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Geoheritage of the Keweenaw Peninsula

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GEOHERITAGE OF THE KEWEENAW PENINSULA

By

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Dedication

To all who marvel at the wisdom and magnificence of the talking rocks of the Keweenaw Peninsula.

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Preface

Chapter 2, Advancing Geoheritage in the United States: Examples of Geoeducation, Geotourism and Geoconservation in Michigan's Keweenaw Peninsula is being submitted to *Geoheritage Journal*; the author's dissertation advisor, William I. Rose, has co-authorship. The author's contribution toward the manuscript includes all writing, literature review, and collation of photos and figures. The co-author's contribution included formative discussion and creation of the Keweenaw Geoheritage website; both authors have been heavily involved in the creation of a geoheritage network/partnership and developing methods for education and outreach in the Keweenaw. Figures created by the authors unless otherwise referenced in text.

Chapter 3, Geoparks in the United States – Michigan's Keweenaw Peninsula is also being submitted to *Geoheritage Journal*; the author's dissertation advisor, William I. Rose, has co-authorship. The author's contribution toward the manuscript includes all writing, collation of photos and figures, geosite inventory analysis, development of SWOT analysis, and creation of Geopark management plan (Appendices). The co-author's contribution included formative discussion and the creation of the Keweenaw Geoheritage website hosting all geosite information; both authors have been heavily involved in the creation of a geoheritage network/partnership in the Keweenaw. Figures created by the authors unless otherwise referenced in text.

Chapter 4: The Unintended Outcomes of Geoscience Professional Development – the MiTEP Affect is being submitted to the *Journal of Geoscience Education*. It is co-authored with Mark Klawiter and the author's dissertation advisor, William I. Rose. The author's contribution toward the manuscript was approximately 95% including the writing, photography, creation of figures and tables, conducting interviews, transcribing interviews, and data analysis. The co-author's contribution included formative discussion on the content of the manuscript and comments and edits with respect to its revision. William I. Rose was instrumental in the development of the MiTEP summer

field course and was the principal instructor working with teachers. The author acknowledges and thanks Carol Englemann for collating the exit survey data as part of her dissertation (Engelmann, 2014). All photos and figures are the authors.

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Abstract

The Keweenaw Peninsula is a compelling intersection of cultural, industrial, and mining heritage - all of which is rooted in its ancient geologic underpinnings. The incredible geodiversity of the Keweenaw expresses a billion year geologic history that has shaped the landscape and resulted in the discovery of one of the largest native copper deposits on Earth; in turn, originating one of the oldest metal workings in the Western Hemisphere, and the famed mining boom of the Keweenaw in the late 1800's. This rich human story intertwined with globally significant geosites has endowed the Keweenaw with a strong geoheritage.

Geoheritage considers the protection, management, and conservation of landscapes and geologic features and the varied personal values assigned to them. This variation affords the opportunity to communicate the societal importance of Earth science in a way that resonates with people *personally*. A prolific outreach and education initiative has been developed in the Keweenaw embodying this philosophy; a breadth of activities and engagement strategies employed are described herein.

The innovative outreach efforts in the Keweenaw support the overall advancement of geoheritage at the national level as the US begins to engage an evolved and growing global community. The advancement of geoheritage in the US is concomitant with the emergence of the US Geoheritage and Geoparks Advisory Group. UNESCO Geoparks are community developed initiatives that encourage education, sustainable economic development, and the conservation of places with globally significant geology in tandem with an intriguing cultural story. The Keweenaw categorically meets all criteria for a geopark designation and as such could be the first in the United States.

The benefits of geoheritage in the Keweenaw Peninsula are vast and include: increased Earth science literacy; the development of sustainable economic opportunities; enhancement of a "sense of pride" in locals; and increased stewardship, conservation and appreciation of abiotic nature. Through a thriving community partnership,

geoheritage is directly contributing to the overall well-being of this unique and captivating community.

1. Introduction

Improved communication of Earth science issues to the general public is a topic of increasing importance. While the scientific community advances our understanding of Earth system processes, the public are isolated from this breadth of knowledge. This could be attributed to the disconnect between the academic geoscience community and how we communicate what we know; it could be a measure of how much exposure people have to abstract Earth science concepts in their K-12 experiences; or it could be that Earth sciences are simply eclipsed by the attention devoted to biotic nature. Geoheritage is a means of addressing these issues through education, opportunities for sustainable economic development, and conservation.

Geoheritage encompasses significant geologic features, landforms, and landscapes which are conserved in consideration of the full range of values that society places on them, including scientific, aesthetic, cultural, educational, recreational, commercial/tourism, and other values, so that their lessons and beauty will remain as a legacy for future generations (Hill, 2010). Its strength is the inclusion of natural and cultural elements affording the opportunity to resonate with all members of the general public. Geoheritage aids in the development of Earth science literacy and is highly important for communicating contentious subjects such as mining or natural hazards, so the concept is ever evolving and changing as geology and society advance.

Geodiversity is defined by Gray (2004) as the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes which form and alter them. Of further importance, geoheritage pronounces the connectedness between bio- and geodiversity and the need to not only conserve and protect biotic nature but to value and conserve our natural geological sites and landforms, or abiotic nature – geoconservation (Burek and Prosser, 2008, Henriques et al., 2011). Geosites (geological sites with scientific relevance) and geodiversity sites (geological sites with educational or touristic value) (Brilha, 2015) help foster a meaningful sense of place that local populations may embrace. There are health benefits associated with geoheritage programming in that it gets people outside and active. Geoheritage also promotes sustainable economic development in one's community focused on geologic features or landforms – geotourism – and is considered at many scales ranging from individual local initiatives, to state and national parks, and United Nations Educational, Scientific and Cultural (UNESCO) Global Geoparks and World Heritage sites.

1.1 Global Geoparks

Landscapes and geological features provide a window to Earth's deep history and are determinants for future development. Geoparks recognize this significance and afford communities opportunities for protection, education, and sustainable development surrounding this philosophy (Eder and Patzak, 2004). The geopark concept arose in the mid-1990s as a response to the need to conserve and enhance the value of areas of geological significance in Earth history. In 2004, with the support of UNESCO, seventeen members of the European Geoparks Network and eight Chinese Geoparks came together to create the Global Geoparks Network (GGN). The International Geosciences and Geoparks Program (IGCP) exists under the UNESCO International Science Program alongside of the International Hydrosphere Program and the Man and Biosphere Program. The UNESCO General Conference recently ratified the creation of this new label for Global Geoparks in November, 2015 underscoring the importance of governmental recognition of abiotic nature and its holistic management and protection.

Geoparks are places that: 1) are defined by the geology of the landscape and transcend boundaries of protected areas, 2) operate as a bottom-up partnership between people and land managers working to promote Earth heritage through education and sustainable tourism, and 3) are nationally or globally significant geologic areas. There are currently 120 Global Geoparks in the world, none of which are located in the United States.

1.2 Geoheritage in the United States

While geoheritage has been developing for nearly two decades in Europe, Asia and Australia, it is a relatively new concept in the United States. An official position statement on geoheritage was published by the Geological Society of America in 2012 illustrating the benefits of geoheritage for the US and how varied stakeholders can work to advance this concept nationally. An invitational workshop exploring the advancement of geoheritage in the US was held in Denver in 2013; the meeting included representatives from government agencies, industry, academia and others (National Academy of Science, 2014). Since this meeting, a number of initiatives to promote this concept have evolved such as the joint publication on American's Geologic Heritage by the National Park Service (NPS) and the American Geosciences Institute (AGI) (2015), and the designation of "Our Shared Geoheritage" as the theme for the 2016 AGI Earth Science Week. Most recently, the US National Committee for Geoparks was created with the purpose of an advisory role for pre-aspiring geoparks wishing to submit official applications to the UNESCO Global Geopark program.

1.3 Geoheritage in the Keweenaw Peninsula

Michigan's Keweenaw Peninsula offers an important window into Earth's past. Its significant geodiversity comprises a flood basalt sequence associated with the Late Mesoproterozoic Midcontinent Rift, then covered by a sequence of red bed fluvial sediments. A massive thrust fault uplifted these layers bringing native copper to the surface. The unearthing of one of the world's largest native copper deposits has resulted in one of the oldest metal workings in the Western Hemisphere, and the more recent mining boom of the Keweenaw in the late 1800's. This rich cultural, mining, and industrial heritage in tandem with significant geodiversity, including numerous glacial features and Lake Superior itself, make the Keweenaw an ideal place to promote geoheritage and geoconservation efforts. While locals and visitors appreciate the natural beauty and mining history of the Keweenaw, there is an opportunity to encourage people to learn how to read their landscape with more fluidity, to ask bigger questions about the place that they live in, and ultimately become more literate in the geosciences. With its strong geoheritage, the Keweenaw meets the criteria for the designation of a geopark and could be the first in the United States.

1.4 Description of work

This dissertation addresses two central questions: 1) "What is geoheritage, and how is it being defined and developed in the United States? 2) Within the specific context of Michigan's Keweenaw Peninsula, how has geoheritage been applied, and what are the ways that it can potentially benefit this region through its varied manifestations?"

Chapter Two provides a literature review exploring how geoheritage is defined and advancing in the context of the United States. This chapter also investigates how geoheritage has been applied at the local level in the Keweenaw Peninsula and offers ways it benefits this region. Chapter Three defines the potential for a Keweenaw Geopark, the necessary factors required to meet this end, and advantages of this designation for the Keweenaw community. An evaluation and inventory of Keweenaw geodiversity is also presented in this chapter. Chapter Four describes formative experiences working with educators in the Keweenaw that has influenced education and outreach programs created to advance geoheritage, and the development of an inventory of significant geosites for the purpose of education.

An expanded description of each chapter and methods addressing the central questions is provided below. This body of research is driven by the following motivations and objectives:

1) increased Earth science literacy among a broader public
2) deepened community connection to abiotic nature
3) development of geotourism in the Keweenaw
4) need for identification, inventory, and classification of significant Keweenaw geosites for the purpose of education, economic development and conservation

5) development of a proposal for Global Geopark designation
6) increased national and international visibility of the Keweenaw as a leader in advancing geoheritage

1.4.1 Description of Chapters

Chapter Two, *Advancing Geoheritage in the United States: Examples of Geoeducation, Geotourism and Geoconservation in Michigan's Keweenaw Peninsula,* presents a case study exploring how geoheritage has been applied at the local level in the context of the Keweenaw Peninsula and proposes ways it benefits this region. A literature review synthesizes the current state of the art of geoheritage globally, within the context of the United States, and within the Keweenaw, emphasizing its geological and cultural significance. Methods employed to engage the Keweenaw community are also presented in this chapter.

A grassroots outreach strategy focused on education and interpretative programs of the local geology and cultural history of both the Keweenaw Peninsula and Isle Royale is described. As a multifaceted concept that considers the protection, management, and educational value of our planet's geologic features and sites, both in situ and ex situ, proper communication of these values requires a diverse group of partners to ensure a connection is made with the general public. Within this community we have fostered a collaborative partnership with a variety of local organizations offering differing expertise to aid in public education and conservation of geologic features in the Keweenaw. The chapter describes methods for, and benefits of: 1) the establishment of a geosite inventory and associated website for the Keweenaw Peninsula and Isle Royale, 2) academic and public field trips and "geotours", 3) professional development for K-12 teachers, 3) interpretative materials and boulder gardens, 4) public meetings concerning the concept of a potential Keweenaw Geopark designation, 5) public presentations with local museums, conservation groups and minerals clubs, 6) building strong partnerships with parks, schools, municipalities, local businesses, non-profit organizations, and industry.

The concept of a geopark designation for the Keweenaw Peninsula is introduced in this chapter. Through an extensive education and outreach program, community partnership, and collaboration with colleagues both nationally and internationally, we have worked to meet the criteria for designation of UNESCO Global Geopark, as detailed in Chapter 3. Chapter Two is being submitted to *Geoheritage Journal*, an international journal that explores and promotes all aspects of global geoheritage.

Chapter Three, *Geoparks in the United States – Michigan's Keweenaw Peninsula*, presents an argument for why the Keweenaw is an exemplary nomination for a Global Geopark designation and how a geopark might benefit the region. It expands on Chapter Two providing a more rigorous synthesis of the globally significant geodiversity, cultural values, economic background, and levels of protection for geoheritage in the Keweenaw. A qualitative and quantitative evaluation has been employed to establish an inventory of key geosites and geodiversity sites in the Keweenaw that exemplify scientific, educational, and touristic values. Documenting the significance of the Keweenaw and its world-class geodiversity is paramount for the advancement of a geopark proposal.

For the past five years a growing community of colleagues have worked together to advance geoheritage and geoconservation in the Keweenaw and within the United States. As outlined in Chapter Two, efforts have focused greatly on education and interpretative programs of the local geology as well as the cultural history. A significant component of this outreach is vested in the development of a website that hosts information and location details for an inventory of hundreds of geosites identified in the Keweenaw (www.geo.mtu.edu/KeweenawGeoheritage). A broad classification of geoelements have been developed, diversity of features within each of these themes expands from the macro to micro scale. Recognizing that geosites have varied uses, sensitivities, and threats an inventory of sites that best serve educational and touristic purposes for a geopark designation have been identified through both quantitative and qualitative assessment. As geoparks are an emergent initiative within the United States, a Keweenaw Geopark could serve as the first designation of its kind within our national boundaries. Chapter Three is also being submitted to *Geoheritage Journal*, complementing the submission of Chapter 2.

Chapter Four, *The Unintended Outcomes of Geoscience Professional Development – the MiTEP Affect*, is a prequel to the efforts described in Chapters Two and Three. Through use of quantitative and qualitative survey data and semi-structured interviews, this chapter reflects on the unexpected consequences of teacher participation in the Michigan Teacher Excellence Program (MiTEP). The 5-year research and professional development program worked to advance Earth science content knowledge and inquiry-based teaching methods among middle-grade Earth science teachers from selected urban districts in Michigan with the intention of igniting reform on a national level. While this project met a number of its intended goals, the unintended outcomes of this work are highly significant and can be partially credited for the origination and advancement of geoheritage and a geosite inventory in the Keweenaw.

Evaluation and data collected from teachers regarding their summer field experiences in the Keweenaw have been invaluable for shaping an understanding of how people learn and what misconceptions the general public might have about abstract geological concepts. Teachers also piloted and tested the feasibility of key educational sites in the Keweenaw Peninsula. In preparing for summer field schools sites were identified that had didactic potential and the capability of hosting large groups of twenty or more. Teacher experiences and input have unquestionably advanced of education and outreach programs aimed at the local and visiting public to the Keweenaw. This chapter is being submitted to the *Journal of Geoscience Education*; there are currently no publications in this journal describing geoheritage offering the opportunity to introduce this concept to a new audience.

Chapter Five, *Conclusions*. Future work is described in the concluding chapter. Particular emphasis is placed on the completion and submission of an official geopark application and letter of intent to the newly formed US National Committee for Geoparks in December 2016. This is supported with accompanying appendices describing the necessary factors required for a Keweenaw Geopark management and action plan; a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the feasibility of a Keweenaw Geopark is presented, as well as a list of all events and publications to date directly related to the advancement of geoheritage in the Keweenaw.

1.5 Conclusion

This work recognizes the fascinating industrial, mining, and cultural heritage of the Keweenaw Peninsula while emphasizing the global significance of its geologic underpinnings. Through this work a number of initiatives have been met to advance geoheritage in the Keweenaw. Outcomes of this work are described in detail within the separate chapters but include:

- Evolving community partnership
- Inventory of scientific, educational, and touristic sites
- Educational materials and outreach
- Geoconservation – public land access for significant geosites
- Global Heritage Stone designation of the Jacobsville Sandstone
- Economic development - business plan for geotourism
- Geopark proposal
- National Marine Sanctuary proposal
- National and international visibility – recognized as one of three pre-aspiring geoparks in the US

This work categorically illustrates that the Keweenaw meets all of the criteria for a Global Geopark designation and could be the first in the United States. Geoheritage provides multiple benefits to the Keweenaw community including education, sustainable economic opportunities, and conservation of significant geosites. As this concept continues to develop in the US we stand to develop a model for community engagement, education, and economic development that are derived from the exemplary geodiversity exhibited in the Keweenaw Peninsula.

2. Advancing Geoheritage in the United States: Examples of Geoeducation, Geotourism and Geoconservation in Michigan's Keweenaw Peninsula[1]

2.1 Abstract

Geoheritage embraces the protection, management, cultural, and educational value of geologic features and sites. It underscores the importance of the personal and wide-ranging values that people assign to sites of geologic significance and as such is a compelling way to advance Earth science literacy. Geoheritage is a rather new concept in the United States, despite its advancement in Europe, Asia and Australia for nearly two decades. With its tremendous geodiversity, the US has recently joined this global movement; an overview of the state of the art for geoheritage in the United States is presented as introductory context.

Michigan's Keweenaw Peninsula is imbued with a deep sense of place based on its fascinating and globally significant geologic and rich cultural histories. We present a grassroots effort in the Keweenaw Peninsula to advance this strong geoheritage through education and interpretative programs of the local geology and cultural history. Efforts are focused on identifying, interpreting, sharing, and promoting the significance of local geosites with educators, interpreters, decision makers, businesspeople, and the broader public. Through these efforts, a growing coalition of community stakeholders are attracted to the benefits of geoheritage which include educational community outreach and engagement, sustainable economic development opportunities, and the conservation of abiotic nature for future generations. Through this community based effort, we promote the Keweenaw Peninsula as an exemplary Global Geopark designation and continue to advance geoheritage locally, nationally and internationally.

[1] The material contained in this chapter is being submitted to *Geoheritage Journal*.

2.2 Introduction

Improving the communication of Earth science issues to the general public is of increasing relevance and importance. Most Earth scientists are cognizant that the general public requires more information about Earth science if they are to make informed decisions for a sustainable and high quality future. While we work to investigate and understand the Earth at varying spatial levels, we often omit the fundamentally important component of peoples' connection to the Earth, the landscape which ultimately guides decisions on land use issues such as natural resources, geotourism, or natural hazards. In other words, we fail to recognize the varied universal values that people assign to place, or what makes learning about geoscience relevant to them personally.

Geoheritage is a multifaceted concept that considers the protection, management, cultural, and educational value of geologic features and sites, both in situ and ex situ. Most importantly, it focuses on the diverse values that people attach to place and affords opportunities for connecting with a broader audience on pertinent geoscience issues (Calder and DeMont, 2010, Miller, 2009) (Figure 2.1). Geoheritage has relevance in that it promotes the conservation of natural, non-renewable resources at risk to varied threats (Brilha, 2013). It is paramount that the significance of abiotic nature is imparted to the broader public so that these sites remain as lasting scientific, educational, cultural, and touristic resources for future generations (Gray, 2004).

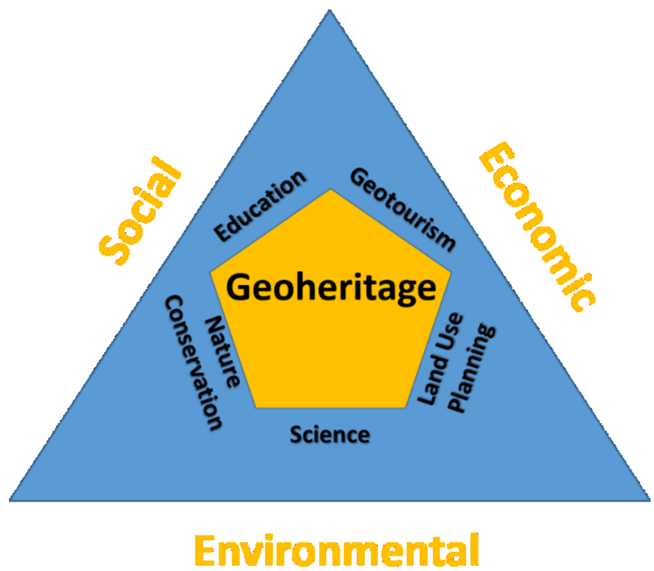

Figure 2.1: Varied values and opportunities of geoheritage (modified from Brilha, J., 2013, 2009).

The tremendous geodiversity within the landscape of the United States, with its varied tapestry of shoreline, plateaus, plains, mountains, volcanoes and glaciers provided vast opportunities for the advancement of geoheritage awareness through partnership and collaboration. The benefits of advancing geoheritage in the United States include:

1. improved science literacy, citing the lack of consistent Earth sciences curriculum in the U.S.
2. improved economic benefit, especially in rural and remote impoverished areas
3. improved health and well-being, as geoheritage inspires people to explore nature
4. enhanced geoscience concepts and ideas, including preservation and collections in museums.

As geoheritage, in a formal sense, is an emerging concept in the United States, a brief overview of the current state of the art of the geoheritage movement in the US follows.

A portfolio of local partnership and engagement efforts for geoheritage programming in Michigan's Keweenaw Peninsula, aimed at education, economic development, and geoconservation, serves as an example for methods of advancing geoheritage at the community level. A central focus of our work is imparting the exceptional geoheritage of the Keweenaw Peninsula and Isle Royale to educators, decision makers and planners, businesspeople, tourists, and the general public. Although many feel this powerful geoheritage, life-long residents often have difficulties articulating it or have misconceptions about how our place was formed. We describe varied educational outreach efforts focused mainly on identifying, locating, interpreting, and promoting the significance of local geosites. A subsequent publication arising from this work details an inventory of geosites, lending support to the designation of the Keweenaw Peninsula as a vibrant and exemplary Global Geopark.

2.3 Geoheritage in the US – the state of the art

While geoheritage has advanced in parts of Europe, Asia, and Australia for nearly two decades, it is still a nascent concept in the United States. In recent years formal steps have been taken in response to the absence of the US's voice in the international arena. In 2012, the Geological Society of America (GSA) adopted an official position statement on geoheritage. GSA, a non-profit organization founded in 1888, works for the advancement of geosciences and the professional growth of it's over 26 000 members. The statement encapsulates GSA views regarding the conservation of geosites, a definition of what geoheritage sites are and why they are important, the endorsement of United States' participation in the Global Geopark program, and strategies for conserving geoheritage sites (Hill, 2010).

To foster national partnerships and collaboration, "America's Geologic Heritage Invitation Workshop" was held in Denver, Colorado in March of 2013, the first meeting of its kind in the US. This meeting brought together a wide range of stakeholders comprised of US government and state agencies, non-profit organizations, academia, museums, and industry. The objective of this meeting was to establish a collective commons for geoheritage principles and to promote collaboration between stakeholders to advance geoheritage and geoconservation within the United States. The main themes for the workshop included: 1) value and relevance, 2) inventory and assessment, 3) sustainability and stewardship, 4) museums and collections, and 5) education and outreach.

Next steps for the US were prioritized as inventorying and assessment, regulations and protection measures, and education and outreach. This meeting was a vital step in connecting varied stakeholders from across the country, and internationally, working to advance the field of geoheritage in their respective area of expertise. A report from this workshop has been published by the National Academy of Sciences (2014). Since this workshop, the US geoheritage working group has met at various professional meetings to continue constructive dialogue (Casadevall et al., 2015, Rose et al., 2013a, Rose et al., 2011, Vye et al., 2015, Vye et al., 2013).

2.3.1 Protection of geoheritage sites in the US

The United States hosts numerous geoheritage sites which include officially designated sites and areas with a high level of distinct conservation management such as National Parks, National Monuments, World Heritage Sites, National Historic Landmarks, and National Natural Landmarks (Hill, 2010).

2.3.2 Global level

The US has been involved with the United Nations Educational, Scientific and Cultural Organization (UNESCO) and affiliated programs since its inception in the late 1970's (Kimball, 2015, Bailey, 2015, Morris, 2015). Recently, the UN's General Conference vote to grant Palestine observer status created political dissonance; as a result, the US has not paid membership dues for nearly four years. Despite this ongoing disagreement, there are presently twenty-three World Heritage sites in the United States, sixteen of which are eminently related to geological processes, such as Yellowstone, the Grand Canyon, and the Everglades (National Park Service and American Geosciences Institute, 2015).

UNESCO Geoparks have emerged as an important element of the global geoheritage movement. Although the concept has been promoted within the United States and has gained momentum, the US has yet to formally participate in the Global Geopark program (Bailey, 2010, Bailey and Hill, 2010, Calnan et al., 2010, Cook and Abbott, 2015, Nowlan et al., 2010, Hill, 2010, Casadevall, 2015). An official US National Committee for Geoparks has recently formed in 2015, with a formal review process for potential candidates under development. At present, three groups have expressed interest in a geopark designation in the United States; two regions in Colorado and Michigan's Keweenaw Peninsula (Cook and Abbott, 2015, Casadevall, 2015)

Other internationally significant geosites in the US include designation under the Global Stratotype Sections and Points (GSSP), a program initiated by the International

Commission on Stratigraphy. The GSSP program identifies and marks places where exact boundaries of particular units of geologic time in well preserved and well exposed rocks. There are seven sites in the United States; most are unmarked sites on public land (National Academy of Science, 2014 report).

2.3.3 National designations

Official protection of geologic heritage in the US can be traced to March 1872 with the protection of Yellowstone; the first occasion in the US when public lands were protected for recreation and education (Nowlan et al., 2010, Shaver and Wood, 2001). Since then, the National Park Service has increased to over 410 units, many hosting exemplary geologic resources. Ex situ geological collections are protected in park museums on the order of 35, 000 specimens as well as 416, 000 paleontological specimens. In addition to these in situ and ex situ resources, the park service administers the National Natural Landmark (NNL) program and the National Register of Historic Places (NRHP). The NNL program recognizes sites of extraordinary biologic or geologic value for conservation on both public and private lands. The NRHP recognizes places of historical significance worthy of preservation on accordance with the National Historical Preservation Act of 1966. These sites add significantly to the value of our shared geoheritage on a national level.

The significance of the parks' geodiversity has traditionally been eclipsed by biotic and cultural resources, both in terms of recognition and interpretation. Acknowledging that these sites were seen more as a backdrop and underappreciated for the educational opportunities they offered prompted the creation of the Geologic Resource Division (GRD) in 1995 (Shaver and Wood, 2001). The Geologic Resources Division now supports NPS managers by providing technical information, regulatory tools, and specialized services to effectively manage geologic, energy, and mineral resources. The group encourages national and local geoscience partners to become involved with park research, to collaborate with parks on the development of interpretative and educational material, and to promote citizen science in the parks and planning (Shaver and Wood, 2001). Most recently, it has worked to establish principles of geoheritage, or geologic heritage, in the US and to develop programs to support this effort (Wood, 2015).

The Geoscientist in the Parks program, a partnership between the National Park Service and the Geologic Society of America helps parks meet the growing demand for geoscience expertise and interpretation by placing experienced geoscientists is the parks for internships that best serve the research and educational needs for park development and management.

Recently, the Geologic Resource Division launched an Unofficial National Register of Geoheritage Sites. The GRD database enables anyone to upload geosites, their location, and their importance to the national register (Wood, 2015). While other countries have qualified national inventory programs (Brilha, 2015, Calder, 2014a, De Wever et al., 2015, Erikstad, 2013, Fuertes-Gutiérrez, 2010, Joyce, 2010, Pena dos Reis and Henriques, 2009, Wimbledon, 1999), this is an auspicious start to an ambitious undertaking considering the enormity and breadth of geosites within the United States.

2.3.4 National Geoheritage Outreach and Earth Science Literacy initiatives

A summary of the geoheritage movement's history and opportunities in the United States is documented in "American's Geoheritage – An Invitation to Leadership" (2015) (Figure 2.2). The product of a collaboration between the National Park Service and the American Geosciences Institute (AGI), it describes geoheritage and its main principles in the context of the United States, offering opportunities and suggestions for how all partners within the US can actively participate in advancing this concept. AGI is a non-profit federation of forty-five geoscientific and professional associations aimed at advancing important themes in Earth Science while working to bring these concepts to the general public. As part of its promotional activities AGI organizes a yearly Earth Science Week event. This event focuses on a different theme of Earth science every year

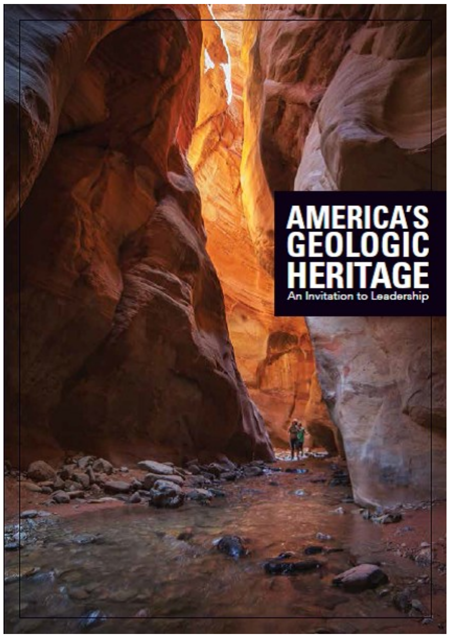

Figure 2.2: The big ideas of geologic heritage, publication by the National Park Service and the American Geosciences

providing teachers and museum staff with hand-on materials and lesson plans in addition to organizing events national wide in an effort to engage the boarder public. “Our Shared Geoheritage” had been selected as the 2016 theme offering an unprecedented opportunity to raise awareness of this movement and its benefits to teachers, students, interpreters, and museum staff nationwide.

Prior to this collaboration, AGI has worked to address the overwhelming lack of communication and knowledge of Earth science in the US resulting in the 2009 publication of *Earth Science Literacy Principles (ESLP)*, with support from the National Science Foundation (*Earth Science Literacy Initiative. “Earth Science Literacy Principles: The Big Ideas and Supporting Concepts of Earth Science”.* 2009) (Figure 2.3). This initiative identified and outlined key principles that geoscientists consider to be the important for Earth science knowledge. The ESLP was designed in an effort to guide decisions by government and industry, while at the same time providing an excellent curriculum guide for both formal and informal education. The initiative defines Earth science literacy as “an

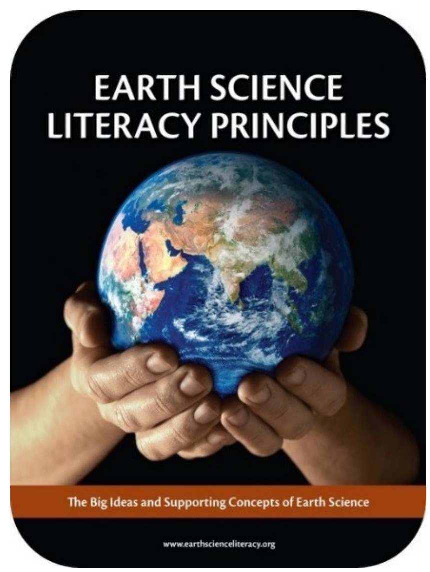

Figure 2.3: “Understanding of Earth’s influence on you and of your influence on Earth”, the Big Ideas connect the broader public to Earth science (National Science Foundation publication).

understanding of Earth's influence on you and of your influence on Earth".
Higher education institutes globally are afforded numerous opportunities to interact with local communities and to communicate findings and discoveries, advancing geoheritage. If we pause to consider the traditional roles of institutes of higher education, particularly, "universities," we are reminded that they are the collective commons of scholars and students working to reveal truths. Within the United States, the National Science Foundation made the decision in 2007 to explicitly require a "Broader Impacts" review criterion to be submitted with every proposal formalizing this need. This criterion obliges all grant applications to examine how and why the proposed research is of importance to more than the academic community. This initiative is meant to aid universities in broadening their audience, to allow public access to the relevancy of research being conducted. This approach creates great synergy for increasing the awareness of the public and advancing geoheritage.

2.2.5 Native Americans and Geoheritage

Native Americans in North America have long been powerful ambassadors for geoheritage and geoconservation with traditions and oral histories rooted in a deep connection to the Earth and a philosophy in which many consider themselves as direct relatives to their homeland. This deep connection fosters a natural respect and care for scared sites, an integral part of our shared geoheritage within the United States (Semken, 2005b, Semken, 2005a).

In light of the sometimes differing philosophies of nature between indigenous and Euro-American cultures, there is great value in weaving the two for a learning experience that resonates for all. Research has been conducted documenting success in integrating indigenous knowledge into geoscience courses throughout the US in efforts to broaden participation of Native Americans in the geosciences (Bueno Watts, 2011, Palmer et al., 2009, Reano and Ridgway, 2015, Riggs and Semken, 2003, Riggs and Semken, 2001, Semken, 2005b, Semken, 2011). The Geoscience Alliance combines these differing values in order to broaden participation of Native Americans in Earth Science. The

National Science Foundation funded program encourages the participation of K-12 and university students, tribal elders, academic institutes, informal educators, and research centers through workshops and internship opportunities for students to share indigenous knowledge in their contributions to Earth science.

Frog Bay National Tribal Park, located near Bayfield, Wisconsin on Lake Superior, is the first of its kind in the US. and encourages access for the general public and tribal membership alike (Probst, 2012). As more tribal parks are designated a rich and valued layer of indigenous history is added to the geoheritage and geoconservation of North America, and the spiritual worldview of the general public is expanded through access to these sacred tribal lands. For a truly shared US geoheritage, an open dialogue on the importance of sacred lands and their significance to Native American cultures is germane.

2.4 Geoheritage of the Keweenaw Peninsula

Located in the middle of North America, jutting out into Lake Superior, Michigan's Keweenaw Peninsula is imbued with a deep sense of place (Figure 2.4). Far from interstates or any major city centers, the Keweenaw offers a powerful experience for visitors who oft times return due to the simple beauty, and deep connection they feel to the landscape. The region has a small population of 38,200 over a total land mass of 1540 square miles divided into Houghton and Keweenaw Counties. The area is host to two national parks, Keweenaw National

Figure 2.4: Location of the Keweenaw Peninsula and Isle Royale on Lake Superior.

Historical Park and Isle Royale National Park (part of Keweenaw County), the Copper Country Trail National Scenic Byway, two state parks, two universities, museums, conservation groups, and outdoor education specialists.

While many people appreciate the natural beauty and are acutely aware of the mining history of the Keweenaw and Isle Royale, they don't necessarily consider geology as a part of the collective heritage. This significant geodiversity in tandem with a fascinating cultural history make the Keweenaw an ideal place to promote geoheritage and geoconservation efforts; there is a profound opportunity to connect with and encourage people to learn how to read their landscape with more fluidity and to consider the possibility of conserving it for others to enjoy. This section presents a brief description of the geologic background and cultural history and examples of the communication of geoheritage with and for the Keweenaw Peninsula.

2.4.1 Geological background

The Keweenaw Peninsula and Isle Royale offer an important window to Earth's past, exposing the heart of the Mesoproterozoic Mid-Continent Rift. Located on Lake Superior in Michigan's Upper Peninsula (Figure 2.5), the abundant geodiversity sites are the result of a ponded flood basalt sequence comprised of hundreds of voluminous lava flows, interbedded and covered by a vast sequence of fining-upward redbed fluvial sediments.

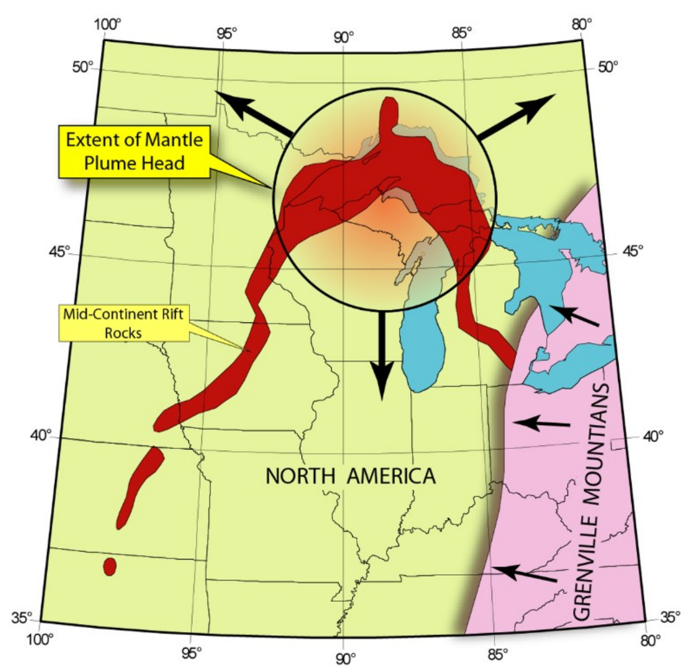

Figure 2.5: Extent of rifting associated with the Mid-Continent Rift (K. Schulz, USGS).

An upwelling of heat and magma from a hot spot initiated great lava flows erupting from the rifting of supercontinent Rodina. The rift created a ~3000 km U-shaped feature in the center of North America that extends from Kansas, through what is now Lake Superior, and apparently terminating in Ohio. Some of the largest lava flows on Earth were erupted and ponded in massive magma oceans on the order of many centuries. During quiet times, red-brown conglomerates and sandstone were deposited between flows in high energy alluvial fans (Figure 2.6). The interbedded lava flows and sedimentary layers were normally faulted resulting in a syncline feature that extends from Isle Royale to the Keweenaw Peninsula, now the basin for Lake Superior (Figure 2.7).

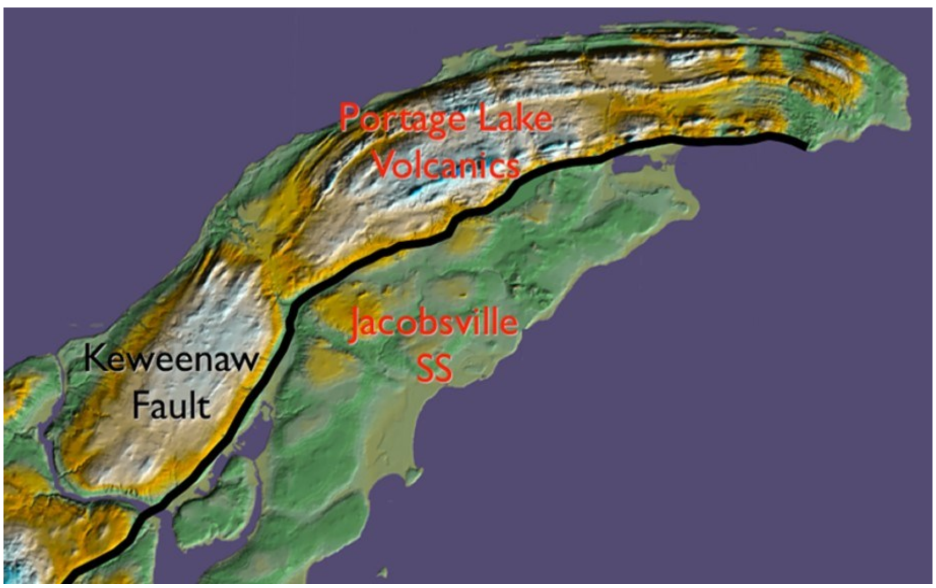

Figure 2.6: The Keweenaw Peninsula divided by the Keweenaw Fault. Volcanic rocks with interbedded clastic sediments to the north, rift flanking sandstone on the southern side.

The Grenville Front, an orogeny in eastern North America eventually ended the Keweenaw Rifting episode (Cannon, 1994). This continental collision reactivated graben-bound normal faults creating massive thrust faults in the regions. The most prominent fault of the region is the Keweenaw Fault, a massive thrust fault which was the focus of hundreds of high magnitude earthquakes uplifted rocks, including vast resources of native copper and silver, to the surface. The area has also been affected by dramatic continental glacial features and surrounded by the world's largest freshwater lake, Lake Superior. The lake acts like an ocean in the middle of North America creating strong and unusual hydrospheric environmental conditions.

The Keweenaw is noted for one of Earth's largest native copper deposits in the world, the focus of ancient indigenous mining nearly 9000 years ago (Martin, 1999) and later began the first great metal mining district in the United States. From 1845 to 1968 ~11 billion pounds of refined copper were produced in Keweenaw Mines making it the cornerstone for the American economy (Bornhorst and Barron, 2011, Bornhorst and Lankton, 2009). The region has been extensively mapped and researched since the mid 1800's as a result of the discovery of copper and subsequent mining boom. The geology of this region is described in further detail in an associated publication reviewing the Keweenaw's qualifications for Global Geopark designation (Vye and Rose, in prep).

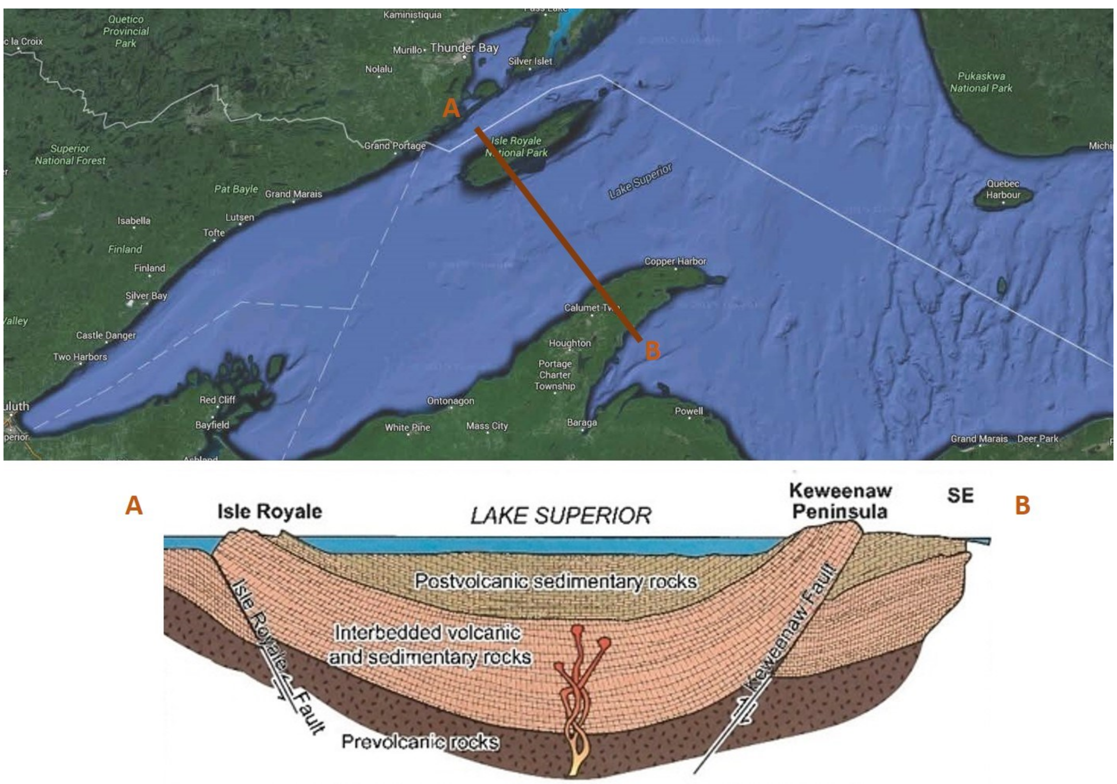

Figure 2.7: Cartoon depicting the syncline connecting the Keweenaw and Isle Royale (modified from Huber, 1983 and Google Earth).

2.4.2 Early geoscience investigation

A remarkable, yet largely unacknowledged part of the Keweenaw's history is vested in its early geoscience investigations dating back to the early 1840's with Euro-American exploration and the discovery of copper by visionary Henry Schoolcraft and Douglass Houghton (Figure 2.8). Their reports brought masses to the area not only to prospect for copper but others to further investigate the science of these exemplary geosites. Archival documents spanning a century from 1850 offer a wealth of knowledge and awareness generated on the geology of the Keweenaw and Isle Royale, some research still uncontested as an authoritative source on the subject (Butler and Burbank, 1929, Irving and Chamberlin, 1885). The work of these explorers and scientists is a tremendous contribution to geoheritage on a local, national and global scale, and should be recognized as such.

Figure 2.8: Douglass Houghton, Michigan's first state geologist (left); Henry Schoolcraft, ethnographer, geologist, geographer – a leader in understanding the copper deposits of the Keweenaw (right).

Some of today's principle scientific institutions in the Keweenaw were founded as a result of these investigations. Michigan Technological University originated as the Michigan Mining School in 1885, a small school to train mining engineers. The school later expanded to become the Michigan School of Mines increasing the number of degree programs offered. The A. E. Seaman Mineral Museum was originally created at this time by mineralogist Alfred. E Seaman as a teaching tool for geologists at the Michigan College of Mines. Today, it hosts a vast and comprehensive collection of specimens from all over the world and has the potential to serve as a junction between the historic scientific investigations of the area and its continued mission of educating people on the rich history of the Earth.

2.4.3 Cultural background

Copper mining has left an indelible mark, earning the region the nicknames, “Copper Country” and *Kuparisaari* (“Copper Island”) by the Finnish immigrants who worked in the mines. The Keweenaw’s strong geodiversity defines our landscape and has greatly contributed to the cultural and economic development of the United States. Keweenaw (pronounced KEY-wa-naw) is a Native American word meaning portage, or a place where a portage takes place. Its place is history is firmly established based on 9000 years of Native American mining, and is recognized as the site of the earliest known metalworking in the Western Hemisphere (Martin, 1995, Martin, 1999). The mining boom brought a massive diaspora of European cultures to the Keweenaw and served as the cornerstone of American economy. The area also contributed greatly to the labor rights movement; the 1913-14 mine worker’ strike was one of the longest and most violent labor disputes in twentieth century history. Perhaps the best known place in the Keweenaw to a broad American public is the Italian Hall, the scene of the 1913 “massacre” when 73 people died while reacting in panic to a false fire alarm at a Christmas party, tragically, most of the victims were children.

Today, the heavily mined area is decorated, or marred – depending on one’s perspective - by tailings piles, stamp stands and decaying mining infrastructure. Many identify with these sites having relatives who worked in the mines; for others they serve as a reminder of primitive, less responsible ways of extracting Earths treasures (Figure 2.9). Also prominent in the area are countless buildings constructed from Jacobsville Sandstone, an easily distinguished red sandstone with light spots or streaks. This gorgeous stone was in vogue in the early 1900s and was used as an attractive building material throughout the US; it is currently up for nomination as a Global Heritage Stone Resource (Rose et al., in prep)

Figure 2.9: Torch Lake stamp sands an old dredge for refining copper tailings (photo courtesy of Steve Brimm).

2.5 Building a grassroots partnership for geoheritage in the Keweenaw

Acknowledging the rich geodiversity and compelling cultural heritage of the Keweenaw, we have developed a grassroots partnership to advance and promote the strong geoheritage of the Keweenaw. Our strategic goals have been to:

1) increase local knowledge of and interest in local geoheritage among teachers, students, politicians, businesspeople, tourists and the general public

2) develop a strong partnership of local organizations who support geoheritage programming

3) illustrate the economic benefits of our geologic heritage

4) identify and develop an inventory of geosites for the Keweenaw and Isle Royale

5) work with local groups and decision makers who share a common goal of conservation and public access to geosites

6) build grassroots support for a Keweenaw Geopark. Broad categories of our work include education, economic development, and geoconservation.

2.5.1 Education

Like all places in the world, Earth science has broad influence and implications for people living in the Keweenaw. Issues include global warming, sources of energy, land conservation and perhaps most prevalent among the broader public, the possible revival of mining in the future. These topics cross the political and social spectrum and geoheritage offers a way into our shared conversations about them.

A large component of our work in the Keweenaw was motivated by a National Science Foundation funded Math Science Partnership aimed at improving their Earth Science content of nearly sixty K-12 teachers throughout the state of Michigan. The Michigan Teacher Excellence Program (MiTEP) was a 5-year research and professional development program that targeted middle-grade earth science teachers from selected urban districts in Michigan for intensive teacher training, leadership development, and student engagement. Core partners included academic institutes, Michigan public schools, and the National Park Service. Teachers took part in intensive summer field schools and professional development training days over the course of three years and with the option to participate in a three week national park internship as a capstone project (Engelmann, 2014, Klawiter and Engelmann, 2011). The field portions and place-based education components was most beneficial for teacher professional development (Figure 2.10).

Deliverables from participation in field courses and national park internships created a foundation for much valued and greatly needed geologic interpretative materials for the region (Vye, 2011). Teacher-created products, such as EarthCaches, have significantly contributed to the geosites inventory (Gochis, 2013). EarthCaches offer an opportunity to visit and learn about a unique feature of the Earth and are found via GPS coordinates. Teacher created caches also include lesson plans increasing their value as educational geosites. Many of these sites have been further developed with interpretative signage for the boarder public. This research project fostered strong partnerships amongst educators at the local and regional level and has created a network with the Michigan Science Teachers Association and the National Association of Geoscience Teachers to advocate geoscience education resources. Many people contributed to this success of this project, a number of them contributing to a succeeding project which focuses on the redesign of state and national science standards. The Michigan Science Teaching and Assessment Reform (MiSTAR) project focuses endeavors to test a model for the reform

Figure 2.10: Author Bill Rose during a MiTEP summer field school with Michigan teachers, learning to read the landscape.

of science curriculum, teaching, and learning in the middle grades. The program take an integrated approach that helps connect people to societal issues.

2.5.1.1 Geosite inventory and website

An inventory of over 150 local geosites (sites for scientific relevance) and geodiversity sites (sites with educational or touristic value) (Brilha, 2015) have been compiled on a public website devoted to raising awareness of the geoheritage of the Keweenaw (Figure 2.11). This website offers a platform to share technical, geographic, and cultural information of the Keweenaw Peninsula and Isle Royale. For outreach with the broader public, we have broadly identified five main geoelements as a focus for education and interpretation: 1. lavas and the Midcontinent rift, 2. rift-flanking sandstone, 3. the Keweenaw Fault, 4. glacial activity, and 5. Lake Superior itself. Each theme is accompanied by recoded lectures, short videos and information on events and tours in the area. The site has been advertised locally and regionally through public presentations and press releases encouraging more people to visit local geosites; all are invited to share their input throughout this process including ways geoheritage outreach can be improved, a platform for sharing experiences or stories related to geoheritage.

Figure 2.11: Keweenaw Geoheritage website, access via QR code.

2.5.1.2 Boulder gardens in public places for landscape/educational use

The Keweenaw Peninsula is ripe with glacial erratics offering a unique and tactile learning experience. We have relocated some of the most exemplary larger glacial erratics from our region to a public place in the center of the Michigan Technological University campus to serve as an educational and cultural hub (Rose, 2011) (Figure 2.12). The boulders often have fresh, glacially polished surfaces and represent an assemblage of dozens of outcrops enabling one to visit all lithologies of the Keweenaw Rift at one location. This garden is a collaboration of geoscience experts, local artists, and landscapers who consciously arranged the boulders and interpretive signage in an attractive installation intended as a tactile learning hub to be touched, crawled over and played on.

Figure 2.12: Boulder gardens offer rich educational opportunities for all ages. Left - Students on a "rock types of the Keweenaw" scavenger hunt; Right – Using the garden as a stopping point on a trolley geotour.

The site has drawn educational attention, and has proven especially useful as an introduction to local field trips for both formal and informal learners. Local teachers that have visited with students have requested smaller scale replicas to be installed on school property; a pilot project in two local schools will see that the gardens become a part of their Outdoor Learning Center initiatives. Following the success of the Keweenaw Rift garden, a second garden was installed exhibiting outstanding examples of banded iron formation and a boulder of the Sudbury impact ejecta representing regional mining operations in the Upper Peninsula of Michigan. An indoor exhibit of exception massive sulphide boulders donated from the nearby Eagle Mine has been placed in a highly frequented area on campus. The site includes interpretive signage describing the significance of the boulders from a scientific perspective and from that of Native Americans in the region. As the Eagle Mine operation is highly controversial, this installation was created in an effort to educate our local community on all aspects of the story and to open dialogue between both industry and environmental proponents.

2.5.1.3 Signage and self-guided geoheritage tours

Considering the prolific use of smartphones by a wide-ranging demographic and the rising popularity of digital treasure hunt apps, we piloted a self-guided geoheritage tour focused on twenty-five geodiversity sites within the city of Houghton, MI (Rose et al., 2013b). The tour interprets former mines, aa and pahoehoe large lava flows, faults, veins, glacial features, river deltas, kame terraces and anthropogenic features in the town. Coordinates for the geosites can be downloaded from a locally distributed brochure and are found on the Keweenaw Geoheritage website. An 8.5 x 11 inch sign has been installed at each site with a brief inquiry based question about said feature (Figure 2.13). A QR code can be scanned to access more information and link passersby to all sites on the larger tour. Information for these sites is hosted on a webpage with *.kmz files, photos and accompanying information, this page can be used anywhere in the world as a “virtual tour” of the Keweenaw. The tour encourages people to explore the area, to visualize landscapes, to read rocks, to understand how they link to the cultural resources, and to develop geospatial skills. A number of these sites are teacher-developed EarthCaches providing the added value of a lesson plan.

Based on the success of the pilot tour, community partners have awarded funding to develop three additional tours for frequently visited parts of the peninsula. The geoheritage tours dovetail to articulate the broader geologic and cultural story of the entire peninsula. Inspired by the tours, additional opportunities with potential to foster partnerships with other groups in the Keweenaw continue to emerge. For example, the concept of geotours that span the length of the peninsula helps support outreach and educational initiatives for organizations such as the Copper Country Trail Scenic Byway.

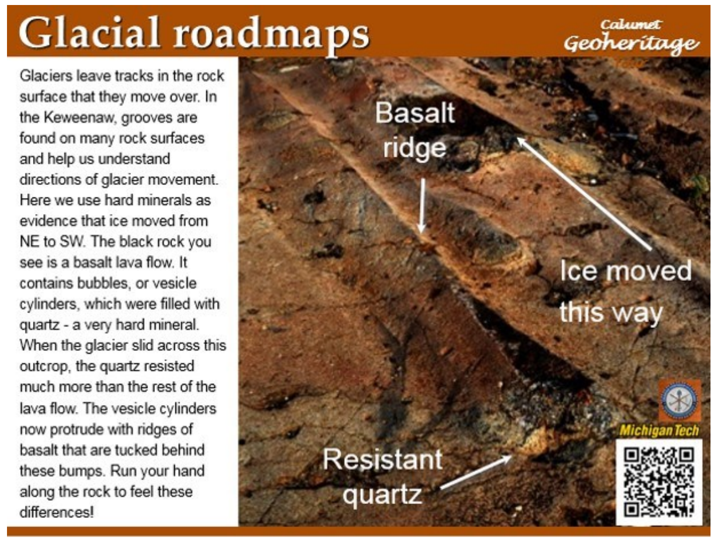

Figure 2.13: Examples of geotour signage; signs focus on a key theme but are liked to further information and other sites via a QR code.

Since being established, the tours have been fashioned as guided walking tours, bike tours for local bike advocacy groups and as a fundraiser by means of local trolley (Figure 2.14). The varied tours ensure that people of all mobility levels can engage in geoheritage

Figure 2.14: Trolley geotours afford a fun and unique learning experience for all ages and mobility levels.

activities. All are family friendly and encourage people to stop and ask questions and places pf geologic interest that they might otherwise pass every day.

2.5.1.4 Partnering with the National Parks

The Keweenaw is host to two national parks; Keweenaw National Historic Park and Isle Royale National Park. The Keweenaw Park is not a traditional gated park, rather a composite of heritage sites scattered throughout the peninsula, attracting visitors by the cultural and industrial heritage of the region. Isle Royale, also designated as an International Biosphere Reserve, known for its focus on biotic nature, enables visitors to experience wilderness, particularly interactions between moose and wolf populations. The geology is the same for both parks, a natural connection linked via the syncline. Geology is integral to the story of both places but the interpretation of the peninsula's abiotic nature is eclipsed by other themes.

In partnering with the parks, we have been able to assist with interpretive efforts through the development of a geoheritage book for both parks (Rose and Vye, in prep), field trip guides (Rose and Olsen, 2013), interpretative signage and videos, and other teacher-developed materials created during internships in the parks. These formal and informal educational resources help promote the rich geoheritage of the parks and dovetail with the parks' commitment to interpreting our area as described in Public Law 102-54, Section 1. (b):

> *(1) to preserve the nationally significant historical and cultural sites, structures, and districts of a portion of the Keweenaw Peninsula in the State of Michigan for the education, benefit, and inspiration of present and future generations; and*
>
> *(2) to interpret the historic synergism between the geological, aboriginal, sociological, cultural technological, and corporate forces that relate the story of copper on the Keweenaw Peninsula.*

Collaboration with regional colleagues studying the Midcontinent Rift has led to an interpretive video on key rift sites within the Midwest national parks. This adds significantly to interpretive materials and will be distributed in visitor centers throughout the entire Midwest region of the United States (Stein et al., 2015c)

2.5.2 Economic Development

The definition for geotourism has developed greatly over the past decades but can broadly be defined as sustainable tourism based on abiotic nature that promotes education and conservation of geodiversity (Dowling, 2010, Hose, 2012, Hose and Vasiljevic, 2012, Farsani et al., 2012, Burek, 2012). Geotourism has a somewhat different meaning within the United States where the use of "geo" by National Geographic refers to geographical tourism excluding the consideration of geodiversity (Burek, 2012). As we endeavor to develop a deeper appreciation of abiotic nature in the Keweenaw, we align with the former definitions of *geo*tourism, enabling locals and visitors to further develop their knowledge and awareness of the natural history of a region while also connecting to their cultural heritage. The Keweenaw Peninsula and Isle Royale's rich geoheritage affords wide-ranging opportunities for geotourism.

2.5.2.1 Keweenaw Geotours

The geosites of the Keweenaw and Isle Royale offer an extraordinary outdoor classroom that engages learners, not only through an intellectual connection to Earth resources, but also through an emotional connection via culture, history, and sense of place. Many of the geosites are best visited, or exclusively accessible, by boat. The wave washed shorelines are both scenic and educational revealing reefs, minerals, veins, and other treasures. This vantage point affords a truly unique experience for learning about the processes that formed this region.

One-day and one-week Geotours have been developed that focus on the main geoelements of the Keweenaw and Isle Royale: flood basalts/hot spots, redbed fluvial sandstones, thrust faults, continental glaciation and great lakes Earth science (Figure 2.15). Trips focus on the scientific background and include significant content related to the cultural heritage of the Keweenaw, with quest experts invited to share their knowledge with the group. The informal trips efficiently use both land and water access for minimal transit times and are open to all ages and varied mobility levels.

Figure 2.15: Live-long learners examine sediment samples from the lake bottom aboard the Michigan Tech RV Agassiz.

A previously unexplored economic resource, these trips were piloted in 2014. Community demand and visiting education groups requesting tailored trip experiences have led to an increase in the number and frequency of tours, lectures and field trips. This suggests that geotourism could help stimulate business ventures that encourage visitors to stay in the area and visit the outdoors. We have since developed a business plan to develop the tours as a seasonally operating business in the Keweenaw.

2.5.2.2 Copper Country Geocache Passport

Geocaching is popular activity in over 180 countries with nearly every demographic and there are over 15 million geocaching accounts created to date. The recreational activity entails searching for and finding a hidden object by means of GPS coordinates that are posted on a website or found in a brochure. This activity has become so popular that communities worldwide are developing Geocache Passports, offering a localized hunt of a collection of geocache sites centered on a common theme. In most cases, the caches do not offer an educational experience, rather the “thrill of the hunt”. The Copper

Country National Scenic Byway developed the “Geo-Trail” passport to attract people to the region (Figure 2.16). Although traditional geocaches offer opportunities to develop geospatial skills, the opportunity for education opportunity is often lost. In partnering on this project, we were able to embed geoheritage as a theme and complement the passport with an educational layer. Interpretive signage related to the cache has also been installed at each site, without revealing the whereabouts of the hidden cache.

Figure 2.16: Cover of the Geo-trail passport brochure (Courtesy of WUPPDR).

2.5.3 International partnership

Throughout the process of developing education materials and economic opportunities it is paramount to increase one’s awareness of how geoheritage is being advanced in other parts of the world. International partnership has enabled us to learn from more experienced colleagues on a global scale. We value collaboration with our European colleagues at Chaîne d’Puys – faille de Limagne, Clermont-Ferrand, France who have successfully developed grassroots community geo-education programs during their quest for World Heritage designation (Van Wyk de Vries, 2013). One such example draws on the value of anthropogenic geosites for the learner experience. Lemptegy volcano, formally a quarry, has been transformed into an interpretative visitor center allowing visitors to learn about the anatomy of volcanos and how the surrounding area is formed. This otherwise finite extractive venture has been transformed into a sustainable economic opportunity that educates and connects people to the landscape. The Keweenaw hosts many sites derived from human interactions with the earth that allow people to learn about Earth system processes and the rich industrial heritage together and provide opportunities for similar economic growth.

2.5.4 Geoconservation

Geoconservation has emerged as a new discipline within the geosciences and considers the protection and management of sites of exceptional scientific, touristic, education of cultural value (Burek and Prosser, 2008, Prosser et al., 2013, Henriques et al., 2011, Matthews, 2014, Prosser et al., 2011, Gordon and Baker, 2015, Gray, 2004, Brihla et al., 2012). While it aims to conserve non-renewable geologic resources for future generations, it also promotes the appreciation of abiotic nature through education and sustainable economic development fostering an enhanced sense of stewardship (Gray et al., 2013, Prosser et al., 2011, Prosser et al., 2013). Geodiversity is rarely considered in matters pertaining to legal protection as it is oft time not on the radar of decision makers and planners (Brihla, 2002). The conservation of abiotic nature is thereby supported through education and demonstrating the economic benefits to varied stakeholders. To promote this within the Keweenaw, we have connected directly with decision makers, planners, conservation groups and artists.

2.5.5 Decision makers

Influencing policy, legislation and development design is a paramount step in the protection of geodiversity. Connecting with local politicians and recreation planners, we have highlighted the significant geodiversity of the Keweenaw and the varied values of this inventory of previously unacknowledged sites. Geoheritage and geotourism have officially been accepted into local township recreation plans recognizing the wide-ranging benefits in protecting and developing these sites for multiuse.

Figure 2.17: Houghton-Douglass Falls, a key geosite in the Keweenaw, soon to be accessible to the public.

The best example of this is Houghton-Douglass Falls, the highest waterfall in Michigan, typifying the powerful geologic forces that have shaped our region (Figure 2.17). The falls have been privately owned for a number of years, with no public access granted due to the tragic deaths of climbers in the past. Recently, the Department of Natural Resources expressed an interest in purchasing the falls for public land. In emphasizing the geological significance of the falls and the importance of the site with respect to early scientific investigations in the area, decision makers were influenced to secure the purchase of the site by the state. The area will subsequently be developed into a state park with infrastructure for safe visitor experiences and interpretative signage. The popularity and wish for access to this site is heralded by a recent community action project that successfully protected public access to Hungarian Falls (near to Douglas Houghton, both created by the Keweenaw Fault). With high visibility, and a place many have frequented for years, this area has since had geoheritage signage designed and installed by teachers to alert visitors to the abiotic wonders of the falls. These are triumphs for geoheritage and geoconservation in our community and encourage the hope of opening access to other valuable geosites to the public and developing an increased sense of stewardship for our region.

Figure 2.18: Learning about the rift and what a syncline is at Black Creek, a Michigan Nature Association conserved site.

Land trusts and conservation groups have expressed great interest in understanding the significance of abiotic nature on conserved lands within the Keweenaw as geoheritage advances in our region. As a result of this interest, we have been requested to lead field trips, provide community lectures, provide expert advice on the significance of geosites on potential public land projects and easements, and present at annual meetings to impart the value of geoconservation in the Keweenaw community (Figure 2.18).

2.5.6 Artists

Geoconservation is perhaps best supported by developing a “sense of wonder” for people (Gordon and Baker, 2015, Tilden, 1957, Louv, 2009, Gordon, 2012). Finding abstract ways to connect people to geologic themes develops a sense of responsibility to conserve and protect geosites. While interpreters have focused on abstract ways to increase peoples’ connection to the geologic landscape (Mathis, 2009, Lillie et al., 2011, Lillie, 2005), artists are uniquely positioned to communicate a sense of place and encourage stewardship through their creative works.

The Keweenaw’s natural beauty has been a draw for a many artists. Creations inspired directly by the landscape open a dialogue with art enthusiasts to ask how this place came to be the way it is now. Geoheritage is naturally embedded in the works of a variety of visual artists (Figure 2.19) and is the crux of the Soundscapes of the Keweenaw Project that focuses on recording natural sounds to interpret how the Keweenaw was formed. This perspective and its connection to the broader public is highly valued and is the focus of upcoming events such as public land art, choir concerts in the stopes of old mines, and a geoheritage themed art exhibit.

2.6 Future Work

The combined geologic history and human story of Michigan’s Keweenaw Peninsula and Isle Royale make the region an exemplary place to promote geoheritage in the US. While the concept of geoheritage is still emerging within the Unites States, we have developed effective programs through creative pedagogy and community partnership at the local level.

We are continuing to advance community-wide opportunities for Earth science education, while simultaneously fostering economic development and conservation of geosites other projects in the character of geoheritage.

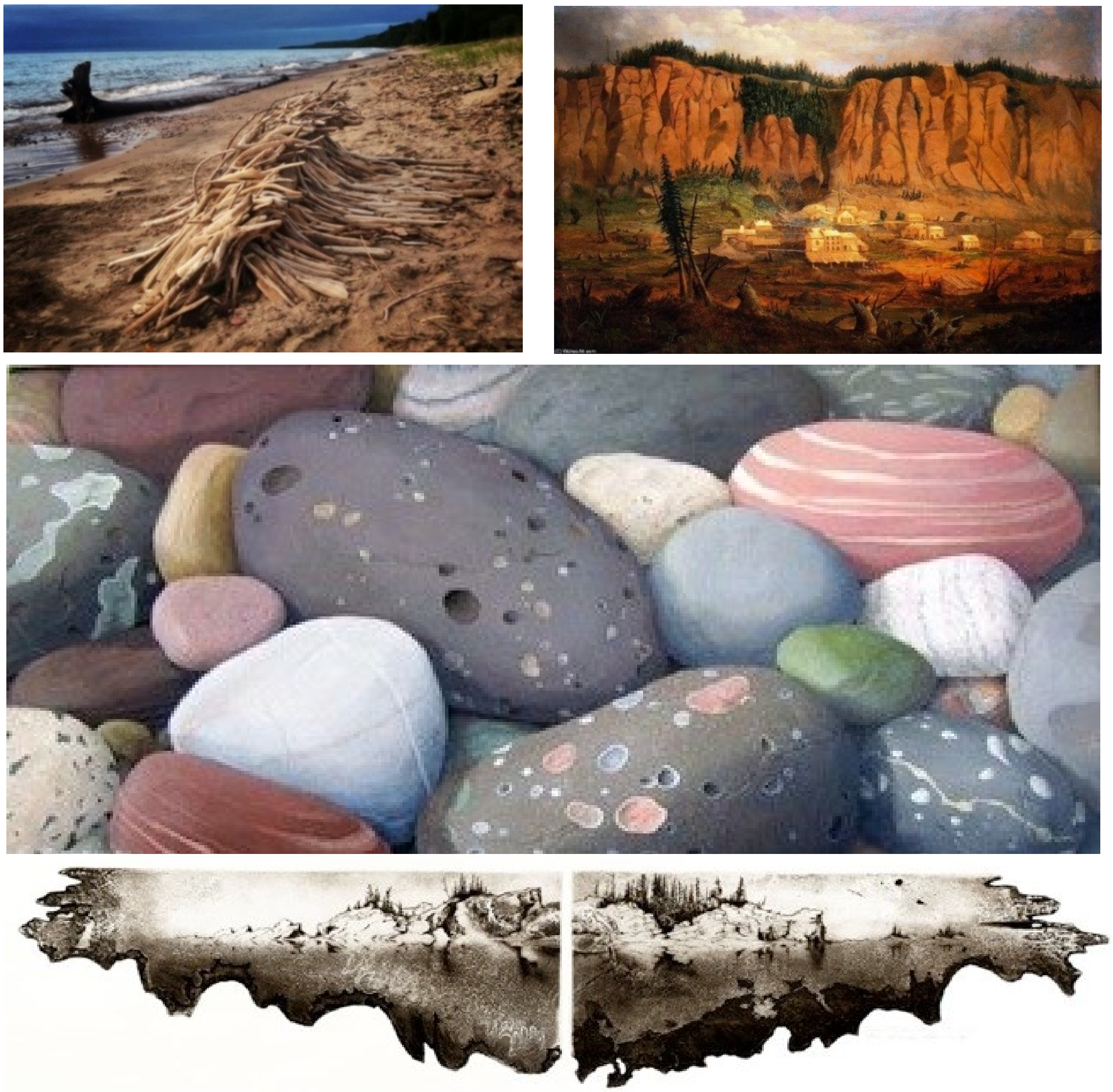

Figure 2.19: Land art on the Lake Superior shore by Randy Wakeham; 2) "The Cliff", a depiction of the first successful European metal mining district in North America by Robert Duncanson, 1848; 3) Susan Robinson's "The Elusive Lake Superior Agate"; 4) "From the Depths of the Minong" etching by Ladislav Hanka.

2.6.1 Marine Geoconservation

While the conservation of abiotic nature is a well-established practice in parts of Europe, the concept of marine geoconservation is only now beginning to advance

(Prosser et al., 2013, Burek et al., 2013). We are working closely with community partners on a proposal for a National Marine Sanctuary designation that focuses on the marine geoheritage of the Keweenaw and Isle Royale. The National Oceanic Atmospheric Administration funded designations typically focus on cultural or biological features; by focusing on the geologic underpinnings and advocating for the conservation of these significant marine geosites we stand to pioneer this nascent concept on a global scale. Further, locals and visitors will be afforded increased opportunity to better understand the connection of the terrestrial environment through preservation and interpretation of the marine environment of this region.

2.6.2 Value of public lands

Next steps in imparting the values of geoheritage and conservation work lie in communicating the benefits and value - fiscally, spiritually, and educationally - of public land. A key concern for many people in our rural area is the loss in revenue from protected land being removed from the tax roll. We need empirical evidence that illustrates the benefits of public land for communities – in a fiscal sense and for quality of life.

2.6.3 Geopark Proposal

We are building a grassroots program for local geoheritage that is truly community driven. This diverse partnership stands to bridge the gap between experts and the general public through an open and clear dialogue. Our collective activities are the foundation for the effort needed to propose the Keweenaw Peninsula as a geopark, possibly the first geopark within the United States. This theme is explored in detail in an associated publication.

2.7 Conclusion

The themes of education, economic development and geoconservation are intrinsically linked; together these pillars stand to help the Keweenaw community cultivate existing features in a sustainable way that ensure their being for future generations. As this is a nascent concept and not well-established in the United States, the significance of the Keweenaw as a geopark, coupled with effects upon education, economic growth, and other as yet potentially unknown opportunities, is profound and far reaching. We continue to share our efforts with a growing community of colleagues, both nationally and internationally, who are working toward the advancement of geoheritage and geoconservation in the United States.

3. Geoparks in the United States – Michigan's Keweenaw Peninsula[2]

3.1 Abstract

Geoparks are community developed initiatives that promote geologic significance and conservation, educate locals and visitors on Earth's history, and develop sustainable economic growth locally through community partnerships. Although there are 120 geoparks globally, there are no such designations in the United States. Michigan's Keweenaw Peninsula has a rich and globally significant geodiversity in tandem with a fascinating cultural story; the site of one of the largest native copper deposits known on Earth, one of the oldest metal workings in the Western Hemisphere, and recent diaspora of European cultures that flocked to the region for copper mining in the late 1800's have created an entangled mosaic of cultural, mining and industrial heritage. The intersection of these disciplines, founded on exemplary geologic history, make the Keweenaw Peninsula and Isle Royale a superlative contender for a geopark designation. The Keweenaw has a well-developed infrastructure and a community desire to foster sustainable economic growth that supports a quality of life economy. An extensive education and outreach program has advanced the strong geoheritage of the Keweenaw and continues to develop through an allied community partnership surrounding this theme. Further, there are ample opportunities for scientific research and opportunity for community involvement in contentious issues such as the anthropogenic impacts of mining in the region. By these measures, the Keweenaw surpasses the established geopark criteria. This designation would further support outreach and education efforts, foster community engagement, and promote sustainable economic development opportunities and the conservation of abiotic nature in the Keweenaw.

[2] The material contained in this chapter is being submitted to *Geoheritage Journal.*

3.2 Introduction

Since its inception in 2004, the Global Geoparks program has advocated a community-led approach to advance the recognition and protection of sites rich in geoheritage, thereby promoting sustainable economic well-being while augmenting education efforts of local communities (Eder and Patzak, 2004, Calnan et al., 2010). With over 120 geoparks now designated in over thirty countries, geoparks have engaged people at the local level and connected communities on a global scale. Despite the growing numbers, only two geoparks are found in North America, with Canada being the first in the continent to advance the concept. The Canadian National Committee for Geoparks started in 2009 and has since advanced two geoparks to the United Nations Educational Scientific and Cultural Organization (UNESCO) Global Geopark Network: Stonehammer in New Brunswick and Tumbler Ridge in British Columbia. There are ten additional pre-aspiring parks in various locations throughout Canada. Given the tremendous geodiversity of the United States (US), and as geoheritage continues to advance, geoparks offer an effective way to promote geologic significance and develop sustainable economic growth locally, while connecting to a supportive, growing global community. Despite its tremendous geodiversity, there are currently no geopark designations within the United States, though three pre-aspiring parks have expressed interest in joining the global network. Two are located in Colorado – the Western Colorado Dinosaur Geopark near Morrison and the Goldbelt Geopark southwest of Colorado Springs (Meyer, 2015, Sciences, 2014); the third is located in Michigan's Upper Peninsula - the Keweenaw Peninsula.

This paper supports the claim that the Keweenaw is exemplary of a geopark designation; it has geoheritage that extends back to human arrival in North America, well-defined boundaries in accordance with geopark criteria, it hosts publically accessible geosites of varied type and significance, it has a stunning aesthetic and diverse cultural tapestry, and it features well-developed infrastructure and robust partnerships to support the management of the community-led designation. While founded in the more tangible geological underpinnings of the Keweenaw Peninsula, the development of a geopark will offer a window of opportunity to not only explain how this place came to be but also to address the more intangible issue of how the Keweenaw makes people feel, and to inspire people to ask questions such as: "*How does Earth science guide us and influence our living and culture? What are the elements of geology here? What does this place teach us about Earth history? How does the Keweenaw window into Earth's history contribute to our world view?"*

3.3 Michigan's Keweenaw Peninsula

The Keweenaw Peninsula, located in the Upper Peninsula of Michigan, has a rich geodiversity in tandem with a fascinating cultural story. The geologic story of the Keweenaw is captivating, bookended by two vastly different periods in Earth's history resulting in the revelation of one of the largest native copper deposits known on Earth. The Keweenaw hosts one of the oldest metal workings in the Western Hemisphere and a place where Euro-American explorers arrived in droves in the late 1800's, launching a mining boom resulting in a cornerstone of the American economy. This economy faltered when mining declined in 1945 and closed in 1968; the lack of other major industries has since led to high rates of poverty in the two counties that form the peninsula. Keweenaw County is the largest in the state of Michigan (6,000 square miles, only 540 of these are land mass) with a population of 2,200 residents. Isle Royale National Park, a wilderness island in Lake Superior, is part of Keweenaw County. Houghton County has a population of 36,000 and is 1540 square miles, 1000 as land (Figure 3.1). Poverty levels in the two counties are 15% and 21% respectively (KEDA, 2015). Strewn with the visible remains of mining infrastructure and land alteration, the Keweenaw reveals to most residents and visitors vivid reminders of the mining and industrial heritage of the area related to the extraction of copper.

The Keweenaw encapsulates an enthralling interface among mining, industrial, cultural, and geoheritage facets. Although there is a clear distinction between geoheritage and mining heritage (Brilha, 2015) it is nearly impossible, and would be a disservice, to fully separate these in the Keweenaw. This is supported by the argument that former mining sites contribute significantly to the understanding of Earth science and may provide additional opportunities for economic development based on the unearthing of new features, including sites that can be repurposed for tourism (López García et al., 2011, Kavčič and Peljhan, 2010, Van Wyk de Vries, 2013). As mining is clearly important for societal advancement, a geopark would provide a platform to increase understanding and formalize a dialogue regarding such practices in an area with tangible affects. Further opportunity lies in elevating the under-interpreted, but globally significant, geology while increasing the value and attraction of already interpreted cultural, mining and industrial heritage sites in our region. This is evidenced in other geoparks such as the Copper Coast Geopark in Ireland and Italy's Tuscan Mining Park and Geological and Mining Park of Sardinia.

3.3.1 Geologic significance of the Keweenaw

The geologic history of the Keweenaw is of categorically global significance from the macro to micro scale. The Keweenaw and Isle Royale are nearly completely comprised of rocks related to the Late Mesoproterozoic Midcontinent rift system, part of the middle

Figure 3.1: Location of Michigan's Keweenaw Peninsula and Isle Royale on Lake Superior

Keweenawan Supergroup (Figure 3.2). The rifting of supercontinent Rodinia created a ~3000 km long U shaped feature in the center of North America extending from as far as Texas to Ohio (Figure 3.3) (Cannon and Nicholson, 2001, Stein et al., 2015b), and contains rock assemblages typical of rift zones - mafic rocks interbedded with redbed sediments. The volcanic rocks were extruded as a result of a rising mantle plume impinged on the base of the crust. Underplating of a thick supercontinent, which acted like a blanket over the plume heat may have caused rifting, extending the crust and causing inward dipping normal faults (Huber, 1983).

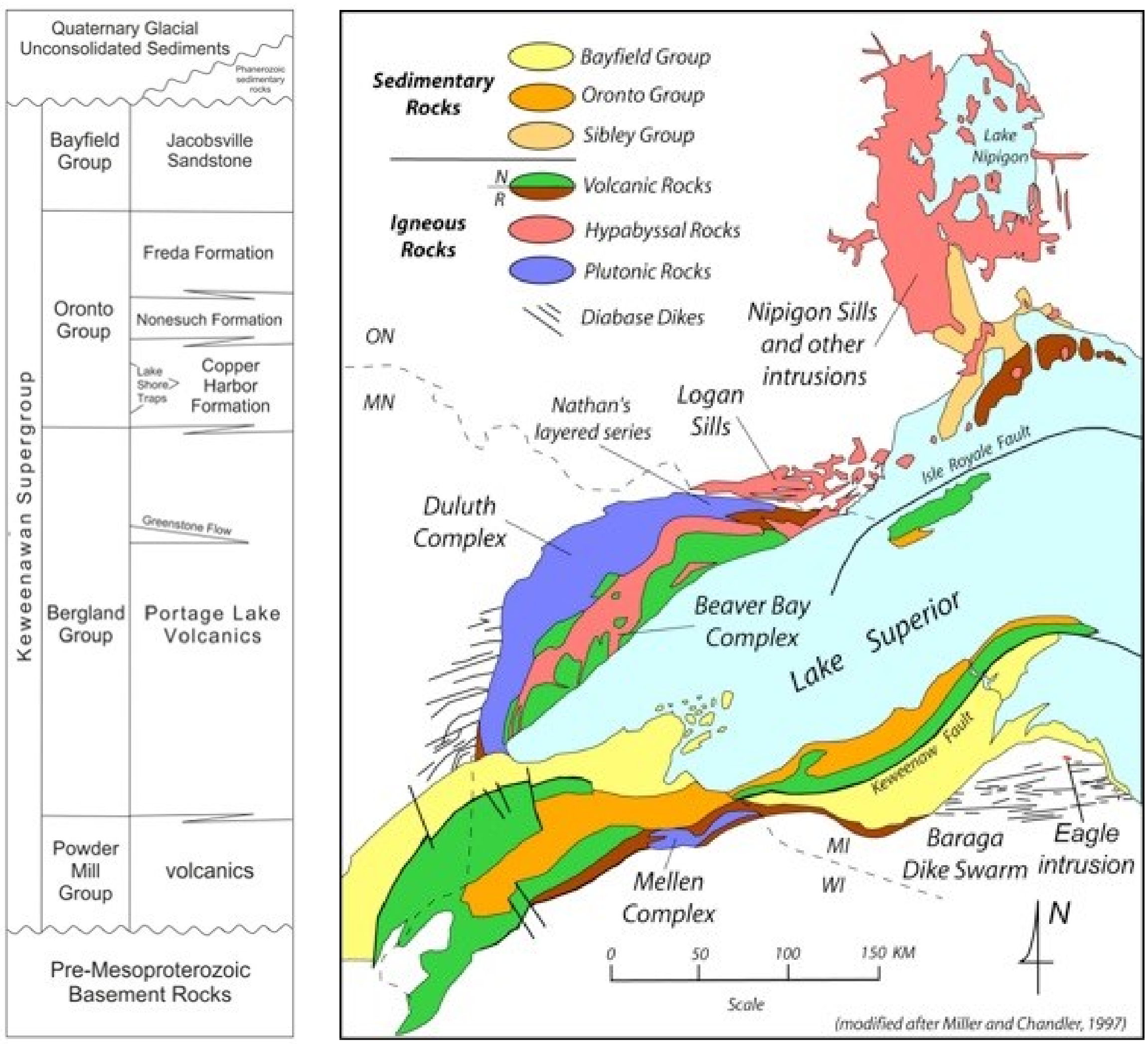

Figure 3.2: Stratigraphic section and geologic map of the Keweenaw Peninsula and Isle Royale (Bornhorst and Barron, 2011 and Miller, 2007).

The oldest rocks in the region belong to the Bergland Group (Figure 3.2) and are comprised of massive flood basalts that contributed to one of the greatest outpourings of lava on Earth - the Portage Lake Volcanics (PLV). PLV flows are typically 10-20 m thick exhibiting a massive base and interior and vesicular flow top, locally termed amygdaloid. The flows were erupted subaerially from linear fissures (Huber, 1983). The largest known lava flow on Earth, the Greenstone Lava flow, is estimated to have a volume of approximately 1500 km^3 and to have remained molten for centuries to millennia. It has a maximum thickness of 400 m and extends over 90km, including both sides of the syncline, and represents the geographical and cultural "spine" of the Keweenaw Peninsula. The massive volume of these flows and longer cooling rates (some on the order of millennia) have resulted in features such as pegmatoids or pegmatites. Ophitic texture is common in the PLV, created by the compaction and slow cooling of the lower part of the massive flows, where vesicle cylinders and segregation cylinders are also found (Longo, 1984).

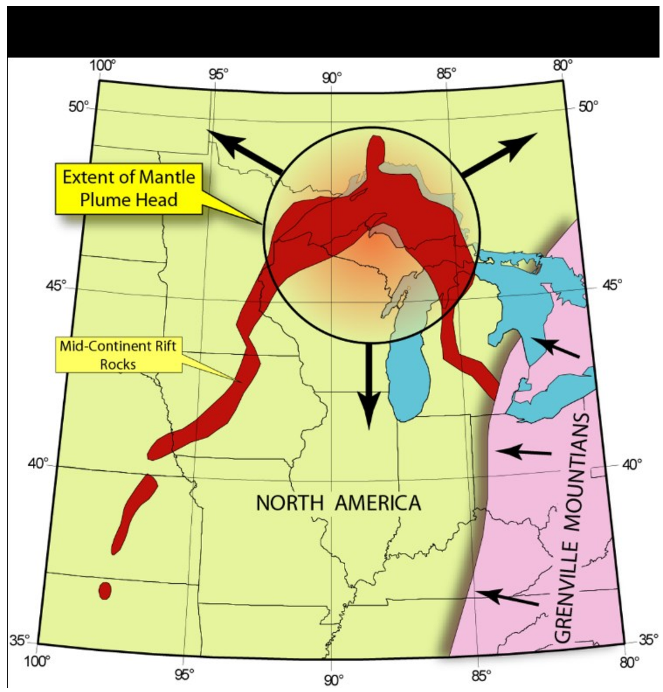

Figure 3.3: Estimated extent of rifting Midcontinent event, (K. Schulz, USGS).

The Keweenaw syncline, now the Lake Superior Basin, is the result of normal faulting and subsidence from the weight of the lava flows. The Keweenaw Peninsula makes up the south end of the syncline with mirrored rock types to the north on Isle Royale (Figure 3.4).

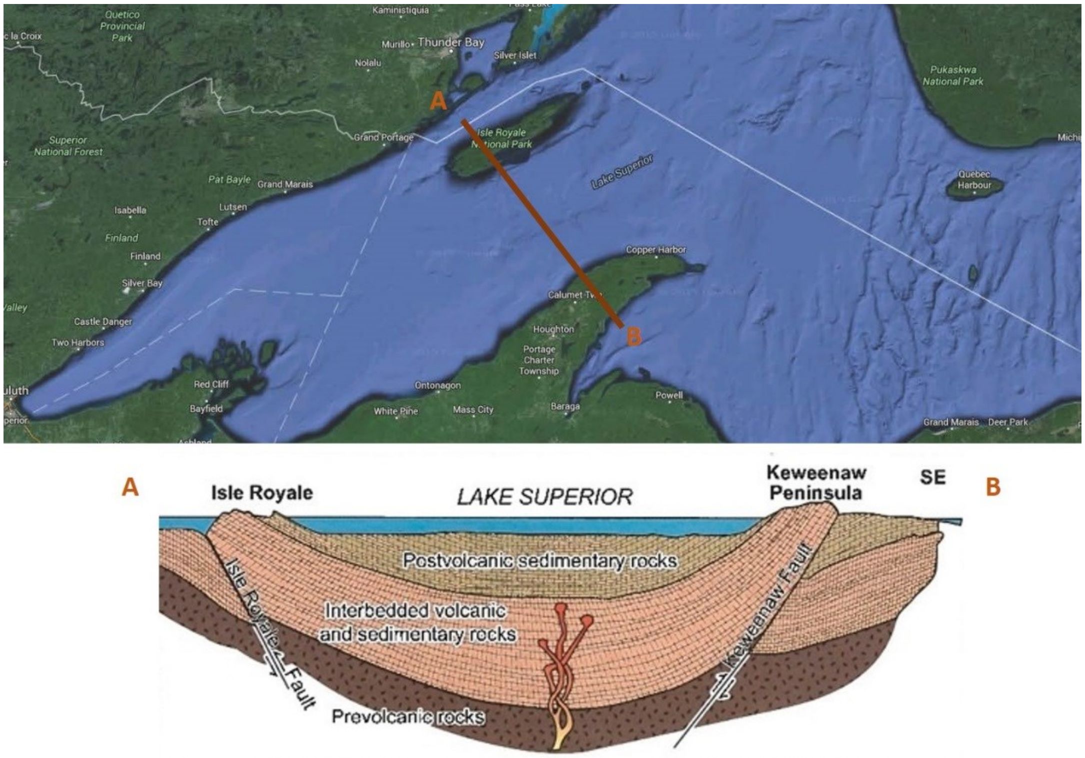

Figure 3.4: Syncline between the Keweenaw Peninsula and Isle Royale (Modified from Huber, 1983 and Google Earth).

Basaltic lava flows 25 km deep overlain by clastic sediments 8 km deep occur in the rift below Lake Superior (Cannon et al., 1993). Clastic sedimentary layers deposited within the PLV are typically 40 m thick and make up less than 5% by volume of the rift filling volcanic material. The composition of Copper Harbor Formation (the base of the Oronto Group) is principally comprised of red-brown conglomerates and sandstones deposited in alluvial fans (Elmore, 1984) (Figure 3.2). The lower part of the Copper Harbor Formation contains interbedded basaltic lava flows, the Lake Shore Traps (LST). The conglomerates there are punctuated by prominent exposures of stromatolites. The subaerial LST flows mark the end of magmatic activity within the Keweenaw rift zone. The Nonesuch Shale overlies the Copper Harbor Formation, consisting of grey-black siltstones, shales, and black-grey sandstone. The youngest rift-filling unit, and top of the Oronto Group, is the Freda Sandstone, red-brown sandstone, siltstone and mudstone deposited by shallow rivers (Bornhorst and Barron, 2011).

Overlying the Oronto Group and rift volcanics, the Jacobsville Sandstone (JS) is a variegated red and white, rift-flanking fluvial deposit marked by river channels sourced, in part, from the ancient, and once massive, Huron Mountains that eroded and filled the great valley of the Keweenaw rift. JS rocks are highly visible throughout the Keweenaw as they are used as ornate building materials (Figure 3.5). The date on this unit is currently debated ranging from 1 Ga associated with the end of the rifting period to Late Neoproterozoic (Rose et al., in prep, Stein et al., 2015a). The maximum range of 959 ± 18 Ma is constrained by detrital zircons dated with U-Pb methods but it is older than ~542 Ma. (Craddock et al., 2013).

Figure 3.5: Firefighters Museum heritage site in Calumet, built out of the ornate Jacobsville Sandstone.

It has been suggested that the Grenville Orogeny, the Mesoproterozoic orogenic event spanning much of the North American continent and ending the assembly of Rodinia, eventually ended the Keweenaw Rifting episode (Cannon, 1994). Continental collisions associated with the Grenville Orogeny are thought to have reactivated graben-bound normal faults within the Keweenaw, creating massive thrust faults, the most prominent of which is the Keweenaw Fault. Much of the Keweenaw and Isle Royale exhibit ridge and valley topography with rocks tilted at varied degrees (15- 60) toward the rift valley. The tilted areas are bounded by great thrust faults and have flat lying sandstones on the footwall side. These faults are key structural elements that represent major offsets of several miles of thrusting. The Keweenaw Fault has many exposures at the surface and complex minor faults associated with it. The faults have major influences on rivers, shorelines, waterfalls and copper mineralization.

This Keweenaw Fault was the focus of hundreds of high magnitude earthquakes, resulting in the splitting of the peninsula lengthwise and uplifting rocks, including native copper, to the surface (Irving and Chamberlin, 1885) (Figure 3.6). Native copper is found in the flow tops of lava flows (58.5% production), within the conglomerate beds (39.5%) and less abundantly in veins (<2% production). 11 billion tons of native copper were mined in the peninsula (Bornhorst and Barron, 2011). Other minerals in the region are considered highly valuable and collected for use as gems, including datolite, Lake Superior agates and “greenstone” (chlorastrolite) - Michigan’s state gem. All are part of a hydrothermal metamorphic mineralization episode that postdated the rifting episode by several tens of million years (Jolly, 1974, Bornhorst et al., 1988).

Figure 3.6: Sketch from an USGS report by Irving and Chamberlin who reviewed the arguments about interpretation of the Keweenaw Fault in several places in the Keweenaw where the law of superposition is violated (Irving and Chamberlin, 1885).

The “missing chapter” in the Keweenaw would feature the Phanerozoic sediments that once covered the Midcontinent rift system in the Keweenaw (Bornhorst and Lankton, 2009). Glacial activity in the Pleistocene eroded these sediments leaving only a few outcrops remaining. During glacial erosion the underlying and harder, more resilient rocks, such as the Portage Lake Volcanics, remained as prominent ridges; softer and younger overlying sedimentary layers were eroded. The retreat of the glaciers 11 000 years ago revealed the copper deposits and left dunes, eskers, kettle lakes and other prominent glacial features in the region.

Lake Superior is an impressive culmination of the syncline created with the rifting event and glacial retreat; its size causes it to act like an ocean in the middle of the North American continent exhibiting strong wave actions and currents, special weather features, active seiches, and an observable Coriolis Effect. The lake has a significant impact on the regional climate and weather patterns and its currents redistribute sediments and mining waste (stamp sands) along the shoreline. The lake interacts dynamically with the coastal features such dunes, rivers, and deltas and creates dramatic features such as ice volcanoes in the winter months (Figure 3.7).

Figure 3.7: Massive ice volcanoes on the Lake Superior North shore (photo courtesy of Steve Brimm).

Educational outreach activities already conducted in the Keweenaw have classified its geologic history into five broad *geoelements* (Table 3.1) for education and outreach efforts in the Keweenaw – the “big take homes” of geologic history. Field trips and community presentations often revolve around one or more of these classifications.

Table 3.1: Main geoelements of the Keweenaw

Geoelement	General description
1. The Hot Spot, Lavas, and Copper Mineralization	Keweenaw's black rocks offer a window to a deep Earth volcanic past; the site of Earth's largest lava outpourings when magma oceans existed in this region. This massive lava outpouring was driven by abnormal heat from the deep Earth.
2. Rift-filling Redbed Sediments	The red rocks of the Keweenaw originate from the ancient, and once massive, Huron Mountains that eroded and filled the great valley of the Keweenaw rift. These rocks are highly visible throughout the Keweenaw as they are used as building materials.
3. The Keweenaw Fault	A massive thrust fault which was the focus of hundreds of high magnitude earthquakes and which split the peninsula lengthwise and uplifted rocks, including copper, to a place where people could find it. This feature has shaped and beautified the Keweenaw but is no longer an active hazard.
4. Continental Glaciation	The Keweenaw Peninsula was recently covered with more than two miles of ice, the intense erosion and the complex glacial deposits are dramatic and have left many sand and gravel resources and shaped the landscapes.
5. Lake Superior	The existence of Lake Superior in the midst of North America makes for a unique environment which significantly affects weather and climate of the lake region, with features such as lake effect snow and moderating severe continental temperature extremes.

3.3.2 Aesthetic and cultural value of the Keweenaw

The forested landscape of the Keweenaw is a curious combination of stunning natural vistas and recreation areas (shoreline preserves, old growth forests, world class mountain biking trails) punctuated with the pervasive ruins of the copper mining era (mine tailings, old mine shafts, mining company buildings and company-provided housing). Natural and anthropogenic features alike imbue the region with a strong sense of place offering “something for everyone”.

There are conflicting opinions on the value of the decaying mining infrastructure. An example of this is the Quincy Dredge No 2 near Torch Lake, a dredge built in 1914 used to refine tailings for further extraction of copper as technology evolved (Figure 3.8). For some it is a peculiar landmark that inspires questions related to mining practices; for others it serves as a reminder of family members that worked with the dredge or in the mines. For others still, it is considered an eye sore, dilapidated and hazardous, with need of removal. This diversity reveals a stark reality of how our landscape is regarded by inhabitants and visitors; moving forward, we need to be inclusive and understanding of how these natural and anthropogenic sites are valued in developing a cohesive geopark management plan. In other words, the conservation of geosites and geodiversity sites is equally important as the preservation and interpretation of our historic landmarks associated with the mining era.

The Keweenaw reflects the cultural diaspora and associated traditions and customs for a long and diverse passage of people; from the Native American copper metal workings 9000 years ago (Martin, 1995, Martin, 1999) to the more recent Euro-American settlement spanning the past 150 years. Humans first came to North American from Asia approximately 12,000 years ago (Waters and Stafford Jr., 2007) when an ice-free corridor opened through a retreating

Figure 3.8: Old Quincy dredge – compelling or an eyesore?

continental ice sheet (Dyke et al., 2002). Soon after their arrival, the explorers discovered and began mining copper (Pompeani et al., 2015, Martin, 1995). This marks the beginning and most long-lasting part of the geoheritage of the region, and makes the district one of Earth's oldest metal mines. More recently, the discovery of copper in 1840 by Douglass Houghton, Michigan's first state geologist, triggered the epic copper boom of the Keweenaw that would propel the region to world fame, build the cornerstone of the American economy, and attract people from all over the world to work in the area.

Our historical monuments and heritage sites reflect these diverse cultural backgrounds; the vast collection of abandoned buildings also pays homage to the multitudes of people that came to this region for copper mining and related work (Figure 3.9). The legacies and impacts initiated by these varied cultures are still alive in the Keweenaw and are an enormous draw for people wishing to learn more about this period or about their ancestors. The cultural and industrial heritage of the Keweenaw has been preserved and interpreted in greater detail by the Keweenaw National Historical Park and other interpretive centers. A geopark designation would highlight the reason *why* this region flourished based on the geology, something largely left out of the story of the Keweenaw.

Figure 3.9: Mural of Calumet depicting the height of mining era by Barbara Flanagan (photo courtesy of Keweenaw National Historical Park).

3.3.3 Economic considerations within the Keweenaw

Geoparks are intended to benefit communities through increased sustainable economic activity, education, and conservation - a philosophy that dovetails with the current strategy for economic growth in the Keweenaw. The economy of the Keweenaw, once supported by the prosperous copper mines, is evolving and diversifying from extraction resources to opportunities related to the area's natural environment and entrepreneurial support, in essence a quality of life economy (Harmon, 2012).

Harmon (2012) summarizes growth opportunities for the Keweenaw economy in five areas:

- Start-ups and expansions of existing firms by local entrepreneurs.
- A growing technology sector fueled by research, intellectual property and corporate relationships at Michigan Technological University.
- Expansion of the manufacturing sector as it integrates technology and advanced processes.
- Attraction of branch offices of established companies that want access to Michigan Tech's technological resources and the Keweenaw Peninsula's relatively lower cost of doing business.
- Expansion of the tourism sector, particularly silent sports.

While the high-tech sector offers opportunities for significant job growth in the future, groups like the Keweenaw Economic Development Agency (KEDA) advocate that the basis for this growth is specifically related to the quality of life and outdoor recreational opportunities (KEDA, 2015). KEDA recently held a leadership summit soliciting input from forty-five prominent leaders in the community for the development of an economic strategic plan for the area. Input and analysis revealed that the region's principal strengths are:

- Quality of life
- Outdoors
- Natural resources

- Technology and research skills from Michigan Technological University
- Business development support infrastructure

…and prime opportunities lie in:

- Tourism
- Natural resources
- Placemaking
- Developing public/private partnerships to solve problems
- Expand and improve Career and Technical Education in schools

One of five overarching goals within the plan sets out to "Enhance Culture and Recreation Opportunities." This goal specifies increased signage highlighting points of interest, a balance between natural resource protection and historic preservation through managed growth, and ensuring the identification and accessibility of cultural and recreational sites. Recent renewed interest in exploration for copper mining has sparked divisiveness between environmentalists and extractive industry interests. Businesses that rely on tourism are more interested in investing in activities and businesses that dovetail with the needs of those interested in recreation. The Keweenaw's rugged landscape has led to the development of four world-class mountain biking trail systems (Figure 3.10). In 2014 the Copper Harbor Trails (based in a town with a population of 95) registered over 20,000 people intending to pass though the main trailhead between May and October. These numbers are expected to exceed that by upwards of 20% in 2015. Further

Figure 3.10: Cyclists riding on an ancient alluvial fan, world-class mountain bike trails on Brockway Mountain, Copper Harbor, MI (photo courtesy of Steve Brimm).

opportunity for growth in geotourism, specifically, has been illustrated through the success of a series of summer geotours. The tours employ combined van and boat transport to visit many remote Keweenaw sites (Vye and Rose, in prep). The goal is to facilitate public Earth science literacy, stewardship, and to create seasonal economic opportunities for local community partners. In keeping with the Keweenaw's current preference for a *quality of life* economy over finite *industrial mineral extraction* economy, a geopark designation would help shift the balance to a more sustainable means of developing the local and regional economy.

3.3.4 Protected areas in the Keweenaw

Geoheritage is recognized throughout the world at various levels ranging from UNESCO World Heritage sites to small locally protected and celebrated geosites. A large number of geosites and geodiversity sites in the Keweenaw are protected through a variety of designations ranging from the federal to private level; geoheritage figures prominently in the recent development of interpretation and signage at a number of these sites (Vye and Rose, in prep). A geopark designation would promote further interpretation of these places and, through a heightened awareness of their global significance, encourage further protection and public access of these and other relevant sites. By including this vital component of our natural history we are able to enhance informal educational opportunities for stone buildings, quarries, abandoned mines and other protected sites associated with mining or industrial heritage in our evolving inventory of significant sites in the Keweenaw.

National designations

The Keweenaw includes two national park designations. The Keweenaw National Historical Park is a collection of heritage sites located throughout the peninsula largely celebrating the mining, cultural, and industrial heritage of the area. Isle Royale National Park, part of Keweenaw County, is a remote wilderness island fifty-six miles across Lake Superior from mainland Michigan. It was designated as an UNESCO Biosphere Reserve in

1980 celebrating the unique and long running predator-prey relationship between moose and wolf on the island. Both parks exhibit the same geology, the north and southern flanks of the rift related syncline. Other national designations include:

- The Copper Country National Scenic Byway, a forty-seven mile stretch of US Highway 41 that runs the length of the peninsula. The Byway designation is conferred by the US Department of Transportation as a means of protecting “less travelled” scenic roadways with the intent on increasing tourism.
- Seventy-five sites on the National Register of Historic Places (NRHP), a National Park Service designation that works with public and private groups in identifying and preserving historically and archeologically significant sites.
- Three National Historical Landmark (NHL) designations, conferred by the National Park Service to assure preservation of historically significant places that contribute to the interpretation and understanding of the national heritage of the United States. Designated sites include the Quincy Mine Historic district, the Calumet Mine Historic district and the Keweenaw National Historical Park.

State and local designations include two state parks (McLain and Fort Wilkins), twenty-eight state beaches, fifteen townships parks and preserves, four recreational trail systems, and thirty-seven privately protected areas, established by nature conservancy and local land trusts.

In addition to the pristine and protected areas in the Keweenaw, the mining industry has had palpable negative impacts on the region. The best example of this is Torch Lake (Figure 3.11). The site of the former Quincy Mine Company’s copper mill is now listed by the Department of Environmental Quality (DEQ) as one of twelve Areas of Concern due to the detection of tumors in fish. The area was heavily impacted by industrial waste from the mid 1800’s until the late 1960’s. The lake was filled by approximately 20% volume with 200 million tons of stamp sands and other mining waste such as slag. A study is underway involving many locals experts with varied background to address the gaps in data needed to fully understand the history of this site and to work with the local community to determine what sites are in need of remediation (Mandelia, 2013, Urban et al., 2013). While these mistreated sites create a bitter and undesirable stigma they provide an outstanding opportunity for education – connecting people to landscape, broadening their degree of Earth science literacy in order to make critical decision about where they live – and therefore are vital geodiversity sites for a geopark proposal.

Figure 3.11: Torch Lake from above (source: "Torch Lake" Google Earth, 2014)

3.3.5 Education and Partnership in the Keweenaw

3.5.1 Outreach and partnership

Education and outreach of the Keweenaw's geoheritage is facilitated through community partnership. The Keweenaw is host to a close-knit professional community comprised of two national parks, two state parks, two universities, twenty-six museums and interpretative centers and other nonprofits throughout the peninsula. It is through cooperation with these partners that it has been possible to embed messages related to the geologic underpinning in programs that resonate for all while connecting with the more widely recognized aspects of industrial, mining, and cultural heritage.

Our education and outreach activities include the following and are detailed in a related preceding paper (Vye and Rose, in prep):

- The initiation of a geosite inventory and associated website for the Keweenaw Peninsula and Isle Royale
- Academic and public field trips - "Summer Geotours"
- Earth science professional development field schools for over sixty K-12 teachers
- Public meetings regarding a Keweenaw Geopark designation
- Public presentations with local museums, conservation groups and minerals clubs
- Cooperative interpretation efforts with national and state parks, school campuses with geosites, cities, towns and village parks, businesses with outdoor space
- Cooperative interpretive work with local nonprofit museums
- Land conservation/access/acquisition efforts with conservation organizations
- Advancing the concept of geoheritage regionally through Lake Superior lecture tour
- Advancing the concept of geoheritage nationally and internationally through organized sessions at scientific meetings and academic publications
- The development of interpretative signage, videos, field guides and books

3.5.2 Research

The rich geodiversity of the Keweenaw has prompted the accumulation of a vast, comprehensive body of scientific research over the past 175 years and continues to kindle wide-ranging research opportunities. Some of this research is based on scientific aspects of the Keweenaw's geodiversity, while other research focuses more on the complexity of anthropogenic intervention in our quest to understand the mining history and its environmental impacts.

Although the narrative of the rift has been generally accepted over the past several decades, recent research has challenged some of the conventional wisdom associated with this region, instigating further studies to determine the age of the Jacobsville sandstone. The Keweenaw is a hub for paleomagnetic studies investing Large Igneous Provinces (LIPS) and associated dyke swarms. Other subjects include the unexplained occurrence of native copper associated with the rifting event.

The Keweenaw hosts the largest stamp sand deposits in the United States, course sand remaining form the process of mining copper. Pertinent investigations focus on currents around the Keweenaw and how they redistribute the stamp sands. Companies external to the Keweenaw have expressed interest in removing these stamps sands and transporting them to Chicago to be repurposed as roofing shingles. The stamps sands are known to contain higher traces of arsenic, but precise quantities are unknown, as are other effects on the local environment both in situ and ex situ. Torch Lake, a DEQ Area of Concern, mentioned previously, also presents many opportunities to work with cross-disciplinary experts in solving some of the unknown effects of mining in our region. The remaining mining infrastructure has many vertical mine shafts, some reaching depths of over 5000 feet. Water temperatures at these depths have been recorded at 70 degree F and present an enticing mathematical and engineering problem targeting the potential development of geothermal energy extraction methods and related industry in our area.
This ongoing and developing research provides educational fodder for a geopark and provides an integrated way of educating local inhabitants and visitors on environmental issues and natural sustainable resources in the Keweenaw.

3.6 Key Geosites and Geodiversity Sites of the Keweenaw

Geosite inventories are advanced in many parts of the world and are applied at varying scales - park, municipality, regional, and national levels. These measures have been advanced throughout Europe, predominately within the UK, Spain, Portugal, Russia, and

Switzerland (Brilha, 2015, Fuertes-Gutiérrez, 2010, Wimbledon, 1999). In North America, geoheritage inventories have been evolving in Nova Scotia and Quebec, Canada (Calder, 2014b). The Unofficial Register of Geoheritage Sites has been created in the United States through the National Park Service in an effort to collect more data from all regions of the US, in or outside of park boundaries. Common themes for inventories include aspects of geologic significance, accessibility, educational value, touristic value, safety measure and fragility and current designation; collectively, these themes require a comprehensive geological knowledge of area, clear definition of inventory aims, and engagement with members of the Earth science community.

We have initiated an inventory of geosites and geodiversity sites in the Keweenaw and Isle Royale with varied uses, sensitivities, and threats. The developing inventory is hosted on the Keweenaw Geoheritage website (http://www.geo.mtu.edu/KeweenawGeoheritage) and includes compilations of scientific publications related to each site, photos and general information on the geologic setting and other associated values with the site. Key sites are found under the five main geoelements subheading we have established for the area (Table 3.1). We initiated our inventory based on field studies with longitudinal and latitudinal diverse participants (teachers and life-long learners) that facilitated the identification of key locations for optimal educational experiences in tandem with low impact to sensitive and unsafe areas; in other words – what worked best in practice with a group of twenty people. We have further assessed the sites with a method developed by Brilha (2015). This quantitative assessment affords an unbiased method of identifying the scientific, educational and touristic value of geosites and geodiversity sites best suited for our Geopark proposal. Scoring criteria for these respective categories are found in Table 3.2. The development of our geosites and geodiversity inventory serves a number of purposes:

- Provides a list of alluring and easily interpreted sites for locals, visitors, teachers and others to learn more about the geology processes of the area (including anthropogenic impacts)
- Connects people to the five main geoelements of the Keweenaw
- Illustrates the international and national significance of geosites and geodiversity sites for a Keweenaw Geopark proposal and development of a management plan.

Table 3.2: Quantitative assessment scoring criteria for the scientific, educational and touristic value of geosites and geodiversity sites (Brilha, 2015).

SCIENTIFIC VALUE	**EDUCATIONAL VALUE**	**TOURISTIC VALUE**
Representativeness	Vulnerability	Vulnerability
Key locality	Accessibility	Accessibility
Scientific knowledge	Use limitations	Use limitations
Integrity	Safety	Safety
Geological diversity	Logistics	Logistics
Rarity	Density of population	Density of population
Use limitations	Association of other values	Association of other values
	Scenery	Scenery
	Uniqueness	Uniqueness
	Observation conditions	Observation conditions
	Didactic potential	Interpretive potential
	Geologic diversity	Economic level
		Proximity of recreational areas

3.6.1 Key geosites and geodiversity sites

The following sites represent the wide ranging geodiversity found in the Keweenaw including the largest lava flow on Earth, alluvial fans, stromatolites, glacial features, and historic copper mining sites (Figure 3.12). These places are also significant for the cultural, mining and industrial heritage they represent. They offer ideal teaching opportunities and are located in areas with low sensitivity. Most are protected, open to the public, and frequently visited.

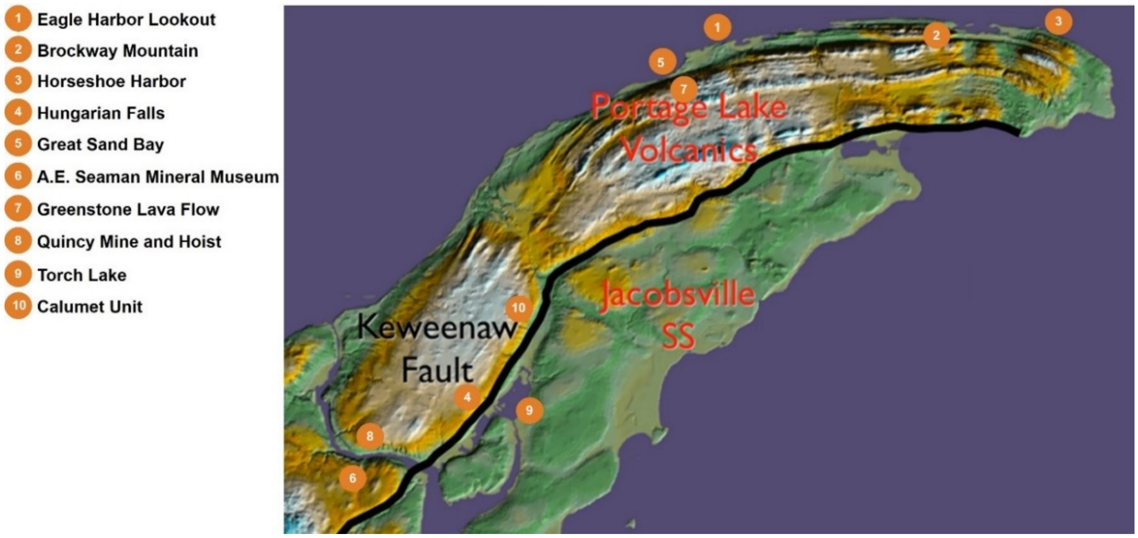

Figure 3.12: Location of key geosites and geodiversity sites of the Keweenaw Peninsula (photo courtesy of Steve Brimm).

1. Eagle Harbor Lookout (Figure 3.13)

Figure 3.13: Eagle Harbor, bays and points illustrate differential erosion of lava flows (photo courtesy of Steve Brimm).

Geologic interest: Lake Shore Traps

Description: One of the best places to learn how the reefs and shoreline of the Keweenaw have been created. Eroded flow tops (bays) and resilient flow bottoms (points) help describe the process of differential erosion. The site also hosts the Eagle Harbor Lighthouse and a Life-saving Museum.

Current protection: National Register of Historic Places

2. Brockway Mountain (Figure 3.14)

Geologic interest: ancient alluvial fan, Copper Harbor Conglomerate

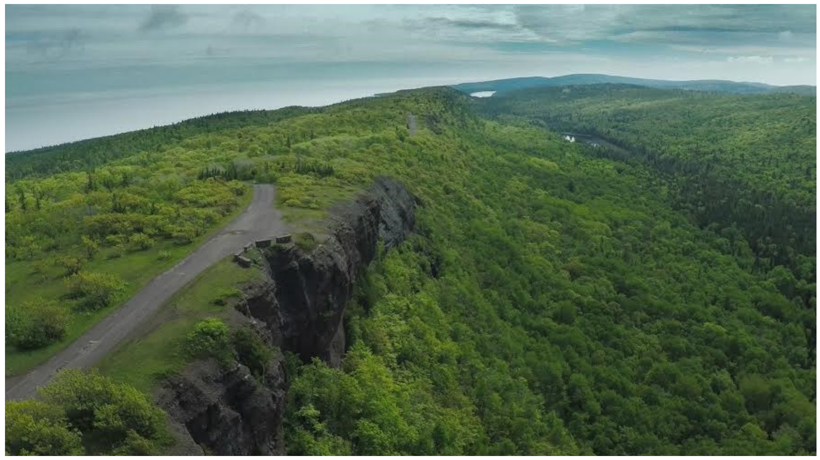

Figure 3.14: Brockway Mountain looking East (photo courtesy of Steve Brimm).

Description: Brockway Mountain offers incredible vistas of the Keweenaw Peninsula (on a clear day one is afforded a glimpse of Isle Royale). Brockway hosts world-class mountain bike trails and is regarded as the best place to observe the hawk migration in the spring. As a result of the extraordinary views in all directions, this is an excellent place to describe the geomorphology of the Keweenaw and to explain concepts such as the formation of the syncline and high energy alluvial fan deposition.

Current protection: Keweenaw Coastal Wildlife Corridor

3. Horseshoe Harbor (Figure 3.15)

Geologic interest: stromatolites, Copper Harbor Conglomerate

Figure 3.15: Copper Harbor Conglomerate at Horseshoe Harbor, stromatolites found at base of outcrop (photo courtesy of Steve Brimm).

Description: The site offers an opportunity to learn about changing atmospheric conditions and origins of life on Earth. Situated on Lake Superior, there is strong cultural and historical significance as this was a place of passage for French Voyageurs and Native Americans.

Current protection: Mary Macdonald Preserve, Michigan Nature Conservancy

4. Hungarian Falls (Figure 3.16)

Geologic interest: Keweenaw Fault, glacial activity

Description: Having a strong sense of place for locals, this site is protected as a result of community action focused on assuring continued open public access. Hungarian Falls is an excellent site to learn how faults create beautiful places in the Keweenaw like waterfalls and lakes. The underfit stream enables people to imagine the energy and power of melting glaciers required to create the massive gorge that it flows through. A geotour is installed at this site with signage for self-guided exploration.

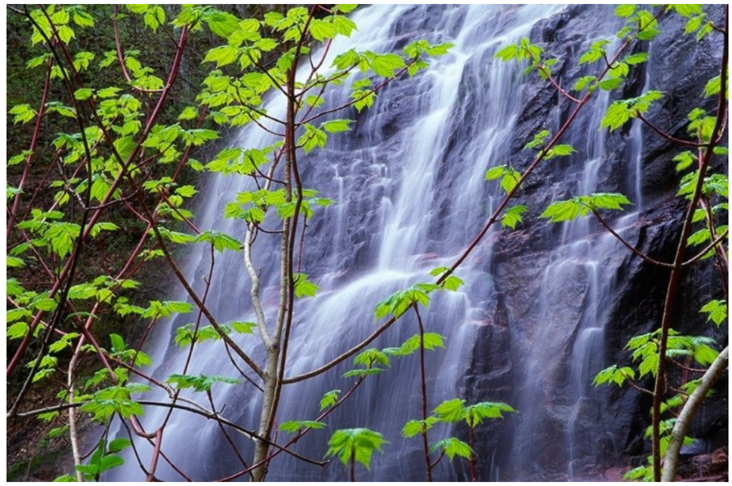

Figure 3.16: Upper Falls at Hungarian Falls. Peninsula (photo courtesy of Steve Brimm).

Current protection: Keweenaw Land Trust (upper falls) and the Michigan Department of Natural Resources (lower falls)

5. Great Sand Bay and Redwyn Dunes (Figure 3.17)

Geologic interest: dunes

Description: One of the most frequented beaches on the north shore of the Keweenaw, Great Sand Bay and Redwyn Dunes allow visitors to learn about significant glacial sand

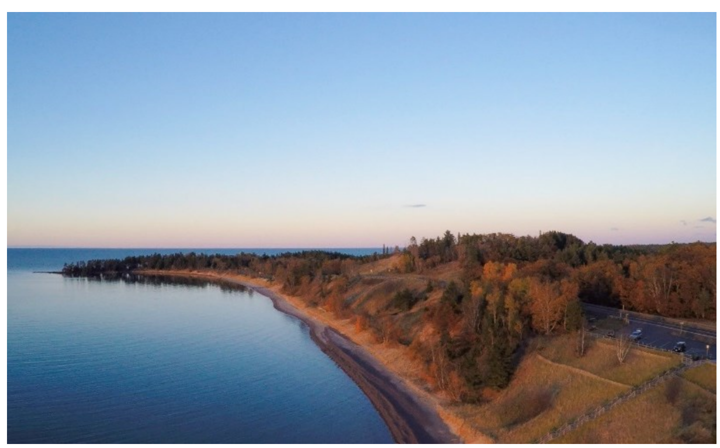

Figure 3.17: Dunes on the north shore of Lake Superior (photo courtesy of Steve Brimm).

deposition, erosion, and redistribution through interaction with Lake Superior.

Current protection: state beach and Keweenaw Land Trust

6. A.E. Seaman Mineral Museum (Figure 3.18)

Geologic interest: ex situ globally significant collections

Description: Originating as a teaching tool for geologists to whet their understanding of Keweenaw rocks and minerals in the late 1800's, visitors now have the opportunity to peruse over 25000 specimens from all over the world. The site is close to the Keweenaw Boulder Garden on the Michigan Tech campus, a collection of ex situ glacial boulders representing all the rock lithologies of the Keweenaw.

Current protection: Michigan Technological University

Figure 3.18: Entrance to to A.E. Seaman Museum, float copper greets visitors

7. Greenstone Lava Flow at Clifton (Figure 3.19)

Geologic interest: ponded basalt flows, pegmatitic and ophitic textures

Figure 3.19: The mighty Greenstone lava flow, looking west (above, Steve Brimm). Cliff mining operation at base of Cliff early 1900's (Courtesy of Michigan Tech archives).

Description: The largest known lava flow on Earth, the Greenstone Lava flow is the site of the first successful European mining venture in the United States. This massive flow allows people to learn about the anatomy of a lava flow and about minerals common in the Keweenaw. There are often public digs hosted by the Industrial Archaeology department at Michigan Tech inviting people to learn more about the "spine" of the Keweenaw Peninsula and its rich mining heritage.

8. Quincy Mine and Hoist (Figure 3.20)

Geologic significance: Portage Lake Volcanics, native copper

Description: The iconic Quincy No. 2 shaft is the gateway to the Keweenaw. The site operates surface and underground tours for visitors to learn about the process of mining and the conditions that many worked in between 1908-31.

Current protection: National Historic Landmark, Heritage site within Keweenaw National Historical Park

Figure 3.20: Left - Quincy Mine and Hoist in early days (Michigan Tech archives) and as an icon of the peninsula today (above, Steve Brimm).

9. Torch Lake (Figure 3.21)

Geologic significance: natural and anthropogenic created deltas, contaminates in lake as a result of industrial waste

Description: As a result of many years of mining waste the area has been designated as one of twelve Department of Environmental Quality Areas of Concern. Torch Lake offers a central learning opportunity to consider how mining practices, watersheds and humans connect and invites the public in the decision making process for what needs to be done with respect to remediation. The site is attractive to many wishing to visit the old mining infrastructure and locals parks and recreation areas.

Superfund site, DEQ Area of Concern

Figure 3.21: Torch Lake Area of Concern, stampsands, the old dredge and a smokestack (photo courtesy of Steve Brimm).

10. Calumet Unit (Figure 3.22)

Geologic significance: native copper, Calumet Conglomerate lode (CCL)

Description: The greatest copper mine of the Keweenaw was discovered in Calumet Township. The Calumet Geoheritage tour provides a self-guided means of exploring nearly thirty sites associated with this important part of Keweenaw history. The tour visits outcrops of the CCL, old mine shafts, glacial features, buildings constructed out of

Jacobsville Sandstone, and cultural sites associated with the people who led and worked in this community and the places they frequented.

Current protection: Keweenaw National Historical Park

Figure 3.22: Keweenaw National Historical Park Headquarters, the old Calumet and Hecla Mining Co. office building (left, NPS photo). Main Street Calumet filled with people in the early 1900's (Michigan Tech archives).

3.7 Conclusion

With its impressive geology and rich cultural history, the Keweenaw Penisnsula is ideally suited for a geopark designation. Geologic events have shaped this region in a way that is important to the well-being and lifestyles of the members of our community, and the story of how this region developed is worth telling. The Keweenaw is an ideal outdoor classroom that engages learners, not only through an intellectual connection to Earth science subject matter, but also through an emotional connection via culture, history, and sense of place.

Although we have developed a strong community partnership in support of a Keweenaw Geopark, it has not been without challenges. We have encountered political dissonance over the concern of geoparks being an official UNESCO program and general resistance of the notion of conserving or protecting lands for the public. However, our concomitant geopark proposal has substantive overlap with the development of a National Oceanic and Atmospheric Agency proposal for a Natural Marine Sanctuary with the theme of marine geoconservation. The boundaries of the sanctuary essentially extend from the high water mark of the Keweenaw Peninsula to the National Park boundaries of Isle Royale 56 miles away encompassing Lake Superior. The two concepts merge well and foster economic and education opportunities that enable people to make connections between geologic underpinning of both the terrestrial and marine environment.

The Keweenaw has globally significant and attractive geosites and geodiversity sites with a budding inventory system being developed for this region, a compelling human story, well-developed infrastructure and economic groups that support start-up and a quality of life economy, and an advanced education and outreach program. The UNESCO Geopark designation would support other historic preservation efforts related to mining and industrial heritage. It would promote stewardship for areas of concern and community involvement in restoring the overall health of the region. It has contentious sites that enable a frank means of connecting people to broader concepts of Earth science. By elevating awareness for globally significant geosites in the Keweenaw, we are able to nurture deeper connections to the rich and diverse cultural, mining and industrial heritage of the area.

4. The Unintended Outcomes of Geoscience Professional Development – the MiTEP Affect[3]

4.1 Abstract

Imparting the societal importance of Earth science literacy to the broader public is both a privilege and responsibility for geoscientists. Challenges in finding ways to resonate with a larger audience and to avoid jargon can be assuaged through shared community partnerships. The Michigan Teacher Excellence Program (MiTEP) aimed at the development of Earth science content in urban middle school teachers in Michigan is one such example. The National Science Foundation (NSF) funded project brought together academic institutes, middle school teachers from urban Michigan, and the National Park Service to foster deeper understanding of Earth science content knowledge through intensive teacher training, leadership development, and student engagement. While the project was successful at meeting its overall objectives, it is the unintended outcomes that are most compelling and worthy of exploration. These significant findings include: a) recognition of the challenges and realities of implementing professional development in the classroom; b) personal affect – changes in ways of thinking both professionally and personally among participants and academic personal, citing institutional change; c) the advancement and development of a geosite inventory recognizing sites with didactic potential for the Keweenaw Peninsula; and d) the overall advancement of geoheritage in Michigan's Keweenaw Peninsula based in part on teacher developed geologic interpretive materials. Geoheritage embodies the protection, management and educational value of geologically significant sites; it recognizes the personal values that people assign to such sites offering an inclusive point of departure for increasing Earth science literacy among a broader public.

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[3] The material contained in this chapter is being submitted to the *Journal of Geoscience Education*.

4.2 Introduction

A challenge, and responsibility, facing geoscientists is finding innovative ways of communicating the societal impacts of Earth science to the broader public. Universities are aptly positioned to advance Earth science literacy offering state of the art expertise and connected community partnerships. This is evidenced by experiences in the Michigan Teacher Excellence Program (MiTEP), a National Science Foundation (NSF) program aimed at developing Earth science content in urban middle school teachers in Michigan. A partnership between academic institutes, public schools and the National Park Service and specific initiatives within this program are described herein. Although many of the intended goals were met successfully, the unintended outcomes of this program are highly significant having palpable effects with emphasis on personal philosophical shifts in thinking of participants and instructors and in determining hindrances in implementing professional development.

Teacher participation in MiTEP summer field institutes and internships in Midwest national parks have created the foundation for much valued and needed geologic educational materials for the region, such as interpretative materials and EarthCaches. This paper also addresses how working with teachers on increasing their Earth science content knowledge in the field serendipitously helped to create a geosite inventory, contribute to the development of educational interpretive sites and self-guided geotours, and ultimately to advance geoheritage in Michigan's Keweenaw Peninsula. Geoheritage, a relatively new concept in the United States, considers places of geologic significance and the varied values people assign to abiotic nature – scientific, cultural, recreational, spiritual, economic, and educational. By recognizing that geology resonates with people in different ways, communication of Earth science issues can be more effective and reach a larger population.

4.3 MiTEP: The Initial Design

The Michigan Teacher Excellence Program (MiTEP), a 5-year research and professional development program working with middle-grade Earth science teachers from selected urban districts in Michigan. This National Science Foundation (NSF) funded Math Science Partnership (MSP) project focuses upon improving Earth science teaching and learning through intensive teacher training, leadership development, and student engagement. Core partners include Michigan Technological University and Grand Valley State University academic institutes, Grand Rapids, Kalamazoo and Jackson public schools, and the National Park Service (Figure 4.1). Academic institutes provide the foundation upon which greater depth and enrichment of Earth science content can be realized. K-12 educators are recognized as excellent communicators, and they find innovative ways of integrating and applying newly acquired content in an appropriate fashion in their classrooms. Partnering with the park service enables teachers to create valuable educational materials that highlight the rich and under-interpreted geodiversity within Midwest parks.

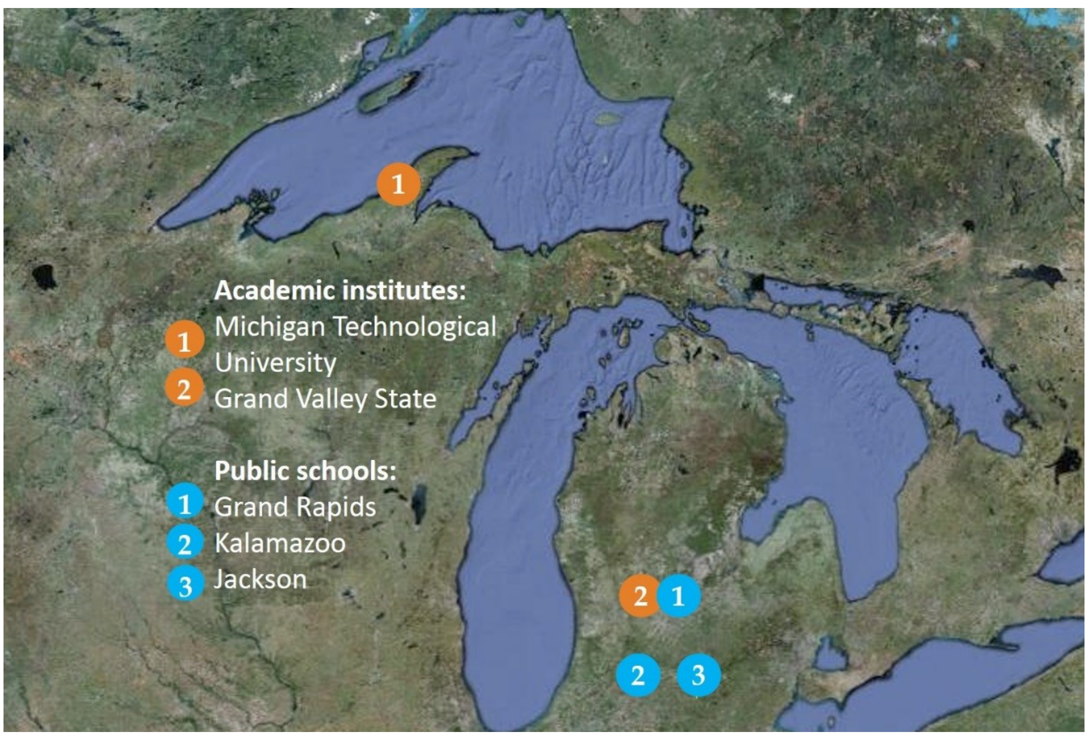

Figure 4.1: Location of MiTEP partners in the Upper and Lower Peninsula of Michigan.

The MiTEP program was comprised of varied resources and opportunities for four cohorts of teachers to develop their Earth science content through field work and pedagogy days, and to connect with a growing community of like-minded educators through participation in conference and professional meetings. A list of specific initiatives within MiTEP that were created to enhance the teachers' skillsets is identified as:

Coursework for Credit

Fieldwork in the Upper Peninsula (1 week)

Fieldwork in the Lower Peninsula (1 week)

Pedagogy days (4 days throughout the school year)

Lesson Study Course (semester)

Earth System Science Content Online Course (semester)

Science Learning Materials, Inquiry, and Assessment Online Course (semester)

National Park Internship (3 weeks)

Resources

Michigan Geography and Geology Text

Vernier LabQuest Pro probe devices

Commercial posters, booklets, pamphlets

MiTEP grants for classroom supplies

Scaffolded Leadership and Professional Membership

Scaffolded over three years (awareness, membership, professional presentations at state/regional conferences, encouragement and support for national attendance/participation)

Membership in MSTA

Attendance at the MSTA Conference

Participation in MSTA Conference

Membership in NSTA

Participation in GSA Regional and National Conferences

Ongoing Support

MiTEP Field Course Website

Classroom visits by colleagues

Classroom visits by MiTEP personnel

Scientists on Call

4.3.1 Evaluation

As stated in the original NSF proposal, “This project has the potential to initiate nationwide reform. The evaluation results will provide data needed to demonstrate that teachers who have access to high-quality curricular materials, are skilled in inquiry-based instruction, and have collegial and collaborative relationships with content-area and pedagogical experts can be successful in leading change that results in improved student outcomes.”

Extensive evaluation of this program and the concomitant development of new evaluation tools is described by Engelmann (Engelmann, 2014), who targeted identification and mitigation of misconceptions, attitudes, and content mastery in her suite of evaluation activities. The development of, and reception to, professional development training in the first summer’s field course is described by Klawiter (Klawiter and Engelmann, 2011). The overall evaluation results indicate that the intended outcomes of MiTEP were generally accomplished (to varying degrees) and mid-course corrections were employed in response to these evaluative efforts. These corrections included an expanded focus on connections between and among traditional geoscience content expectations (targeting the local and state along with emergent Next Generation Science Standards) with applications from other domains of science, mathematics, and history. Additionally, “churn,” initiated at the district level, resulted in layoffs or reassignment of most of the teachers into different buildings, grade levels, and/or disciplines. This precipitated a shift in focus from a one-topic, one-textbook teacher training mode to a more encompassing experience. Prior to the second year of the program, Engelmann initiated the “MiTEP Model,” an effort to correlate and map the multiple content and grade level expectations from assorted disciplines with the existing geoscience underpinnings that represented the original MiTEP goals. As the first cohort of teachers began their second year of training, many field topics and inquiry methods had been altered to include mathematical problem solving, physics, chemistry, biology, environmental science.

As landscapes are created in diverse ways, and the meanings we attach to them vary greatly, an interdisciplinary approach to learning is essential. Geoheritage represents a fusion of Earth’s dynamic processes that create natural landscapes and geologic features with our own attributed cultural, educational, and aesthetic values related to these features – in other words, there is a learning opportunity for everyone. This awareness is currently evolving in Michigan’s Keweenaw Peninsula through a wide-ranging community partnership that was largely founded on MiTEP teacher field experiences. The nature of the summer field course and national park internships specifically encapsulate this concept and are reviewed below.

4.3.2 Summer field institute

A central objective of the summer institute was to introduce Earth Science content to middle school teachers through field experiences. It was designed to emphasize the development of the participants’ problem-solving skills and to employ inquiry-based pedagogy techniques. An important part of the course introduced various tools and techniques employed by Earth scientists to conduct research, and to hone the teachers’ observational, geographical, descriptive, analytical and interpretive skills. It repeatedly applied a sequence of logical questions that can be tested, so that hypotheses can be rejected or refined. The predominant subject matter focused on the fundamentals of Earth science; participants were engaged in understanding, interpreting, applying, analyzing, synthesizing and evaluating their own observations in the same way as scientists do. The two week long course brought teachers to the Upper Peninsula of

Michigan for field work in the Keweenaw, the second week was conducted in and around their school district in the Lower Peninsula in order to provide local examples of Earth system processes. Field experiences connected sites by first telling the broader story of how geologic processes shaped the landscape; further connections were made by describing how these geological processes triggered resource exploration, economic opportunities, inspired art, and led to the human settlement. Essentially, the rich geoheritage and varied values of the field sites created the foundation for a fulfilling and deeply connected field experience (Figure 4.2).

Figure 4.2: Summer field institute in the Upper Peninsula. Clockwise from upper left: Teachers learn about paleomagnetism along the north shore of the Keweenaw; learning about the anthropogenic effects of mining in the Keweenaw at the Gay stamp sands; observing a chrysocolla vein at the site where copper was discovered in the Keweenaw; a visit to the former Cliff mine, the first successful European copper mine in North America.

In preparing for the summer field schools in the Upper Peninsula specifically, efforts to develop an inventory of accessible geosites with significant education value for the Keweenaw Peninsula were initiated. Prospective field sites were evaluated and selected according to the following criteria: a) a place where teachers could learn about significant Earth system processes and features (both in situ and ex situ); b) have qualities that fit the “Earth Science Literacy Principles” (AGI 2009); c) be accessible for groups of twenty participants; and d) have aesthetic qualities to captivate learners (Figure 4.3). Thirty-six sites were developed into EarthCaches by teachers as part of their course deliverables (Gochis, 2013) (Gochis, *in prep*). These EarthCaches help educate

Figure 4.3: Examples of ex situ sites, the Michigan Tech boulder garden (left) and in situ sites, Great Sand Bay along the North shore of the Keweenaw (right).

visitors and locals and have been adapted into interpretative signage highlighting the rich geoheritage and geodiversity of the area.

4.3.3. National Park Internships

As a capstone project, MiTEP teachers had the option of participating in an intensive three-week, hands-on summer internship in a Midwest national park. The internships aspired to foster in the teachers a deeper understanding of diverse learner needs in the learning of science, an inquiry-based exploration of the natural environment, an increase in their Earth science content knowledge, and an expectation that they create highly valued interpretative materials for national parks (Vye, 2011).

The four parks featured in the program included Keweenaw National Historical Park, Isle Royale National Park, Sleeping Bear Dunes National Lakeshore, and Pictured Rocks National Lakeshore (Figure 4.4). Geodiversity among these four parks is vast; the Late Mesoproterozoic Midcontinent rift geology and copper deposits in the Keweenaw and Isle Royale; sand dunes and glacial features associated with Sleeping Bear Dunes; and the mineral stained sandstone cliffs and glacial features of Pictured Rocks.

The parks generally lack resources to developing their own geologic interpretation, lesson plans, guided walks and other ways of engaging formal and informal learners. Geodiversity in national parks is sadly under-interpreted nationally and generally eclipsed by biotic nature and more popular cultural histories. The Geologic Resource Division was created by the park service in 1994 in an effort to remedy this lack of attention to abiotic nature and to help support park staff in protecting significant abiotic nature and managing Earth system processes in the parks (Shaver and Wood, 2001). The development of programs such as “Geoscientists in the Park” has supported the parks’ creation of more geoscience-focused educational materials and management and research initiatives. These gaps are further bridged through partnerships offered by programs such as MiTEP, which provide guidance and support in assisting the teachers to coordinate with the park personnel in forging a path that is mutually beneficial.

Figure 4.4: Midwest national parks participating in the MiTEP program.

Participants lived in or near the parks and worked directly with national park staff, Michigan Tech, and other community partners on individual and group projects including interpretative trail guides, evening program scripts, lesson plans, podcasts, media clips, activity totes, EarthCache passports, public safety messages regarding natural hazards, improving park literature on geologic features and invasive species (Figure 4.5). As EarthCache authoring activities had proven to be successful in the MiTEP summer institutes, it was included in the list of deliverables for the national park internship. Of note, a number of teachers presented their experience in the park at the Geological Society of America annual conference (Baldus, 2011, Bowen et al., 2011, Burd, 2011, Clough, 2011, Deur-Vis et al., 2011, Diekema et al., 2011, Rizley et al., 2011, Wilson, 2011).

Internship experiences inspired many teachers to develop similar projects in their own schools and to share their experiences with students and colleagues. Examples include:

1. A component of interpretation already employed by the National Park Service is the inclusion of traditional knowledge and the blending of both physical and social sciences. A MiTEP participant holds a week long, place-based science and social study excursion to Michigan's Grand Isle State Park (near Pictured Rocks) every year for her eighth-grade students. Grand Isle offers numerous geological and water features, making it an excellent outdoor classroom for a variety of Earth Science disciplines. Importantly, this park carries a tremendous sense of place arising from its rich cultural and geological history. Activities during this excursion are varied and include scientific inquiry, cultural understanding and development, and general wilderness survival skills; all activities rely heavily upon Native American traditional knowledge with visits from local elders.

2. A teacher of special education high school students, participating in an internship at Keweenaw National Historical Park, embarked on the building and piloting of an underwater remotely operated vehicle (ROV) to examine underwater geologic features. While not a conventional project for the park, the teacher was able to

connect with many local people in the area associated with the parks who were able to assist him with how and where to apply his technology. His work with the park has since led to receipt of a $3000 grant supporting his plan to initiate a student engineering opportunity which allowed his students design, build, and modify underwater ROVs. His approach allows students to develop problem solving skills in the design process and subsequent application rather than to provide them with a step-by-step construction "recipe."

3. Inspired by the Michigan Tech boulder garden she visited in the summer field institute, one teacher collected rock and mineral samples during her summer internship at Keweenaw National Historic Park. Her collections have provide teachers in her district with representative samples of rocks from the Upper Peninsula and her school campus now has its own rock garden with samples from all over Michigan. As a direct result of her internship with the Keweenaw National Historical Park, she was able to make contacts with representatives of the Michigan Earth Science Teachers Association (MESTA) and other local partners, who assisted her in developing a plan to bring a group of students to Michigan's Upper Peninsula in summer 2013 for the purpose of rock identification and collecting. She also served as a member of MESTA's executive board.

4. A former Earth science co-teacher now working with students with behavior issues described how her internship experience helped her in the classroom:

   "I don't teach science right now, my room is used as a behavior compliance for students with behavior issues, and maybe adults with behavior issues. So, definitely I use my room, there's pictures of my experience, pictures that show the geology part but also the personal part of bullying going on in our lakeshore area and our national parks. I've got all my rocks from the past three years that kids come in and ..sigh…I suppose it's silly but suppose we all have some kind of

rocks in our heads and we talk about behavior and the rocks and the boulders that are creating obstacles."

"I made a lesson plan on bullying and diversity at Sleeping Bear Dunes National Lakeshore and so, because of where I teach and work there can be a whole lot of bullying going on and the is a whole bunch of diversity."

5. Teachers were encouraged to participate in a photo elicitation exercise while interning in the parks by taking a photo of something within the park that represented each one of the Big Ideas of Earth Science (*Earth Science Literacy Initiative. "Earth Science Literacy Principles: The Big Ideas and Supporting Concepts of Earth Science".* 2009) with a short one line narrative. One teacher has since included the AGI Big Ideas of Earth Science pamphlet as a secondary text for her 8th grade Earth science class and requires a photo elicitation exercise and a field journal as deliverables from her students.

Figure 4.5: Clockwise from upper left: learning about lava flow features at Isle Royale National Park; MiTEP teachers interviewed by local TV station on the MiTEP/NPS partnership at Sleeping Bear Dunes National Lakeshore; examining structures in sedimentary rocks at Pictured Rocks National Lakeshore; working on an industrial archeological survey at Keweenaw National Historical Park.

4.3.4 Field experiences

Data points used in this paper are drawn from Engelmann's MiTEP exit survey (2014), a mixed-method assessment employing Likert-scale questions and open ended questions, and designed to evaluate the effectiveness of MiTEP tools and teachers' experiences, personal interviews, and personal communications throughout the course of the program.

Exit survey data indicate that, among the specific initiatives enacted in the MiTEP program, the field components of the course were deemed by the surveyed participants to be the most significant. The following tables present responses from the first two cohorts of teachers to have participated in the MiTEP program. The quantitative segment of the survey asked respondents to rate the usefulness of the components of the MiTEP program (listed above) that helped improve their understanding of Earth science content knowledge (Table 4.1) and their teaching skills for student learning (Table 4.2). It also probed what components of the program had the greatest influence on becoming a teacher leader (Table 4.3) and the greatest impact of teaching strategies (Table 4.4). A Likert-scale question format was employed to collect this information.

Table 4.1: Items that were most useful in improving your own understanding of Earth science content knowledge ***n=19, mean based on 10 point Likert scale, 0 (not useful) – 10 (very useful)***	
Fieldwork in the Upper Peninsula	9.69
National park internship	9.69
Fieldwork in the Lower Peninsula	9.25
Pedagogy days	7.06

Table 4.2: Items that were most helpful in improving your teaching skills and your students' learning ***n=19, mean based on 10 point Likert scale, 0 (not useful) – 10 (very useful)***	
National Park internship	9.40
Fieldwork in the Upper Peninsula	8.88
Fieldwork in the Lower Peninsula	8.44
Pedagogy days	8.00

Table 4.3: Items that had the most impact on your interest in being a teacher leader *n=19, mean based on 5 point Likert scale, 0 (not useful) – 5 (very useful)*	
Interest in leading Earth science field trips to national parks with colleagues	4.13
Interest in leading Earth science field trips to national parks with students	4.12
Interest in creating or participating in a MiTEP-based Professional Learning Community	3.94
Interest in networking with college of university faculty	3.06

Table 4.4: Items that had the greatest impact on teaching strategies *n=19, mean based on 5 point Likert scale, 0 (not useful) – 5 (very useful)*	
Using real examples from Michigan	4.50
Using real examples from the national parks	4.19
Using real examples from your local area	4.19
Relating science content to real-world examples	4.00

As the summer field course and national park internships were purposefully designed to illustrate the interconnected nature and varied values involved in teacher participation, it is posited by the researcher that they scored higher in the exit survey data because they included components that transcended the mere description of geologic features or processes. Cultural, industrial and archeologic heritage was purposefully woven into the fabric of these field visits, offering multiple ways for teachers to connect *personally* to the sites.

Through the five-year project, MiTEP's external evaluators were provided with numerous artifacts representing *quantitative* data collected and analyzed by the MiTEP internal evaluation team. However, a more comprehensive evaluation of both the intended features and unanticipated outcomes of MiTEP can be revealed through scrutiny of the underutilized *qualitative* data collected.

4.4 The unintended outcomes of working with teachers in the field

While evaluation of the intended outcomes of the program has indicated success of the MiTEP project, some of the unintended outcomes and their tangible effects on both teachers and the Keweenaw community are rich and compelling. While the project was envisioned to initiate reform on a national level, challenges in implementing professional development were revealed that may have hindered the ultimate success of the project goals. Instead participants were influenced, or reformed, personally. Deliverables and products from both the summer institutes and the national park internships have resulted in the advancement of geoheritage in the Keweenaw through the development of a geosite inventory, educational signage and self-guided geotours, and a successful template for the development of field courses aimed at addressing the needs of life-long learners.

4.4.1 Challenges in implementing teacher professional development

Teachers face tremendous day-to-day challenges and frustrations in the classroom, making it difficult for them to implement new teaching tools or strategies learned through MiTEP or other professional development opportunities. Insightful conversations with participants have highlighted the mitigating obstacles hindering these improvements due to what happens directly, or more aptly what cannot happen, in the classroom. Recognizing that teachers are coping with setbacks and implementing what they have learned is valuable, not just for the MiTEP project, but for research projects being designed in the same vein; understanding the disconnect between academic institutions and public school systems will surely help to strengthen the success rate of future proposals. Interviews and casual personal communications to date have revealed the following possible roadblocks to implementation; results from the MiTEP exit survey data revealed that teacher "churn", involuntary transfers to other subjects or schools, is one of the most significant setbacks to applying Earth science content professional development. Addressing the survey question, "Have you encountered obstacles that have prevented you from improving Earth science education in your school or district? If so, please provide one or more examples of the obstacles you have encountered," respondents replied:

- *Not teaching Earth Science. Being moved into other positions.*

- *Mobility of our teachers. Also the time spent revising is frequently not used to increase student achievement. District connections are not clear and often one doesn't connect with others to enhance programs.*
- *I do not get to teach science. I am moved out of my building and room every year, and there is no continuity. I cannot build up lessons with a basis on anything other than textbooks because my courses change every year.*
- *Yes, movement to Math Coach position.*
- *People get moved around too much. My own thinking that I was dumb in science. GRPS politics. Not daring, then to speak up. I am not in science anymore.*
- *Yes- since science is no longer a co-taught subject, it has taken away special education (resource) teachers access to having any real influence in the course.*

Three years after their inaugural year of MiTEP, of the *fifteen* Earth science teachers, only *two* remained in Earth science classrooms. In informal discussions with teachers, other “elephant-in-the-room” hindrances to adoption of MiTEP strategies emerged:

- “Out of field” and grade-level teaching certification issues in Michigan
- Disenfranchisement
- Mutual mistrust (teachers with other teachers, administrators, school board, etc.)
- Top-down administrative approach
- “Value Added Measures” (reliance on student test scores to promote/retain teachers)
- Inability of teachers to engage in “teachable moments” (e.g. natural hazards in the news, oil spills in the Kalamazoo River, flooding) due to lockstep, school-wide (or district-wide) common curriculum and common testing.

- Integrated approaches to teaching required by the district
- Student migration
- Burgeoning class sizes
- Shrinking budgets

While many limitations and hindrances identified by MiTEP teachers are universal, the district's inability/unwillingness to address them has undoubtedly led to diminished success in MiTEP's acquiring the traction needed to "initiate nationwide reform."

4.4.2 Personal affect

The MiTEP grant proposal states:

"..teachers play a critical role in determining the curriculum in terms of its content, scope, sequence, and delivery. Teachers must share reform goals if changes are to succeed."

Understanding what hinders reform in this capacity is not merely germane; it is *crucial*. While perhaps not yet driving systemic change in Earth science education at the district level, these teachers, through their own individual experiences, represent islands of hope. Good teaching can perhaps be likened to a cooking show – sometimes you don't necessarily follow a recipe strictly, you just have "the stuff" and go from there. Evidence from the program evaluation suggests that MiTEP has amply provided MiTEP participants with "the stuff", but the personal changes that may be even *more* compelling.

4.4.2.1 Professional changes

Exit survey data indicate that the MiTEP program has made positive impressions on participants personally with respect to their understanding of Earth science and improved teaching skills. A notable theme that emerges from the qualitative questions in the exit survey refers to gains in confidence. When asked how MiTEP had changed their attitudes toward teacher leadership, teachers responded:

- *MiTEP has given me the confidence and knowledge of science that makes it easy to be in a leadership position.*
- *I am more confident and open to leadership roles.*
- *I dared to: speak, ask, try. Make and claim, give evidence, and reasoning. Change my way of thinking based on evidence, not just an idea. Product was presenting at conferences, challenged colleagues thinking, and impassioned to further my knowledge and lead.*
- *I became involved in a MiTEP leadership role. I presented at conferences, which I never would have done if it weren't for MiTEP, same with co-leading PD [professional development] for teachers.*
- *MiTEP made me more willing to participate in leadership events.*
- *Still more comfortable with students. I really did enjoy sharing and discussing teaching skills and Earth Science concepts with my MiTEP group - great experience.*
- *I have become more vocal and willing to stand for my beliefs more than I would have before.*
- *I feel more comfortable now when I'm helping my students with their science homework.*
- *I would definitely not be on Instructional Council for the district were it not for MiTEP. I helped assemble and keep running a group of 3 teachers at Central HS required a group. I am a rep for the union.*
- *It encouraged/forced me to face some fears in the realm of presenting to a group of peers and experts. Through my experiences of presenting at MSTA, NSTA, and the GSA conferences. I have gained confidence in my abilities which has led me to choose to be the head of various committees in my school.*

The program helped build confidence in teachers to feel that they can discuss Earth science concepts with colleagues and experts and to take on leadership role as Earth science experts within their community. It's not just about having the content knowledge but being able to teach, and lead, with confidence and to be able to make broader connections to societal impacts of Earth science issues. When asked if MiTEP had an influence on their attitudes on the societal importance of Earth science literacy, participants responded:

- *Yes! MiTEP exposed me to new scientifically literate groups of people. I found these groups to be intellectually stimulating and healthy to be around. I also witnessed first-hand people finding a lot of pleasure out of learning earth science.*
- *Yes it has. Going into MiTEP I had basic knowledge of earth science. Everything I knew came from high school courses or co-teaching 8th grade Earth Science, which proved to be very limited. MiTEP offered so many hands-on inquiry based activities at places such as Copper Harbor, which to the naked, un-trained eye is just simply a beautiful place, but upon closer look hold vital information about the earth's past. Knowing this has helped me to look deeper at my surroundings and to appreciate the changes the Earth has undertaken to allow us to function today.*
- *To stay informed of current events. In particular the increase in wind energy and the debates it has caused.*
- *Yes, I think we need to take Earth Science back to high school and look at it as the foundation for good citizenship. We did water source and looked at the landfill with methane use for electricity.*
- *Really… it is important for our students to be taught how this world works and how we need to care for it.*
- *Earth Science literacy is the backbone to understanding our Earth and how it works. Gay Sands and Mining Practices/Tour [in reference to sites in the Keweenaw].*

- *I always knew Earth Science Literacy was important, but MiTEP reinforced that.*
- *Like of course! My own growth in Earth Science Literacy has changed my own habits and actions. If I can hook the curiosity and hunger for knowledge in students, then they can then make a difference as well. Examples: 1) Watershed in our area= proper care for our land; 2) E-botulism knowledge= understanding the bullies in our environment and steps we can take to prevent this; 3) Sources of energy; 4) Trees... how to protect and why. More/Deeper Earth Science Literacy in me --> Greater/Deeper Earth Science Literacy in students --> Greater and Healthier Change and that = healthier Earth!*
- *I've always thought this was lacking…. MiTEP provided many resources though.*
- *I have always believed in the societal importance of earth science literacy.*
- *Yes, going into working mines or municipal locations where scientists work.*

4.4.2.2 Personal transformations

A significant transformation for one participant - philosophically, spiritually, and professionally - is described below. In an interview, the participant describes her beliefs and awareness of Earth science content in advance of participating in advance of participating in the summer field courses and national park internship and the processes that have influenced her both personally and professionally:

"I was raised very conservatively and um…took a lot of things out of this big book the Bible very literally. So I didn't believe in glaciers, but I went to place up in Canada and it was called Heavens Peak, and I thought if I went up to Heavens Peak I would be closer to my mother who died when I was very young and so was she. And so, I got up there with my kids and my husband at the time and would you know it? There's a sign at Heavens

Peak that says what it is. It says it's a glacier, and my world came crashing down. I was probably about 38, 39 when that happened. So that affected a sense of place scientifically and maybe mentally, academically, spiritually, everything for me."

"I'll give it in a timeline of sorts, or perhaps a flow map. Just realize there is no end, because I'm still growing, so my views will also… evolving with further knowledge. 0-18 year old= Dad, a minister preached literal translation of the Bible-re- Earth's Age. He said that God created all lakes, all animals, and humans. Just as we see it, He did it! 19-28 years old. Black and white world, I wouldn't even consider the possibility of dinosaurs and glaciers! 29-48 years old. Took my own kids on trips. Saw things and couldn't make "sense" of <u>time</u> and <u>how</u> things happened. 49-50 years old. Taught Earth Science and there was major clashing! Friction! 51-53 years old. MiTEP. Claim-Evidence-Reasoning! Our Earth is billions of years old!! My God still cares for me and is one awesome Being! 54 years old to Infinity and Beyond!"

She reflects on her change in attitude as a result of her experiences:

"I really didn't have an understanding of how scientists do science….and actually I wasn't even curious! Isn't that sad? While I was co-teaching Earth Science, 8th Grade, as I viewed the textbook I realized how little I know. Praise God. MiTEP came along. While challenging in subject material, I was hooked by [the lead instructor's] knowledge, style of presentation and his passion for Earth Science. It's as if he eats and drinks geology. The professors' non-judgmental personalities allowed me to listen, wonder, and question. I embraced the "claim, evidence, reasoning" in science, and the theory--> hypothesis --> testing, and the inquiry processes. That enabled, more like empowered me to observe, question, create ideas, theories, and dig deeper. Not only now would I marry a scientist, but aim to be one as well, in my own way"

"I was scared to join MiTEP. And I was scared every time we had a MiTEP meeting because I didn't know half, I didn't know three quarters… I probably didn't know one tenth of what academic teachers would now, Earth Science wise. Really scared of that and really scared of how people would be talking and that I wouldn't understand them. So, why participate? And it's probably the best thing I could have done in my life, also to accept other people that we're all different and isn't it wonderful that we're all in the same world? And that I don't have to agree with them, but….wow, can I learn a lot. And then how to bring that back to kids. And that's the most exciting thing, you know. I would rather have it not be over, and it really isn't over because it's just begun."

She reflects on how she now sees herself as a professional:

"Okay, the short, but deep of it is this: I thought that teachers see SPED [special education] teachers as not knowing much, or sticking up for the "little people". I then dumbed myself down. What I gained was a passion for learning for questioning, and working together. This transformed me into a grounded professional who wants to continually learn, question, and work together for the better of our students. That means that I lead when I need to and LOVE the journey of being a teacher and a learner."

4.4.2.3 Personal changes in academic staff: "Institutional Change"

Geoscientists are aware of the central need to share their knowledge of Earth systems processes with the broader public. Exposed to the most current advances in this field, the challenge lies in imparting the societal importance of this knowledge while avoiding jargon or esoteric language. Styles of teaching often reflect a didactic lecture style approach leaving little room for inquiry or more Socratic methods of teaching that encourage open dialogue. While part of the focus on the MiTEP program was to encourage teachers to think like scientists, there also emerged a significant shift in how scientists started thinking like teachers as evidenced by the evolving instructional approach employed by the summer institute lead instructor. Changes of this type were referred to in the MiTEP proposal under the heading of "Institutional Change."

MiTEP's Principal Investigator (PI), a veteran geoscientist with an accomplished and productive career in the academic arena (featuring internationally renowned scholarship and research in volcanology), now retrospectively acknowledges his own epiphany. After working with teachers, listening to their questions and noting how they observed and interpreted geosites, he pressed himself to reconsider the way he communicates science to the broader public and to petition for increased participation of the scientific community, perhaps the real reform required nationwide. This has led to a paradigm shift in his way of thinking and inspired a passionate focus on community outreach and advancement of geoheritage of the Keweenaw. This shift in thinking is reflected in the inquiry-rich questions he has embedded in interpretative signage and also in books, videos and detailed websites, all developed to help locals and visitors understand geologic processes in the Keweenaw.

Far beyond the pages of textbooks and the monotonal mumblings of endless lectures, it is through the *personal changes* that people develop confidence, passion and the interest in devouring knowledge and leading new initiatives. Whether it is leading a Professional Learning Community in Earth science or advancing a global concept, the experiences create the outcome.

4.4.3 Advancing geoheritage in the Keweenaw

4.4.3.1 Context - the state of the art in the US

Geoheritage recognizes significant geologic features, landforms, and landscapes and the range of *values* that society places on them, such as aesthetic, cultural, scientific, recreational, tourism and educational (Brocx and Semeniuk, 2007, Hill, 2010). Geosites serve to advance knowledge and open dialogue about wide-ranging and sometimes contentious Earth science issues, such as mining, natural hazards, groundwater supply, and climate change. Conservation of these sites is vital so that their lessons, beauty, recreational use and sustainable economic benefits will endure for the enjoyment of future generations. This concept of geoheritage has been prevalent in Europe and Australia for over three decades; in North America the concept is advancing with increasing support among many partners ranging from US government and state agencies, non-profit organizations, academia, museums, industry and K-12 educators. Benefits of geoheritage include:

- Improved science literacy, citing the lack of consistent Earth sciences curriculum in the U.S
- Improved economic benefit, especially in rural and remote impoverished areas
- Improved health and well-being, as geoheritage inspires people to explore nature
- Enhanced geoscience concepts and ideas, including preservation and collections in museums.

In 2015 the National Park Service (NPS) partnered with the American Geosciences Institute (AGI) to create a document outlining the overarching themes of geoheritage; "America's Shared Geologic Heritage: An invitation to leadership" (Service and Institute, 2015). In similar fashion to AGI's "Big Ideas of Earth Science," the document presents five central ideas of geoheritage, termed "geologic heritage," in their effort (NPS and AGI 2015):

1. America's geologic landscape is an integral part of our history and cultural identity. We have a proud tradition of exploring and preserving our geologic heritage;
2. America's geologic heritage, as shaped by geologic processes over billions of years, is diverse and extensive;
3. America's geologic heritage holds abundant values – aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific – for all Americans;

4. America’s geologic heritage benefits from established conservation methods developed around the world and within the U.S.;
5. America’s geologic heritage engages many communities, and your involvement will ensure its conservation for future generations.

Other initiatives include “Earth Science Week,” an AGI initiative, which is a yearly event that aims to provide formal and informal educators with resources and events related to important themes in Earth science. This year’s theme, “Our Shared Geoheritage,” offers an opportunity to advance this concept nationally through the work of K-12 educators and informal learning professionals.

4.4.3.2 Geosite inventory

The advancement of geoheritage relies on increased public awareness of Earth science along with thoughtful stewardship of geosites. While working in the field, participants were encouraged to observe and interpret sites considering all values people might place on them, to consider significant patterns or connections. As a result of teachers’ participation in the two summers of field experiences and the national park internships, an inventory of accessible geosites with didactic potential has evolved. Teacher input was a vital component of the qualitative assessment of educational geosites, and provided compelling answers to the questions; What worked? What provided a good teaching moment? What sites were more conducive to inquiry based training? What places can accommodate a group of twenty people?

The compiled information accumulated from the teachers at these sites has been incorporated into the Keweenaw Geoheritage website, which offers information for planned visits or virtual field trips for both formal and informal learners. They are divided into the five geoelements for simplified understand of the overarching themes of Keweenaw geology; the “Big Take-homes” (Table 4.5). The result of this work has been an essential component in building public awareness of the surrounding geoheritage.

Table 4.5: Geoelements of the Keweenaw with description

Geoelement	General description
1. The Hot Spot, Lavas, and Copper Mineralization	Keweenaw's black rocks offer a window to a deep Earth volcanic past; the site of Earth's largest lava outpourings when magma oceans existed in this region. This massive lava outpouring was driven by abnormal heat from the deep Earth.
2. Rift-filling Redbed Sediments	The red rocks of the Keweenaw originate from the ancient, and once massive, Huron Mountains that eroded and filled the great valley of the Keweenaw rift. These rocks are highly visible throughout the Keweenaw as they are used as building materials.
3. The Keweenaw Fault	A massive thrust fault which was the focus of hundreds of high magnitude earthquakes and which split the peninsula lengthwise and uplifted rocks, including copper-rich units, to a place where people could find it. This feature has shaped and beautified the Keweenaw but is no longer an active hazard.
4. Continental Glaciation	The Keweenaw Peninsula was recently covered with more than two miles of ice, the intense erosion and the complex glacial deposits are dramatic and have left many sand and gravel resources and shaped the landscapes.
5. Lake Superior	The existence of Lake Superior in the midst of North America makes for a unique environment which significantly affects weather and climate of the lake region, with features such as lake effect snow and moderating severe continental temperature extremes.

4.4.3.3 Educational Signage and Self-guided Geotours

An invaluable contribution to geoheritage in the Keweenaw has been the development of interpreted signage and self-guided geotours, with brochure-content for many of these sites, has come directly from MiTEP teacher-developed EarthCache sites. Tours feature small unobtrusive signs providing an inquiry-based question related to a feature or outcrop that people pass every day. A "Quick Response" (QR) code in the bottom corner enables people to access further information and to connect to other sites on the tour. The signage adds a layer of outreach extending beyond geocache and EarthCache enthusiasts and attracts anyone to learn about significant places in the Keweenaw.

Figure 4.6: MiTEP teachers lead a guided geotour of Hungarian Falls created as part of their summer internship experience (above); example of signage developed by teachers and installed on site.

Three geotours have been completed in the Keweenaw, and two are currently being developed. One of the tours was created entirely by MiTEP participants as part of their summer internship project and interprets Hungarian Falls, one of the most visited geosites in the Keweenaw (Figure 4.6). This tour has voiced the importance of significant geosites to decision makers and the broader public alike and was influential in highlighting the importance of Houghton-Douglass Falls and the importance its protection by the state of Michigan.

4.4.3.4 Training for local teachers

The Lake Superior Stewardship Initiative engages educators and students in all aspects of STEM education in the Keweenaw. Increased geoheritage signage and educational outreach prompted geoheritage training and workshops for local teachers to highlight significant geosites in the Keweenaw and resources available via the Keweenaw Geoheritage website. A significant challenge facing educators is engaging individuals unable to experience and visit a site first-hand. Web-based tools such as Google Earth™, personal testimonies, and photos are all excellent methods of bringing the field to the student. The geotours created afford formal and informal learners the visceral experience of visiting and exploring significant geosites and key geoelements of the Keweenaw Peninsula. Training and collaboration on how to create caches and geosites on school properties had also been addressed. Currently, two school sites are working to develop boulder gardens similar to that on the Michigan Tech campus on their school properties. Students are developing content similar to that which MiTEP teachers developed for their EarthCache sites and will present it as interpretive signage.

4.4.3.5 Economic development through geotourism

MiTEP summer institutes provided a strong educational and logistical background for operating tours of more than twenty people. Summer geotours are offered to the public and follow a structure similar to that employed by MiTEP, with the addition of boat transportation to visit inaccessible geosites (Figure 4.7). Local teachers are invited to participate in these geotours at a reduced cost. This activity is a potential business that could expand educational geotourism in the Keweenaw.

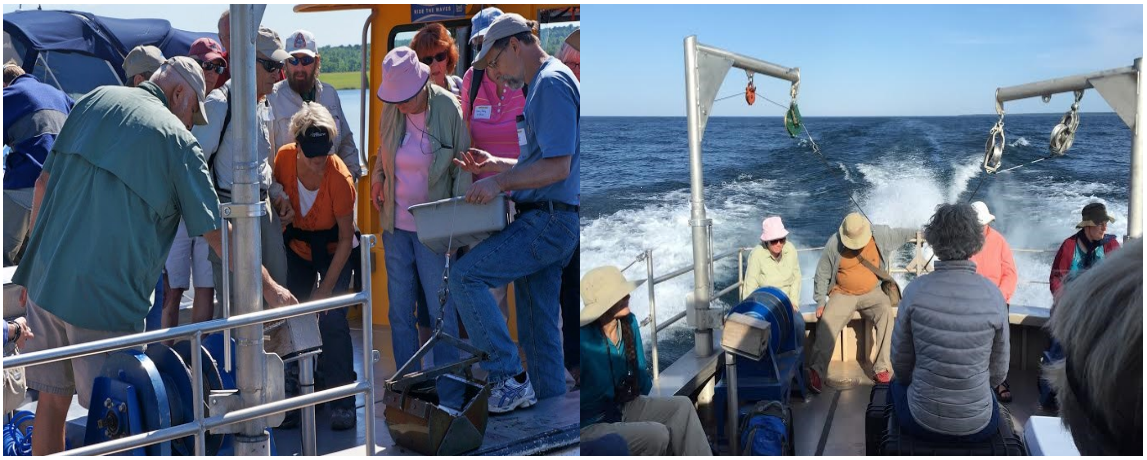

Figure 4.7: Summer geotours with life-long learners aboard the Michigan Tech RV Agassiz.

4.4.3.6 A Keweenaw Geopark

Geoparks are grassroots, community developed initiatives that offer an effective way to promote geologic significance and conservation, educate locals and visitors on Earth's history, and develop sustainable economic growth locally through community partnerships (Eder and Patzak, 2004, Bailey and Hill, 2010). The Global Geopark Network, a United Nations Educational Scientific and Cultural Organization (UNESCO) initiative, has expanded since its inception in 2004 to include 120 geoparks around the world; there are currently no designations in the United States.

An added benefit to the valuable interpretive materials created during the Upper Peninsula summer field school and internships at Keweenaw National Historical Park and Isle Royale National Park, is the strengthened community partnership with the park service. This partnership is critical for the foundation of a sound geopark proposal and has continued to expand to include conservation groups, local decision makers, and industry. There is an escalated momentum in our community aimed at advancing this concept; the Keweenaw Peninsula could be the first such designation in the US.

4.5 Conclusion

Field experiences and personal development were important components of the MiTEP project; the program started with some hesitation on behalf of some participants who openly returned each year and volunteered for an additional three weeks in the national parks regardless of what subject they are teaching. Many participants return to the Keweenaw with their families in the summer after completing the course. Relationships developed and open conversations on the realities of what happens “in the trenches” have revealed obstacles that teachers face each day and can be factored into the development of future proposals focused on professional development. Developing the confidence to teach is equally important and concomitant with gains in content knowledge. The unforeseen successes of the MiTEP project have stemmed from the products and learning tools developed in the field, the inventory of geosites that have teachable moments, and strongly enhanced of community partnership.

The rich geoheritage of the Keweenaw has created a foundation for fulfilling field experiences, while teacher participation has created the foundation for which to advance the concept. In turn, experiences with educators in the field have helped advance geoheritage programming in the Keweenaw and have nurtured programs dedicated to sustainable economic development based on geotourism and to the geoconservation of the Keweenaw. Drawing on experience gained over the past five years, we continue to connect public and private agencies from throughout the Keweenaw in an effort to build a robust consortium devoted to developing educational programming and exhibitions devoted to the area’s rich geoheritage; a partnership that may achieve the prominent designation by UNESCO as a Geopark, possibly the first of its kind in the United States.

5. Conclusion

As the United States engages an advanced global geoheritage community a number of new initiatives are emerging fostering development of geoheritage at the national level. The Geological Society of America (GSA) recently published an official position statement on geoheritage defining it as the protection, management, and conservation of landscapes and geologic features and the varied personal values society assigns to them. The statement represents the views of the GSA with respect to the conservation of geosites and strategies to meet this end, the endorsement of US participation in the Global Geopark program, and the benefits of geoheritage for the US. The creation of the US National Committee for Geoparks further supports efforts to advance geoheritage by developing outreach initiatives surrounding this concept and serving as an advisory role for pre-aspiring geoparks wishing to submit official applications the UNESCO Global Geopark Program. Community engagement and outreach efforts at the local level, as demonstrated in the Keweenaw Peninsula, also help to promote the advancement of geoheritage in the US.

The rich intersection of mining, cultural, and industrial heritage in the Keweenaw are underscored by globally significant geodiversity affording many opportunities and community benefits related to its strong geoheritage. These include improved Earth science literacy, opportunities for sustainable economic development, improved health and well-being through encouraging the broader public to explore the outdoors, and the conservation and appreciation of key geosites. These benefits are surfacing through continued development of a prolific and extensive geoheritage outreach and education program for the Keweenaw Peninsula. Of paramount importance in advancing this concept, these efforts have fostered a growing community partnership and geoheritage working group. Other significant outcomes of this work include:

- An inventory of Keweenaw scientific, educational, and touristic geosites and geodiversity sites
- Valued educational and interpretative materials and prolific community outreach
- Geoconservation – public land access for significant geosites
- Global Heritage Stone designation for the Jacobsville Sandstone
- Sustainable economic development opportunities - business plans for geotourism
- National Marine Sanctuary proposal (recognizing marine geoconservation)
- UNESCO Global Geopark proposal
- National and international visibility – recognition of the Keweenaw Peninsula as one of three pre-aspiring geoparks in the US

Future work

Geoheritage, geodiversity and geoconservation curriculum is common in many academic institutes in Europe, some universities offer master's degree programs in these emerging geoscience disciplines. Michigan Technological University is afforded an opportunity to lead as one of the first universities in the United States to offer a course exploring geoheritage, geodiversity and geoconservation. This concept bestrides the geology, industrial archaeology and humanities departments and as such stands to engage students from varied backgrounds in understanding the broad underpinnings of how landscapes are formed and the varied values people develop in relationship to their interaction with them.

As geoheritage draws on the varied values that society place on geologic sites and landforms, other strategies to advance geoheritage include the engagement of the arts community. Artists are skilled at depicting landscapes and landforms and through their creations help people deepen their sense of wonder and understanding of place. This connection is highly valuable for engaging people in learning and stewardship, affording connections that resonate with a wider public.

An important theme emergent of this exploratory research is the local concern of the loss in revenue by removing public lands from the tax roll. Studies focused on exploring and understanding the economic and health benefits of public lands for the Keweenaw community are germane.

As geoheritage advances in the US the Keweenaw stands to contribute with a grassroots effort to develop a geopark proposal, perhaps the first of its kind in the United States. The following documents are included as appendices to illustrate central activities and accomplishments towards this designation:

- APPENDIX I: SWOT (strengths, weaknesses, opportunities and threats) analysis on the benefits of a Keweenaw Geopark including scientific, management, and political perspectives
- APPENDIX II: Geopark Action Plan - includes a list of key community partners, a project calendar, a Geopark Guideline application checklist, and management plan template
- APPENDIX III: Events and publications related to geoheritage and the geopark effort

The Keweenaw Peninsula embodies the central philosophy of the UNESCO Global Geopark program and meets all of the physical criteria required to achieve said designation: a) globally significant and attractive geosites and geodiversity sites; b) an evolving inventory system; c) a compelling human story, d) well-developed infrastructure and economic groups that support start-up and a quality of life economy; e) opportunities for community engagement; and f) an advanced education and outreach program. A geopark proposal is complimentary to other education and conservation initiatives in the Keweenaw community and stands to concomitantly support education and preservation efforts related to the impressive industrial and mining heritage. Whether an official designation of UNESCO Global Geopark comes to fruition or not, the Keweenaw Peninsula will continue to benefit from efforts that advance the globally significant geoheritage of this region.

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7. Appendix I: Keweenaw Geopark SWOT Analysis – Scientific, Management, Political

7.1 Scientific

STRENGTH	OPPORTUNITY
• world class geosites • high level geodiversity • have background and focus for application • one of the best mapped areas of the US on account of copper exploration	• no Geoparks in US yet • could encourage further research in the Keweenaw • revived scientific visibility/recognition of Keweenaw and Isle Royale • potential resources at the university

• copper mining history, highly researched area • have excellent combination of natural and human history • two universities • excellent international contact with current research • small community, connected • website created, geosite inventory created • have chaired/presented in many conferences in the US and internationally • two geoheritage publications in prep • excellent images of geosites for publications and interpretive materials	• bridge gap in environmental and mining dialogue • increased Earth Science literacy for broader public • push to develop Geoparks in the US by IUCN, etc
WEAKNESS • not as well known in the US • lack of media/publication plan (broader public and scientific community) • lack of funding	THREAT • no Geoparks yet • setting up committees too early

7.2 Management/Community Engagement

STRENGTH	OPPORTUNITY
• numerous museums (Seaman, Quincy, Carnegie) • two national parks • have created signage and brochures • strong community partnerships • trust from partners • good visibility, legit • sparked the interest of the tourist and convention center • diagnostic plan • growing list of public presentations/outreach • quantitative assessment of Keweenaw geosites • successful geotours • strong non-extractive industry, mountain biking, kayaking etc • have interest of local land planners • pending physical space for management of geoheritage matters (Quincy House) • remote geographic location - not “on the way” to other places • shared vision of “Copper Country” heritage	• geotourism • geoconservation • improved infrastructure for geosites that people currently visit • land acquisition opportunities for key geosites (Douglas Houghton Falls) • increased interpretation/signage • bridge a gap in environmental and mining mentality • increased Earth Science literacy for broader public • connecting communities and underrepresented groups in plan • upstream process with IUCN/UNESCO • do not set up committees too early • develop a network of ambassadors and volunteers (to advocate with local politicians) • training for local tourist personnel • long term planning for region for community partners • increased connections to
WEAKNESS	**THREAT**
• need funding for management • remote geographic location - not “on the way” to other places • unreliable service with airport • new ground, need training • liability issues • need more support from economic development groups locally • lack of human resources • need training in Geopark management (Global and European Geopark networks trainings) • cell service poor in areas • reluctance to change • decline of buildings in the Keweenaw, too much to preserve	• Teaparty adversity • Agenda 21, UN • large-scale geosites and multiple landowners • liability issues • how to reconcile differing activities and interests with different user groups • public fear of changes in land access

7.3 Political

7.3.1 Local

STRENGTHS	OPPORTUNIITES
• good visibility, legit • interest and help from local politicians with whom we have direct access to • existing designations with NPS, understanding of cultural heritage and importance	• could be first in the US • connects community, sense of place and pride • connecting ethnic backgrounds • failed economy, chance to develop something for declined economy • create new jobs
WEAKNESSES	**THREATS**
• lacking a political champion • poor area, declined economy • lacking data on increased visitation in other Geoparks • lack of funding for advertising/promotion • lack of understanding on how long change will take	• too linked to a person, needs to be grassroots • balance of “wanting tourists, and having too many tourists”, lack of understanding • Teaparty adversity • Agenda 21, UN involvement

7.3.2 Political – National

STRENGTHS	OPPORTUNITIES
• good visibility, legit	• could be first in the US • regional developments in geoheritage
WEAKNESSES	**THREATS**
• need contact • need to know the exact chain of decision/process • lack of political and communication strategy	• UNESCO issues • funding for national parks and heritage matters • why spend time on Geoparks? • too naïve, not credible? • Agenda 21, UN involvement

7.3.3 Political – International

STRENGTHS	OPPORTUNITIES
• good visibility, legit • park system is well known and trusted • good connections with Canadian committee	• could be first in US • UNESCO wants to endorse park in the US • Potential for North American geopark committee

• direct access and support from US Chair of US Geopark Committee	
WEAKNESSES • not connected	THREATS • US not paying dues to UN, relations are inactive

7.4 Next steps

- Who will endorse application (political leader, need to sell)
- Application
- Set up committees and governance plan
- Management plan: diagnostic plan – define with all stakeholders with decision makers
- Convention to make sure all roles are clearly stated, take time to create committees
- Stable ahead of moving to international level
- Clear memo about what will happen/process clearly laid out

8. Appendix II: Keweenaw Geopark Action Plan

Includes:
8.1 Partners
8.2 Geopark Project Calendar
8.3 Geopark Guideline Application Checklist
8.4 Geopark Management Plan template

8.1 Keweenaw Geoheritage Partners

8.1.1 Education

Michigan Technological University – MTU
Lake Superior Stewardship Initiative – LSSI
Keweenaw National Historical Park – KEWE
Isle Royale National Park - ISRO
Quincy Mine and Hoist Museum – QM
Seaman Museum – SM
Copper Country Trail National Byway – CCTNB
Carnegie Museum – CM
Copper Harbor Arts Center – CCAC

8.1.2 Conservation

Keweenaw Land Trust – KLT
Keweenaw County Historic Society – KCHS
Houghton County Historic Society – HCHS
Houghton Conservation District – HCD
Trails Club – TC
Cross Country Sports – CCS

8.1.3 Economic

Keweenaw Convention and Visitors Bureau – KCVB
Keweenaw Economic Development Agency – KEDA
Keweenaw Chamber of Commerce - KCC
Calumet Township – CalTwp
Osceola Township - OT
City of Houghton – CoH
Grant Township – GT

Table 1: Keweenaw Geopark project calendar

8.2 Geopark Project Calendar			
Research work/feasibility	Start	End	Stakeholders (with MTU)
Develop list of geosites	Jan 2011	March 2016	
Keweenaw geoheritage website/database	Jan 2011	ongoing	
Build bibliography	Jan 2011	ongoing	
International partner consultation	Mar 2013 June 2014 April 2015 Nov 2015 June 2016	ongoing	Ben van Wyk de Vries, Cecile Olive
Proposal development			
Review GGN guidelines and checklist (see attached Geopark Proposal Application Checklist)	March 2013	Dec 2015	
Confirm latest version of GGN guidelines for US	Jan 2016	Dec 2015	Tom Casadevall
Identify scientific advisory team	Jan 2011	Mar 2016	
Select photos for application	June 2014	Mar 2016	Brimmages
Create maps for application	Jan 2011	Dec 2015	
Geosites inventory analysis	Jan 2015	Dec 2015	
Develop geopark management plan	Nov 2015	-	
Draft of proposal for internal review	May 2016	-	
Field visit by chair of US National Committee for Geoparks	June 2016	-	
Letter of intent to US National Committee for Geoparks	Sept 2016	-	
Letter of intent for submission to UNESCO	Dec 2016	-	
Awareness			
Local public events, dissemination, education programs	March 2011	ongoing	
Regional public events, dissemination, education programs	June 2014	ongoing	
Public geoheritage website announcement	April 2014		
Complete academic publications related to geoheritage in the Keweenaw	Jan 2015	May 2016	
Meet one on one with community partners	Jan 2012	ongoing	

Geoheritage community discussions	Mar 2011 April 2012 Mar 2013 June 2016	-	
Academic conference proceedings	November 2010	ongoing	
Organize sessions related to geoheritage and Geoparks at academic conferences	November 2011	ongoing	
Training			
America's first geoheritage workshop	Mar 2013	-	
Attend 6th International Conference on Global Geoparks	Sept 2014	-	
Present at 7th International Conference on Global Geoparks	Sept 2016	-	
Professional training in Geopark management			
Create inter-university geoheritage "help" group	April 2015		Jose Brilha, Marco Giardino, Ben van Wyk de Vries
Community/Partner engagement			
Identify local partners	Jan 2013	Nov 2014	
Consult with local stakeholders	Jan 2012	ongoing	
International partner consultation	Jan 2011	ongoing	
Develop links with other geosites around Lake Superior	May 2014	ongoing	Pete Hollings, John Green, Geologic Society of MN, Michelle Walk (SSM)
Develop links to other pre-aspiring Geoparks in the US	Mar 2013	ongoing	Herb Mayer, Tim Connors
Develop links to other Geoparks in North America and globally	Mar 2013	ongoing	John Calder, Godfrey Nowlan, Marco Giardino, Jose Brilha
Consult with international geoheritage experts	Mar 2013 June 2014		Jose Brilha, Tim Badman
Partner planning meeting	Oct 2014 April 2016		
Consult with economic partners	Jan 2016 April 2016		KEDA, KCVB, WUPPDR
Gain support of local political figures	June 2012	ongoing	All key partners
Gain support of regional political figures	Sept 2015	ongoing	All key partners
Gain support of national political figures	June 2016		Tom Casadevall

Create committees with partners: 1) education, 2) economic 3) conservation and 4) management	April 2016		All key partners
Solicit letters of commitment and support from partners and committee actors	April 2016		All key partners
Partner communication plan	Feb 2016		
Political lobbying	Dec 2016	Sept 2016	Key partners, KLT LSSI, NPS

Table 2: Global Geopark Guideline checklist

8.3 Geopark Guidelines Application Checklist			
A – Identification of the Area	Have it?	Formatted to meet proposal guidelines?	Stakeholders to involve (outside of MTU)
1. Name of the proposed Geopark	Yes	December 2015	
2. Surface area, physical and human geography characteristics of the proposed Geopark	Yes	December 2015	
3. Organization in charge and management structure (description, function and organogram) of the proposed Geopark	partially	March 2016	
4. Application contact person (name, position, tel./fax, e-mail)	Yes	December 2015	
B – Geological Heritage	Have it?	Formatted to meet proposal guidelines?	Stakeholders to involve (outside of MTU)
1.Location of the proposed Geopark (please include a geographical map and the geographic coordinates longitude and latitude coordinates)	Yes	December 2015	
2. General geological description of the proposed Geopark	Yes	December 2015	
3. Listing and description of geological sites within the proposed Geopark	Yes	December 2015	
4. Details on the interest of these sites in terms of their international, national, regional or local value (for example scientific, educational, aesthetic)	Yes	December 2015	

4. Listing and description of other sites of natural, cultural and intangible heritage interest and how they are related to the geological sites and how they are integrated into the proposed Geopark	Yes Need more on IA	December 2015 April 2016	IA department NPS
C – Geoconservation	Have it?	Formatted to meet proposal guidelines?	Stakeholders to involve (outside of MTU)
1. Current or potential pressure on the proposed Geopark	Yes	December 2015	KLT, Houghton Conservation District
2. Current status in terms of protection of geological sites within the proposed Geopark	Yes	March 2015	Houghton Conservation District, UPAEA, KLT, NPS
3. Data on the management and maintenance of all heritage sites (geological and nongeological).	Yes	March 2015	
4. Listing and description of non-geological sites and how they are integrated into the proposed Geopark	Yes	April 2016	IA department, NPS
D - Economic Activity & Business Plan (including detailed financial information)	Have it?	Formatted to meet proposal guidelines?	Stakeholders to involve (outside of MTU)
1. Economic activity in the proposed Geopark	partially	May 2016	KEDA, WUPPDR
2. Existing and planned facilities for the proposed Geopark (e.g. geo-education, geotourism, tourism infrastructure etc)	Yes	March 2016	Houghton Conservation District, KLT, LSSI, KEDA, KCVB
3. Analysis of geotourism potential of the proposed Geopark	Yes	March 2015	KEDA, KCVB
4. Overview and policies for the sustainable development of: - geo-tourism and economy - geo-education - geo-heritage Please include examples illustrating activities in these sectors	partially	May 2016	All key partners
5. Policies for, and examples of, community empowerment (involvement and consultation) in the proposed Geopark	partially	May 2016	All key partners

6. Policies for, and examples of, public and stakeholder awareness in the proposed Geopark.	partially	April 2016	All key partners
E – Interest and arguments for joining the GGN	yes	April 2016	All key partners

Table 3: Keweenaw Geopark management plan

8.4 Geopark Proposal Management Plan Template			
	Start	Finish	Stakeholders to involve
Establish the Geopark management team and develop a management structure			
Determine the management body responsible for the Keweenaw Geopark			
Commit partner time to help administer and develop the geopark			
Employ a full-time Geopark project director			
Ensure the Geopark is embedded in the key strategy framework documents for the economic development and community plans of the Keweenaw. Work with the following groups: National Marine Sanctuary (HCD) Keweenaw Economic Development Strategic Plan (KEDA) National Park Centennial (NPS) Community recreation plans (Bill Olson) Keweenaw Museums (Quincy, Delaware, Seaman) Tourist bureau			
US National Geopark Committee			
Submit application dossier for acceptance to US National Committee for Geoparks			
Obtain endorsement letter from US Committee			
Develop codes of conduct and policies for all participating organizations			
Budget monitoring			
Develop a fund from Geotours and other local organization income to help generate			

interpretative improvements and outreach events			
Seek MI state oil and mineral funding through DNR recreation passport – acquisition or development funds			
Work with partners to seek funding from grants and other funding sources, Dow, Artplace etc			
Geosites and conservation			
Establish advisory scientific team			
Identify and assess geosites in the Keweenaw for educational, scientific, touristic and conservation value			
Add Keweenaw geosites to unofficial NPS national geosite inventory			
Ensure that policies in next revision of Keweenaw recreation plans recognize geosites			
Work with land owners of geosites and establish dialogue to improve access and install interpretative materials			
Encourage research on Keweenaw's geological heritage			
Develop improved public access to key sites including Douglas Houghton Falls, Torch Lake, Keystone			
Promote geotours as a means of viewing inaccessible sites from the lake			
Communication/Promotion			
Create and manage a Geopark website			
Liaise with the KCVB and other advertisers to ensure widespread use of geoheritage in all marketing literature			
Review all signage to and within Michigan to feature the Geopark designation where appropriate			
Work with local artists on creating Geopark projects that draw people to the area			
Develop a Geopark Visitor Centre - gateway to the Keweenaw			
Geoeducation and geotourism			
Work with partners to organize an annual Geopark training and awareness event for tourism sector			
Develop an education and interpretation plan that connects a range of different site			

users, including geological/technical groups, school groups, and general visitors			
Develop new exhibition facilities at museums, and visitor centers, art center, airport to provide improved access to geoheritage			
Launch the "year of geoheritage"			
Help teachers develop/access curricular resources			
Offer field trips to Geopark sites to schools and community groups			
Work with the Youth Advisory Committee to develop a geological community arts project			
Develop the Torch Lake trail with interpretative signage			
Develop the Calumet Geoheritage tour with interpretative signage			
Develop the Copper Harbor Geoheritage tour with interpretative signage			
Develop the Eagle Harbor Geoheritage tour with interpretative signage			
Improve the Houghton Geoheritage tour with interpretative signage			
Connect with other natural heritage attractions such as			
Develop themed Geopark events and tours for adult and family audiences			
Develop life-long learning packages on the Geopark theme			
Improve interpretation and education facilities at key Geopark magnet sites: Quincy Mine, Seaman museum			
Foster educational links with other natural heritage attractions such as Keweenaw National Historical Park			

9. Appendix III: Geoheritage Presentations, Events and Interpretive Initiatives

9.1 Tours, walks, events

Field trips

- Keweenaw Geotours: 2014, 2015
- Minnesota Geologic Society Field Trip, 2015:
- Isle Royale: Keweenaw Rift Geology tour, May 25-30, 2013

Carnegie Museum Trolley tours:
"Bill Rose's Houghton Geoheritage Trolley Tour", Bill Rose - Aug 22, 2013
"Tracing the Remains of Houghton's Isle Royale Mine", Erika Vye and Will Shapton – June 24, 2014
"Tracing the Remains of Houghton's Isle Royale Mine", Erika Vye and Will Shapton – September 13, 2014

Michigan Nature Association geology walks

- Black Creek – August 9th, 2013
- Bare Bluff – August 2nd, 2014
- Estivant Pines – July 18th, 2015

Bike tours

- "Bike! Geoheritage Bike Tour", Calumet, June 1, 2015
- "Geo Heritage Mountain Bike Tour - Historic mining and geo heritage areas near Calumet". U.P. Mountain Bike Week, August 14, 2015.

Other Events

- National Park Service Open House, geology tours at Quincy Mine with Erika Vye, August 26, 2015.
- Manitou Island Sunset Cruise, Manitou Lighthouse fundraiser – geology Q&A, 2014 and 2015
- Geoheritage website announcement to public, June 2014
- Michigan Tech Boulder garden dedication, April 22, 2011
- Gratiot Lake Field Trip 29 August 2013
- Hungarian Falls KLT teacher led geotour, July 2013.

Public presentations

- “Keweenaw Geohistory and Geoheritage” Bill Rose, UP Environmental Coalition, Celebrate the UP! Conference, Mar 19 2016
- “Keweenaw Geoheritage” Bill Rose, MESTA 2015 Meeting, Lansing MI 10 Oct 2015
- “Geotourism in the Keweenaw” Bill Rose and Erika Vye, MSU Extension Workshop, 8 Oct 2015
- “Communicating Keweenaw Geoheritage” Bill Rose, SME Meeting, Houghton, 7 Oct 2015
- “Wait..did you say the Keweenaw is *one billion years old*?” - Erika Vye, Fort Wilkins State Park evening program, August 19, 2015.
- “Keweenaw Geoheritage” Bill Rose, Michigan Tech Alumni Reunion, Houghton 6 August 2015
- “Origin of Keweenaw Copper” Bill Rose, Lake Superior Copper Workshop, Houghton, 8 August 2015
- “Keweenaw Geoheritage” - Karl Larson, NPS ranger, Calumet Visitor Center, July 30, 2015
- “Keweenaw Park Geology” Bill Rose, St Anne’s Calumet 14 July 2015
- “Wait..did you say the Keweenaw is *one billion years old*?” - Erika Vye and George Schaefer, Fort Wilkins State Park evening program, July 16, 2015
- “Geoheritage, the Keweenaw and Isle Royale” - Bill Rose and Erika Vye, Keweenaw County Historical Society “Adventures in History” series, July 8, 2015.
- “The Geology of the Keweenaw” – Erika Vye, staff training for Keweenaw Adventure Company tour guides, June 10th, 2015
- “The Geology of Torch Lake” - Bill Rose, Torch Lake Watershed Management project meeting, Houghton, May 25, 2015
- “National Significance Spotlight – Bill Rose and Keweenaw Geoheritage” Keweenaw National Historical Park Advisory Commission Annual Meeting, January 13, 2015
- “Keweenaw Geoheritage” Bill Rose, Copper Country Rock & Mineral Club, Dollar Bay; 16 Oct 2014
- “New Geoheritage Work in the Keweenaw” Bill Rose, Houghton Rotary Club, 13 Nov 2014
- “Keweenaw Geoheritage Outreach Communications” Bill Rose, CE Graduate Class, MTU 20 Oct 2014
- “Jacobsville Sandstone and Chassell Township Geology” Bill Rose, Chassell Heritage Center, 21 August 2014
- “Keweenaw Geoheritage” Bill Rose, Michigan Botanical Society Houghton Meeting Keynote 11 July, 2014
- “The Geoheritage of the Keweenaw” - Karl Larson, NPS ranger, Fort Wilkins State Park, August 20, 2014
- “Geoheritage of the Calumet Area” – Bill Rose, Friends of the Calumet Public Library, June 4, 2014.

- “Keweenaw Geoheritage” Bill Rose, Society of Mining Engineering, Marquette 10 April 2014
- “The Keweenaw Fault” - Bill Rose, Gratiot Lake Conservancy Annual Meeting, Eagle Harbor, July 29, 2013
- “Keweenaw Geoheritage” Bill Rose, MTU Forestry Department, 3 Dec 2013
- “Keweenaw Geoheritage” Bill Rose, Houghton Rotary Meeting 14 Nov 2013
- “Keweenaw Geoheritage” Bill Rose, Calumet Lions Club, Miscouwabic Calumet 20 Nov 2013
- “Keweenaw Geoheritage” Bill Rose, IRKPA Meeting Calumet 4 Oct 2013

9.2 Geopark public meetings

March 26th, 2013
“A Geopark in the Keweenaw”, with invited guest Benjamin Van Wyk de Vries, Fisher 138, Michigan Tech campus.

March 18th, 2012
Community meeting on the Keweenaw Geopark proposal with keynote speaker Bob Lillie, Finlandia Heritage Center.
Letter to the editor concerning geoparks:
http://www.mininggazette.com/page/content.detail/id/524795/Doesn-t-want-geopark.html?nav=5002

March 18th, 2011
"*Experiences with the Bohemia Geopark initiative in Europe and the European perspective of Geoparks*," led by Benjamin Van Wyk de Vries, Professor, Universite Blaise Pascal, Clermont Ferrand, France, Michigan Tech campus.
http://www.mininggazette.com/page/content.detail/id/519519/Exploring-Keweenaw-geoparks-possibilities.html?nav=5006
http://keweenawnow.blogspot.com/2011/03/keweenaw-geopark-proposal-to-be.html

9.3 Lecture series

- Keweenaw Natural History Heritage lecture series (2014-15), Carnegie museum
- Environmental Awareness in the Keweenaw: Lake Superior Futures (2015-16) Carnegie museum
- Geoseminar (2015-16), Michigan Tech

9.4 Regional outreach

"The Geoheritage of Michigan's Keweenaw Peninsula" Bill Rose and Erika Vye, Geological Society of Minnesota lecture series, April 27, 2015. Minneapolis, MN

"The Geoheritage of Michigan's Keweenaw Peninsula" Bill Rose and Erika Vye, University of Minnesota, Duluth, April 28, 2015

"Geoheritage and Place-based education" Bill Rose, Erika Vye. GSA North-Central Section Meeting, Madison Wisconsin 19-20 May 2015.

"Geoheritage Discussions with Red Cliff Community" Erika Vye and Bill Rose, Lake Superior Forum, Red Cliff, WI 14 Nov 2014

"Geoheritage Symposium Organization" (several public talks) Bill Rose, Erika Vye, Mark Klawiter, Emily Gochis; Geological Society of America, Minneapolis 27-30 Oct 2013

9.5 K-12 outreach and teacher training

- Michigan Teacher Excellence Program - NSF grant 2009-2014
- LSSI Kick-off EarthForce – "How to Integrate Geoheritage in your classroom" - September 25th, 2015, ISD, Hancock, MI.
- MiSTAR teacher training – half day workshop on geoheritage in the classroom and the community, field trip to visit Calumet geoheritage sites – July 20th, 2015
- LSSI Water Festival, September, 2014: "Wait...did you say the Keweenaw is ONE BILLION years old?!" Boulder garden scavenger hunt for school kids.
- Calumet geoheritage workshop for local teachers – December 2015

9.6 EarthCaches in the Keweenaw

Coordinated by Emily Gochis: http://mitep.mtu.edu/earthcache.php

9.7 Interpretative efforts

Signage

- Houghton Geoheritage tour
- Hungarian Falls Geotour
- Calumet Geoheritage tour
- Copper County Trail National Byway and Geocache passport
- Copper Harbor Geoheritage tour – 2016
- Eagle Harbor Geoheritage tour -2016

Videos
Bill Rose and Erika Vye
Keweenaw Geoheritage
Part 1: The Hot spot
Part 2: The Mighty Midcontinent Rift
Part 3: Redbeds fill the Great Rift Valley
(on Vimeo)

Karl Larson, NPS

- Geoheritage of the Keweenaw
- Lavas in the Keweenaw

Northwestern University collaboration:
Midcontinent Rift video
Steve Brimm
Drone footage of key geosites

Boulder gardens

- Michigan Tech campus: Keweenaw Geology, Mining heritage
- Eagle Boulder exhibit in the Dow atrium:
- E.B. Holman School – being developed
- Calumet elementary school playground – being developed

Exhibits
Carnegie Museum: "Written in Stone: Exploring the Natural History of the Jacobsville Sandstone", 2012

Collaboration and other initiatives

- National Marine Sanctuary proposal
- Moyle land acquisition
- Douglas Houghton Falls
- Torch Lake Watershed Management plan
- Grant Township recreation plan
- Copper Island Kayak Challenge

9.8 Related publications and conference proceedings

Vye, E. and Rose, W.I. (in prep). *Advancing Geoheritage in the United States: Examples of Geoeducation, Geotourism and Geoconservation in Michigan's Keweenaw Peninsula.* Geoheritage.

Vye, E. and Rose, W.I. (in prep). *Geoparks in the United States – Michigan's Keweenaw Peninsula.* Geoheritage.

W. I. Rose, E. C. Vye, C. A. Stein, D. H. Malone, J. P. Craddock, Stein S. (in review). *Jacobsville Sandstone: A nomination for "Global Heritage Stone Resource from Michigan, USA*. Episodes.

Rose, W.I., Vye, E., Stein, C., and Stein, S. (2015, November 2). Geohistory and geoheritage of the Keweenaw and Isle Royale faults, Michigan. Presented at the Geological Society of America annual meeting, Baltimore, MD.

Rose, W.I. and Vye, E. (2015, November 2). *Geo field trips by land and lake highlight geodiversity of Michigan's Keweenaw*. Presented at the Geological Society of America annual meeting, Baltimore, MD.

Vye, E and Rose, W.I. (2015, November 2). *Creating an inventory of the geodiversity of the Keweenaw Peninsula and Isle Royale*. Presented at the Geological Society of America annual meeting, Baltimore, MD.

Rose, W. I. (2015, October 8). *Keweenaw Fault and Geoheritage/Geohistory of the Copper Country*. Paper presented at the Society for Mining, Metallurgy and Exploration annual meeting, Houghton, MI.

Vye, E. and Rose, W.I. (2015, October 8). *Geotourism in the Keweenaw*. Paper presented at the Connecting Entrepreneurial Communities conference in Houghton/Hancock, MI.

Rose, W.I. (2015, May 19) *Building local understanding of strong geoheritage, Michigan's Keweenaw and Isle Royale.* Paper presented at the GSA North-central regional meeting, Madison, WI.

Vye, E and Rose, W. I. (2015, May 19). *Geoheritage - a positive influence on public perception of earth science.* Paper presented at the GSA North-central regional meeting, Madison, WI.

Vye, E. (2014, November). *Geoheritage and Community Engagement*. Paper presented at the 2014 Great Lakes Place-Based Education Conference, Grand Rapids, MI.

Rose, W. I. and Vye, E. (2014, May). *Tools for interpreting Keweenaw geoheritage to a broad public.* Paper presented at the Institute for Lake Superior Geology annual meeting, Hibbing, MN.

Vye, E., Ernstes, J. Kuiphoff, Y. and Wagner, D. (2013, March). *Bringing the Midwest National Park to the Classroom*. Paper presented at the Michigan Science Teachers Association Annual meeting, Lansing, MI.

Gochis, E., Rose, W.I., Vye, E., Hungwe, K., Mattox, S. and Petcovic, H. (2013, October). *Increasing awareness of geoheritage sites & earth science literacy through teacher-developed Earthcaches*. Paper presented at the Geological Society of America Annual meeting, Denver, CO.

Rose, W.I., Vye, E., Klawiter, M. and Gochis, E. (2013, October). *Geo/bike walk communicates geoheritage in Houghton, Michigan*. Paper presented at the Geological Society of America Annual meeting, Denver, CO.

Vye, E., Rose, W.I., Klawiter, M. and Gochis, E. (2013, October). *The Importance of Partnerships for Improved Earth Science Literacy and the Communication of Geoheritage*. Paper presented at the Geological Society of America Annual meeting, Denver, CO.

Rose, W. I., Klawiter, M., Vye, E., Gochis, E. (2013, December). *Geoheritage and Possible Geopark in Michigan's Copper Country.* Paper presented at the American Geophysical Union, Fall Meeting, San Francisco, CA.

Vye, E. (2012, March) *Bringing the Midwest National Parks into the Urban Classroom*. Paper presented at the Michigan Science Teachers Association Annual meeting, Lansing, MI.

Rose, W.I. (2011, October). *Keweenaw boulder garden—a revitalized kame terrace on campus, used as a teaching laboratory*. Paper presented at the Geological Society of America Annual meeting, Minneapolis, MN

Rose, W.I. and Vye, E. (2011, October). *Discussion of a Keweenaw Geopark*. Paper presented at the Geological Society of America Annual meeting, Minneapolis, MN.

Vye, E., Rose, W.I. and Nash, B. (2011, October). *Using the national parks as way to engage diverse learners in Earth science education.* Paper presented at the Geological Society of America Annual meeting, Minneapolis, MN.

Vye, E., Rose, W.I., Nash, B., Klawiter, M., Huntoon, J., Engelmann, C., and Gochis, E. (2011, December). *Parks, Place and Pedagogy - Education Partnerships with the National Park Service*. Paper presented at the American Geophysical Union, Fall Meeting, San Francisco, CA.

Vye, E., Huntoon, J., Nash, B., and Matteo, E. (2010, November). *Partnering with the National Park Service: improving Earth science education nationwide*. Paper presented at the Geological Society of America Annual meeting, Denver, CO.

Vye, E., Rose, W.I., Huntoon, J. and Nash, B. (2010, December). *Sense of place and the national parks, strategies for communicating the interconnected nature of earth science*. Paper presented at the American Geophysical Union, Fall Meeting, San Francisco, CA.

Invited presentations

Rose, W. I. and Vye, E. (2014, June). *Educational Partnerships in Geoheritage - lessons from comparing the Chaîne des Puys and Limagne fault project to the Keweenaw Rift project, USA*. Invited for presentation at the Université Blaise Pascal, Clermont-Ferrand, France.

Rose, W.I. and Vye, E. (2013, March). *Geoheritage in the Keweenaw*. Invited for presentation in the Education and Outreach session of America's Geologic Heritage Invitational Workshop, Denver, CO.

Chaired sessions

Casadevall, T.; van Wyk de Vries, B. and Vye, E. (2015, November). T53. Geoheritage Matters, Geological Society of America Annual Meeting, Baltimore, MD.

Casadevall, T.; van Wyk de Vries, B. and Vye, E. (2015, November). Geoheritage Matters informal discussion. Geological Society of America Annual Meeting, Baltimore, MD.

Vye, E., Gochis, E. and Rose, W.I. (2015, May). T21. Geoheritage and Place-Based Education. Geological Society of America North-central regional meeting, Madison, WI.

Coratza, P., Zwoliński, Z., van Wyk de Vries, B. Co-conveners: Giardino, M., Najwer, A., van der Ancker, H., Kluiving, S., Reynard, E., Skridlaite, G., Vye. E., Kisser, T.; Zecha, S. (2015, April). SSS9.11/EOS10/GM4.4. Geoheritage, Geodiversity and Landscapes: a key issue for present and future studies (oral) (poster). European Geosciences Union General Assembly, Vienna, Austria.

Vye, E. (2015, April). SPM1.55 Geoheritage, Geodiversity and Landscapes: a key issue for present and future studies (public), splinter meeting. European Geosciences Union General Assembly, Vienna, Austria.

Rose, W.I., van Wyk de Vries, B. and Olive-Garcia, C. (2013, December). ED13F. Global Partnerships in Geoheritage and Improved Earth Science Literacy. American Geophysical Union, Fall Meeting, San Francisco, CA.

Vye, E., Rose, W.I. and Casadevall, T. (2013). T122. Geoheritage and Sense of Place in the Context of Earth Science Education. Geological Society of America Annual Meeting, Denver, CO.

Rose, W.I., Vye, E. and Klawiter, M. (2011). T158. Sense of Place, Geoparks and National Parks: Strategies for Improved Earth Science Education. Geological Society of America Annual Meeting, Minneapolis, MN.

Field trip guides

Rose, W. and Olson, J. (2013). *Isle Royale: Keweenaw Rift Geology Field Trip.* Institute of Lake Superior Geology.