, support programing conducted for and by the TEST (including obtaining funding); to provide professional development opportunities related to content and pedagogy (e.g., Gibson and Byerly, 2024, this volume); to promote Tennessee Earth Science education at the state, regional, and national levels; to provide continuity to the TEST; and to ultimately expand the number of Earth science and geology courses taught in middle and high school in Tennessee. As with any formal organization, written bylaws and procedures were needed, especially if the group was to be recognized as a 501(c)(3) IRS-recognized nonprofit organization, which the TEST later became. By 1995, the TEST finalized a constitution and by-laws, elected its first slate of officers, and had opened a bank account to fund its activities.

PRIMARY ACTIVITIES OF THE TEST

The primary gathering venue for the TEST was the annual meeting of the Tennessee Science Teachers Association, usually held in early November of each year. To prepare for The TEST activities at this meeting, several regional meetings would be held, beginning soon after the previous meeting was over. The leadership of the TEST would plan their activities for that year and schedule additional meetings to achieve these goals. At first, just a few hour-long sessions were offered at TSTA, but by 1995 the TEST was providing day-long, paid (teachers paid a fee to attend) workshops in additional to the free one-hour sessions. The TEST soon became active in writing science curricula, selecting textbooks, giving teacher awards, and more. By 1997, the TEST had achieved one of its primary goals, to increase the impact of Earth science and geology in Tennessee schools. Following are descriptions of the most important and recurring activities of the TEST.

Tennessee mineral, rock, and fossil boxes

The TEST developed a series of box kits that contained samples of minerals, rocks and fossils native to Tennessee. Over the years, these kits evolved from a combined kit to be separate boxes, with curriculum each year (TABLE 1, FIGURE 3) and the topics of kits becoming thematic. Samples of Tennessee minerals, rock, and fossils were collected by the TEST members from across all regions of Tennessee and the boxes were usually assembled in early fall at a meeting held in a central location. The boxes were used annually at the TSTA conference. The TEST teachers developed State- and National Standards-based activities tied to the sample kits and assembled support materials to accompany the box kits. At the TSTA meeting, paid and free sessions were offered in which the teachers received a box kit and the supporting materials, as well as demonstrations of activities and instructional training on the geology of Tennessee. Funding for the kits came from grants to the TEST or to the advisors

TABLE 1: Resource box kits used in professional development workshops by the TEST.

Year	Box/kit topic	Venue (paid session/free session)
1995	Economics of Natural Resources Rock Box	Free Sessions
1996	Tennessee Rocks Giveaway	Free Sessions
1999	Tennessee Rocks Giveaway	Free Sessions
1998	Tennessee Rock Giveaway	Limited Ticketed Free Sessions
1999	Tennessee Fossil Box	Limited Ticketed Free Sessions
2000	Great Smoky Mountains Rock Box	Paid and Free Sessions
2001	Great Smoky Mountains Rock Box	Paid and Free Sessions
2002	Tennessee Rock Box	Paid and Free Sessions
2003	Tennessee Fossil Box	Paid and Free Sessions
2004	Plate Tectonics	Paid and Free Sessions
2005	Economics of Natural Resources	Paid and Free Sessions
2006	NSTA: Economics of Natural Resources	Paid Session
2007	Teaching Evolution	Paid and Free Sessions
2008	Astronomy	Paid and Free Sessions
2009	Tennessee Fossil Box	Paid and Free Sessions
2010	Plate Tectonics	Paid and Free Sessions
2011	Teaching Chemistry with Geology	Paid and Free Sessions
2012	Environmental Geology and Reading	Paid and Free Sessions
2013	Tennessee Rocks!	Paid and Free Sessions
2014	Teaching Evolution	Paid and Free Sessions
2015	Great Smoky Mountains Geology	Paid and Free Sessions
2016	Coon Creek Science Center NSTA Trip*	Paid Fieldtrip
2017	Teaching Sea Level Change	Paid and Free Sessions
2018	Effective 3-D Mathematics Applied to Global Sea Level Change	Paid and Free Sessions
2019	No Sessions	
2020	Earth Science Field and Virtual Field Experiences at the University of Tennessee Coon Creek Science Center (online)	Online Delivery – COVID-19
2021	Miscellaneous Geology of Tennessee Topics	Free Sessions
2022–24	No Sessions	

(e.g., NSF, Tennessee Department of Education, etc.), commercial and non-commercial donations (e.g., Wal-Mart, Memphis Archaeological and Geological Society, Middle Tennessee Rockhounds, East Tennessee Geological Society), as well as the TEST membership dues.

Tennessee Earth science and geology standards

In 1993, the TEST was given the task of revising the state curriculum in both Earth science and geology by the State Department of Education. This new Tennessee curriculum was to be firmly rooted in both the newly published National Science Standards, based upon the principles of Earth System Science, which was a national initiative at that time, as well as using inquiry as the primary pedagogy (see summary in Gibson and Byerly, 2024, this volume). For the next decade and a half, the TEST was the primary group of teachers responsible for reviewing and revising the Earth science and geology portions of the Tennessee Standards. Additionally, the TEST produced a Standards Sampler for teachers, which was a document to help teachers to incorporate the curriculum into their classrooms.

Communication and information dissemination

The TEST TUBE, a quarterly newsletter, became the primary means of communication for the TEST. The original newsletter was only one-page in length, but by the late

FIGURE 3: An example of a Tennessee rock box kit. This kit was prepared for the workshops that focused on plate tectonics and included mapping activities, sediment from Trinidad, and supplies to complete the activities. Each teacher would receive one kit as part of their workshop. Additional kits were available or purchase.

1990s had expanded to be up to eight pages long. There were standard inclusions to the newsletter, such as "The President's Corner" in which the president had an open forum to discuss issues related to Earth science teaching and TEST. An announcements section listed up-coming meetings for TEST, state and national meetings, workshops, professional development, and deadlines for grants. Additionally, advisors often authored sections that were thematic in nature, such as the following: "Evolution Corner" about the teaching of evolution in Tennessee; "What's In Your Backyard?," a column about local geology; and contests, such as "Where in Tennessee" and "Mystery Fossil," in which readers were challenged to identify a Tennessee landform or fossil from pictures. Many of the museums in Tennessee submitted short contributions highlighting their exhibits and professional development opportunities. Teachers could submit original works as well, including artwork and poetry. One important inclusion to the newsletter was a listing of "kudos" for teachers who won awards for their Earth science endeavors. Eventually, the newsletter added e-mail delivery to its members. Due to declining participation, discussed below, the final TEST TUBE was published in 2016.

TEST Net

During the early 2000s, the TEST developed a web page. TEST Net struggled from the onset. Developed early in the days of the Internet before the development of user-friendly author software, web page development required some degree of programing skills, was time consuming, and required a "host." Consequently, "webmaster" skills and continuity were problematic for the TEST, as was finding a host for the webpage. The TEST advisors attempted to get their institutions to host the website; however, the administrators indicated that they could not host non-University groups. TEST Net only lasted a few years before it was abandoned. Ultimately, this proved to be one of the major contributors to the decline of the TEST because Internet communication ("online") soon became vital to any organization's survival as "pen and paper" newsletters and advertising gave way to online as the primary source for information.

Awards

NAGT OEST Award

One of the activities in which the TEST excelled was in recognizing excellence in teaching Earth science and geology, especially in K-12. The TEST serves as the primary vehicle through which the National Association of Geoscience Teachers (NAGT) operates in Tennessee. Awardees are identified by the TEST Awards Committee through its own activities and through nominations made by school administrators, students, and fellow teachers. They are then nominated to the NAGT each year for their prestigious Outstanding Earth Science Teacher (OEST) award (NAGT, 2024). The TEST notifies school system officials and local newspapers of all winners. The Awards Committee members would work closely with school systems in Tennessee to find a teacher who the committee felt met NAGT's criteria for the award and works with the teacher and their school administrator to help them prepare the dossier that would accompany the award application. The Tennessee OEST winner was, and still is, automatically entered into the southeastern regional competition for the Regional OEST award. In the case of Tennessee, the impact that the TEST had on teacher effectiveness in Tennessee was so great, that Tennessee OEST teachers also won NAGT's southeastern region award each year from 2001–10 with the exception of 2009 (Table 2). The OEST award was the only national award regularly offered by TEST and the winners were presented their OEST plaque at the Awards Banquet for the annual meeting of the TSTA (Figure 4). The OEST award was only one of two Earth science awards presented at the TSTA conference and was reported in the press, as well as published in the Journal of Geological Education, or their website (NAGT, 2024), with pictures of the awardee and notification of the teacher's school system administration. In addition to the plaque, NAGT provided a treasure trove of resources to the teacher and provided a means for that teacher to attend a Geological Society of America meeting to further network with other Earth scientists and teachers.

Ptero Award

The TEST developed its own award. The Ptero Award, named after the official state fossil for Tennessee—*Pterotrigonia thoracica*—affectionately nicknamed "Ptero," was, and still is given to an individual or organization who made outstanding contributions to Earth science education in Tennessee. The award recipient receives an engraved personalized wooden plaque with an authentic 76-million-year-old fossil "Ptero" attached to the plaque (Figures 4 and 5). Table 3 lists the recipients of the Ptero Award.

The TEST had been instrumental in getting the fossil established as a state symbol by the State Legislature in 1997 (Gibson, 2024). The "Ptero" fossil represents the vast geologic and paleontological riches across Tennessee and commemorates their utility as an educational resource. Many of the TEST's fossil workshops included interdisciplinary uses of Ptero to teach science, mathematics, art, history, and civics. As with the TEST's mascot "Peck," a "Ptero" caricature was designed by Valerie Hunt (Figure 6). The Ptero Award is the TEST's highest-profile internal award as the presentation of the award occurs at the Tennessee Science Teachers Association

Table 2: Tennessee National Association of Geoscience Teachers' Outstanding Earth Science Teachers award winners.

Year of award	Winner and school system
2023	Dr. Greg Smith (John Overton High School, Nashville, TN)
2021–2022	No Award
2020	Kari Hughes (Selmer Middle School, Selmer, TN)
2019	Andrea Starks (Houston Middle School, Germantown, TN)
2017–18	Jana Young (Northeast Middle School in Jackson, Tennessee)
2016	John Griffin, Southside Highschool, Jackson, TN
2013–2015	No Award
2012[2]	Dr. Chris Vanagas (School for Science and Math, Vanderbilt University, Nashville, TN)
2011	No Award
2010[1]	Bryan Freeman (Clinton High School, Clinton, TN)
2009	Frances Hamilton (Blanche School, Taft, TN)
2008[1]	Tina Coleman (Martin Middle School, Martin, TN)
2007[1]	Pat Royal (Camden Middle School, Camden, TN)
2006[1]	Bryan Byrne (Cox Middle School, Columbia, TN)
2005[1]	Rose Lummus (Dyersburg Middle School, Dyersburg, TN)
2004[1]	Tina King (West Elementary School, Mt. Juliet, TN)
2003[1]	Christine Henry (Knox County Schools, Knoxville, TN)
2002[1]	Jane Luhn (Knox Country Schools, Knoxville, TN)
2001[1]	Virginia Cooter (North Greene High School, Greeneville, TN)
2000	Mary Ann Stephens (Kenwood Middle School, Clarksville, TN)
1999	Greg Bailey (Fulton High School, Knoxville, TN)
1998	Jim Hunt (Chattanooga School for the Arts and Sciences, Chattanooga, TN)
1997[1]	Jane Skinner (Farragut High School, Knoxville, TN)
1993, 1996	Jim Watson (Soddy-Daisy School, Soddy-Daisy, TN)

[1] Also southeastern regional OEST award winner that year.
[2] Not nominated by TEST

Figure 4: TEST awards. The TEST presents it awards in association with the Tennessee Science Teachers Association annual meeting awards banquet. Left to right: TEST founder Don Byerly (University of Tennessee Knoxville) holding the 2004 Tennessee Economics of Mineral Resources Kit, State Geologist of Tennessee Ron Zurawski received the Ptero Award on behalf of the Tennessee Geological Survey, NAGT OEST state and regional sward winner Tina King, and TEST advisor Michael Gibson who presented all of the awards at the Tennessee Science Teachers Association awards banquet.

annual convention in front of the conference banquet attendees along with the OEST.

Additional TEST activities

Over the years, the TEST has participated in numerous geoscience education initiatives. Thematic Earth/Environmental Science at the Middle School-Secondary Level: An Interdisciplinary Approach (1998–1999) was funded through the Tennessee Higher Education Commission (THEC) and was a collaboration of the TEST and the Center for Excellence in Science and Mathematics Education (CESME) at the University of Tennessee at Martin. The project brought together 16 Tennessee teachers (eight Earth science teachers and eight teachers from non-science disciplines, including mathematics, language arts, history/social studies, and the fine arts) to implement action research on a pilot program using Earth science as an interdisciplinary basis for integrating other disciplines with science and mathematics. CESME and the TEST felt that one way to get Earth science into a school was to partner with established programs to demonstrate the cross-disciplinary nature of

Figure 5: The TEST Ptero award. (A) The original plaque design with a fossil Ptero attached to the plaque. (B) The redesign of the Ptero award in 2019. All plaques featured an authentic *Pterotrigonia (Scabrotriginia) thoracia*, the official state fossil of Tennessee.

Earth science. The teachers, working as teams of two, developed and taught interdisciplinary thematic unit, reporting the results at the national Geological Society of America meeting in Denver, CO (Bailey et al., 1999). There are many examples of TEST teachers presenting their programs and research at professional geology meetings (e.g., Crews et al., 2007; Bailey and Gibson, 2007). This same approach was utilized to use Earth science or geology as a vehicle to teach the other sciences (e.g., Gibson and Byerly, 2018).

TABLE 3: Tennessee Earth science teachers Ptero award winners.

Year	Recipient
2022	Governor Bill Lee
2021	Ron Brister, Curator of Collections, Pink Palace Museum, Memphis
2015–2020	No Awards
2014	Jim Watson, Soddy-Daisy School, Chattanooga
2013	Dr. Ann Holmes, University of Tennessee at Chattanooga
2011–2012	No Award
2010	Dr. Lionel Crews, University of Tennessee at Martin
2009	No Award
2008	Vulcan Materials Parsons Quarry
2007	No Award
2006	Memphis Archaeological and Geological Society (MAGS)
	Knoxville Gem and Mineral Society (KGMS)
2005	Pink Palace Museum and Coon Creek Science Center
2004	Tennessee Division of Geology
2003	Bob King, Lebanon School System
2002	Nancy Stetten, State Department of Education
2001	Dr. Michael A. Gibson, University of Tennessee at Martin
2000	Dr. Don Byerly, University of Tennessee Knoxville
1999	Tennessee Representative Mark Maddox and Senator Roy Herron
1999	University of Tennessee at Martin GeoClub
1998	Dr. Linda K. Jordan, Tennessee State Science Consultant

Perhaps the most successful and longest running programing that involved the the TEST, and that was the catalyst for creating the TEST, were the GeoCamps that were run from 1990 through 2004. The legacy of these multiweek field-oriented camps is the "rock box" program described above. In 1990 the precursor model for GeoCamps was offered—Earth Sciences for K-12 Tennessee Teachers—but by 2001 the series had expanded to six separate camps that spanned the breadth of the Earth sciences. Most of the GeoCamps were funded through the Eisenhower Title II Professional Development Program grant program with the TEST advisors serving as the PI's of the grants. The TEST was called upon each year to suggest the topics for the next GeoCamp professional development, to help in grant writing, which included pedagogy and curriculum, and to participate during the geocamp as "master teachers." Two goals drove the GeoCamps program: (1) to cultivate science awareness through greater knowledge of geosciences and (2) to enhance teacher confidence and competence for teaching Earth Science and Geology.

Each of the six multi-week duration GeoCamps were designed to achieve content-specific goals. GeoCamp I: Geoscience Basics provided the basic field skills, was oriented as a general introduction into Earth materials and processes, and was a prerequisite for participation in later GeoCamps. GeoCamp II: Landform Evolution/Surface Processes focused on surface processes and landform evolution using the east Tennessee region, especially the Great Smoky Mountains and Valley and Ridge provinces, as its natural laboratory. GeoCamp III: Earth History, Geologic Time, and Life was based at the Coon Creek Science Center in McNairy County and at UT Martin in West Tennessee. Earth history, geologic time, and paleontology were the central focus of this camp; however, earthquake hazards associated with the New Madrid Seismic Zone were also included in this camp. GeoCamp IV: Tennessee Maps was based at UT-Knoxville and focused on interdisciplinary activities emphasizing mathematics and history using a variety of maps, aerial photographs, and satellite imagery featuring the Great Smoky Mountains and Cumberland Plateau regions. GeoCamp V: Weather & Climate was also based at UT Martin and focused on the basic atmospheric processes of weather and climate with applications to Tennessee's physiographic regions and causes of "extreme weather." GeoCamp VI: Paleoceanography of Tennessee was based at UT Martin. Its focus was on overcoming the handicap of teaching oceanography in "land-locked" Tennessee by using the rich geologic record of ancient oceans that once covered the state. Additionally, this GeoCamp placed emphasis on the uniformitarian approach to historical science by comparing modern Gulf Coast environments, working out of the Dauphin Island Sea Lab in Alabama, to ancient counterparts that the teachers studied in Tennessee.

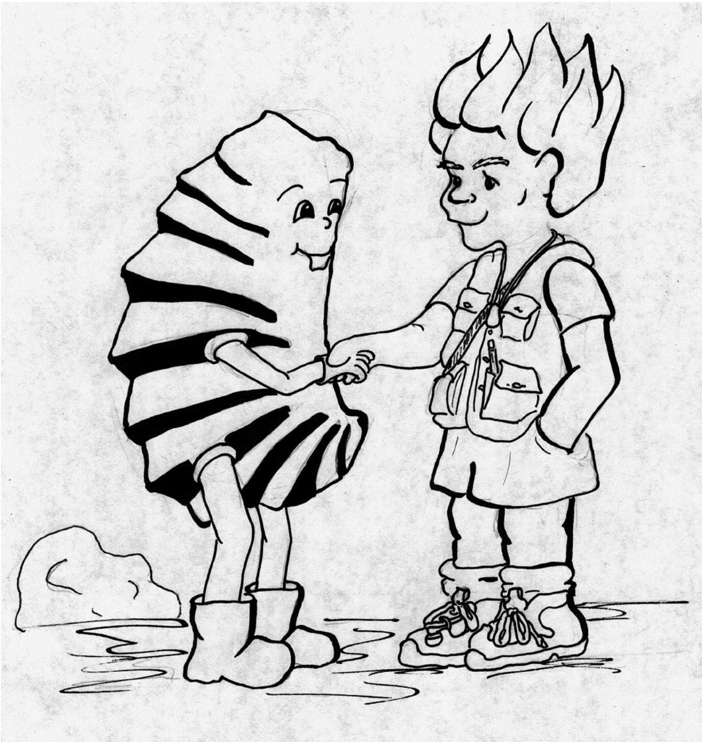

FIGURE 4: Peck and Ptero. These caricatures were used as fun advertising for the TEST, T-shirts, and field trip guides in written materials produced by the TEST. Valerie Hunt designed this caricature as part of the campaign to identify an official state fossil for Tennessee.

In all camps, the TEST members were called upon to meet with the participants of the other GeoCamps to further the networking process, thus providing these teachers with an extended resource base after completion of the program. By the end of the early 2000s, the Title II funding source dried-up and it was becoming more difficult to recruit teachers to leave their homes during the summer for multiple weeks, so many of these camps were downsized to a series of day-long workshops of the same names, some offered at the TSTA annual meeting, with follow-up sessions at the annual Tennessee Earth Science Teachers meetings. One reason for the decline was the rise of "virtual field trips" available on the Internet. The number of smaller workshops shrank as the years wore on, but several remained popular (e.g., Tennessee rock box programs geared at Tennessee resources, plate tectonics, fossils, and evolution) especially at the annual TSTA meeting. Over 200 teachers matriculated through the various fieldtrip-oriented GeoCamps over the years.

Until 1997, all of the field trips sponsored and run by the TEST were restricted to Tennessee. TEST desired to upgrade their fieldtrip opportunities, so in 1997, the first GeoTrek was conceived. GeoTreks followed the same inquiry-based field format that was successful in the GeoCamps, but the destinations were to areas outside of Tennessee. The first, GeoTrek 1997, was three-weeks in duration and included a week-long trek across all physiographic provinces in Tennessee followed by a two-weeks of field activities within Yellowstone National Park region, including calculator-based lab (CBL) geochemistry studies of the geysers and mudpots in the park. This trip also included a hosted fossil dig at the Ashfall Fossil Beds in Nebraska. The coastal region of Dauphin Island, Alabama was a repeatedly offered GeoTrek with teachers participating in the Dauphin Island Sea Lab's Discovery Hall programs and included boat trips into the Gulf of Mexico to core for sediment and trawl plankton and fish. Some GeoTreks were international in scope including several trips to the Quintana Roo region of Mexico, Belize and Guatemala, Central America, and to Scotland to see the classic early history of geology.

The TEST participated in test-piloting the American Geological Institute's EarthComm® Curriculum (AGI, 2024) from 1998–2001. The TEST was tasked with writing position statements on Teaching Earth Science and Teaching Evolution in Tennessee for the State Department of Education. TEST members routinely populated the Textbook Selection committees established by the Tennessee Department of Education. TEST advisors were members of the 2010 review of the Tennessee Teacher Licensure Standards.

WHY HAS THE TEST BEEN SUCCESSFUL FOR EARTH SCIENCE IN TENNESSEE?

The TEST has been in existence for 34 years, since 1990, and has certainly made a positive impact on Earth science and geology teaching in K-12 in Tennessee. What were the attributes that contributed to this grassroots organization's longevity? The TEST was an organization run by Tennessee teachers with higher education professional scientist advisors for support. All activities of the TEST were designed to provide teachers with resources related to Earth science in Tennessee. The TEST has endeavored to maintain frequent contact with members and advisors and to foster active connections to other state organizations (e.g., TEA, TSTA) and national organizations (e.g., NAGT, GSA, NESTA, NMEA). The TEST has reached out to partner with, and are often also members of, other Tennessee teacher groups, such as the Tennessee Educators of Aquatic and Marine Sciences (TEAMS). The TEST used a strong reward system for teaching excellence and developed a consistent presence through its meetings (e.g., Fall retreat, TSTA, summer workshops), all devoted to Earth science, and maintained a strong, visible, and consistent attendance at teacher-venue conferences. Perhaps the greatest strength was that early on, the TEST attracted and maintained a strong nucleus of "life" members that remained active and were devoted to Earth science as their primary science. These teachers always infused Earth science into whatever other science they were teaching, using geology to teach chemistry, biology, physics, and environmental science (e.g., Gibson and Byerly, 2018). Over the years, many teachers came into the TEST and many moved on to other opportunities; however, the original dedicated core group remained consistent for most of the run. Finally, the TEST spent a great deal of time and resources constantly trying to recruit (e.g., brochures, newsletter, prizes, hosting social gatherings at meetings). The annual TEST Reunion Party that was held at the TSTA convention hotel, hosted by the higher education advisors in their hotel rooms, was a highlight that attracted many new teachers and alumni. It was followed by a dinner at a local restaurant with as many as 30 dining. The TEST and their higher education advisors were successful at finding external funding and many TEST teachers were successful at grantsmanship. The TEST was consistently active in state science meetings providing service and giving awards, recruiting, and making Earth science as visible as possible to all science teacher attendees.

The TEST was also a timely organization in that it came on the scene in time to participate in some major K-12 education challenges. The 1990s saw a time of public education evaluation and revision with programs such as No Child Left Behind and innovations in pedagogy, such as the move to inquiry (Gibson and Byerly, 2024, this volume). In terms of Earth science content, the 1990s was the time when Earth Systems Science took center stage as the new organization for Earth science, with NASA leading the charge and professional societies producing national curricula.

Post Covid-19 Pandemic TEST

Unfortunately, as of this writing, the TEST is not the organization that it was, although it still exists, and can certainly revitalize. The TEST has seen a difficult decline over the past decade, such that, it is now effectively in a state of suspension without active officers and only one advisor. The decline of TEST is a useful lesson for all grassroots organizations.

Noting the attributes listed above that contributed to the rise of the TEST, a core of dedicated "life" members is essential to the vigor and continuity. By 2016, most of the original 1990s teachers that were that reliable core had reached retirement age and attrition began to take place, without a strong complement of new replacements with the same dedication. One of the most common lamentations of the "old timers" of the TEST is that the "younger generation" of teachers coming into the profession are less interested in investing their personal time and energy, much less commitment to travel, that is required to maintain the level of involvement that the TEST had developed. They noted that the advent of online professional development, professional development with stipends, and virtual field trips was making it too easy to not be part of intensive workshop participation such as what the TEST ran.

Another Tennessee issue that impacted participation was the increased focus on performance by teachers and their students on standardized tests, especially after No Child Left Behind. Most teachers were focused on "teaching to the test" and on those sciences in which their administrators wanted strong test performance for school evaluations (the PCB's). Earth science's reputation of not being a valid high school science on par with the PCB's, along with the fact that it is not strongly represented on Gateway and End of Course testing was again contributing to the decline of Earth science in Tennessee curricula. Additionally, the most recent revisions of the Tennessee Science Standards for grades K-8 had moved most Earth science topics downward in grade level (TDE, 2016).

The last official TEST officer meeting and elections in the TEST were carried out in 2018. The Covid-19 global pandemic struck at the end of 2019 with Tennessee schools entering a shutdown mode by February of 2020. Already in decline, TEST activities essentially ceased to occur, except for a few online appearances by the TEST advisors and a few officers for the annual TSTA meeting. There was never a quorum of members for voting according to the bylaws. The in-person events with resource giveaways that had served the TEST so well for years, ceased to happen. By the time schools reopened in 2022, the TEST was dormant with no teacher leadership or plans for immediate recovery and Earth science was again being ignored by teachers and administrators.

Contributing to the attrition of seasoned TEST core members was the retirement of some of its higher education advisors that had been relied upon for so long. TEST founder Don Byerly retired in 2000, but remained active until his death in 2018. Ann Holmes, who had come on board in 2002, retired in 2018 without a replacement. Both Peter Lemiszki and Wayne Leimer became inactive within a couple years of becoming advisors and Leimer retired in 2021 during the pandemic. By 2018, the only active TEST advisors were this author and Dr. Lionel Crews, both of UT Martin. In 2018, the author took over directorship of the University of Tennessee at Martin Coon Creek Science Center (UTMCCSC) forcing him to withdraw most of his participation in the TEST. In 2023, the author retired from UT Martin and as director of the UTMCCSC; however, remains the primary higher education advisor to the TEST.

Many of the activities of the TEST continue on a smaller scale by the staff and faculty of the UTMCCSC. The UTMCCSC is a 234-acre Earth science field site in McNairy County, West Tennessee. The reader is referred to Gibson (2024) for a history of that site and its programing, which includes a discussion of the TEST's involvement with the site. The UTMCCSC has continued to run Earth science teacher professional development and the TEST is a listed partner in these activities. All TEST records and leftover geology resources are housed at the science center.

SUMMARY

The Tennessee Earth Science Teachers (TEST) is a grassroots teacher organization that has functioned successfully for 34 years in Tennessee. The TEST has been heavily involved in K-12 teacher professional development related to the Earth sciences and geology with a long list of achievements and has successfully achieved almost all of its goals established in its mission statement. Unfortunately, the primary goal of the original advisors that prompted the founding of the TEST, that of increasing the number of Earth science and geology courses at the secondary level in Tennessee, has not been realized. Today, the TEST is in a state of decline, primarily due to the changing landscape of public education in Tennessee and in infusion of technology and online professional development opportunities. The rise and decline of the TEST mirrors many state-level teacher groups with periods of growth and prosperity along with periods of decline. The TEST has allied itself with another teacher development resource that is devoted to the Earth sciences and geology, The University of Tennessee Coon Creek Science Center, which should ensure that the TEST continues to be a strong resource for Tennessee teachers, and perhaps a revitalization to its heydays.

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Research Article

The journey into inquiry land in Tennessee: How to get there from anywhere? Lessons learned over 25 years

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ABSTRACT

Driven by changes in the National Standards during the 1990s, inquiry became the pedagogical methodology of choice for K-12 sciences as a major paradigm shift. Inquiry was chosen because it realistically and accurately modeled how scientists conduct scientific studies. Scientific inquiry is itself a learning process, and early educational research suggested that students learned more efficiently through inquiry. However, inquiry was a difficult pedagogy for teachers to learn and for students to experience, as it appears chaotic and decentralized. K-12 Earth science in Tennessee was in need of revitalization, in terms of shifting to the new Earth systems curriculum and incorporating inquiry as the pedagogy of delivery. To tackle both problems in tandem, the authors collaborated with the Tennessee Department of Education, Tennessee Science Teachers Association, and Tennessee Earth Science Teachers (TEST) to develop a series of Earth science professional development opportunities in which inquiry was modeled as the pedagogical vehicle and content was organized into Earth systems. We provide an anecdotal before-and-after perspective that spans 25 years of experiential lessons the workshop leaders learned about the "journey into inquiry land" from any other pedagogy. These lessons, applicable to all sciences, serve as the cornerstone to teaching inquiry to new teachers, as well as to seasoned veteran teachers making the switch to the inquiry-driven classroom.

KEYWORDS

Inquiry, geoscience education, Tennessee, standards

INTRODUCTION

Formal education traditionally has relied on a reductionist approach that condensed vast amounts of content into an organized progression of topics that purportedly covered the breadth of a topic to some reasonable depth, but also had a hierarchical organization that facilitated the learning process efficiently, primarily through notetaking. In this method the teacher is center stage, the owner of the information, and the controller of its dissemination. Students were viewed as sponges to passively, but efficiently, absorb (memorize) the knowledge. In actuality, this is not how the process of science unfolds. The traditional "chalk and talk" approach to science education may be efficient, but it is not realistic, and decades of research shows that it may not be the best learning method. For the past quarter century, inquiry, especially open-ended inquiry, has been replacing traditional teacher-centered education. Inquiry, as a pedagogy in science education, is defined as "the creation of a classroom where students are engaged in essentially open-ended, student-centered,

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hands-on activities" (Colburn, 2000, p. 42). According to the National Research Council (NRC, 1996; 2000) and American Association for the Advancement of Science (AAAS, 1993; 2013), real scientific inquiry requires that the learner (1) be engaged in scientifically oriented questioning, (2) give priority to evidence in responding to questions, (3) can formulate explanations from that evidence, (4) can connect explanations to scientific knowledge, and (5) finally, justify and communicate these explanations. While there has been a plethora of scientific research on the theory behind benefits, and challenges of inquiry, little has been written about the hurdles that new and seasoned teachers faced, and still face, in learning to implement inquiry as a central pedagogy (e.g., Furtak, 2006; Inoue and Buczynski, 2011), especially for the Earth sciences (e.g., Brown et al., 2006; Penuel and Gallagher, 2008; Gray, 2014; Newman et al., 2017; Fang, 2020; Harrell et al., 2023). Additionally, little has been written about the hurdles of developing Earth science teacher training opportunities that are modeled on inquiry. In this paper we offer a retrospective about the application of inquiry as a teaching methodology for K-12 Earth science education in Tennessee and how Tennessee teachers responded to this decentralized approach to teaching. Specifically, we focus on the encountered realities of adopting the inquiry approach, and realizations that were learned from providing professional development to teachers seeking to adopt this pedagogy in Tennessee, when inquiry pedagogy was initially introduced in the 1990s and 25 years later after implementation in Tennessee.

1990 – INQUIRY INTRODUCED AS THE NEW TEACHING PEDAGOGY

Science education was undergoing a complete revitalization during the late 1980s and 1990s, especially with the broad reforms, and subsequent problems of implementation and accountability of the No Child Left Behind Act (NCLB) of 2001 looming (e.g., NCLB, 2002; Goertz, 2005; Beatrice et al., 2009). Reading any of the Tennessee Science Framework Grades K-12 documents published since the early 1990s will demonstrate that the Earth sciences (astronomy, meteorology, oceanography, and geology), and especially geology, have been considered integral components of Tennessee education, at least on paper (e.g., Tennessee Department of Education, 1995; 2000; 2001; 2016). Earth science has been historically underrepresented in the curricula of a majority of schools in the State of Tennessee (e.g., Byerly and Gibson, 1999; data supplied by Tennessee Department of Education) and nationally (NSTA, 1988; Meyer and Armstrong, 1990; Rutherford and Algren, 1990; American Geological Institute, 1991; Ireton et al., 1996; NRC, 1996; Holbrook, 1997; Office of Educational Research and Improvement, 1997; Ridky, 1998; Shea, 1997). The National Science Education Standards (NRC, 1996) had given Earth science parity with biology, chemistry, and physics. It was recognized that geology, in particular, was an ideal vehicle for inquiry-based science education (e.g., Prather, 1996; Prather and Shrum, 1984) and the discipline of geology was used as the primary example of inquiry in *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (NRC, 2000, p. 1–5).

Our discussions with the State of Tennessee science consultant and geoscience education leadership at the National Science Foundation led to the realization that there were three issues facing revitalizing Earth science education in Tennessee. First, Tennessee needed more teachers having up-to-date content training in the Earth sciences to meet state and national standards (there were only 21 schools teaching Earth science courses in 1995, data supplied by Tennessee Department of Education). Second, a plan was needed to encourage more Earth science courses to be offered in Tennessee schools, especially within rural west Tennessee. Third, new Earth science courses in Tennessee had to be inquiry-based using the Earth systems approach. In the pipeline teacher recruits to Earth science and the existing teacher workforce needed training to be versant in the new pedagogy of inquiry that was now expected to become central to all science education in Tennessee. It was clear that there was no quick fix to the dilemma.

Because of tight budgets and already full curricula for students, the most efficient way to introduce a new Earth science course into any Tennessee school at this time was to find an existing teacher, usually a biology or chemistry teacher, to offer a single geology or Earth science class as a special section in their school (often without remuneration) and then allow popularity with the students to ensure the course continued. Several hurdles existed including (1) finding teachers interested in adding Earth science to their curriculum, (2) finding school systems whose administration was receptive to the new course, at least on an experimental basis, (3) finding teachers with the content knowledge to teach Earth science, and (4) ensuring that these courses were based upon inquiry methods.

The 1995 revision of the Tennessee Science Framework for Grades K-12 was looming, so the authors worked closely with the Tennessee Department of Education science consultant to begin the task of revising and revitalizing Earth science education across Tennessee. One of the most important aspects of this collaboration was the establishment of the Tennessee Earth Science Teachers (TEST; see Gibson [2024A], this volume, for a history of TEST) to identify and organize practicing Earth science educators in Tennessee, recruiting new teachers to Earth science, and providing resources and training for inquiry as pedagogy. Thanks to support by the Tennessee Science Consultant, Dr. Linda K. Jordon, and the Tennessee State Department of Education, the primary responsibility for revising the benchmarks and indicators for this new framework was given to the Tennessee Earth Science Teachers (TEST) with advisors from higher education institutions across Tennessee. Their impact was almost immediate. In the revision of the 1995 Tennessee Science Framework, TEST redesigned the Earth science curriculum to focus more on a systems approach to Earth science and geology and incorporated opportunities for inquiry-based teaching into the standards (e.g., Byerly and Gibson, 1999; Hoffman and Barstow, 2007).

It was recognized that teachers for grades K-8 had science education needs that differed from those of secondary science teachers who focused on one or more specific disciplines (biology, chemistry, geology, etc.) and at a more advanced level of instruction. Additionally, most Earth science in Tennessee is delivered at the middle school level (grades 5–8). Another trend in Tennessee is that many of the topics in Earth science require a grade level maturity higher than the grade level in which Earth science is taught. As more science content is added to secondary level classrooms (e.g., expanded genetics concepts, technology, etc.), Earth science in Tennessee has tended to be moved to earlier grade levels and over-generalized (e.g., dinosaurs as an interest grabber; extreme weather). It can be argued that Earth science is better used as a capstone experience as it incorporates the principles of physics, chemistry, and biology that are not covered in classes until the secondary level. Earth science in Tennessee had become deemphasized.

The K-8 teacher's role is vital in preparing their students to become scientifically literate in these disciplines for three primary reasons. First, the likelihood of a student becoming interested in science often depends upon their earliest exposures to science education in the classroom. Good early experiences with science can lead to more favorable impressions of science, or of aspiring to become a scientist, especially for females. Alternatively, but equally important, is that negative experiences with science education at these grade levels can be the trigger that closes the door to favorable student perceptions and understanding of science for their future.

Second, the K-8 teacher will introduce their students to the basics of scientific inquiry (science as process) during the student's formative years. This period can have profound implications for later learning as it also molds student's attitudes toward learning science and shapes their "personal theories" that color their understanding of scientific processes, principles, and applications (e.g., Brown and Melear, 2006; Brown et al., 2006; Leonard et al., 2009). It is in these earliest years that students become aware of the world around them and develop a natural curiosity about how it works. K-8 teachers must be able to instill in their students an attitude that promotes science learning and develops self-motivation in the students. It should also be noted that at this age, most students show a keen interest in science topics, hence science is a natural motivator for cross-disciplinary learning (mathematics, writing, reading, etc.).

Third, these teachers will provide the initial Earth science content material that will form the foundation for all later learning. It is essential that this foundation be strong, with accurate information, and exemplify scientific inquiry as a "way of knowing" that is applicable to all phases of everyone's life (Moore, 1984; Chiappetta, 1997). The Earth sciences are much more integrative in that they use chemistry, physics, and biology (the base components of the "exact" sciences) to describe and explain the working Earth system. Additionally, the Earth sciences, essentially an interpretive science, adds the component of deep time to the sciences that is not present in chemistry and physics.

For these reasons, K-8 teachers in Tennessee needed to be proficient in a breadth of sciences (biology, chemistry, physics, Earth sciences) rather than be experts in one or two of the sciences (as secondary teachers are). K-8 science as it was promoted in The Benchmarks (AAAS, 1993), *Scope, sequence, and coordination of school science: Volume 1: The content core* (e.g., Tennessee Department of Education, 1995; 2016), and *The Content Core: A Guide for Curriculum Designers* (NSTA, 1993), emphasized inquiry-based education with the student as the center of the learning process, and the instructor as non-centered facilitator. It also emphasized learning using some form of the Learning Cycle. The science skills needed of this new generation of K-8 teachers was therefore different from that of the average science user because these teachers would be charged with the task of teaching the material to students who had a different cognitive development level than adults. These teachers were professionals who needed to have the content material presented to them in a form that would allow them to adapt it to accomplish all of these goals, either in their formal collegiate training or as part of professional development.

Once we recognized and acknowledged the professional needs of Earth science students in Tennessee, we could develop a training approach suitable for training those teachers (existing or new) who would teach Earth science to them as outlined in the competencies listed in the Tennessee Science Standards and consistent with the newly emerging national standards of content and pedagogy. These competencies had to be addressed in the science content courses required of students, as well as the elementary science methods course required in the teacher preparation program. What was needed were training opportunities for K-8 teachers that focused on inquiry as the vehicle using Tennessee Earth science content specifically.

We recognized that the circa 1990 Tennessee teaching work force consisted of two primary populations of teachers: those who have long established classroom skills developed upon their initial training and honed through years of practical experience within their personal teaching environments and the new work force teacher fresh out of college well imprinted with the supposed "newest" concepts and pedagogies geared to applying this college training. The seasoned vet had developed "tried and true" formulas for accomplishing educational goals that they were comfortable with and felt worked within their school and with their students using their existing (often limited) resources. There was inertial comfort in this approach because it is familiar, predictable, and they knew the results. It has always worked for them, so why change it? Thus, one impediment to introducing both inquiry pedagogy and Earth science content was that it was going to force the teacher out of their comfort zone and require them to take a risk in their teaching.

The solution to these impediments lay in the newly formulated National Standards, and by extension, the local state science frameworks that had determined that inquiry should be the foundational pedagogy to model because it results in more scientifically literate students. Inquiry, especially open-ended inquiry, was closer to what working scientists do in practice, so model it for the student. We might have suspected this somewhat obvious answer, but as lamented by many of our teachers, had the people that did the decreeing ever try it day-in and day-out in your school system with your students on your budget while being watchdogged by your administrator and questioned by your student's parents?

The second population of Tennessee teachers were the new recruits who most probably have already been immersed into the inquiry approach during their college training, have memorized the terminology, and been fed the theory long enough that it is their new paradigm. Under controlled settings and with lots of mentor support these teachers have used tentatively the inquiry pedagogy, but they lacked the "under fire" experience necessary to truly fathom the method. This group of teachers was in for a shock when they entered a school setting where inquiry was not the standard and they had to find a way to implement it; not in the more controlled college science education classroom atmosphere while surrounded by sympathetic peers, but in a real K-8 classroom full of less sympathetic students who are used to a different approach. They had to implement, in an operational sense, what had been idealistically planted into their professional psyche, but that they had little "real world" experience to draw upon and did not yet fully realize the numerous other day-to-day obstacles of being in an operational school system.

So, how do you make the transition from teacher-centered information broker to student-facilitator and information guide for the inquiring student? How do you motivate students to responsibly take charge of their own education by becoming inquiring discoverers? Beyond the theory and study of why inquiry is good for us, what do you need to know to implement inquiry, an inherently chaotic process, successfully? Below, we step outside of the theory and, through our experiential learning, outline the practical hurdles that we encountered and overcame during our 25-years of professional development programs and that our experience shows need to be overcome by anyone who implements inquiry.

We conducted a series of inquiry-based, hands-on workshops focused on basic geology, meteorology, and oceanography weaknesses in geoscience education in Tennessee. In 1990, 1991, 1992, 1993, and 1999 we offered iterations of Eisenhower Grant-funded GeoCamps which eventually evolved into a standardized basic prerequisite "boot camp" Geoscience Basics (GeoCamp I). GeoCamp I was followed by Surface Processes/Landform Evolution (GeoCamp II), and Earth History: Time & Life (GeoCamp III) (Byerly and Gibson, 1993; 1999). In 1997, we offered a modified version of the GeoCamps, funded through Educate America Act, Goals 2000 (called GeoTrek), and took teachers to study the Greater Yellowstone ecosystem (Byerly and Gibson, 1997). Later GeoTreks included international travel (e.g., Scotland, Belize). By the early 2000s, new GeoCamps had been developed which focused on meteorology, oceanography, and technological applications in the Earth sciences. All GeoCamps used open-ended inquiry as modeled instruction and emphasized local Earth science resources and local geology as content.

LESSONS LEARNED

The observations we offer are real obstacles encountered during the workshops we conducted for teacher training, from working with education students and Earth science majors at the college level, running programs for life-long learners, field testing with teachers for the American Geological Institute's Earth System Science in the Community and Investigating Earth Systems curricula, and discussions with teachers who have tried to make the switch (successfully and unsuccessfully). We offer some practical solutions to these issues that may help overcome them as they are encountered or to avoid them altogether by anticipating them.

Teacher as facilitator, not head-master instructor

We have found the most difficult impediment for teachers implementing inquiry is for them to step outside of center stage in the classroom… and stay there. We certainly found this to be a challenge for us while conducting training workshops, as we often felt the "teacher drive" to lecture, guide, push, and focus students and teachers to the goal we knew was at the end of the "instruction." In the traditional classroom, the teacher is the administrative head in control of the knowledge and its dissemination. There is a plan, and students are to follow the script. In inquiry, the teacher is a passive guide through most of the process. The students are the active participants and have ownership of the learning processes. They must make the process and product their own. An inquiry teacher spends much class time quietly walking around and observing, as if an interested tourist, whose presence alone offers enough authority to guarantee the students stay on task, but still allowing the students to own the timing and direction of investigative discovery.

When writing traditional lesson plans and outline notes (the ultimate in reductionist education), the progression of thought is determined for each student a priori. In reality, this approach is an attempt to herd students down a path that is believed to be discovery, but that ultimately arrives at a preconceived set of informational content, skill tasks, and critical thinking eureka moments. In the case of open-ended inquiry, however, the beginning point may be set (or more often arbitrarily prompted), but the path to the final product is not established by the instructor, nor will the outcome be the same for each student and each time. Each student, or working group, will follow a more or less disorganized, often seemingly random path, that is itself part of the discovery process, hopefully to lead up to the teacher's final list of desired outcomes. Often teachers found it difficult not to intervene when they thought that the inquiry process was heading in the wrong direction, did not proceed quickly enough, or did not seem organized and efficient. The natural urge was to step in, correct the situation, and get the students back on the right track. We had the same issues when we modeled the behavior during our GeoCamp professional development. It helped us to work as a team with one of us in the role of decentralized teacher and the other in the role of watchdog for the teacher to be sure that we did not slip into the non-inquiry behavior. Inquiry is about self-discovery, and like science itself, often appears disorganized and random for the teacher.

How do you keep from jumping into the center ring when the urge occurs? We have found that mobility is a simple, yet powerful tool. Get off center stage (usually the desk, podium at the front of the room, middle of a circle, front of a group on an outcrop, or some key control position that exudes top-down authority), and walk around your classroom constantly, briefly visiting with the students on "their turf." Keep walking, spending enough time with each student or group to offer some authoritative presence, effectively keeping them on task by showing that you are watching, keeping yourself informed of their progress and thought process, but transient enough not be the guiding presence. There is a natural tendency for the students to stop their process upon your approach and turn to ask you for an answer or to see if they are on the right track. This means they are seeking feedback, hopefully positive, and reinforcement; however, it does not mean that you have to take center stage again. Ask a question or two that will allow the students to evaluate their progress or to see another direction to pursue if they are heading down the wrong pathway. Once asked, they may attempt an answer. A positive response should be met with another question, a gesture showing your confidence in their progress in inquiry, or perhaps a query as to whether their other "scientist colleagues" in the class have suggestions for them (introducing the value of peer review). We found that a simple "sounds good so far" followed by simply walking on to the next group, thus signaling that "all is well" there, no need to stay and "fix" anything, and to "keep up the good work while I check on the progress of the others" did well.

Pay attention to recurring questions or pathways

In your decentralized role of outside observer, you will notice that most students and student groups will often encounter the same hurdles to their understanding, or come across some of the same eureka moment observations and interpretations, as part of their inquiry and discovery process. Watch for these as they become the milestones for your guided instruction. You can see their progress as they discover the intended outcomes and will gleam insight from the order or timing of their eureka moments. Sometimes the progression of the inquiry process will be the same for most everyone and may nearly always occur in a particular order; however, be especially vigilant for those alternate pathways as they occur. Once you see the patterns that are developing, you will be able to provide the right guiding question or comment to help push the inquiry process in a particular direction. Also, you may be able to predict what resources you will need to provide later as the inquiry unfolds.

For example, one of our in-the-field activities involved reconstructing ancient depositional environments using real geologic materials. The development of multiple working hypotheses is always encouraged in Earth sciences. We often encountered a situation where, based upon physical evidence that the student (or teacher) had observed already, they would attempt to conclude an environment or event, for example, sea level had dropped and the environments shifted from marine to terrestrial. Note that we are shifting from observations to interpretation (which was actually meant to be a hypothesis). All scientific hypotheses need to follow the scientific method and have predictability and testability. As the outside observers, we noted that the person doing this reasoning accepted this as a factual occurrence without critical evaluation (hypothesis testing), so we would ask them what types of sedimentary structures might they expect to see in the new environment that would support their interpretation (hypothesis). Usually, they would say something like mud cracks or raindrop impression in the rocks would be expected next. Here was a chance to provide positive feedback, but in a way that supported inquiry. Because the pattern had occurred in earlier iterations of the activity, we had previously amassed a set of samples that we could produce, only if the situation arose, that either reinforced or refuted their predicted hypothesis. After encouraging the students to vocalize (predict) the possible test possibilities (e.g., what sedimentary features that they could go look for would support or not support their predicted environmental interpretation), we would step in to provide that "newly discovered" specimen as the test of their hypothesis, as if they had gone looking for it and found it themselves (e.g., mud-cracked red sandstone, raindrop impressions in siltstone, terrestrial footprints, etc.). We found that this preparation from experience allowed us to infuse any necessary evidence, observations, specimens, or situations into the supposed non-predictability of inquiry without sacrificing open-ended inquiry itself. In other words, we learned to be prepared for eventualities in the process based upon repeated running of the inquiry process. We just needed to wait for the student's inquiry path to reach the point where that information was now needed.

Model inquiry for the students

You will need to model the behavior that you are asking your students to undertake. Keep in mind the three H's: *holism* (the whole cannot be understood by just learning the parts), *heuristic experience* (learning begins along empirical lines using rules of thumb to gain knowledge), and *hermeneutics* (science is an interpretive process based upon personal observation and knowledge). Do not expect them to be able to accomplish their own inquiry, much less accept it as a useful process to emulate, if you do not adopt it also. This is a matter of commitment and confidence that end-of-course goals will eventually be achieved while being flexible in the process pathway. Students learn by emulating good role models. One cannot successfully teach inquiry as a method by lecturing it. The Socratic method is useful in this regard. Avoid direct answers when a supportive question will achieve the same result. It is useful for students to see you be uncertain of an outcome or a process, but then go through the inquiry procedure as well. In other words, practice what you preach.

For example: Often, while examining sedimentary rock samples a student may become intrigued by the varied colors of the specimens and asks the teacher why a particular rock is colored red. The teacher's response could be one of the following depending upon what prior knowledge the student has: where are red earth materials found today, what do you recall about the process of weathering or, perhaps, why does a pocket knife or bicycle turn reddish in color when left outdoors? These leading questions could stimulate a dialog whereby the student recalls the processes involved in forming sedimentary rocks and might reach a conclusion where the student understands that iron in the sediment was either oxidized (weathered) at the source area and deposited as red sediment or that the sediment was subaerially exposed at the depositional site and the iron oxidized during deposition (by diagenesis).

Be patient; Don't watch the clock

Inquiring and discovering on one's own is not an efficient process to watch take place. It is, however, a realistic and reliable method to learn not only process of science, but also content. Inquiry is a form of experiential learning that becomes part of the student's life experiences, thus is more likely to be retained and used as a pattern for other endeavors. Most Earth science phenomena occurs locally and readily lends itself to this process as it is occurring in the student's world, so it is experiential in nature and personally relevant. So, although it does not seem efficient while it is occurring and the experience may be agonizing for the teacher, the long-term benefit results in more efficient learners, with greater self-confidence, more self-drive to investigate, and more experience to draw upon.

Postdiction in inquiry is prediction in practice

How does one know what resources students will need if their pathway isn't orchestrated? As illustrated by the previous geologic examples, this is one of the more challenging aspects of inquiry and to becoming a master teacher-facilitator. When designing the activities, a list of materials must be made and there should be a general idea of the timing of events, but this list is only a beginning list to get the inquiry moving. Inquiry is not predictable, but it is postdictable. A prepared facilitator needs to constantly be building classroom resources, manipulatives, and means of information access, so that when students reach a stage where they do need something that only a teacher can provide (some hands-on resource or access to information), one can be ready to facilitate their acquisition of that resource. Facilitators remain outside of center stage, but are more like "Johnny on the Spot" to keep things running smoothly, making efficient use of time, and not serve as dead ends.

Understand up front, it takes time to develop the resources to be an effective facilitator. The activity will constantly evolve and rarely become static. This means that one must learn what resources are needed to be prepared for the students when they need them. How can such needs be predicted when one did not design the entire process and cannot be sure of the pathway of discovery the students will take? You can't! Only repeated trials will supply this information. In this sense the teacher becomes not only a model of inquiry, but becomes a "learner" living the experience at the same time as their students. It also gives the teacher a better understanding of some of the obstacles the students are facing, from their perspective. Just as an effective teacher encourages students to keep a journal, it is useful for the teacher to jot notes in a journal about materials that are asked for (so they can be kept on hand), information needed (so that access can be provided), and typical inquiry pathways that seem to reoccur with student groups. In this way one can partially anticipate needs, but more importantly, be prepared to obtain what students need to facilitate their progress.

Versatility is a side benefit of the experiential development of one's resources

As inquiry activities are rerun and as on-site resources build, one will find that they are more confident in their role as facilitator (because of greater preparedness). Stress of being caught off-guard and unprepared will be reduced and the students will also see that they can accomplish inquiry successfully with them in charge and the teacher as their support. As we have run our inquiry activities, we have noticed that, over time, certain somewhat predictable directions of inquiry emerge more often than others. We keep resources on hand, out of sight, so that we can provide them at the time needed (which is never at the same time for each time the activity runs or at the same time in an activity for each group), reduce the amount of wasted time finding resources, and realistically model the process of science.

There is a certain amount of confidence building students obtain when they have control over the progress of their inquiry and have what appears to be authority to request information and supplies upon demand (rather than the "MacGyver approach" of being creative with whatever is on the table).

For example: In one activity used at the University of Tennessee at Martin Coon Creek Science Center for students and for teacher professional development we use an open-ended inquiry approach in which participants are divided into "research groups" and each group has a stratigraphic sequence of rocks to describe, identify, and reconstruct the history of the outcrop. This activity is assigned far enough into the course that the participants have already covered the numerous sea-level changes and orogenies throughout the Phanerozoic Eon in North America and the methods of determining geologic time, so one of the prompted questions the instructor gives is "which sea level sequence and geologic orogeny produced your package of rocks?" To answer this, the participant needs to know (a) where the rock sequence was collected (given information) and (b) the geologic age of the rocks (unknown at the beginning of the activity). When the participant asks what the age of their sequence is, the instructor asks in return, "How do you determine age of geologic materials?" Participants generally respond with "fossils" or "radiometric dating" (notice these are just nouns, not process answers, so the answer is not complete, but is their way of offering a half-hearted hypothesis). At this point the teacher/facilitator pulls a business card out of a pocket for a fictitious company called "Acme Geochronology Associates" which also has a list of fossils with geologic ranges (if the students responded with "fossils") or the results of radiometric testing (usually in the form of percent parent remaining or atoms of parent remaining so the students do the final calculations) on the back of the business card.

The participants, having arrived at the next needed information, were prompted with the necessary results at the time they requested. Notice that there is enough variability in the process that allow different groups to approach the same problem in slightly different ways, all realistic to geological inquiry. Notice that the participants then integrated previous knowledge into their next step. And finally, notice that the teacher never gave an answer, only facilitated the next step, and reinforced the student's progress simultaneously.

Inquiry is not the only method

Inquiry is one of many teaching styles, but certainly not the only one. The National Standards advocates using inquiry as the primary vehicle for education, but there is a place for other approaches, even traditional "chalk and talk." State frameworks adopted the inquiry philosophy and mandated inquiry as part of educational reform. Our experience in teacher training shows that many teachers mistakenly assume that they are being asked to wholesale shift to inquiry and use it exclusively over other more traditional methods. This is not the case, and there are many instances in which more traditional teacher-centered instruction will be the most efficient and produce the best results. It is necessary for you to determine which situations should remain teacher-centered and how to blend the approaches for a smooth transition from one arena to the next. This may not be predictable; rather you will find that you will experiment with different combinations of inquiry and non-inquiry for several teaching cycles before finding the right mix that works in your setting. One of the best uses of traditional lecture is at the end of an inquiry session when the teacher wants to (1) reiterate and reinforce what content knowledge was used in the activity, (2) introduce content knowledge that was not discovered during the inquiry activity, but still needs to be mastered, (3) to set the stage for the next step in inquiry, and to (4) finally reestablish the beneficial organization and orderly attention that a traditional teacher-centered classroom offers (a sort of "reset moment").

There is no magic formula for transition

Adopting new teaching approaches can be time consuming, initially resource expensive, and often a personally challenging task, but it does work. Of course, we all look for professional development opportunities and resources that will make this transition run smoothly and quickly; however, it is the nature of inquiry not to behave in these norms! Why should we expect the transition to be so organized if the actual inquiry method itself is not a rigid formula?

Take advantage of holistic nature of Earth science

The thin ranks of trained Earth science teachers, especially in Tennessee, necessitates recruitment of science teachers teaching other disciplines. While this is seen as a pitfall, it is also an opportunity to take advantage of a fundamental strength of Earth science. Earth science is the science pertaining to all aspects of the Earth, hence is holistic by nature. As noted above, it is an ideal "capstone" science in that backgrounds of the students can be varied, and that variation is raw material for their participating in the inquiry. This same characteristic holds true for teachers as well. Your students take other subjects either from you or other teachers. The process of investigation does not have to stop at your door. Science works in collaborative teams and so should you. Team with other teachers to carry over your activities in their classrooms by finding ways to reinforce one another's efforts. These do not need science classrooms. History, especially, is the result of Earth science impacting people through time (e.g., severe droughts and hurricanes that affected the settlement of Virginia in the late 1500s, eruptions of Santorini and Vesuvius, etc.).

Inquiry and holism require constant communication and reflection among the participants and some degree of orchestration ahead of time, but be careful not to reverse the inquiry atmosphere. Collaboration is more than sharing resources and coordinating outcomes. It is about reinforcing each other and demonstrating relevance of the content outside of the classroom setting in which that content is the primary resident. Interdisciplinary collaboration also affords the opportunity for teachers to become "active learners" as well as facilitators.

For example, we offered a teacher development program entitled, Thematic Earth Science for Tennessee Teachers, which was funded through the Tennessee Center of Excellence in Science and Mathematics Education (CESME) at UT Martin. The goals of the professional development included linking Earth science teachers and teachers from disciplines that appeared far removed from science to develop collaborative and complementary activities. One teacher in Knoxville linked with an English teacher to do a unit on caves and groundwater (Bailey et al., 1999). The students studied the formation of caves and groundwater quality in science class that included a field trip to a cave. Students then read and wrote poetry about caves in English class. Many of the English students were not enrolled in the Earth science class, but became exposed to the science through English. There was mutual benefit for both student groups as each group became "teachers" by sharing their new knowledge. For example, the science students were given a new medium (poetry) to couch their knowledge of caves, and a new and more creative way of demonstrating their mastery of content than standardized testing.

Use a field setting for basic inquiry skills

The relevancy of Earth science in making observations in the "every day" environment is obvious (Holbrook, 1997). Field experiences can be defined as extended field trips off campus, just outside of the classroom, or even virtual ones using the internet. Scientists routinely talk about getting into the field to study, which is another way of saying go where the subject is and get out of the black box. Nearly any experience that is not contrived and canned can be considered "field." Encourage students to find real world examples of all Earth science processes. The newspaper or television/internet news offers daily examples of Earth science topics and their constant change and occurrence underscores the importance of the topic to students. Building stones and aggregates occur and are used widely and are encountered often. Skillful scientific observation required practice. In the Earth sciences, observation occurs wherever you are, at any time, and in any situation.

Use field trip experiences as much as possible

Not only do field trips serve as wonderful platforms for student inquiry, but adventurous trips for educators also provide opportunities for recruitment of Earth science teachers and for instilling the powers of inquiry. They demonstrate the "real world" nature of their inquiry. Most of all, they are just fun and a change of pace from regimented education. Field trips contain impromptu opportunities (sometimes called "teachable moments") that the inquiry teacher learns to rely on, and on which to base much of their learning experience for later use. A field excursion can assist in learning to be flexible and making the most use of resources in the community.

Recap and wrap-up for the students

Inquiry activities need closure for reinforcement. As noted above, this may be the appropriate time for the teacher to take center stage again. At the end of each inquiry activity, summarize for all what was accomplished. Draw their attention to the method of science they used and then tally the results for all to share. Often there will be surprises, as there are all scientific inquiry, that are teachable moments to take advantage of. Even the "mistakes" and "tangents" are useful in this regard, especially as these mistakes may provide useful information for later inquiry. What about those content or process areas that you, as a teacher, know the student's needs, but somehow did not get addressed during the inquiry activity? Traditional lecture delivery, or an appropriate summary handout for homework, to tie-up loose ends is useful here to efficiently add this material, thus finishing all objectives and building upon the student's experiences. It may also provide an opportunity for a more even-handed grading activity that provides positive assessment feedback.

The importance of having appropriate resources

Earlier we discussed that resources would continue to build the more inquiry activities are utilized. However, one should not expect to be fully prepared the first few times of running inquiry activities. Shifting to inquiry can be fortified by adopting existing inquiry-designed curricula (e.g., Earth System Science in the Community [EarthComm for grade 9–12] and Investigating Earth Systems [for grades 5–8], developed by the American Geological Institute, were 1990s examples). Also, connections should be sought with local resources (college, industry, commercial, geoscience education societies, etc.) that can provide materials and expertise. Not all such resources are tangibles. Intellectual and creative resources are useful. Invited contacts from the community can often offer inquiry activities for students to work on or to help one design "issues" for a class to investigate. As a relationship with these intellectual resources builds, it may soon be realized that modeling real world applications of science is occurring, and the group effort nature of science is being demonstrated.

One must be willing to stay current

Science is about change and new knowledge, even in the Earth sciences where the focus is on history. Have the courage to put away "old" methods (activities, etc.), "outdated" concepts, "comfortable" pet topics and approaches to explore new directions. Many inquiry activities will be experimental and there is no guaranteed complete success at the beginning. This is okay and is a demonstration of the scientific method and progress.

Not every activity is going to work; do not be afraid to fail at first

Some inquiry leads to greater understanding than others. All inquiry is educational. Eventually a repertoire of useful inquiry activity favorites will be developed along with additional activities to fall back on when the need arises. Inquiry does not mean changing to a total chaotic teaching approach, but rather development of a new toolbox of activities that can be pulled and used when needed.

As we mentioned earlier, inquiry activities must be run several times before they are honed to optimum use. Buying into inquiry and new ways of teaching requires more preparation time initially than teaching by lecturing, which generally gives the teacher the feeling of classroom control. A good practice is to design and evaluate a curriculum by developing concept maps and rubrics in conjunction with the state science standards, rather than course outlines. Map these out in detail deciding what objectives are mandatory and what objectives are less important, but desirable. Use concept maps to map how a particular inquiry activity progressed as it unfolded. Mark potential pitfalls and areas of divergence for later reference.

Choose those objectives and activities to tackle first that can implemented successfully

Select inquiry activities that can be evenly spread throughout a curriculum so that different learning preferences are addressed and there are opportunities for reflection between activities. Once these activities are well established and smoothly running, identify and implement others to complement existing inquiry components. Keep in mind that the National Standards and Tennessee State Standards do not advocate all instruction as inquiry. Total conversion is not the goal. However, a wise philosophy is to eventually develop inquiry approaches to all curriculum components possible, so that one can have flexibility as a teacher when balancing inquiry pedagogy with traditional teacher-centered instruction.

Become part of a support system for the teachers willing to use inquiry

Higher education (not necessarily a good model for inquiry) should mentor with pre-collegiate educators. However, unless geoscience departments have faculty devoted to geoscience education, this is not likely to happen—historically tenure and promotion do not give very high rating to this type of activity; however, this trend has been changing in recent years as more and more universities are adding geoscience education positions. Contact and talk to teachers that have implemented inquiry and to graduates who participated in inquiry. Ask them questions such as "what were the most difficult aspects for you," "how did you overcome these," and "what was the most effective aid for you."

Student feedback

Student journals offer great potential for feedback (formative or summative assessment) on the effectiveness of an inquiry activity and allows them to vent frustrations with the process. Students should be encouraged to be candid with their comments and appraisal of activities. The ratings of students should be compared with one's own rating. Teacher in-service sessions can also afford opportunities to involve peers in activity evaluation, especially "new" activities. Rubrics for designing and evaluating activities should involve student input and considered integral to inquiry. Again, the goal is to encourage the student to be a part of the entire process and feel some degree of ownership.

Professional development opportunities.

Teachers should be life-long learners personally and professionally. Inquiry contains elements of both content and pedagogy. All school systems offer professional development. Use them regularly, including presenting your experiences as well as sitting-in on what others have done. You have experiences that others need to hear.

25 YEARS LATER: TENNESSEE EARTH SCIENCE INQUIRY PROGRESS 2024 SUMMARY

The itemized suggestions above were formulated by the year 2000 and incorporated into all of the Earth science workshops we ran for the next 25 years. We included these experiential tips as part of TEST programs and annual professional development at the annual Tennessee Science Teachers Association workshops and teacher sessions. These tips are also central to the mission and programing of the University of Tennessee at Martin Coon Creek Science Center (Gibson, 2024B). How have they stood-up over time?

Educational paradigm shifting is an evolutionary process that is best evaluated historically. It is also important to realize that education in general is continually evolving and paradigm shifts come and go. Inquiry was not a "flash in the pan" pedagogy that was tried, failed, and then discarded. It has remained the centerpiece of sound education. Yes, it did take time for those students who were introduced to the paradigm of learning through inquiry to work their way up through the educational system. As with most new procedures, there was a lag time where the benefits were not visible as the population of participants in the process increased. Inquiry has stood the test of time and is now the cornerstone of not only K-12, but also collegiate education.

Over the years of working with Tennessee teachers to improve K-12 Earth science education in Tennessee, the authors experienced many positive outcomes and many negative outcomes. We have seen a decided improvement in the incorporation of Earth science into the science curricula in Tennessee, mostly by infusing it into biology, physics, and chemistry at the secondary level (e.g., Gibson and Byerly, 2018). Most Earth science exposure has continued to shift lower in the curriculum to fifth-grade level in the newest state standards (Tennessee Department of Education, 2016). However, inquiry methods, especially open-ended inquiry, are now commonplace in Tennessee at all grade levels.

SUMMARY

The paradigm shift to inquiry-based learning/teaching was not necessarily easy for teachers of the Earth sciences in Tennessee. Along our 25-year journey to train Tennessee Earth science teachers in inquiry, however, we recognized certain attributes that we needed to hone within ourselves, and that we needed to instill in our participants. So, in addition to the practical considerations outlined above regarding implementation inquiry into Earth science education, we summarize with the personal encouragements that are also important to successfully implementing Earth science inquiry, or any educational paradigm shift, into your teaching:

- **Courage:**
  Be willing to take chances with something new and out of one's comfort zone.
- **Patience:**
  Be patient with students as they experience the new method.
- **Persistence:**
  Do not panic when activities do not go well at first and do not revert back to the "old ways."
- **Check yourself:**
  Step out of the center ring and let the students guide the progress of the activity.
- **Be resourceful:**
  Develop your "Johnny on the Spot" materials as time passes.
- **Be flexible:**
  Allow student creativity to direct; you follow with

support.

- **Get out of the box:**
  When possible, use field-oriented activities.
- **Community resources:**
  Gear activities to be relevant to the community ("place-based") and make good use of the resources available in the community.
- **Stay current:**
  Take advantage of professional development opportunities – content and pedagogy.

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NEWS UPDATE

Sigma Gamma Epsilon chapter and student awards for academic year 2023–2024

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ABSTRACT

The Society of Sigma Gamma Epsilon (SGE) encourages efforts to broaden the education and impact of its members through community outreach. In academic year 2023–2024, four awards were given at the chapter level: The Chapter Service Award to Gamma Sigma and Gamma Chi; and The James C. Walters Quality Chapter Award to Gamma Sigma and Gamma Chi. Individual merit was recognized through the W. A. Tarr awards given to twenty-nine members by their respective chapters. Two awards, the Austin A. Sartin and Charles J. Mankin Outstanding Poster Awards, were given to three students for merit in scientific communication at the 35th Annual SGE Student Poster Session at the Geological Society of America annual meeting in Pittsburgh, Pennsylvania, on October 16, 2023.

KEYWORDS

Sigma Gamma Epsilon, SGE, Service Award, Quality Chapter Award, W. A. Tarr Award, Outstanding poster award, Austin A. Sartin Award, Charles J. Mankin Award, annual student poster session

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INTRODUCTION

Sigma Gamma Epsilon (SGE), the honor society in the Earth Sciences, provides awards to honor outstanding achievements by our chapters and our members. For Academic Year 2023–2024, The National Council is pleased to announce the SGE chapters that have qualified for the Chapter Service Award and the J. C. Walters Quality Chapter Award (formerly the Quality Chapter Award). The Council also announces twenty-nine individual members that were awarded the W. A. Tarr Award at their respective chapters as outstanding students in the Earth Sciences. Finally, the results of the 35th Annual Student Poster Session at GSA Connects, Pittsburgh, 2023 are discussed including the two Outstanding Poster Awards (Austin A. Sartin and Charles J. Mankin Awards). The National Council invites all active chapters to submit applications for the Chapter Service Award, The James C. Walters Quality Chapter Award, and to nominate a worthy member for the W. A. Tarr Award.

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CHAPTER SERVICE AWARD

The Society of Sigma Gamma Epsilon values the engagement of its members in the educational enterprise, both for their betterment and for improving understanding and impact of Earth Science in the broader community. To that end, members are expected to help with service projects in their departments, schools, and community. The SGE Chapter Service Award is presented to chapters that exhibit exemplary service to their communities. Required service hours are based on the number of active members in the Fall semester and an average of six hours must be documented per Award Year. For 2023–2024, two chapters, the Gamma Sigma Chapter at the University of Northern Iowa and the Gamma Chi Chapter at Eastern Illinois University, demonstrated their commitment to engagement with the campus and broader community. Numerous activities were described in each chapter's application.

Gamma Sigma had ten specific activities in three broad categories. Members helped improve the environment directly with assistance in prairie restoration and burning, cleaning various hike and bike trails in the area, and participation in the Iowa Department of Natural Resources Frog and Toad Day, an assessment of numbers and habitat for these amphibians. Members helped educate the public through assistance at Sunday at the Quarry Open House, continued operation of an Earth Science Halloween House for children, and answering questions from guests at weekly observatory and planetarium shows. Peers were educated through open labs and tutoring for several classes, and various departmental majors were promoted through the "Majors in Minutes" activity.

Gamma Chi continued environmental improvement by cleaning up their assigned Adopt-a-Highway section in both Fall and Spring (Figures 1 to 3). Members provided education opportunities to the public about the total solar eclipse in April 2024 at a satellite viewing location the Lincoln Log Cabin Historical Site. Visitors were able to view the eclipse through special glasses, telescope projection, and "pegboard" (Figures 4 and 5). Departmental interaction was fostered through a Halloween Pumkin Carving contest, and a sample of entries is provided (Figures 6 to 8). This is a subset of activities that supported engagement and education.

Figure 1: Fall 2023 Adopt-a-Highway crew (Photo: Gamma Chi Chapter).

Figure 2: Two Gamma Chi members have collected hefty bags of trash (Photo: Gamma Chi Chapter).

Figure 3: Members of the Gamma Chi Chapter pose during an Adopt-a-Highway event in Spring 2024 (Photo: Gamma Chi Chapter).

Figure 4: Students and the public view the solar eclipse at the Lincoln Log Cabin Historical Site, April 8, 2024 (Photo: Gamma Chi Chapter).

Both chapters reported combined volunteer hours that were greater than the 6-hour average per member minimum. This award is acknowledged with a certificate and monetary

Figure 5: A telescope is employed to safely project an image of the solar eclipse (Photo: Gamma Chi Chapter).

Figure 6: Students hard at work carving pumpkins for the Gamma Chi Pumpkin Carving Contest (Photo: Gamma Chi Chapter).

Figure 7: Students hard at work gutting pumpkins for the Gamma Chi Pumpkin Carving Contest (Photo: Gamma Chi Chapter).

Figure 8: Some handywork from the Gamma Chi Pumpkin Carving Contest (Photo: Gamma Chi Chapter).

award. The National Council extends its congratulations to Gamma Sigma and Gamma Chi for their efforts.

JAMES C. WALTERS QUALITY CHAPTER AWARD

At the 2022 Biennial Convention, delegates voted unanimously to rename the Quality Chapter Award as the James C. Walters Quality Chapter Award. Details of Dr. Walters's long affiliation with SGE are highlighted in Ford and Potter (2024). To qualify for this award, Chapters must regularly report returning and new members, list officers, award the W. A. Tarr award to an exceptional student, and provide at least two hours service to the community per member each academic year. Two chapters applied for the award in Spring 2024 and met the qualifications for the award. They are Gamma Sigma (University of Northern Iowa) and Gamma Chi (Eastern Illinois University). These chapters demonstrate the qualities described above and received a certificate and monetary award. Details of the service component for each chapter are noted under the Chapter Service Award above.

The National Council extends congratulations to these chapters for their work to exemplify the reporting and service that defines a quality chapter, and to increase their departments' visibility in the community at large through education and service.

W. A. TARR AWARDS

The W. A. Tarr Award was established in March of 1949, to distinguish exceptional students in the Earth sciences. Twenty-nine students received the Tarr Award during the 2023–2024 academic year (Table 1). Qualifying Criteria for this award is defined by the following:

> "Any student in the Earth Sciences and an active member of the Society of Sigma Gamma Epsilon at a school with an active chapter of the Society is

Table 1: W. A. Tarr Awardees for academic year 2023-2024 listed by chapter and school.

Name	Chapter	University
Oluwafemi Salami	Eta	Missouri Univ. of Science & Technology
Mackenzie L. Choffel	Chi	University of Kentucky
Megan Humphrey	Alpha Kappa	Johns Hopkins University
Isaiah McKinney	Alpha Mu	Virginia Tech
Ryan E. Haag	Alpha Chi	The University of Alabama
Caitlin E. LaBonte	Gamma Zeta	Kent State University
Kathryn Mudica	Gamma Lambda	Indiana State University
Kelly Biscoglia	Gamma Sigma	University of Northern Iowa
Melanie Ertons	Gamma Phi	Stephen F. Austin State University
Lex Watts	Gamma Chi	Eastern Illinois University
Jake Swartz	Delta Beta	Auburn University
Natalie Tolls	Delta Theta	Rensselaer Polytechnic Institute
Audrey Davis	Delta Xi	Trinity University
Lauren Bryan	Delta Omicron	Hope College
Emily Siedel	Delta Tau	Slippery Rock University of Pennsylvania
Aaliyah Knight	Delta Psi	Western Illinois University
Alexis Christopher	Epsilon Zeta	Midwestern University
Liam Rogers	Epsilon Sigma	University of North Carolina at Charlotte
Even Cizler	Zeta Zeta	College of Charleston
Natalie Hudson	Eta Alpha	University of Tennessee at Martin
Erik Larsen	Eta Gamma	Weber State University
Danielle E. Tryon	Eta Lambda	Susquehanna University

Continued...

TABLE 1 (*Continued*): W. A. Tarr Awardees for academic year 2023-2024 listed by chapter and school.

Name	Chapter	University
Kathleen R. Farr	Eta Nu	James Madison University
Marissa Pickett	Eta Sigma	Middle Tennessee State University
Hunter G. Mason	Eta Phi	Northern Illinois University
Noelle Kidd	Theta Xi	Allegheny College
Matthew Levy	Theta Sigma	University of Arkansas at Little Rock
Baylee MacBeth	Theta Chi	Georgia Institute of Technology
Annie Kennedy	Iota Gamma	Sewanee: The University of the South

> eligible to receive the Award. An active chapter is one which submits annually the members form with appropriate dues by November 1. The recipient of the Award must be majoring as an undergraduate or be a graduate student in some phase of the Earth Sciences, (e.g., Geology, Metallurgy, Mining, Petroleum or Geological Engineering, Ceramics, Geophysics, Hydrology, Oceanography, Environmental Sciences). The Award preferably should be granted to a graduating senior or graduate student. (It is not contemplated that the Award will be made more than once to the same person)."

Scholarship is the essential basis of the Award, but personality, leadership, contribution to the school, and ability to get along with people are worthy of consideration. The selection of the student to receive the Award shall be made by a committee consisting of members of the Active Chapter and three faculty members—two of whom shall be members of the Society. The Faculty Advisor, in conjunction with the chapter, shall set up the method of selecting the Award Committee.

35TH ANNUAL STUDENT POSTER SESSION, GEOLOGICAL SOCIETY OF AMERICA ANNUAL MEETING AND OUTSTANDING POSTER AWARDS

The Society again hosted its annual Student Poster Session at the Geological Society of America annual meeting (GSA Connects 2023, Pittsburgh, Pennsylvania) on Monday, October 16 from 8:30 to 11:00 AM. This is the 35th consecutive annual venue for student work at GSA. The session was sponsored by SGE, and by GSA Quaternary Geology and Geomorphology Division and GSA Limnogeology Division. Judging for the two Best Poster Awards was completed by National Officers Richard L. Ford, Steve Bennett, Diane Burns, Claire Marshall, and Alexander Stewart. Following recovery from the COVID-19 pandemic slowdowns, abstract submissions rebounded, with sixty-three abstracts accepted.

Judges awarded the two Best Poster awards to the authors of two posters. Each award included a certificate and monetary award. Complete abstracts and author information for the sixty-three papers are provided by Beason (2024), as well as published as Geological Society of America Abstracts with Programs. Vol 55, No. 6. The National Council thanks all the authors for communicating their research at this venue and congratulates the winners of the Outstanding Poster awards.

The Austin A. Sartin Award

The 2023 Austin A. Sartin Award was awarded jointly to **Kathleen Farr** and **Michael Buchanan**, two members of the Eta Nu Chapter at James Madison University in Harrisonburg, Virginia (FIGURE 9). Kathleen and Michael were co-authors on a poster presentation that reported on the use of a variety of data sets to produce a 1:24,000-scale geologic map of the southern half of the 7.5-minute Rawley Springs Quadrangle in western Virginia. The detailed mapping increased knowledge of the North Mountain thrust fault system and the fluvial geomorphology of the region. Their abstract is found online at: https://gsa.confex.com/gsa/2023AM/meetingapp.cgi/Paper/394003.

The Charles J. Mankin Award

The 2023 Charles J. Mankin Award was awarded to **E Vigil**, a member of Theta Omega Chapter at Tennessee Tech in Cookeville, Tennessee (FIGURE 10). E was a co-author on a poster presentation that reported on the analysis of insect herbivory on fossil leaves from the Claiborne Formation (Middle Eocene) of Kentucky. The amount and diversity of insect damage were shown to be positively correlated with changes in the partial pressure of CO2 and temperature, thus

FIGURE 9: Austin A. Sartin Award Winners Kathleen Farr (left) and Michael Buchanan (right) receive certificates from SGE President Steve Bennett (L.S. Potter photo).

FIGURE 10: Charles J. Mankin Award winner E K Vigil receives the award from Steve Bennett (L.S. Potter photo).

providing an analog for the consequences of future climate change. Their abstract is found online at https://gsa.confex.com/gsa/2023AM/meetingapp.cgi/Paper/394978.

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News Update

Sigma Gamma Epsilon student research poster session, Geological Society of America Annual Meeting 2023, Pittsburgh, Pennsylvania, USA

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ABSTRACT

The Society of Sigma Gamma Epsilon sponsors an annual poster session at every Annual Meeting of the Geological Society of America. The 35th Sigma Gamma Epsilon undergraduate research poster session took place during the 2023 Geological Society of America Annual Meeting in Pittsburgh, Pennsylvania, USA, on Monday, October 16, 2022. Sixty-three (63) posters were presented in Exhibit Hall B at the David L. Lawrence Convention Center between 8:00 AM and 5:30 PM at the poster session. Titles, authors (italics for the presenting author), affiliations, and abstracts for each poster are listed in this report.

KEYWORDS

Sigma Gamma Epsilon, poster session, student research, Pittsburgh, Pennsylvania, Geological Society of America

THE SOCIETY OF SIGMA GAMMA EPSILON

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Poster 96-1, Abstract 396248, Booth 38

ASSESSING CHANGES IN THE DAKOTA AQUIFER POTENTIOMETRIC SURFACE IN NORTHWEST IOWA BETWEEN 2008 AND 2023

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In northwest Iowa, demands on the Dakota aquifer have increased due to the declining quality of surface water, lack of other productive aquifers in the area, and increases in pumping for municipal, rural, and private water supply, ethanol production, and confined animal feeding operations. The last study focused on the Dakota aquifer in Iowa was completed in 2008 by the Iowa Geological Survey. The objective of this current study was to collect water levels from existing wells across the Dakota aquifer extent to update the regional scale potentiometric surface for the unit. In Iowa, the Dakota aquifer exists primarily across a 16-county area in the northwest corner of the state. It is composed primarily of sandstone and conglomerate units of the Nishnabotna Member of the Dakota Formation and the sandstone-rich portions of the overlying Woodbury Member. To identify wells suitable for water level measurements across the study area we used the GeoSam database maintained by the Iowa Geologic Survey. There are 1,302 Dakota aquifer wells in Iowa. However, the precise hydrostratigraphic characterization for many of these wells is uncertain because of a lack of well construction data, stratigraphic picks, or both. For example, the stratigraphy defined for many of the Dakota aquifer wells was simply described as 'Cretaceous' which means the well could be open to the Nishnabotna Member, the Woodbury Member, and/or the overlying upper Cretaceous units. Consequently, we focused on a set of 52 wells that were deliberately drilled for a Dakota aquifer study conducted in the early 1980s. Water levels were collected from all measurable wells and used to generate a potentiometric surface representative of 2023 conditions. A

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preliminary comparison to the 2008 potentiometric surface shows spatial variability in the changes in magnitude and inferred regional groundwater flow directions likely related to areas where more or less pumping has occurred. Currently, continuous water level data collected from three USGS Dakota aquifer monitoring wells are being used to assess the rate of change between the 2008 and 2023 potentiometric surfaces. These analyses help to quantify the impacts of increasing use on the Dakota aquifer and will be valuable to help determine new Dakota aquifer drilling and monitoring well locations for future phases of the study.

Poster 96-2, Abstract 390238, Booth 39

GEOMORPHOLOGICAL AND VEGETATION CHANGES AROUND BEAVER DAM ANALOGUES, RED CANYON CREEK, WY

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Beaver Dam Analogues (BDAs) are an inexpensive, biodegradable form of stream restoration that function similarly to natural beaver dams. BDAs are expected to help redistribute water spatially into the floodplain to return the stream and surrounding floodplain to a more natural state. Geomorphic changes are expected with the implementation of BDAs, including increased sediment retention, aggradation, increased sinuosity, and reduced slope. Coupled with this, vegetation changes are also anticipated. However, evaluations of morphological and vegetation changes associated with BDA restoration sites are limited. Here we show geomorphic changes in the streambed and vegetation changes in the surrounding floodplain around 45 BDAs in Red Canyon Creek, Lander, WY. Our analysis builds on multiple years of observations, as well as recent data acquisition in summer 2023. Vegetation changes are observed in terms of NDVI around the BDAs, with imagery collected via drone in late July of 2017, 2019, and 2022. Geomorphic changes build on observations from 2022 and 2023. This work offers an understanding of what changes may occur when BDAs are implemented as a restoration technique.

Poster 96-3, Abstract 391099, Booth 40

ARCGIS PRO BASED HYDROGEOLOGICAL VULNERABILITY MAPPING OF GROUNDWATER RESOURCES IN EASTERN KENTUCKY

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Groundwater is vital as a reliable water supply due to its continuous availability, reasonable natural quality, and ease of diversion to underserved communities at a lower cost and with greater speed. To ensure the preservation of this valuable resource, it is crucial to identify and protect areas with high groundwater potential. In this research conducted in the Eastern Kentucky study area, remote sensing data and geographic information system (GIS) techniques were employed to assess groundwater potential. The methodology employed in this study offers a rapid, precise, and practical approach. Key parameters influencing groundwater potential and recharge, such as land use/cover, soil characteristics, lithology, rainfall patterns, drainage density, lineament density, slope, and elevation, were derived from datasets including the Operational Land Imager 9, digital elevation models, soil data, lithological data, and rainfall data. To validate the results, borehole data was utilized. The analysis was conducted using ArcGIS Pro 3.1 software, facilitating the design of various digital thematic maps. The parameters affecting groundwater potential were mapped and analyzed using spatial analysis tools. The relative influence of each parameter was determined by applying the Analytical Hierarchy Process, thereby assigning weights according to their percent of influence on groundwater potential and recharge. The consistency ratio obtained for the weight allocation was 0.033, below the threshold of 0.1, indicating an acceptable weight allocation. Weighted overlay analysis found that slope, land use/cover, and lithology contributed equally, each accounting for 24% of the overall influence

on groundwater potential. This study shows that the soil group exhibited negligible influence, comprising only 2% of the total weight allocation. The resulting groundwater potential map classified areas into five ranks (1, 2, 3, 4, and 5) representing Very Low, Low, Moderate, High, and Very High potential, respectively. This classification was based on the availability of groundwater potential within each rank and class. The outcomes of this scientific study hold great promise for regional planners and policymakers involved in sustainable groundwater development and management.

Poster 96-4, Abstract 395482, Booth 41

GEOSPATIAL ANALYSIS OF ST. LAWRENCE UNIVERSITY CAMPUS ROAD NETWORK TO ASSESS IMPACT ON EMERGENCY RESPONSE TIMES

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Collegiate emergency medical service (EMS) agencies provide valuable services to college and university campuses across the United States through quick response times and peer-to-peer assistance. However, the unique layout and road network of a college campus can provide unique challenges, such as limited vehicle access to inner campus and indirect routes to high volume call areas. Geospatial analysis of the St. Lawrence University campus in Canton, NY was used to gain a better understanding of the impact of these factors on the response time of St. Lawrence University Emergency Medical Services (SLU EMS).

GPS points were acquired at every entrance to buildings on the main campus, using an EOS Arrow 100 mobile GPS unit and the Esri Field Maps app on an iPhone 13. This data collection was performed in a feature layer designed in ArcGIS Online. Other feature layer datasets, used to account for the designated parking locations of the SLU EMS response vehicle, were created within ArcGIS Online. All datasets were migrated into ArcGIS Pro for spatial analysis. Data will be combined with pre-existing roadway feature layers to analyze routes through the campus with the lowest travel times.

The entrances dataset contains 406 collected GPS points. Within the two feature layers for vehicle locations, 62 points were created. High call volume areas of campus were determined by assessment of SLU EMS call records (2,126 calls) in the period between August 2014 and May 2023. The data was entered into Excel and transferred into ArcGIS Pro. Spatial analysis was then performed to determine areas of high volume.

Preliminary results suggest that the fixed gates on the north end of campus may increase response times. Further data processing will provide more insight as to the extent of this effect. Future work may consider additional factors such as travel on foot as well as by vehicle when delineating the most efficient response routes.

Poster 96-5, Abstract 392036, Booth 42

ANALYSIS OF HYPERSPECTRAL VERSUS MULTI-SPECTRAL DATA FROM DRONE-BASED ACID MINE DRAINAGE MONITORING IN PERRY CANYON, NV

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Remotely operated aerial systems (drones) are effective for monitoring temporal change at remediated acid mine drainage sites (Cramer et al. “Mapping Potentially Acid Generating Material on Abandoned Mine Lands Using Remotely Piloted Aerial Systems”. Minerals, 2021, 11, 365). In June of 2021, hyperspectral data of Perry Canyon, NV was acquired in 271 spectral channels in the visible and near-infrared (VNIR) and 270 spectral channels in the short-wave infrared (SWIR). This project seeks to evaluate whether the increased spectral fidelity justifies the increased cost for the hyperspectral analysis of acid mine drainage sites. These hyperspectral images were analyzed using Environment for Visualizing Images (ENVI) software to map different spectral signatures throughout the site. This analysis provides evidence of three unique spectral signatures that could be associated with potentially acid generating material (PAGM). These spectra are classified as Yellow Soil (jarosite), White and Blue Soil (efflorescent mineral salts), and Red Soil (iron oxides and secondary iron-rich coatings indicative of acid mine drainage). Jarosite is an iron-bearing sulfate used to locate areas of PAGM, and red soils can isolate heavy metals that generate acidic water. Both jarosite and iron-oxide bearing soils have a diagnostic spectral reflectance which makes them useful at locating PAGM. Classification models such as Spectral Angle Mapper (SAM), Maximum Likelihood (ML), and Band Math Ratios (BMR) delineate areas where these spectra are observed. These classification models will be used to corroborate both VNIR and SWIR datasets as well as to compare spectral fidelity. Inclusion of SWIR data will increase knowledge of possible benefits or setbacks when using these data to map PAGMs. SWIR data also provides a greater range of spectral wavelengths that can lead to increased accuracy when determining pixel choice for PAGMs because most have stronger absorption and reflectance features in SWIR. These new surface compositional maps allow the comparison of our results to those of the previous 5-channel data, which were only analyzed using VNIR. It is expected that the increased spectral fidelity will offer more information, and greater detail, of PAGM at this site.

Poster 96-6, Abstract 395390, Booth 43

ANALYSIS OF HYPERSPECTRAL VERSUS MULTI-SPECTRAL DATA FROM DRONE-BASED ACID MINE DRAINAGE MONITORING IN PERRY CANYON, NV

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The Big Bend region of Texas is located in far west Texas, west of the Pecos River and north of the Rio Grande. The region includes a diverse natural habitat and varied geologic and other natural and cultural attractions. Several state parks and the Big Bend National Park are located in the region, as well as the towns of Marfa, Alpine, Marathon, Fort Davis, Terlingua, Lajitas, and Presidio. The region is located in the Chihuahuan desert and receives ~ 17 inches of annual precipitation. All public water supply in the region comes from aquifers; these aquifer sources include the "igneous" aquifer, the "west Texas bolsons" aquifer, and an unnamed Cretaceous carbonate aquifer. The three counties in the region (Brewster, Jeff Davis, and Presidio) have Groundwater Conservation Districts (GCDs) as enabled by the state Water Code Chapter 36. These districts and the Texas Water Development Board are the primary means of monitoring and regulating groundwater use.

Increased tourism in the Big Bend region in recent years has caused concern regarding the sustainability of the groundwater resources. The population within the region is not expected to increase significantly, but the number of transient water users is clearly increasing and is presumably resulting in increased groundwater consumption. Our research is focused on estimating this increase in water usage. We are gathering various data on vacation rentals by reviewing local hotel tax logs and internet advertising, conducting verbal surveys, and analyzing repeat aerial imagery to identify structures constructed for rental purposes only. The results of this data-gathering effort, combined with estimates of per-user consumption, will allow us to provide local water managers, such as the GCDs, with valuable information regarding this otherwise undocumented increase in groundwater use.

Poster 96-7, Abstract 391114, Booth 44

REFINING THE POLLUTION HISTORY OF THE FORMER MUNROE FALLS DAM IMPOUNDMENT, CUYAHOGA RIVER, OHIO

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The Munroe Falls Dam was first built on the Cuyahoga River, Ohio in 1817. The dam created a low-velocity impoundment that trapped the river's sediment load and led to poor water quality. In 2005 the dam was removed in order to improve water quality and ecosystem health. Prior to the dam's removal the impoundment sediment was cored and measured by Atomic Absorption Spectrophotometer (AAS) to characterize heavy metal concentration. This present study remeasured the cores by X-ray Fluorescence (XRF) to characterize more elements than had been measured by AAS in order to provide additional details of the pollution history. The prior study had identified a buried oily layer, having elevated Cu, Pb, Cr, and Zn concentrations and ^{210}Pb-dated to the time of the Great Flood of 1913. This contaminated layer was likely sourced from the inundated Erie Shops railroad repair facility located upstream in Kent, Ohio. The new XRF results show elevated Cd, Fe, and S in the oily layer. The elevated Cd and Cr are likely due to their use in electroplating train components. The elevated Fe concentration is likely due to increased metal particles washed in from the Erie Shops site. The elevated S concentration is likely due to the oil in the flood layer and thus the sulfur profiles provide an additional means of identifying the oily flood layer throughout the dam impoundment. Because the XRF method is more rapid and inexpensive than the AAS method, a greater number of samples were measured, thus allowing the spatial extent of the 1913 flood layer to be better characterized.

Poster 96-8, Abstract 391132, Booth 45

PALEOFIRE AND PALEOENVIRONMENTAL DYNAMICS REVEALED IN JACKSON LAKE SEDIMENTS (GRAND TETON NATIONAL PARK, WYOMING, USA)

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Jackson Lake, located in the Grand Teton National Park (Wyoming), is characterized by an alpine climate that is influenced by the Teton range, which receives heavy winter precipitation annually. The lake is surrounded by coniferous forest and shrublands, and seasonal wildfires are common. Despite its unique geological setting, which includes earthquakes, hydrothermal activity, and a history of extensive late Quaternary glaciation, much remains unknown about environmental changes in Grand Teton National Park, including the paleofire history. This study analyzes a 13.83 m sediment core from Jackson Lake in order to reconstruct the fire history using fossil charcoal, as well as signals of limnological change using bulk organic geochemistry. The core, dated using radiocarbon, covers the Early Holocene (~10.4 cal ka BP) to the present, with an average sedimentation rate of 0.14 cm/yr. Samples of known volume were collected every 5 cm along the length of the core, yielding ~300 samples for analysis. Given the age-depth model, this sampling provides decadal temporal resolution for the charcoal and geochemical proxies. The samples were pretreated using standard techniques and washed through a 106 µm sieve to separate charcoal fragments. The residues were examined under a stereomicroscope in gridded petri dishes, counted, and statistically enumerated. Charcoal morphological characteristics, such as size and shape, were also documented. These parameters provide insights on the intensity and scale of paleofire events, and the identification of the plant types involved (e.g., grasses versus trees). In addition, samples underwent geochemical analyses, focusing on TOC, TN, $\delta^{13}C$, and $\delta^{15}N$. Preliminary results indicate TOC variability over time, with lower concentrations near the bottom of the core (~2 wt. %), and higher concentrations at the top (3.6 wt. %). Research is ongoing, and the outcomes of this study seek to significantly contribute to our understanding of the history of fire dynamics in Grand Teton National Park. This knowledge will have implications for broader ecological studies and management strategies related to fire in this alpine environment.

Poster 96-9, Abstract 393489, Booth 46

HUMAN IMPACTS OF LARGE CHANNEL MOVEMENT IN EFFINGHAM COUNTY, EAST-CENTRAL ILLINOIS, USA – A PRELIMINARY STUDY

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The Little Wabash River, a tributary to the Wabash River, originates in Coles County and is around 240-mile (390 kilometers) long. The meanders of the Little Wabash River found in Effingham County have been researched for everything from acreage changes to agricultural usage of the surrounding land (e.g., Rhoads et. al, 2009), but there was little investigation into how much of the land was impacted in human terms. This includes changes to tax parcel sizes/levies as well as usage of the land – agricultural, forested or similar. Using USGS and USDA maps as well as parcel documentation from the Effingham County Supervisor of Assessments, this project extends the previous work on identifying meanders by investigating the human impacts resulting from a large channel migration in Effingham, Illinois.

Poster 96-10, Abstract 395892, Booth 47

"LEGACY ISLANDS"- UNINTENTIONAL ANTHROPOGENIC ARTIFACTS FORMING IN THE SUSQUEHANNA RIVER (NORTH BRANCH)

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"Legacy Islands" formed in the Susquehanna River from both glacial and legacy sediments deposited upstream from manmade fish weirs. These islands are distinct from other alluvial islands due to their low elevation, V-shaped structure, sparse vegetation, and length to width ratio. The name "Legacy Islands" is proposed here to describe these landforms due to their anthropogenic origin.

Aerial imagery (1939-present) was used to locate buried fish weirs where islands formed. This study examined an unnamed island near Beach Haven, PA in the North Branch of the Susquehanna River. It was surveyed, and sediment cores were drilled to determine the stratigraphy. Samples were analyzed for grain size, mineralogy, and chemistry. Sand to sandy loam was deposited on top of medium to coarse-grained gravel; the gravel represents high-energy flood events. This sediment was periodically rooted between floods. The finest sediment (clay and silt) was composed of vermiculite, chlorite, muscovite, and quartz. Sand size sediments potentially associated with glaciation consisted of quartz, quartz with magnetite inclusions, andradite, pyrope, chromite, ferroan enstatite, spinel, zircon, and magnetite. Sand size sediments from coal production included anthracite coal, magnetic glass, metallic industrial waste, shale fragments, ferric oxyhydroxide, hematite, and coke. The distribution of fine grain sizes corresponded to trends observed in some of the major oxides (Fe_2O_3, K_2O, Na_2O, MgO, and TiO_2). Increases in these major oxides may be due to high water levels or hydromorphic processes. This is represented by mottled and iron-rich layers in the cores.

Historical aerial images help resolve how these islands form: 1. gravel bars may form upstream from fish weirs, 2. vegetation colonizes gravel and may trap sediment, allowing the island to stabilize, and 3. significant floods may reset the process. There may be more "Legacy Islands" in the Susquehanna, and they may not be restricted to this river. Despite being an unintentional manmade feature comprised of mining waste, these islands provide a valuable habit for many types of organisms. These habits may be threatened by future global climate change due to stronger flood and weather events.

Poster 96-11, Abstract 395301, Booth 48

COMPARING RIVERBED SEDIMENT CHANGES IN RESPONSE TO THE PALEOCENE-EOCENE THERMAL MAXIMUM EVENT, PYRENEES MOUNTAINS, SPAIN

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The Paleocene-Eocene Thermal Maximum (PETM) event occurred 56MA, when the average global temperature increased between 5-9 degrees Celsius. With the increase in global temperature today (July 2023 broke temperature records around the globe), we can look at the PETM to determine what could happen if global temperatures continue to increase, including how landscapes may respond to rising temperatures and changing precipitation patterns. The Paleocene Esplugafreda and Eocene Claret formations exposed in the Pyrenees Mountains, Spain, provide an opportunity to evaluate how ancient rivers responded to the PETM climate change. Using field photos of ancient riverbed deposits from before, during, and after the PETM, I measured attributes of sediment from three study areas and determined paleo-river flow conditions before, during, and after the PETM. In each study area I traced sediment grains on >50 photographs to determine sizes, roundness, aspect ratio, solidity, and circularity of sediment before, during, and after the PETM and used this information to interpret paleoflow conditions throughout the study area. The preliminary results show that there was a significant amount of scatter and overlap for bed-sediment attributes in space and time. An increase in sorting and aspect ratio (more elongated) of grains in the Claret Formation might suggest more sustained floods, but similarity in the 90th percentile of grain size suggests the floods could have had similar peak discharges. These results suggest that changes in interannual discharge variability may play an important role in river activity during global warming events.

Poster 96-12, Abstract 394991, Booth 49

USE OF DRONES (UAVS) TO CHARACTERIZE LARGE WOODY DEBRIS ON THE WHITEWATER RIVER, INDIANA

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Large woody debris (LWD) is critical to the health and function of stream systems and integral to stream restoration design. LWD, consisting of wood >10 cm in diameter and >1 m in length, influences habitat structure, flow patterns, sediment deposition, and pool formation. Although much work has been done on the role of LWD in streams in the western U.S., few studies have been conducted in the Midwest and the Ohio River Valley, in part due to the limited supply of LWD. The Whitewater River in southeastern Indiana and southwestern Ohio, however, has a wide riparian corridor and few dams or bank stabilization measures, allowing for the recruitment and transport of LWD. Collecting data on these logjams has, in the past, been quite labor intensive. It is typically difficult to get to large log jams on the river, often entailing multi-day trips to collect quantitative data on the wood (e.g. size, species, measure of decay, etc.) and stream morphology. The use of unmanned aerial vehicles (UAVs), or drones, to survey LWD could greatly reduce the amount of time it takes to complete these surveys. This study aimed to test the viability of using Phantom 4 drones and Pix4D software to generate high-resolution 3-dimensional images (i.e. point clouds) of large log jams to quantify the lateral dimensions of the jam itself and key members (large logs that are structural to the jam). Log jams were initially surveyed and inventoried via canoe float on the Whitewater River from May 30, 2021 to June 01, 2021. Log jams were categorized based on their position (meander, bar apex and bar top jams) and the number of key members contained. We returned to the site of a few of the large log jams in August of 2022 and 2023 to assess the capability of using the Phantom 4 drones to more easily characterize LWD. As efforts increase to improve water quality in the Ohio River Valley, it will be important to integrate LWD in stream restoration design.

Poster 96-13, Abstract 394002, Booth 50

ESTABLISHING A BASELINE OF STREAM CHARACTERISTICS IN INDIANA COUNTY, PA: LEVERAGING COMMUNITY CONNECTIONS

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Indiana county is located in Western Pennsylvania and is part of the Allegheny Plateau. Almost all of the waterways are headwater streams of the Allegheny River where water quality has been significantly impacted by resource extraction for decades. The Evergreen Conservancy nonprofit organization (based in Indiana, PA) has been focused on the water quality in Indiana County since the founding in 2003, which led to the installation and maintenance of stream data loggers starting in 2011. These locations have been monitored for a variety of stream characteristics that consists of water temperature (celcius), water level (meters), conductivity (microsiemens, converted to TDS in mg/L). Over the past 12 years they have monitored critical water characteristics in 40+ locations in Indiana County with in-stream data loggers to address and look for evidence of pollution and specific

water quality degradation events. This data set has been underutilized and we have started working on leveraging it as well as working with the network of knowledgeable volunteers of the Evergreen Conservancy to guide us in future steps of our research that works to improve the overall health of the streams that reside in Indiana County. As of now, our first step in analyzing and monitoring this data is to assess the quality and quantity of the data and to develop automation of this with python coding. We have started from square one to learn python coding to automate data processing and utilization and have created graphs and other visuals to start our process of correlations and pattern recognition in our data for future research. Preliminary findings show typical seasonal temperature changes for cold water streams (average summer temperatures of <19C) at all seven stream locations we have analyzed so far. We also see little to no change throughout the year in overall average water volume, as would be expected in this region (steady rainfall year round). As well, we find that some of the streams show increased TDS values in the winter months, which seem to indicate possible road salt impacts. Additionally, we see that the daytime temperature ranges are greatest during the month of April. Further studies will expand these analyses to all 40 locations throughout Indiana County to develop a baseline understanding of these headwater streams.

Poster 96-14, Abstract 394831, Booth 51

HYDROLOGIC RESPONSE OF THE GALLINAS RIVER TO THE 2023 SPRING SNOWMELT POST-2022 HERMITS PEAK/CALF CANYON FIRE

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Forest fires are well known to impact the quality of water in a watershed from hillside erosion and fire sedimentation as well as the quantity of water entering the system from decreased soil infiltration, lessened vegetation interception, and increased catchment evapotranspiration. The Gallinas Watershed in northern New Mexico was impacted by the 2022 Hermits Peak/Calf Canyon (HP/CC) Fire, the largest wildfire in New Mexico's history (>340,000 acres). Approximately 115,542 acres burned in the Headwaters Gallinas River Watershed, 21% of which were classified by the USFS Burned Area Emergency Response team as high burn severity. While much research focuses on the increased flooding from monsoonal rains after a forest fire, little data exists about the hydrologic impacts from spring snowmelt runoff. This study tested the hypothesis that post-fire conditions would lead to earlier snow disappearance in the burned watersheds and flashy runoff on the spring hydrograph. We monitored in near real-time the snow water equivalent (SWE), air temperature, and soil moisture in the Gallinas Watershed headwaters (Wesner Springs SNOTEL site) and compared them to amounts and trends in discharge within Gallinas Creek near Montezuma, NM (USGS gaging station 08380500). We looked at historical data as well, with emphasis on the period during the spring snowmelt (March through May) to assess what if any impact the 2022 HP/CC fire had on hydrologic conditions. Historically, the Gallinas Creek hydrograph shows a shallow slope during the winter low-flow period, increases stepwise in response to spring warming, then decreases broadly and diffusely during late spring to early summer with intermittent peaks related to rain events. The 2023 Gallinas River hydrograph pattern is consistent with its historical trend suggesting that post-fire, the watershed has maintained resiliency to snowpack retention and water storage. Continued monitoring in near real-time is imperative to forecast flood stages, manage fire sedimentation, and protect water supplies.

Poster 96-15, Abstract 390693, Booth 52

THE EVOLUTION OF FAULT DAMAGE ZONES WITHIN THE SEVIER NORMAL FAULT SYSTEM, UTAH

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Understanding the development and geometry of fault damage zones is important because these fracture networks control subsurface fluid flow and add to our knowledge of fault dynamics and landscape evolution. We examine the dimensions of and fracture intensity within damage zones in the Jurassic Navajo Sandstone associated with the Orderville Salient of the Sevier normal fault system in southern Utah.

The Orderville Salient is a zone of complex fault linkage where well-exposed damage zones formed in a variety of structural settings. We surveyed damage zone fracture networks in the hanging wall and footwall of isolated fault segments as well as in fault blocks between segments. We gathered data via ground-based scanline surveys as well as using Structure from Motion (SfM) software to generate 3D models of the ground surface from imagery captured by unmanned aerial vehicle (UAV) flights. We used both scanline and 3D model data to analyze fracture orientation, spacing and intensity. Our data show that there is asymmetry in the dominant fracture orientation across the fault – with the dominant fracture set striking ESE in the hanging wall and SSW in the footwall – as well as asymmetry in damage zone width, with the hanging wall damage zone being ~2.5 times wider than in the footwall. We also find that the footwall damage zone can be divided into an inner zone (~5m wide) and outer zone (~40m wide) based on fracture intensity and resulting topographical development, which is consistent with previous research on fault systems in similar lithologies. In our comparisons of footwall damage zone widths within the Navajo Sandstone, we found widths ranging from ~34m to 44m, meaning that the width does not vary significantly based on fault displacement. This work has implications for fields including groundwater, geothermal energy, and oil and gas production, because the intensity and orientation of fractures in a fault system control the movement of subsurface fluids. Our work can also be applied to understanding the impacts of fault dynamics on landscape evolution.

POSTER 96-16, ABSTRACT 395374, BOOTH 53

QUARTZ C-AXIS DEFORMATION THERMOMETRY CONSTRAINS RETROGRADE DEFORMATION WITHIN THE CHUNKY GAL MOUNTAIN FAULT, WESTERN NORTH CAROLINA

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Quartz C-axis opening angle thermometry is used to determine the temperature of deformation in metamorphic rocks, using an empirically derived linear relationship between C-axis slip orientation and deformation temperature. Calibration equations were derived from both experimental and natural data. A recently developed calibration extends the relationship to higher deformation temperatures and documents a shift in slope with a change in mechanism from subgrain rotation (SGR) to grain boundary migration (GBM) at temperatures near 650°C.

This study estimates deformation temperatures from quartz-rich domains in mylonitic samples from The Chunky Gal Mountain Fault, Central Blue Ridge Province, western North Carolina. The fault zone preserves a range of deformation temperatures. Peak metamorphism within the shear zone is estimated at ~800°C with evidence of ductile deformation of K-feldspar porphyroclasts. Muscovite fish swim in the mylonitic matrix and quartz microstructures include both SGR and GBM textures. All study samples (n=5) were collected from the same shear zone. Samples from other shear zones did not preserve a girdle pattern that could be used with this method. C-axis orientation data, collected using Electron Backscatter Diffraction (EBSD) data is plotted on stereonets, referenced to sample foliation and lineation. For samples with a c-axis girdle pattern, opening angles were measured from the net center between girdle limbs in each direction. We employed 3 different opening angle calibration equations.

Opening angles from shear zone samples range from 51° to 71°. Temperature estimates from these angles range from 400 °C to 580 °C and are similar for the 3 different calibrations. Deformation temperature estimates from the opening angle fall within the SGR-related calibration and are distinctly lower than peak metamorphic conditions. Our results may indicate that quartz fabrics document the late stages of shear zone movement.

POSTER 96-17, ABSTRACT 394013, BOOTH 54

ANISOTROPIC MAGNETIC SUSCEPTIBILITY (AMS) FABRIC AS A PALEOGEODETIC MEASURE OF TECTONIC DEFORMATION IN QUATERNARY DEPOSITS: AN EXAMPLE FROM THE ITALIAN APENNINES

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The anisotropy of magnetic susceptibility (AMS) is a proven measure of tectonic strain for rocks that have reached temperatures > 50°C. We pursue the hypothesis that AMS tectonic fabrics can also be encoded in rocks or sediment that have experienced shallow burial (< 250 m) over Quaternary time scales in a neotectonic stress field. We use the well-known shortening to extension Quaternary strain history in the Italian Apennines as a natural experiment to explore AMS fabrics in surficial deposits as a paleogeodetic measure of strain histories. We sampled Quaternary deposits from ten sites in central Italy representing intermontane alluvial and lacustrine facies from active extensional, former wedge-top, and active wedge-top basins. At each site we sampled nine oriented specimens and recorded their AMS fabrics using fifteen position measurements on a Kappabridge KLY-3s. The total strain in all samples is low, typically 1-3%, the sample fabric is mostly oblate, and K1 axis plunges are shallow, typically < 10°. No AMS fabric is recorded in samples buried less than 10 m. A compaction fabric emerges in most of the samples buried more than 10 m, but only a subset of these samples has a K1 direction consistent with a tectonic fabric. Samples buried deeply in the Gubbio and Colfiorito extensional basins have a NE-SW oriented K1 direction consistent with the dominant stretching direction. In contrast, surficial samples in the former wedge top basins typically have no tectonic fabric, but at least one sample has a weak compressional fabric consistent with previously published results. The ability of a specimen to acquire a tectonic fabric is linked to its magnetic mineralogy with magnetite particles displaying a range of maximum susceptibility orientations that contrast with more platy paramagnetic clays that typically are oriented near to the bedding plane yielding better defined compaction fabrics. Experiments are ongoing to determine the dominance of ferromagnetic and paramagnetic carriers. Despite the considerable noise of the nine specimens that constitute a sample, non-random K1 directions are always either consistent with extension or shortening, leading us to conclude that neotectonic fabrics can be encoded in these young deposits, with obvious implications for geodetic interpretations of accordant seismic hazards.

Poster 96-18, Abstract 390755, Booth 55

THE ORIGIN OF CIRCUMFERENTIAL FAULTING ON THE FLANK OF ALBA MONS, NORTHERN THARSIS REGION, MARS

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The characteristics of circumferential faulting give us insight into how shield volcanoes, regional tectonics, and topographic relief interact to affect fault formation. Because Mars' erosion and sediment deposition rates are significantly lower than Earth's, fault morphologies are better preserved than on Earth. The Alba Fossae fault zone, on the western flank of the >500 km diameter shield volcano Alba Mons, is a circumferential system dominated by horst-graben structures. The fault network developed in the Middle to Late Amazonian, which post-dates Early to Middle Amazonian volcanic activity. With high-resolution image data from the CTX camera of the Mars Reconnaissance Orbiter (MRO) and a digital elevation model (DEM) from the Mars Orbiter Laser Altimeter (MOLA), we examine the geometric characteristics of the fault zone to assess its evolution and likely origin. We observed fault segmentation with both soft and hard segment linkage and en echelon geometries. Well-defined relay ramps are commonly intact but also display top- and/or base-breached forms. We subdivide the Alba Fossae fault system into northern, central, and southern zones for ease in description and analysis. The NE-trending northern region displays a ~100 km wide fault zone with 21 major faults (~4.9 km spacing) with a max. throw of ~500 m. The N-trending central region displays 13 major faults across a width of ~85 km (~6.5 km spacing) and a max. throw of ~300 m. The NW-trending southern region displays 11 major faults across a 63 km width (~6.2 km spacing) and a max. fault throw of ~300 m. The horst-graben structure of the Alba Fossae system accommodates extension on the flanks of the volcano, where crustal thickness decreases with distance from the volcanic peak. The fault system is also located along a topographic break between what appears to be a secondary, shield-like topographic high on the western margin of Alba Mons. Our

data and analysis, when integrated with previous studies, suggest that this circumferential fault system may have magmatic origins with fault orientations controlled by the local and regional stress field on the flank of Alba Mons. We suggest that the horst-graben fault network may represent strain that helps accommodate some combination of shallow subsurface dike injection and topographic relaxation of the Alba Mons dome.

Poster 96-19, Abstract 394773, Booth 56

MULTIFACETED STUDY OF THE RED ROCK FAULT, SOUTHWEST MONTANA - RUPTURE AGE, SEISMIC HAZARD, AND RISK ASSESSMENT

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The Red Rock Fault (RRF) in Beaverhead County, MT, is one of a system of NW-trending, range-bounding normal faults that relates to the Basin and Range-style extension as well as Yellowstone-Snake River Plane hydrothermal-magmatic extension. The RRF comprises northern (2.17 km), middle (2.00 km), and southern (4.37 km) segments which collectively separate the Tendoy Range fault-block from the Red Rock Valley graben. As part of the 2023 University of Houston summer field course, we conducted a multipronged study of the RRF at Chute Canyon to estimate its age of rupture, assess its seismic hazard and assess the shake risk to southwestern Montana. Our methods included 1) a literature review to understand context, basic geology, fault physics, and paleoseismology; 2) UAV imagery analysis and field mapping, focused on bedrock exposures, fault scarps, triangular facets, colluvial wedges, steep- and gentle-gradient alluvial fans, and stream terraces; 3) field characterization of soils in offset hanging wall fans and terraces; 4) dGPS fault scarp profiling and diffusion analysis; 5) cGPS velocity determinations from 6 GPS stations (Nevada Geodetic Laboratory GPS Network) spanning the fault; and 6) ShakeMap (USGS) to generate earthquake scenarios. The sharply-developed facets, fresh scarplets, and recent seismicity (M4.7 07/14/23) demonstrate that the fault is presently active. Soils correlated well across the fault with relatively older surfaces (T2) showing greater soil development than younger surfaces (T1). The dGPS and cGPS analyses indicate age of major rupture at 10.9-12.1 ka and slip rate average of 1.0 mm/y. Earthquake moment magnitude estimates range from M5.43 (segmented) to M6.18 (combined) and ShakeMap earthquake scenario predicts shaking intensities of VIII-III posing ground shaking, landslide and liquefaction hazards to the regional infrastructure (highways, railroads, reservoirs, and gas lines). This study provided hands-on instruction to a real-life situation that is geologically significant and societally relevant.

Poster 96-20, Abstract 394450, Booth 57

TRIGGERED SHALLOW FAULT SLIP BY THE 2017 MW 7.3 IRAN-IRAQ EARTHQUAKE

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Earthquakes can cause significant hazards particularly along active plate margins. Following a main shock, aftershocks with much smaller magnitudes generally occur within the same fault system. Sometimes an earthquake can also trigger other fault systems at distance to slip seismically or aseismically. This process is commonly explained by a change of dynamic or static Coulomb stress on the receiver faults from the main shock that decreases fault stability and promotes fault slip. In this study, we use interferometric synthetic aperture radar (InSAR) to map shallow fault slip that were likely triggered by the 2017 Mw 7.3 Iran-Iraq earthquake. Through mapping, we found 230 shallow triggered fault slips. There are two dominant fault orientations, the first (135 faults) oriented at 310 ° with a mean length of 4 km. A second orientation (48 faults) was found oriented at roughly 060 °

with a mean length of ~2 km. The expression of this second orientation is located due south from the epicenter ranging from 57.5-95.5 km in distance from the epicenter. Both static and dynamic Coulomb stress changes for this event were calculated using a coseismic slip distribution provided by the USGS NEIC finite fault solutions. The static Coulomb stress change model suggests that the receiver faults in this area were strengthened against slip, which is unlikely the cause of the triggered shallow slip. To estimate the dynamic Coulomb stress change, we first calculate ground motion during the main shock within 150 km radius from the epicenter using the same finite fault model with a 1D layered Earth structure same as in the USGS finite fault solution. We then calculate peak dynamic Coulomb stress using the same receiver fault geometry as for the static stress change case. The results show that in the region south of the earthquake, despite static Coulomb stress change strengthening the receiver faults, dynamic stress change in this area was estimated to be up to 1 MPa due to a southward directivity of the fault slip process during the main shock. The spatial extent and the amount of stress change could be the cause of these shallow triggered slip. This work demonstrates the importance of taking both static and dynamic stress change into account for earthquake events with unilateral slip history can better evaluate triggered slip in neighboring fault systems.

POSTER 96-21, ABSTRACT 390759, BOOTH 58

THE ROLE OF FAULT DAMAGE ZONE DEVELOPMENT IN STRUCTURALLY CONTROLLED LANDSCAPE EVOLUTION, SEVIER FAULT ZONE, SOUTHERN UTAH

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The relationships between fault systems, weathering, and erosion strongly affect how local landscapes evolve. Fault damage zones, characterized by intense fracturing in the surrounding lithology, form as faults propagate. The Sevier normal fault, located in southern Utah, consists of several linked fault segments. We focused on the Spencer Bench segment, which displaces the Jurassic Navajo Sandstone. Because the Navajo Sandstone is located on both sides of the fault, we hold lithology constant to evaluate differences in damage zone distribution and resulting impacts on erosional processes. In addition, the headward erosion process permits us to use down-drainage cross-drainage profiles as temporal snapshots of valley hillslope evolution in order to evaluate how damage zone fracturing affects valley evolution.

We collected structural data including fracture orientation and spacing, and we used an Unmanned Aerial Vehicle to capture imagery of inaccessible outcrops. We used this imagery to construct virtual outcrop models from which we collected additional structural data. We documented fracture characteristics in the footwall and hanging wall and compared fracture intensity to topography. Cross-sectional topographic profiles constructed perpendicular to the Spencer Bench fault revealed correlations between structural data and slope. Near the uppermost reach of the fault-parallel canyon to the north, representing youthful valley erosion, the topographic profiles are relatively symmetric, with the slope of the hanging wall and footwall being similar (~37° and ~40°, respectively), and at the southern end of the canyon, which in our model represents a more mature landscape, the slopes of the hanging and footwall are ~23° and ~57°, respectively. As expected, this asymmetry is reflected in fracture intensity data, where fracture spacing is only ~1.4 m in the hanging wall relative to ~9.1 m in the footwall. Thus, we hypothesize that the evolution fault-controlled landscapes are strongly impacted by damage zone development, where fracturing associated with fault propagation and slip accumulation leads to the development of the fault-parallel valley, and the asymmetry in damage zone development will lead to an asymmetry in slope, with shallower slopes associated with higher fracture intensity.

POSTER 96-22, ABSTRACT 391383, BOOTH 59

TRACE ELEMENT CHEMISTRY OF SALT SOURCES AND THEIR RELATION TO ANCIENT MAYAN SETTLEMENTS IN SOUTHERN MEXICO AND GUATEMALA

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The use of salt and the access to salt sources has been an extremely important aspect of understanding the health, the mobility, and connectivity of Maya populations of Southern Mexico and northern Central America. Due to the high altitude and inland locations of many settlements and the relative scarcity of meat in the traditional diet, salt was a necessary but difficult to acquire nutritional supplement. In several regions, salt springs can be found flowing from uplifted sedimentary rocks in the region containing salts representing past ocean chemistry result in differing trace element chemistry than modern created salt in the environments near the ocean. Using differences in trace element chemistry, assessing regional geography, and anomalies in bone chemistry from previous work by Friewald, et al., we seek to provide a clearer relationship and understanding of where salt was accessed for diets and the relationships between various Mayan settlements. Samples were collected from several salt water springs in the region and solid salt samples were collected from geologic deposits and modern Mayan villages where salt processing from the springs is still being done. Using Inductively Couple Plasma-Optical Emission Spectroscopy, we analyzed these samples for trace element chemistry of metals and metalloids and made comparative analysis between the brine and solid solutions to shed light on plausible relationships between the two.

Poster 96-23, Abstract 391394, Booth 60

CARBON STOCKS AND EROSIONAL PROCESSES ON SELECT ISLANDS OF THE TIMUCUAN ECOLOGICAL PRESERVE IN NORTHERN FLORIDA

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The Florida Department of Natural Resources designates "critical shoreline erosion" based partially on whether areas adjacent to the Atlantic Ocean or if areas have a value for recreation or development. Due to sea level rise and erosional forces, however, many inlets and estuaries in Florida are also being eroded and eaten away, altering carbon cycling, sedimentation rates, and the release of greenhouse gases into both the ocean and atmosphere. We are investigating Big and Little Talbot Island located in Duval County on the Atlantic Coast of Florida where we conduct research oriented around erosion, carbon stores, and carbon loss. These two islands are of special significance because due to a combination of development and sea level rise are eroding rapidly. High rates of erosion are occurring along the edges of Big Talbot Island (located in the Nassau Sound) and despite the rapid erosion rates and high concentrations of peat in the soils, they are not included as critical erosion shorelines. The soils here are typical spodosols with thick O horizons, often more than 7 cm thick. Vegetation transitions from old live oak hammock forests, to short palmetto dominated, to coastal dune pines and cedars as the elevation descends toward sea level. Our data collection so far indicates that even small islands such as this contain nearly 150,000 tons of below ground carbon and above ground carbon totaling near 100,000 tons. Shoreline erosion rates will be presented based on historical shore line locations.

Poster 96-24, Abstract 391471, Booth 61

USING SOIL AND FOREST TYPE TO MAP BEDROCK AT NEMO, SOUTH DAKOTA

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Bedrock mapping can be used to locate economic deposits, assess natural disaster (e.g., landslide) risk, and decipher the geologic history of a region. Methods such as direct sampling, aeromagnetic surveys, changes in topographic relief and soil cover can be used to map bedrock. This study examines a site at Nemo, SD to assess whether two contrasting types of bedrock produce different soil that result in different types of forest cover. Although bedrock varied, other soil forming factors, including climate, slope, elevation, and the time for soil

development, were uniform. Within an approximately 1 km^2 area, quartzite and metagabbro bedrock, and ponderosa pine and quaking aspen forests were mapped. Samples of surface soil, soil profiles, and bedrock were collected. Elemental composition was measured by X-ray fluorescence. Soil organic content was measured by loss-on-ignition and soil nutrient content measured at a commercial soil testing lab. Both the quartzite and its overlying soil have less Mg and Fe, and greater Si content than the metagabbro and its overlying soil. The soil above the quartzite bedrock is thinner, sandier, has a lower cation exchange capacity, and lower phosphorus content than soil overlying the metagabbro bedrock. The forest above the quartzite is dominated by ponderosa pine (*Pinus ponderosa*). In contrast, the soil above the metagabbro bedrock is thicker, contains more clay, has a higher cation exchange capacity and more phosphorus than soil overlying the quartzite. The forest above the metagabbro is dominated by quaking aspen (*Populus tremuloides*) and contains an iris (*Iris germanica*). A soil with a higher cation exchange capacity holds more nutrients and water than a soil with a low cation exchange capacity. Phosphorus is an important nutrient needed for growth and development of plants. The increased cation exchange capacity and phosphorus content of the metagabbro-derived soil may account for the corresponding quaking aspen forest as quaking aspen require more water and nutrients to thrive than ponderosa pine. Ponderosa pine is more tolerant of nutrient deficient conditions such as the quartzite-derived soil. These preliminary data indicate that at this location soil properties and forest cover can aid in bedrock mapping.

Poster 96-25, Abstract 394003, Booth 62

Austin A. Sartin Outstanding Poster Award Winner

GEOLOGICAL INVESTIGATIONS OF BEDROCK AND SURFICIAL GEOLOGY IN THE SOUTHERN HALF OF THE RAWLEY SPRINGS QUADRANGLE, VIRGINIA

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This field mapping project studied the southern half of the 7.5’ Rawley Springs Quadrangle in western Virginia in order to improve understanding of the North Mountain thrust fault system and structural and fluvial features in the area. The project identified lithologic contacts, structural fabrics, and surficial features in a region where existing geologic maps are at the 1:100,000 scale (Rader and Wilkes, 2000). The project also filled gaps in knowledge of the region where data was either lacking or needed to be reanalyzed and updated. Field data from this project was used to create new bedrock and surficial geologic maps at the 1:24,000 scale, which compliments ongoing mapping in the adjacent Singers Glen and Briery Branch Quadrangles (D. Doctor, M. Heller, R. Orndorff, personal communications). This project provided a capstone experience for senior undergraduate geology students. Early career undergraduate students also participated in the project as field assistants and gained hands-on experiences with fieldwork and geologic map preparation.

Field observations documented four formations in the region: the Hampshire, Price, Greenland Gap and Brallier Fms. Field data was collected using the StraboSpot app. Preliminary strike and dip data were used to infer lithologic contacts, which were subsequently evaluated in the field. Field data indicates shallowly southeast dipping sedimentary rocks throughout the majority of the quadrangle. However, in the southeast portion of the quadrangle, the bedrock is oriented subvertically and synclinally folded and complexly faulted in the footwall of the North Mountain thrust fault system. Surficial mapping used aerial LiDAR data to identify potential landforms with field checking to verify the presence of landforms and associated deposits. The surficial data shows dendritic drainage in the western part of the mapping area that exhibits subhorizontal bedding, which shifts to a trellis drainage pattern across the vertical beds in the southeast. Using field data collected with StraboSpot and aerial imagery, final maps were prepared using ArcGIS. Ongoing mapping continues to refine our geologic understanding of the Mid Atlantic Valley and Ridge region.

Poster 96-26, Abstract 392095, Booth 63

FINDING SUSTAINABLE SOLUTIONS TO SHORELINE EROSION USING DETAILED SLOPE MEASUREMENT WITH A LASER TOOL

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Shoreline erosion is a very serious problem for anyone who lives next to an ocean or the great lakes. This problem has only gotten worse due to climate change causing rising water levels and increasing intense weather causing more erosion. Creating 3-dimensional maps of unstable slopes using devices like Leica's DISTO E7500I, helps us better understand the overall slope dynamics as well as what factors may be causing it to fail.

The focus of my research is to find a more environmentally conscious solution to shoreline erosion that does not negatively affect the existing ecosystems and provides long-term benefits for the people it affects. My current field area is along the shorelines of Lake Superior and Lake Michigan. I am using a Leica DISTO E7500I device to create maps of areas of erosion to better understand their structure. I have found this device incredibly useful as it is able to measure the length of a particular section as well as the angle between two points. Using this device also allows me to safely measure the slope at the bottom as opposed to having to climb a very uneven and unstable terrain. Using this device is also much cheaper and easier than using a drone to take aerial measurements.

Our approach might be able to provide detailed data for implementing remediation measures other than short-term "Hard stabilization" methods such as breakwaters and groins. Those measures often end up making the issue worse in the long run.

Our initial idea is that native plants can be used to help hold the soil in place as well as terracing the slope in order to reduce the undercutting that happens on slopes. We plan to test our hypothesis in small and large scale settings to see if these solutions might be beneficial for homeowners. Erosion will always be a problem and we are not attempting to completely solve the problem, just make it more manageable for homeowners to handle.

Poster 96-27, Abstract 395320, Booth 64

ASSESSING THE STABILITY OF STATEN ISLAND'S EASTERN SHORE: A SEDIMENT ANALYSIS

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For years, the eastern beaches on Staten Island, New York have been undergoing coastal engineering and replenishment, especially after the devastation and inundation caused by Hurricane Sandy. Understanding the processes operating on these beaches is essential to assessing future risks and planning coastal defenses. In this study, sediment samples were collected at low tide from transects on the eastern beaches of Staten Island over the course of a year. Each transect included samples from 1m water depth (offshore), the low tide mark, and the beach face. These samples were analyzed for grain size distribution to confirm that the beaches have the characteristics of a reflective beach. The results show that there are minimal changes to grain size distribution over time. Offshore samples are the most variable, with mean grain size from fine sand to very coarse sand. The low tide mark is characterized by a ridge of sediment that is mostly sandy gravel and gravelly sand. Beach face sediments are generally medium to coarse sands, while medium sands are found higher on the beach profile. These characteristics indicate reflective beaches. Therefore, there should be minimal changes expected to the coastline year by year. One part of the beach that is subject to the most erosion is protected by an artificial dune, which erodes and supplies sand to the beach during storm events. In this area, we observed that the beach sediment is more fine-grained than elsewhere, suggesting that the artificial dune is not composed of sand that is typical of the natural beach. However, as a reflective coastline, it remains extremely vulnerable to storms, which would have the potential to significantly alter the beaches over a short amount of time.

Plans for the eastern coast of Staten Island include the construction of a buried seawall, covered in sand, to protect low-lying residential areas from the effects of future storms. Sea walls potentially increase beach erosion, although this design should "feed" the beach with sand when it is eroded. Future sample collection and analysis after the completion of the seawall will show if there are any significant changes to the Staten Island beaches as a result of this construction.

Poster 96-28, Abstract 395926, Booth 65

COASTAL VULNERABILITY AND RESISTANCE: A YEARLONG STUDY OF STATEN ISLAND BEACHES

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On October 29th, 2012, superstorm Sandy made landfall on the mid-Atlantic coast causing severe damage throughout the region. The eastern coastline of Staten Island in particular showed its vulnerability to storm surges as the neighborhoods around the surrounding area were extremely inundated, resulting in lives lost and billions of dollars in damages. Surveying on the beach during previous studies has shown that the beach in question is reflective, suggesting limited seasonal changes but can experience significant erosion during major storm events. This current work expands on the initial surveying completed in 2018 by taking regular beach surveys over the course of a year. These surveys consist of measuring the slope of the beach in 2-meter intervals, using a ranging pole and a transit, as well as collecting sediment samples at the low tide ridge, the high tide mark, as well as other significant locations throughout the beach.

In this project, beach surveys were conducted between summer of 2022 to 2023 using comparable methodologies. Building upon previous studies, these measurements were also brought into ArcGIS to better understand the coastal morphology. Inverse distance weighted (IDW) interpolation was used to identify values between sampling transects to create a continuous dataset of the beach surface. This technique will help us understand how the coastline has responded to disturbances to better predict the future response of the coastline to storm events.

Results confirm that the beach is reflective, based on the beach face slope (5° to 9°), ridge of coarse sediment at the low tide line and lack of significant variation in morphology over the course of the year. Most of the variability is related to longshore currents interacting with groins, resulting in areas of erosion and deposition with movement of between 1-2 meters. Winter storms also move some beach face and berm sediment offshore, and it gradually builds back over the summer. Overall, this survey provides a useful baseline that can be used to understand changes that will occur after the construction of a buried seawall and the influence of future storms.

Poster 96-29, Abstract 392370, Booth 66

ANALYSIS OF GLACIAL STRIAE AT THE TALCVILLE QUARRY, NY: TRACKING STRIAE PROVENANCE AND ICE DEFLECTION AROUND THE ADIRONDACK MOUNTAINS

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Evidence of a glacier's basal movement can be challenging to discover due to subsequent weathering and covering by the retreating glacier. Thanks to mineral prospecting, however, in Talcville, NY, an approximately 0.3-hectare site of striated talc-tremolite schist became exposed for striae analyses. This "pit", geologically, is part of the greater Frontenac Axis, which geomorphologically represents a hectometer-scale, northeast-southwest ridge-and-valley system (cf. Miller and Stewart, 2014). Using a compass, 2,901 azimuths of type-2 striations were measured across seven exposures (or pods) of polished whalebacks. In addition, 1,989 widths, 342 lengths, and 186 hardness measurements were collected using a caliper/measuring tape and hardness-testing kit. Using the EZ-ROSE program (Baas, 2000), all azimuths (n=2,901, mean of 011.6°, σ of 6.4°) were subjected to the Kuiper, Rayleigh, and Watson tests, all of which demonstrated a unimodal distribution with 99% confidence. Linear data were descriptively analyzed with mean striation length of 44mm (σ=7.0), width of 1.7 mm (σ=2.0), and Moh's hardness of 5.1 (σ=2.1). Local joints and regional structure measure approximately 036-216° (Miller and Stewart, 2014) and are distinct from these striae suggesting the glacier flowed at an acute angle to the regional structure and topography. We estimate, by extrapolating our linear data, that at any one moment, 0.5-1.0m^3 of bedrock was removed from this site (approximately equal to the volume of a standard refrigerator's interior). Inclusion of Moh's hardness data suggests the striators must have been at least greater than the 5.1 hardness on average, but as high as 8.5, and, in conjunction with a 1-standard-deviation striae wedge up ice were likely sourced proximally from <35 km north or distally, from southern Quebec, CAN over 150 km away. Additionally, we infer that the flow of the glacier was not bedrock controlled, but likely deflected around the western Adirondack Mountains during an ice advance, as the glacier flow was more vigorous than topographic control, but not greater than the control of the western Adirondacks Mountain edge.

Poster 96-30, Abstract 392424, Booth 67

CORRELATION OF DISTAL ~13-10 MA COUGAR POINT TUFF UNITS IN THE BIG DEVILS TABLE-SALMON FALLS CREEK AREA, KNOLL BASIN, NE NEVADA, USING MAJOR MINERAL ASSEMBLAGES

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Knoll basin is a Miocene extensional basin adjacent to the Bruneau-Jarbidge volcanic center, which erupted at least nine large-volume ash-flow tuffs known collectively as the ~13-10 Ma Cougar Point Tuff (CPT). The welded CPT XIII unit has been identified by tephrochronology in the eastern part of the basin where it marks the southeastern limit of the unit and typically contains augite as the only ferromagnesian mineral. Our new mapping in the NW portion of Knoll Basin, the Big Devils Table area, reveals the presence of six welded units of the CPT. These units are interbedded with clastic sediment of the Humboldt Formation and are informally referred to as units 1 through 6.

The goal of our research was to correlate units 1-6 to known eruptions of the CPT using the identification of major minerals. Major minerals were extracted from samples by crushing, sieving, and heavy liquid separation. Mineral identification was done using a petrographic microscope and a SEM with an EDS attachment. Our preliminary results indicate that two of the nine known eruptions of the CPT, CPT XII and CPT III, are not represented in the six units because they do not contain minerals diagnostic of those units. The stratigraphically highest and youngest unit, Unit 1, correlates to CPT XIII because of the occurrence of augite as the only ferromagnesian mineral. Units 2 and 3 contain the same mineral assemblage as Unit 1 and are also correlated to CPT XIII, indicating these units have been repeated by normal faulting. This correlation is corroborated by the occurrence of Paleozoic sedimentary and Mesozoic granitic lithic fragments present in units 1, 2, 3, and their absence in other units. The sample from unit 4 did not have enough ferromagnesian grains to conduct an accurate analysis. Units 5 and 6 both contain augite and pigeonite indicating they correlate to two of the following older CPT units: XI, X, IX, VII, and V. Augite in units 5 and 6 show increasing magnesium and decreasing iron content, typical of older CPT units.

In conclusion, testing for diagnostic mineral assemblages is useful for correlating CPT XIII between isolated outcrops. In turn, these correlations allow for recognition of faulting in areas with abrupt sedimentary facies changes and similar looking tuffs.

Poster 96-31, Abstract 396072, Booth 68

LATE-STAGE (CA. 745-740 MA) FELSIC VOLCANISM IN THE MOUNT ROGERS AREA, SW VA: IMPLICATIONS FOR ABORTED RIFTING AND ONSET OF GLACIATION

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In southwest Virginia, along the border of North Carolina and Tennessee, is a relic of a Neoproterozoic failed rift-arm that formed on the (present-day) eastern Laurentian margin as the Rodinian supercontinent began to destabilize and break apart. A bimodal volcanic suite, the Mount Rogers Formation (MRF), erupted onto the rifted crust ~760-750 million years ago. In recent field research, we have identified a younger, late-stage rhyolitic complex, erupted ~745-740 Ma. The Rocky Hollow complex (RHC), as we have informally designated this unit, is comprised of porphyritic rhyolite, crystal and lithic rhyolitic tuff, and volcaniclastic conglomerate, with associated coarse arkosic sandstone. Basaltic dikes of uncertain age intrude the complex. In this study, we describe in detail the lithologies and textures of the Rocky Hollow complex using hand-sample and optical petrography. In addition, we will compare whole-rock geochemistry of the RHC rhyolites to the main MRF rhyolites.

The Rocky Hollow complex appears to fill a transitional period between the volcanics of the MRF and the overlying glaciogenic Konnarock Formation, the latter of which has been interpreted as deposited during the 717-635 Ma Sturtian "Snowball Earth" glaciation. Apparent interlayering of the RHC with the lower part of the Konnarock Formation calls this interpretation into question.

Poster 96-32, Abstract 394708, Booth 69

GRAIN SIZE DISTRIBUTION AND POROSITY'S EFFECT ON URBAN SEDIMENT UNDER LAVA FLOWS

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The purpose of this study is to better understand how sediment characteristics, such as grain size distribution and porosity, affect heat transfer. A better understanding of the heat transfer properties of sediments and soils can help municipalities, urban planners, and private companies plan out projects which are sensitive to high temperatures. The study used an angular limestone sandy gravel, from which a 1 mm and 2 mm size fraction was separated. The sediment was sieved in order to determine grain size distribution and textural group. The size of the sieves used ranged from 4 mm to 0.063 mm. Water filled porosity was calculated by determining each sediment's Visual Pore Volume (VPV) and Different Weight Pore Volume (DVPV). Porosity (VPV) ranged from 23% to 28.75% for the limestone gravel. Porosity for 1 mm limestone gravel was between 43 and 44%, whereas porosity for the 2mm limestone gravel was at 45.75%.

Heat transfer tests were conducted in small laboratory experiments. Heat was applied in the form of remelted basalt (50-60 ml) which was poured on the surface of a dry sediment column above a vertical array of thermocouples at 0 (melt contact), 1, 3, 5, and 7 cm. Thermal measurements were collected for 2 hours after the pour. The time for a temperature of 100 C to be recorded at 3 cm depth was 17 minutes and 37 seconds for the poorly sorted limestone gravel, 19 minutes and 26 seconds for the 2 mm gravel fraction, and temperatures never reached 100 C at a depth of 3 cm for the 1 mm gravel. Max temperatures for 1 mm gravel at a depth of 3 cm were 92.7 C. That temperature was reached 24 minutes and 42 seconds after the start of the pour. Sediments with less pore space were better insulators with slower times for transmitted heat.

This focused study compliments experiments at the University at Buffalo that use larger volumes of melt to explore the heat transfer through sediments with a wider range of characteristics and moisture contents. Future small-scale studies could focus on the relationship between particle shape and heat transfer as particle shape is an important factor of the thermal conductivity of sediments. Quantification of the sensitivity of heat transfer to sediment characteristics is a fundamental first step to providing inputs to urban design and better reading of the geologic record.

Poster 96-33, Abstract 394880, Booth 70

COUPLED ANALYSES OF SEDIMENT MAGNETIC PROPERTIES, TEXTURE, EROSION RATE, AND STRATIGRAPHIC PERIODICITY IN RAPIDLY ACCUMULATING FAN DELTAS

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We explore time series of magnetic susceptibility (χ) and anhysteretic remanent magnetization (ARM) in settings of rapid sediment accumulation rate (SAR) with the goals of partitioning exogenic forcings from autogenic processes and to better understand how these magnetic signals are encoded in sedimentary archives. Environmental signals of

periodic external forcings commonly operate at Milankovitch frequencies, but in rapid SAR settings autogenic processes including channel avulsions and delta lobe switching both shred high-frequency external forcings, or even impart their own quasi-periodic signals. We measure χ using both a hand-held KT-10 magnetic susceptibility meter and a lab-based Kappabridge KLY-3s, and ARM in the < 2 mm size fraction using a GSD-5 alternating-field and a 2G superconducting magnetometers, with all results mass normalized to SI units. We focus on 40 samples collected at 25 cm intervals from 10 m of propagating foresets in a Gilbert delta of the Provo stage of Lake Bonneville at High Creek, Utah. A luminescence-based age model in this delta establishes a mean SAR of 8 cm/yr and terrestrial cosmogenic nuclide concentrations of both delta sediment and alluvium in the source indicates modern and paleoerosion rates (E) ranging from ~60-100 m/Myr (0.006-0.01 cm/yr). Periodicities of 18 and 33 yrs in the rock magnetic time series are greater than twice the compensation time for these foresets where peaks in χ and ARM are positively correlated with fine-grained matrix. We interpret a positive correlation between E and χ as driven by stripping of soil-mantled hillslopes that harbor greater concentrations of magnetic minerals than the underlying bedrock. The encoding of the environmental signal, here interpreted as autogenic cascading of sediment on foreset surfaces, is primarily set by the SAR and depositional processes, which are decoupled from E. Nevertheless, the strength of the magnetic signal in our sedimentary archive varies with E which can be more widely explored as a E-proxy when locally calibrated. These results offer insight into how to isolate the impact of quasi-periodic tectonic forcings on stratigraphic archives at sub-Milankovitch frequencies, where autogenic processes dominate depositional processes but which also encode critical human-dimension natural hazard information.

POSTER 96-34, ABSTRACT 393727, BOOTH 71

SURVEYING THE REACTIVITY OF DISSOLVED ORGANIC CARBON WITHIN THE STREAM-GROUNDWATER INTERFACE OF THE KALAMAZOO RIVER, ALBION, MI

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Dissolved Organic Carbon (DOC) is an important and abundant chemical and physical aspect of stream ecosystems. Urban environments, including infrastructure such as non-permeable concrete and storm drains, change how the landscape conveys water, and therefore DOC, to rivers like the Kalamazoo River. When DOC reaches the river, it interacts with the biogeochemical processes within the river, including within the hyporheic zone. The hyporheic zone is the highly bioreactive, shallow subsurface of the stream bed where stream and groundwaters mix. We hypothesized that DOC degradation will vary across different DOC sources. We created a variety of DOC leachates from deciduous leaves obtained across the Kalamazoo River Watershed. Then, we conducted push-pull tests with a solute that included environmental water, leaf leachates, and a conservative tracer to simulate the rapid input of landscape DOC into the hyporheic zone. Samples were withdrawn from the area in regular intervals over approximately four hours, then analyzed for both DOC and Chloride content. We assessed the reaction rates of each different carbon source and have found that rates do appear to vary across sources.

POSTER 96-35, ABSTRACT 394811, BOOTH 72

EFFECTS OF NITRATE ON ARSENOPYRITE OXIDATION DURING AQUIFER STORAGE AND RECOVERY CONDITIONS

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An increasing number of regions are tasked with combatting groundwater availability and quality issues. A growing reliance on groundwater due to population growth and climatic changes have motivated the onset of groundwater enhancement techniques such as aquifer storage and recovery (ASR). ASR often involves injection of treated wastewater and later retrieval from a dual-purpose well. One the most observed issues with this technique is contaminant mobilization, namely the release of arsenic species via oxidative dissolution of arsenic-bearing minerals. Consequently, previous research has focused on how oxygen, and other electron acceptors facilitate this reaction. However, few studies have thoroughly investigated the specific role nitrate has on arsenic release within ASR conditions. Appreciable amounts of nitrate can be introduced into groundwater via injection during ASR, and other anthropogenic sources. Thus, this research aims to characterize the geochemical changes occurring from nitrate induced oxidation of arsenopyrite during ASR conditions. To simulate ASR conditions, triplicate microcosms were created that contain arsenopyrite, partially treated municipal wastewater, and local Florida groundwater. Microcosms were then sparged with nitrogen gas and sealed to create an anoxic environment. Nitrogen gas bags were attached through tubing to maintain anoxic conditions, along with secondary tubing for sampling. Four additional microcosm triplicates were created as controls for this experiment. Changes in chemical species within the microcosms are being determined using ion chromatography. Preliminary data suggests that non-nitrogen species may preferentially facilitate arsenopyrite oxidation under ASR conditions. Samples are continuing to be analyzed to fully understand the temporal geochemical changes. Further results and analyses will be presented at the 2023 Geological Society of America Connects Meeting. This research will provide improved understanding of arsenopyrite oxidation during ASR that should be considered to assist in minimizing arsenic mobilization in groundwater. The findings of this study will have important implications for protecting human health, enhancing environmental engineering practices, and guiding future research.

Poster 96-36, Abstract 394877, Booth 73

CHARACTERIZING RICE CROP HYDROLOGIC HISTORY AND IMPLICATIONS FOR ARSENIC UPTAKE THROUGH THE USE OF STABLE ISOTOPES

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Rice provides 20% of the calories consumed by humanity and is thus central to the global food supply and human nutrition. However, rice often contains elevated levels of arsenic, which is toxic to humans consuming the rice and to the rice crop itself. Thus, high concentrations of arsenic in rice represent a significant human health risk and a threat to rice yields, posing a risk to food security. The mobilization of arsenic from the soil is dependent on redox conditions which are strongly influenced by soil moisture conditions of the rice paddy. However, the role of soil moisture, which exhibits significant variation within and across growing seasons, on arsenic uptake into rice remains poorly understood. To address spatial and temporal variations in rice grain arsenic, we have collected paired rice and soil samples at approximately 80 field sites in Cambodia. Here we use in-situ and remotely sensed measurements of soil moisture throughout the growing season of the sampled rice, and we connect these soil moisture histories of each field to our measures of rice grain arsenic and stable isotopes of carbon and nitrogen in the rice grain. We aim to apply rice grain stable isotopes of C and N as proxies of the integrated environmental conditions experienced by the rice crop and to relate this to the uptake of arsenic into the grain – an important issue as a large fraction of Cambodians rely on rice farming for their livelihoods and more than 70% of calories consumed within the country come from rice.

Poster 96-37, Abstract 394903, Booth 74

PHOSPHOROUS AND THE IREVIKEN BIOGEOCHEMICAL EVENT

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At least seven major biogeochemical events have been identified within the Silurian Period, with the Ireviken Biogeochemical Event (IBE), occurring at the Llandovery-Wenlock boundary, being the most well-known and well-studied. Previous carbon and sulfur isotope data from the Altajme core, drilled in Gotland, Sweden, demonstrate that this major positive carbon isotope excursion was likely driven by an expansion in reducing marine environments and an increase in organic carbon burial. However, these carbon isotope excursions can also be linked to changes in primary productivity. Whereas phosphorous is a critical nutrient for primary productivity, and therefore a good indicator of any potential productivity events, there are currently no phosphorous data available from this event. To investigate the role of primary productivity in the IBE, samples were taken through this interval in the Altajme core for P extraction.

Phosphorous exists in different phases, and therefore the total P concentration in the sediment cannot be used by itself as an accurate measurement of bioavailable P in the water column through time. As a result, the SEDEX sequential extraction method was used to isolate five different sedimentary P reservoirs for quantification, including Fe-bound P, authigenic P, detrital P, and organic-bound P. The data from these samples provide important information about the timing and magnitude of changes in marine nutrient cycling during this global biogeochemical event.

POSTER 96-38, ABSTRACT 394978, BOOTH 75

CHARLES J. MANKIN OUTSTANDING POSTER AWARD WINNER

INSECT HERBIVORY FROM THE MIDDLE EOCENE CLAIBORNE FORMATION AS AN ANALOG FOR FUTURE CLIMATE CHANGE

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Understanding past increases in atmospheric CO_2 and the potential concomitant shift in habitats is essential for assessing the future impacts of anthropogenic climate change. Despite filling incredibly important ecological niches, it is not well constrained how future climate change will affect insects and their corresponding impacts on the surrounding environment. The Middle Eocene is an interesting analog to future climate change as it is a time when CO_2 levels were two times greater than modern, and therefore offers a unique glimpse into a high CO_2 world. The Claiborne Formation in Kentucky contains fossil leaves with exceptional preservation which allows for a preliminary study of insect herbivory. Here we analyze the frequency as well as diversity of functional feeding groups, specifically specialized feeding, as laid out by Labandeira to gain insight into these interactions during periods of higher CO_2 concentrations. Statistical analysis allows us to correlate feeding groups and amount of insect damage to climate variables. A comparison to previous studies from different fossil localities throughout geologic time suggests that amount and diversity of insect damage are positively correlated with changes in the partial pressure of CO_2 and temperature. The high CO_2 world of the middle Eocene offers a unique analog to study the consequences of climate change on a very important group of organisms: insects.

POSTER 96-39, ABSTRACT 395002, BOOTH 76

USING TESTATE AMOEBAE AS BIOINDICATORS OF WATER QUALITY AND ECOSYSTEM HEALTH IN THE STONES RIVER WATERSHED IN MURFREESBORO, TN

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Tennessee is one of the fastest growing states in the nation. Increasing populations can lead to issues with managing waste. Middle Point Landfill in Murfreesboro is an 808-acre facility that accepts 3,700 tons of waste a day from 34 counties across Tennessee. In 2022, the city of Murfreesboro filed suit in federal court against the owners of the landfill alleging that toxic substances had been released into the East Fork of the Stones River by the landfill. This claim has been denied by the owners of the Middle Point Landfill, who have blamed the adjacent smaller Rutherford County Landfill. In this project, we will analyze ecosystem health in the Stones River watershed by analyzing the populations of testate amoebae. These microscopic, unicellular protozoans are found in sediment from freshwater localities, produce a mineralized shell, and have been shown in numerous previous studies to respond to environmental changes. They are considered to be bioindicators that can serve as a proxy for ecosystem health.

Several other issues are affecting the water quality within the watershed, including urban and residential runoff and infestations of invasive aquatic plant species, including parrot-feather or *Myriophyllum aquaticum*; water primrose or *Ludwigia* sp.; and alligator weed or *Alternanthera philoxeroides*. A study within the waterbodies within the Stones River watershed in 2017 showed eutrophication and hypoxia with high ammonia and chlorine levels in the water. This project focuses upon eight locations within the watershed, including locations up- and downstream of the Middle Point Landfill on the East Fork of the Stones River.

Initial results from the East Fork of the Stones River show that testate amoebae were absent from the sample immediately downstream from the landfill. Further downstream we found both opportunistic species, such as *Centropyxis aculeata*, and species found in areas with high levels of organic content, such as *Difflugia oblonga*. This population is similar to the population found in a sample from the West Fork. Samples from the wetlands infested with invasive aquatic species show high abundances of *Difflugia*, indicating higher organic content. Final results will include statistical analyses of populations from each location.

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Poster 96-40, Abstract 395147, Booth 77

RELATIVE ABUNDANCE DISTRIBUTIONS OF BRACHIOPODS FROM THE LATE PALEZOIC OF NEBRASKA AND KANSAS

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Stratigraphic boundaries typically are defined by faunal turnover, but not necessarily by any major changes in general ecological structures in communities. Here, we use relative abundance distributions (RADs) to summarize basic ecological structure among Pennsylannian and Early Permian brachiopod communities from Nebraska and adjacent regions. In particular, we assess whether differences in faunal composition correspond to degrees of difference in types of best-fit abundance distributions. We use brachiopod specimen counts from 100+ collections found in 14 formations, from the oldest date to the youngest date. For each collection, we find the best-fit models for five basic models: Geometric, Log-Series, Zero-Sum Multinomial, Lognormal and Zipf. The first three models assume that species compete for the same general resources (e.g., all are suspension feeders) and that factors such as immigration rates, population growth rates have much greater effects on relative abundance than do ecological interactions. The final two models assume that ecological interactions such as niche-partition, niche construction, and direct interactions also have strong effects on community structure. We find the most likely distributions based on the probability of the observed numbers of species with 1, 2, etc., specimens given a hypothesized true number of species, a particular RAD and the sample size. We then contrast the distributions with differences in taxonomic composition and environment as indicated by rock lithologies.

Previous results and studies indicate that there is no clear temporal or environmental pattern in differences among RAD. There also is not a clear trend towards increasing "modernization" of RADs moving from the Pennsylvannian to the Permian, which is consistent with the notion that the major shift is concentrated in the Permian/Triassic transition. Our goal then is to see if any shift at all is occurring.

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Poster 96-41, Abstract 395534, Booth 78

PALEOBOTANICAL RECONSTRUCTIONS OF THE CLIMATE AND ECOLOGY OF THE CANADIAN HIGH ARCTIC DURING THE EARLY PALEOGENE

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The early Paleogene was characterized by multiple hyperthermal events, such as the Paleocene Eocene Thermal Maximum (PETM) and the Eocene Thermal Maximum 2 (ETM2), which caused marked increases in temperature that can be recognized in the fossil record by changes in flora and fauna. The Arctic is of significant interest during these hyperthermal events because warming and other climate changes were likely most pronounced in polar regions. We reconstruct climatic and ecological changes of the Arctic during the early Paleogene before and after the PETM using fossil leaves collected by the late L.J. Hickey from Ellesmere and Axel Heiberg Islands in the Canadian High Arctic. We photographed the entire Hickey Arctic collection housed at the Yale Peabody Museum and digitally measured a variety of morphological characteristics, such as blade area and perimeter, petiole width, and margin state, from all leaves that were at least 25% complete. We then reconstructed mean annual temperature (MAT) and mean annual precipitation (MAP) using the leaf physiognomic methods Digital Leaf Physiognomy (DLP), Leaf Margin Analysis (LMA), and Leaf Area Analysis (LAA), as well as reconstructed leaf mass per area (Ma) to estimate leaf lifespan. Preliminary results indicate that the climate of the Paleocene and Eocene was warm and relatively wet and that the floras were temperate forests with predominately deciduous taxa. Future work will assess differences between Paleocene and Eocene climate and floral community ecology. The results of this work help provide a better understanding of high latitude ecosystems. This in turn can help provide important insights into the climate of polar regions during warm times in Earth history which has important implications the future given the current global climatic warming trends.

Poster 96-42, Abstract 395575, Booth 79

HOW THE HISTORY AND DEVELOPMENT OF CLEVELAND'S REDLINED AREAS AFFECT SOIL LEAD CONCENTRATIONS AND OTHER SOIL PARAMETERS

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Today Cleveland remains one of the most segregated large cities in the United States, where the legacy of redlining from the 1930s has been linked to persisting economic, social, and health inequities. Here, we ask whether Cleveland's legacy of redlining is connected to modern environmental metrics such as heavy metals in the soil and soil health. We sampled over 30 sites and 100 subsites evenly distributed among the four Home Owners' Loan Corporation (HOLC) neighborhood categories. Soil lead was quantified by XRF analysis. Other soil parameters, such as soil organic carbon and bulk density, were measured. We analyzed residential lots (near street, yard, and dripline), community gardens, and playground samples using ANOVAs and Linear models. Redlined (HOLC category "D") communities averaged higher lead concentrations but failed to be significant ($p = 0.305$). For residential properties, the best data model determined by AIC included the location within the property and house age ($p = 0.006$), with home age and yard location accounting for 20% of the variation. High-exposure locations such as playgrounds and food gardens generally had lower soil lead levels, with playgrounds having the lowest mean concentrations ($p=0.047$), regardless of the HOLC category. Additional results on other soil parameters, such as bulk density, soil organic carbon, and pH, are pending. We continue our work by exploring other explanatory factors, such as exterior building material and the role of gentrification. Our results are consistent with the historical use of lead-based paint and with those from other cities sampled as part of the Redlining Metal Network.

Poster 96-43, Abstract 395586, Booth 80

INVESTIGATING THE STRUCTURE OF AGATES AS AN EARLY UNDERGRADUATE STUDENT RESEARCH PROJECT AT DELAWARE COUNTY COLLEGE

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Our goal was to analyze a fluid filled agate and note the structures that may be found when one is cut open. Using an electric saw to nick the surface and then a chisel to open and capture some of the fluid. What we found was an interesting needle-like structure within the agate that we wanted to analyze further. Using an electron microscope, to get close images of the structure that were not only beautiful but showed unique features along with an x-ray spectrum to determine the chemical makeup of the agate. Also observed inside were needle like structure that made of Manganese Oxide. These results can tell us the story of the agate and how it formed.

Poster 96-44, Abstract 395599, Booth 81

OAE2 AND THE EASTERN EXTENT OF THE WESTERN INTERIOR SEAWAY IN IOWA

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The Western Interior Seaway (WIS) expanded through much of west-central North America during the Cretaceous. The majority of research on the WIS has been conducted along the axis of the basin, or on the western margin proximal to orogenic events and radioisotopically dateable volcanic materials. By comparison, only a handful of studies have focused on the eastern margin of the WIS and the true geographic extent of the seaway remains a matter of debate.

Here, we produced high-resolution carbonate carbon isotope chemostratigraphy from a core drilled in Sioux County, Iowa, that includes Oceanic Anoxic Event 2 (OAE2) in clearly marine, carbonate-dominated strata from western Iowa. Additional cores in Iowa also preserve the Greenhorn Formation in marine strata and demonstrate that the WIS extended at least well into central Iowa during the maximum transgression during the Late Cretaceous.

Poster 96-45, Abstract 395831, Booth 82

HABITAT ASSESSMENT OF GREAT GRAY OWL (*STRIX NEBULOSA YOSEMITENSIS*) IN YOSEMITE NATIONAL PARK, CALIFORNIA

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Great gray owls (*Strix nebulosa yosemitensis*) in the Sierra Nevada are a genetically unique subspecies (*yosemitensis*) with a small population size and corresponding low genetic diversity. Most of this population resides in Yosemite and the habitat within the park is critical to the persistence of the subspecies. Fortunately, recent technological advances have greatly increased our ability to collect wildlife tracking data yielding precise location and movement information. This information will ensure that imminent habitat modifications meet our objectives of (1) improving great gray owl habitat in the park by producing better foraging habitat and (2) making roadsides less attractive to the owls, thereby reducing wildlife-vehicle collisions. Wildlife-vehicle collisions are the most known source of mortality for adult great gray owls in the park. Fine-scale tracking data will enable a better understanding of roadside conditions that attract or repel the owls, thereby designing tree removal to reduce the chance of future owl-vehicle collisions. In meadows, fine-scale data on habitat use can help inform restoration designs to favor optimal owl forage conditions.

My position title is biology assistant and field technician for the Great Gray Owl Project. The project's goal is to better understand great gray owl nesting and foraging use near roads and reduce owl mortality in Yosemite. Research methods include radio telemetry setup and vegetation protocols for habitat assessment.

Since my first workday (May 22) to my last workday (July 27), I have completed 202 vegetation plots and 101 observation/perch sites recorded from our 4 tagged great gray owls. I learned how to perform radio telemetry setup, VHF tracking, habitat assessment, and observe animals practicing the least invasive method possible. I learned how to complete vegetation protocols for habitat assessment. Through my volunteering in other projects, I was able to learn how to complete owl broadcasting, spotted owl surveys, bird

banding, bat netting, and bear roving. Although data analysis is still ongoing, 30% of the perch sites recorded from owls were less than a mile away from a main road. This proves that research like these is important for wildlife conservation and management in national parks and areas where human presence may alter natural behavior.

Poster 96-46, Abstract 395843, Booth 83

DETAILED STUDY OF UHP PHENGITE FROM A 10-METER TERRANE, TSO MORARI TERRANE, INDIA

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Phengite, the high-pressure form of muscovite, can preserve pressure-temperature conditions and chemical signatures of the fluids present during its growth. The Tso Morari Ultra-high Pressure (UHP) Terrane in NW India is largely made up of white-mica-bearing, quartzo-feldspathic gneiss, which have not experienced retrograde recrystallization, post-UHP, in a uniform manner. On the scale of a 10m traverse perpendicular to the dominant fabric direction, samples in close proximity do not have the same phengite composition. Phengite samples > 5 m from the contact with the eclogite preserved the highest silicon concentrations (6.98 Si p.f.u.) while samples at the contact (TM11) and 2-3 m away preserve intermediate compositions between muscovite and phengite (6.45 Si p.f.u.). If we consider the Si and FeT/Mg values as markers of pressure and temperature respectively, we have grains that grew both at near-peak P-T conditions and at lower pressures during exhumation. Phengite in TM2 have an average Si of 6.88 p.f.u., suggesting preservation of the grains that grew in the UHP event. The compositions of mica grains in TM3 and TM11 have lower counts of 6.42 Si p.f.u. suggesting recrystallization during exhumation. FeT/Mg data shows increasing values from TM2 to TM11, from 2.67 to 6.1 with TM3 at an intermediate value of 4.05. The meter-to-centimeter scale heterogeneity coupled with the strongly expressed banded fabric suggests that the gneiss experienced heterogeneous strain and incomplete recrystallization on its return to the crust. The samples with the UHP phengite preserved will be used in conjunction with another study of boron isotope and trace element data measured in situ on the same grains. White mica (phengite) is the primary mineral used because it is a hydrous, high-pressure phase that characteristically contains boron when tourmaline is absent and is sensitive to P-T changes and in UHP terranes is often preserved even after exhumation. Initial electron probe data has confirmed both high-pressure phengite and retrograde lower-pressure phengite in the samples. The next steps will compare this data to the boron data and see if the micas have distinct in situ δ11B concentrations. Previous studies suggest that the phengite would have low boron concentrations and highly negative δ11B values that are below the range of values expected by MORB basalts and the mantle.

Poster 96-47, Abstract 392781, Booth 84

3D RECONSTRUCTIONS OF AN EDIACARAN SPONGE-GRADE ANIMAL FROM THE PATOM UPLIFT OF SIBERIA

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As a basal metazoan group, sponges are thought to have been among the earliest multicellular animals to develop on Earth. However, the oldest widely accepted examples of sponges in the fossil record date back only to the Cambrian Period, despite estimates from molecular clocks that place their emergence deep into the Neoproterozoic Era. Although reports of Precambrian sponges have been numerous, definitive identification has been complicated by a lack of morphological details or diagnostic features. Here, we provide an update on new work describing recently discovered fossils interpreted as early biomineralizing sponge-grade animals. The fossils are from the Patom Uplift (~565 Ma) in central Siberia, stratigraphically a few hundred meters above the nadir of the Shuram carbon isotope excursion. The centimeter-scale fossil fragments make up a detrital hash, and are preserved three dimensionally in a limestone matrix through mineral replacement of the original tissue by carbonate and pyrite. Earlier descriptions of the fossils highlighted calcified structures interpreted as original biomineralization of a carbonate shell, as well as complex internal canals. We now describe new findings from 3D reconstructions generated via serial sectioning as well as acid maceration. These new analyses have provided an extremely detailed view of the morphology of the fossils. We have expanded upon observations made previously through petrography and microCT observations, and built a more complete model of the fossil organism as displaying mineralized surficial features, an internal lattice-like network of consistently shaped nodes and branches, and abundant exterior pores. These observations are most consistent with a sponge-grade animal assignment. This fossil discovery provides strong evidence for the presence of sponge-grade animals prior to the Cambrian Period, as well as a link between biological evolution and profound changes in the global carbon cycle as revealed by chemostratigraphic events. These observations have significant implications for our understanding of Ediacaran ecology and the evolution of animals.

Poster 96-48, Abstract 395860, Booth 85

SEXUAL DIMORPHIC VARIATIONS AMONG CRETACEOUS HETEROMORPHIC AMMONITES OF A PIERRE SHALE NODULE

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In 2017, an investigative study was performed on an ammonoid specimen from a Campanian-aged nodule obtained from the Pierre Shale Formation in Montana. The specimen was determined to be a microconch of Hoploscaphites nodosus. The nodule also contains a significantly larger specimen encased in a highly indurated matrix of black shale. It is hypothesized that the large specimen may be a macroconch of H. nodosus. Using a microabrasion unit, the matrix will be removed from the larger specimen. Multiple abrasives will be tested to determine the ideal medium to remove the indurated matrix from the specimen. The specimen will then be examined using a camera lucida to image sutures and identify the species and the possibility of sexual dimorphism. The sample will also be measured, and conch characteristics will be quantified using standard calculations. Features, including ornamentation and any mature modifications, will also be identified. The study objectives are determining best practices in microabrasion of a fossil specimen and identifying the specimen as a possible sexual dimorph to the microconch from the 2017 study on the same nodule.

Poster 96-49, Abstract 395949, Booth 86

SOIL CORE ANALYSIS OF THE ASHTON RESEARCH PRAIRIE, IOWA CITY, IOWA

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The Ashton Research Prairie (ARP) is a University of Iowa cross-campus project that is focused on the environmental changes that occur as a landscape is restored to prairie. Subsurface research at the ARP has been delayed because there is a lack of data about the Quaternary succession in the area. Detailed core descriptions, elemental characterization via portable X-ray fluorescence (pXRF), and grain size analyses were conducted on the sediments of the upland area of the ARP to delineate lithologic characteristics and create a basic stratigraphic framework. Using the most complete upland core available, we were able to constrain vertical changes within the succession and correlate sediment packages laterally. Descriptive core logging, monitoring well installation, and stratigraphic determinations were all completed by staff from the Iowa Geological Survey and faculty of the Department of Earth and Environmental Sciences at the University of Iowa. The most stratigraphically complete core was selected to conduct chemical analysis using an Olympus Delta pXRF, as well as grain size analyses using pipette methods and Camsizer. These data have helped better define and distinguish the sediment packages in the subsurface and evaluate water flow through these geologic units. Understanding the Quaternary geology of the Ashton Research Prairie is foundational for several of the hydrologic research projects that are being developed there, including the study of water table fluctuations and how groundwater flows through the Prairie.

Poster 96-50, Abstract 396020, Booth 87

INDIGENOUS PLACE NAMES AS A WAY TO STUDY LAND CHARACTERISTICS

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Indigenous names of geographical locations and towns can grant insight into the area: whether that be the natural features or cultural significance. However, what if the meaning of the name changed? Due to the manner in which settlers from Europe and Native Americans interacted in the 17th-19th century, this was a common occurrence throughout North America. The Indigenous names can give us insight to what the area looked like before settlers arrived compared to now.

For this project my collaborators and I focused on locations in Wisconsin. The primary questions being: what were the original names of areas and how did they relate to the physiographic and environmental features of the area? Many of those features have changed through time due to climate change and/or human actions such as wetlands being drained for farming or forests being cut due to spread of urbanization.

Our project involves: taking the names of Wisconsin locations with original Indigenous names, finding the probable Anishinaabe language(s) in which the place was originally named, then finding possible name meaning(s) with help of a native Anishinaabe speaker. We then examined if the meaning of the original place name is still applicable. In our project, we display our findings with a story map to show the meanings of the original place names.

We hope our project can show how the land features have changed throughout history and learn more about our geologic past. Indigenous place names were originally used to transfer place-based knowledge, and with this story map we can help keep this tradition alive.

Poster 96-51, Abstract 388495, Booth 88

HOW EROSION EFFECTS CARBON ISOTOPIC TRENDS: THE LATE PERMIAN MCKITTRICK LIMESTONE

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Carbon isotopic trends are an essential tool for understanding changes in the global carbon cycle over time and correlating rock units (chemostratigraphy). These applications assume that documented trends are primary and reflect an accurate record of changes through time. However, diagenetic processes and erosion can invalidate this assumption. In this project, we focus on the impact of relatively small-scale (<1 meter) erosion on documented carbon isotopic trends. To accomplish this, we targeted the Late Permian McKittrick Limestone of the Bell Canyon Formation in Guadalupe Mountains National Park. This location is ideal for our study because the outcrop is continuous from crest to slope to basin and previous work allows us to correlate from shallow to deep water environments. We identified a small slump or paleochannel in the McKittrick Limestone that forms the basis of this study. By measuring and collecting samples from two sections within the outcrop, we were able to document how erosion impacted the signal. We have also compared our results to the corresponding rocks in the shallow water of the shelf crest to test for any cryptic erosional events that might have impacted the McKittrick Limestone carbon isotopic record at this location.

Poster 96-52, Abstract 388514, Booth 89

HOW SEDIMENT MIXING AND TRANSPORT INFLUENCES RECORDED CARBON ISOTOPIC TRENDS: PERMIAN REEF TRAIL, GUADALUPE MOUNTAINS NATIONAL PARK

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Carbon isotope geochemistry is a method commonly deployed to help correlate stratigraphic units and to document changes to the global carbon cycle. These applications are based on the assumption that the carbon isotopic value recorded in carbonate sediments reflects the carbon isotopic value of the water at the time of deposition. However, there are possible scenarios where this assumption is not met. For example, allochthonous intraclasts as well as mixing of clasts during deposition could cause recorded values to depart from carbon isotopic values of the water during deposition. In this study we aimed to explore how sediment mixing and transport of clasts influenced carbon isotopic trends by focusing on the Late Permian Yates Formation, Tansil Formation and McKittrick Limestone Member of the Bell Canyon Formation exposed along the Permian Reef Trail in the Guadalupe Mountains National Park. We generated three carbon isotopic records, one for the shallow water shelf crest, one for the slope, and one for the basinal setting. By slabbing samples from the slope, we were able to target and generate carbon isotopic values of various clast types (e.g. intraclasts, transported fossils, micrite). We compared the slope carbon isotopic record to the other settings where mixing and transportation is predicted to be less. From these results, it is clear that transportation and mixing of clasts does impact the generated carbon isotopic trends. This study highlights the importance of choosing what is drilled for carbon isotopic values with care.

Poster 96-53, Abstract 388572, Booth 90

DOES SEA LEVEL CHANGE INFLUENCE CARBON ISOTOPIC TRENDS IN THE LATE PERMIAN DELAWARE BASIN?

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Previous studies from modern and ancient carbonate settings have argued that stable carbon isotopic trends can be influenced by changes in relative sea level. Explanations for this relationship focus on sea level's control on processes like organic carbon burial, basin restriction, carbonate deposition/weathering/mixing, and freshwater input. As sea level rises, the basin becomes well mixed, organic carbon burial increases, aragonite deposition increases, and the influence of freshwater is diminished. This results in increasing carbon isotopic values in the carbonate rocks that form at the time. In contrast, when sea level falls, these processes work in reverse and carbon isotopic values progressively decrease. While previous studies have argued for such a systematic relationship between sea level and carbon isotopes, those interpretations have not been tested quantitatively. For this project we aimed to propose a statistical test for correlation between sea level and carbon isotopes in the Late Permian Delaware Basin. We focused our efforts on the Tansill and Yates Formations exposed in Guadalupe Mountains National Park and Carlsbad Caverns National Park. By pairing high resolution carbon isotopic records with the established sequence stratigraphic framework for these study locations, we performed a series of regression analyses to test for correlation between sea level change and carbon isotopic trends. Our results provide a new method for determining if

sea level is influencing carbon isotopes.

Poster 96-54, Abstract 38574, Booth 91

DO CARBON ISOTOPIC VALUES VARY ALONG THE LATE PERMIAN DELAWARE BASIN SHORELINE?

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In modern carbonate platforms like the Great Bahama Banks and Florida Bay, the carbon isotopic value of dissolved inorganic carbon (DIC) can vary by up to 2‰. This is due to a combination of factors like freshwater input, terrestrial organic carbon, and non-equilibrium conditions with the atmosphere. How these variations in the carbon isotopic value of DIC get recorded in the carbonates that form in these settings has important implications for our use of the record as a paleoclimatic and chemostratigraphic tool. In this study we explore how relative position along shoreline impacts the recorded carbon isotopic values in the Late Permian Delaware Basin. We targeted the Yates and Tansil Formation exposed in Walnut Canyon and the Permian Reef trail in Carlsbad National Park and Guadalupe Mountains National Park, respectively. These two sections represent roughly the same position relative to shore but were separated by ~40 km laterally. By examining the carbon isotopic records of these two sections we were able to demonstrate that there are not significant lateral variations in carbon isotopic values and trends.

Poster 96-55, Abstract 388581, Booth 92

DO CARBON ISOTOPIC VALUES VARY ALONG A DEPTH GRADIENT IN THE LATE PERMIAN DELAWARE BASIN?

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Carbon isotopes are important tools in paleoclimatic and chemostratigraphic studies. Tracing patterns in carbon isotopic trends can be useful for correlation and determining the relationship between different stratigraphic units. Significant fluctuations in carbon isotopic values can be used to infer changes in the global carbon cycle. These applications require that carbon isotopic trends roughly approximate global process and are not overwhelmed by regional/local signals. However, studies of ancient and modern carbonate platforms have demonstrated that carbon isotopic values are different in nearshore versus deep water environments. Nearshore environments tend to have lower carbon isotopic values and the magnitude of excursions are maximized while deep water environments have higher carbon isotopic values and the magnitude of excursions are minimized. This suggests that regional/local factors were contributing to recorded trends. This study explores the issue of depth gradients in carbon isotopes in the Late Permian Delaware Basin. We chose this study location because it is an ancient analog for the Great Bahama Banks (GBB), one of the modern carbonate settings where gradients in carbon isotopic values have been observed. We focused on the Yates Formation, Tansil Formation, and Lamar Limestone Member of the Bell Canyon Formation exposed at the Guadalupe Mountains National Park and Carlsbad Caverns National Park. We measured and described three sections along a depth gradient and placed these rocks into the existing sedimentological and sequence stratigraphic framework. Hand samples for carbon isotopes were collected and drilled to generate trends in the crest, toe of slope, and basin settings. Based on these results, we explore the relationship between carbon isotopic trends and position relative to shore.

Poster 96-56, Abstract 388610, Booth 93

SEQUENCE STRATIGRAPHY AND CARBON ISOTOPES FROM BENBOW MINE ROAD IN MONTANA: DID SEA LEVEL CHANGE INFLUENCE CARBON ISOTOPIC TRENDS IN THE MADISON SHELF?

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The Early Mississippian Lodgepole Formation records a series of carbon isotopic excursions that have been linked to sea level fluctuations on the Madison shelf. One of these excursions is the ~7‰ globally recognized Tournasian Isotope Carbon excursion (TICE). The possibility that one of the largest carbon isotopic excursions in the Phanerozoic was influenced by organic carbon burial associated with rising sea level has significant implications about the role sea level played in the global carbon cycle and Earth's climate history. However, the relationship between sea level and carbon isotopic trends in the Madison shelf is not without complications. Perhaps most important is the fact that there is debate about whether there are two or three sequences in the Lodgepole Formation. This discrepancy regarding the identification and placement of sequence stratigraphic surfaces complicates interpretations of the relationship between sea level and carbon isotopes. To address these issues, this study focused on the Benbow Mine Road section in southern Montana. The Benbow Mine Road section is ideal for this study because in previous studies it provides one of the best examples of correlation between carbon isotope and sequence stratigraphic framework, it is also one of the locations where the three-sequence model for the Lodgepole was first proposed, and despite appearing in multiple studies, a detailed stratigraphic analysis has not been conducted since the early 90's.

We measured and described 141 meters of exposure at Benbow Mine Road. We paired these field observations with targeted petrographic work to assign facies associations and establish the sequence stratigraphic framework. Our results are consistent with a three-sequence model for the Lodgepole Formation. With this framework established we used Spearman Rank Correlation to test for correlation between carbon isotopic trends and sequence stratigraphy. Our results demonstrate that there is no statistically significant relation, suggesting that sea level change was not the primary driver of carbon isotopic trends in the Madison shelf.

Poster 96-57, Abstract 388612, Booth 94

DEEP WATER PARASEQUENCES AND CARBON ISOTOPES IN THE LODGEPOLE FORMATION OF SOUTHERN MONTANA

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The Early Mississippian Lodgepole Formation records a series of carbon isotopic excursions driven by changes in sea level within the Madison shelf. These interpretations are based on the idea that carbon isotopic values rise and fall in accordance with sea level, reflecting a combination of organic carbon burial, freshwater input, and terrestrial organic carbon input. Here we examine the relationship between sea level and carbon isotopes at smaller scales of sea level change (e.g. parasequence level) from deeper water settings where we would expect the relationship to be weakest due to distance from the shoreline and mixing with the open ocean. To accomplish this goal, we addressed three research questions: 1) can we identify parasequences in deep water environments of the Madison shelf, 2) can we see systematic differences in average carbon isotopic values with depth, and 3) can we see any consistent carbon isotopic trends within parasequences? To investigate these questions, we focused on three deep water sections from southern Montana: Baker Mountain, Sappington, and Sacagawea Peak. For each section detailed sedimentological descriptions were paired with petrographic work to assign facies associations and develop a sequence stratigraphic framework. Paired carbon isotopic analyses allow us to directly tie our geochemical trends to sequence stratigraphic boundaries and therefore changes in relative sea level.

Our results suggest that sea level was not the primary control on carbon isotopic trends in deep water settings in the Madison shelf. We were able to confidently identify several parasequences in all three sections. There is evidence for consistently lower carbon isotopic values in the most proximal study location (Baker Mountain) relative to the most distal study location (Sacagawea Peak). These results are consistent with findings in modern carbonate platforms where near shore environments tend to have 2‰ lower carbon isotopic values than distal settings. Despite this evidence that position relative to shoreline did influence carbon isotopic values, we found no evidence of consistent trends at the parasequence level.

Poster 96-58, Abstract 389277, Booth 95

UNDERSTANDING LAND USE AND CLIMATE CHANGES ON CONSERVED FARMLANDS IN NORTHEASTERN OHIO THROUGH COMMUNITY COLLABORATION

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Land use changes leave lasting impacts on the environment. The Killbuck Watershed Land Trust (KWLT) in Wooster, OH aims to conserve land and prevent development. KWLT emphasizes protecting farmland as a majority of this region's soils are considered prime by the USDA, however, they also manage prairies, wetlands, and woodlands. We examined how converting pre-settlement forests into agricultural land had consequences on the region by reconstructing past human interaction at two properties under easement with KWLT, the Biggio and Holtman properties.

We accomplished this with LiDAR mapping, field investigations, and tree ring analysis of trees from the properties. The tree ring data was compared with regional tree ring chronologies from NE Ohio and a barn sampled on the Biggio property. Our chronology shows most living trees dated to the early 1900s, whereas the barn ring-width series ends in 1840. This data also revealed a spike of growth in 1904, which is not seen in the Northeast Ohio chronology, indicating a logging event unique to the Wooster area. Also, on the Biggio property, we found evidence of a mill pond using LiDAR to identify a dam structure. The sediments are from the 1800s when early settlers primarily used mill ponds for hydropower, altering natural stream flow. These legacy sediments impounded by dams can give us clues to past land use, and the type of soil is key information for KWLT to know. The soil on the properties is prime agricultural soil and is well suited for crops, valuable to the region, and vital to conserve. KWLT preserves land because developments, buildings, logging, and land use change can disrupt the environment and surrounding climate. To investigate the climate, we correlated our tree ring chronology with records from the Ohio Agricultural & Research Development Center, with negative correlations for high summer temperatures, and positive correlations for high spring and summer precipitation. This indicates growth of these trees is limited by heat stress but benefits from wetter climate.

Through tree and sediment samples, we see effects of past human interaction with the landscape and climate of the area. Human actions and development interact with climate to generate records found in the soils and trees. It is beneficial to have organizations like KWLT to preserve land and prevent development.

Poster 96-59, Abstract 392156, Booth 96

ENHANCING ENVIRONMENTAL EDUCATION THROUGH VIRTUAL TOURS

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Virtual tours act as a means to explore diverse environments and phenomena from anywhere in the world. Particularly beneficial for individuals facing physical limitations or geographical barriers, virtual tours provide an opportunity to visit remote areas, historical sites, and other locations that may be challenging to access. They also serve as a safe and controlled environment for exploration, catering to individuals with limited mobility or those unable to undertake long-distance travel.

Beyond offering access to hard-to-reach locations, virtual tours can supplement field trips. While nothing can replace the in-person experience, virtual field trips enable those unable to attend physically to participate virtually, reducing anxiety and providing an opportunity to prepare for the trip. Such Virtual tours are already in use by the Stanford University

The project's primary focus is on creating virtual tours for the University of Wisconsin Whitewater's (UWW's) Nature Preserve, the Whitewater Effigy Mounds Preserve, the Koshkonong Effigy Mounds, and the UWW's campus garden. UWW Nature Preserve will be promoted by demonstrating the changes the prairie undergoes, benefiting the UWW Sustainability Office. Furthermore, the virtual tour of the two effigy mound preserves will foster respect for the area and aid in its preservation. Finally, the tour of the campus garden will highlight the efforts to address food insecurities. Future work involves enhancing these tours by adding more information and tailoring them to specific classes or projects. We also plan on creating virtual tours to showcase human impacts on environmentally sensitive locations which might be inaccessible by the general population to ensure their effectiveness, feedback from users will be gathered using a Google form.

In conclusion, virtual tours offer invaluable opportunities for individuals with physical or medical limitations to participate in field trips and explore hard-to-reach locations. While nothing can fully replace the in-person experience, virtual field trips reduce anxiety, help individuals prepare for the trip, and boost confidence.

Poster 96-60, Abstract 395516, Booth 97

SIMULATING CONDITIONS OF SLOPE FAILURE IN THE LAB WITH SAND AND WATER USING A MULTIMODAL MONITORING DEVICE FOR DATA COLLECTION

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Loss of life and property damage can be caused by slope failure. Slope failure is becoming increasingly common along the Great Lakes due to high wave action and increased rainfall caused by climate change. Our main goal is to understand the precursors to slope failure so we can better monitor and predict them. A few benefits of our research include raising public awareness of the dangers of slope failure and protecting communities near shorelines.

We conducted our lab experiments on unsorted sand using a multimodal monitoring device consisting of a strain gauge sensor, four moisture sensors, and eight temperature sensors. The strain gauge sensor, collecting one data point per 0.03 seconds, is run on its own Raspberry Pi platform. The moisture and temperature sensors, each collecting one data point per 10 seconds, are all run by a separate Raspberry Pi platform. We run both platforms simultaneously during our experiments.

Our setup consists of a plastic container to hold sand with a 45-55-degree sloped surface. A buried sandbag (0.05kg) attached to the strain gauge communicates strain information to the Raspberry Pi. Our experiments consist of 10-second intervals of pouring 60 cc of deionized water at the top of the slope. We let the sand settle for one-minute intervals and repeat until failure occurs.

The strain gauge data has been consistent for each test. In the first half, we get negative (push) readings before rapidly rising to positive (pull) readings. The correlation between soil moisture data and strain gauge data is inconclusive, perhaps due to the difference in data collection frequency. Our future work will involve sand layers with different grain sizes to mimic real-life scenarios as much as possible and also to better control water permeability along different layers.

Our project will ultimately lead to designing a system for collecting reliable field measurements for monitoring different triggers of slope failure and remotely transmitting the data in near-real time. This will allow continuous slope monitoring to help protect the public from the aftermaths of slope failure.

Poster 96-61, Abstract 395115, Booth 98

VIRTUAL OUTCROP MODEL OF THE BLAKELEY DAM OUTCROP, BEAR, ARKANSAS: ASSESSMENT AND APPLICATIONS FOR GEOEDUCATION

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This study presents a field based lab learning module for introductory geology students using a rendered 2.5-dimensional photogrammetric virtual outcrop mode (VOM) from the Blakely Sandstone Formation in the area of Lake Ouachita State Park, Bear, Arkansas. The outcrop is a highly-deformed quartz arenite body located at the top of the Blakely Dam, approximately 40 miles northwest of Hot Springs, Arkansas. The structure of the outcrop is the result of the Ouachita Orogeny. The folds present in the outcrop generally trend to the northwest and range from primarily tight and isoclinal folds to less frequent openfolds. Fracture sets are also common within the outcrop with a notable conjugate set that correlates to a maximum stress in the now sub-horizontal direction, consistent with the nearly upright to moderately tilted folding expressed in the rocks. Field work was conducted with a DJI Mini 2 to collect 267 aerial images from different viewpoints within the outcrop vicinity. These images were optimized and modeled in Agisoft Metashape Standard. The accuracy of the 3D model was measured in CloudCompare against field data that was taken on visible joints and fractures in the outcrop using a Brunton compass. Using the Blakely Dam VOM an interactive class activity was created which focused on basic structural geology. This activity is aimed at introductory students and has them analyze geometries within the outcrop and allows students to visualize geologic concepts without requiring in-person field work. The lesson involves finding individual folds in the outcrop, labeling the components,and measuring their orientations. This workflow and ability to navigate a realistic outcrop model allows for student development in recognizing fold components and using those components to identify fold types in outcrops. Our hope is that the process of working with and analyzing a realistic VOM will allow students to gain better spatial awareness and, potentially, an increased competency in the field.

Poster 96-62, Abstract 394464, Booth 99

ARCHIVES AND OUTREACH: THE EASTERN KENTUCKY UNIVERSITY PUCHSTEIN COLLECTION

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A curated fossil collection is an extraordinary resource for a university that may be used to spark interest through outreach, education, and research for students, faculty, and the community at large. In 2019, amateur paleontologist Richard Puchstein posthumously donated an impressive collection of vertebrate and invertebrate fossils to Eastern Kentucky University. These included mostly Paleozoic marine invertebrates, assorted pieces Cenozoic vertebrates, and Mesozoic freshwater invertebrates, in addition to an assortment of Phanerozoic fossils from all over the world. Unfortunately, the collection was donated in a mostly uncurated state, requiring extensive work. While some may have been previously identified some of the data on those specimens have been lost due to improper storage. Some were misidentified, with a fair bit being undiagnosed. Fossil identification has unsurprisingly been a focus, using in house and collaborative resources to diagnose specimens to our highest degree of certainty. After identification the specimen gets an identification number on a card that has all of the definitive information we have on it (taxon, horizon, locality, and age.) This is followed by storage, both where and how must be considered as to preserve both the fossil itself and the information about the specimen. These data are recorded in both a logbook housed in the collection center and in an online database. Specimens are stored in numbered and secured cabinets in both the collections designated room and within classrooms. Certain specimens also require special housing precautions such as needing humidity control, being extreme fragile, or just due to large size. After the work has been done to preserve both the specimen and the information about it the goal then becomes visibility. There are three ways the collections serves the University by being more visible: with poster shows and an online presence it becomes known to more universities so more research could be done using these fossils, outreach programs getting K-12 students interested in paleo sciences, and by using the specimens as teaching aids in the classroom at Eastern Kentucky University.

Poster 96-63, Abstract 393262, Booth 342

GEOCHEMISTRY AND MAGNETIC SUSCEPTIBILITY OF UPPER DEVONIAN CATSKILL FORMATION PALEOSOLS, NORTH-CENTRAL PENNSYLVANIA

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The Catskill Formation redbeds in the northern Appalachian foreland basin (north-central Pennsylvania) record Late Devonian (Famennian) terrestrial paleoclimate. Major element geochemical data from Catskill Formation paleosols preserve evidence of moderate silicate weathering (chemical index of alteration values 63-79), with an up-section increase that perhaps reflects enhanced Upper Famennian seasonality related to the onset of end-Devonian glaciation in the subtropics. To test whether this trend is consistent with a temporal shift to more humid climate conditions overall, or instead, an intensification of seasonality in the Upper Devonian, X-Ray Fluorescence (XRF) geochemical data and magnetic susceptibility (MS) data were acquired on two ~15-20 m-thick mudstone-paleosol intervals from core (Lackawanna County, Pennsylvania). Both datasets were measured at a 20-cm sampling interval with handheld XRF and MS instruments. Preliminary results show a correlation between XRF and MS records. These new data, together with companion detailed (cm-scale) stratigraphy, allow for a high-resolution evaluation of variation in the chemical weathering signal related to climatic change during the uppermost Famennian. Further analysis is necessary (1) to evaluate whether increased seasonality is consistent with pre-to-early mountain glaciation in the Appalachian hinterland, and (2) to assess the influence of geodynamic effects on the chemical weathering signal, especially given the tectonically dynamic and orogen-proximal setting of the Appalachian Basin during this time.

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On the back cover...

The Joseph E. Johnson Engineering and Physical Sciences (EPS) building at the University of Tennessee at Martin, home to the College of Engineering and Natural Sciences.

Photo Credit: University of Tennessee at Martin

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