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PRESERVING THE VERNACULAR POSTINDUSTRIAL LANDSCAPE: BIG DATA GEOSPATIAL APPROACHES TO HERITAGE MANAGEMENT AND INTERPRETATION

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PRESERVING THE VERNACULAR POSTINDUSTRIAL LANDSCAPE: BIG DATA GEOSPATIAL APPROACHES TO HERITAGE MANAGEMENT AND INTERPRETATION

By

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To Ma and Pa

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PREFACE

CO-AUTHORSHIP STATEMENT

The following dissertation contains a manuscript which has been published in a peer-reviewed journal. John Arnold was the principal and corresponding author for the manuscripts. Dr. Don Lafreniere was the co-author providing important guidance, supervision, and review of the manuscripts. The following citations are provided to indicate the destinations of the manuscripts:

Chapter One: Arnold, J., and Lafreniere, D., 2017. The Persistence of Time: Vernacular Preservation of the Postindustrial Landscape. *Change Over Time: An International Journal of Conservation and the Built Environment* 7 (2).

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All deserve my thanks far beyond what I can extend here, but I can at least make a start.

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ABSTRACT

Redundant historical industrial sites, or postindustrial landscapes, face numerous preservation challenges. Functionally obsolete, and often derelict and decaying, these cultural landscapes often retain only a fraction of their original infrastructure. With their historical interconnections made indistinct by their physical separation and obscured by the passage of time, surviving remnants are isolated and disjunct, confounding both their legibility and their consideration for formal historic preservation. Nevertheless, they persist. This dissertation presents a theoretical understanding of the nature of postindustrial landscape preservation, and argues that the material persistence of its historical constituents is the result of previously overlooked processes of informal material conservation, here termed *vernacular preservation*.

Further, this dissertation examines ways that heritage professionals can manage and interpret these vast, complex, and shattered landscapes, using 21st-century digital and spatial tools. Confronted by ongoing depopulation and divestment, and constrained by limited financial capacity to reverse the trend of blight and property loss, communities and individuals concerned with the preservation of vernacular postindustrial landscapes face many unique management and interpretation challenges. The successful heritagization of the postindustrial landscape depends on its comprehension, and communication, as a historically complex network of systems, and I argue that utilizing advanced digital and spatial tool such as historical GIS and procedural modeling can aid communities and heritage professionals in managing, preserving, and interpreting these landscapes.

This dissertation presents heritage management and interpretation strategies that emphasize the historical, but now largely missing, spatial and temporal contexts of today's postindustrial landscape in Michigan's Copper Country. A series of case studies illustrates the demonstrated and potential value of using a big-data, longitudinally-linked digital infrastructure, or Historical GIS (HGIS), known as the Copper Country Historical Spatial Data Infrastructure (CC-HSDI), for heritage management and interpretation. These studies support the public education and conservation goals of the communities in this nationally-significant mining region through providing accessible, engaging, and meaningful historical spatiotemporal context, and by helping to promote and encourage the ongoing management and preservation of this ever-evolving postindustrial landscape.

Keywords: Industrial Heritage, Historical GIS, Postindustrial Landscape, Vernacular Preservation, Heritage Management, Heritage Interpretation.

INTRODUCTION

RESEARCH BACKGROUND

The informal preservation of postindustrial landscapes is pervasive, yet we lack a systematic way of understanding, recording, and interpreting both the complex processes of informal preservation and the landscapes themselves. How do we manage and interpret that which remains using 21st-century digital tools? Postindustrial landscapes pose a unique set of heritage challenges, from the identification of remnant components to their preservation and interpretation. Their vast scale and evolutionary nature requires novel approaches to thinking about and working with historical industrial landscapes.

The first objective of this dissertation is to understand the nature of postindustrial landscape preservation. However meaningful they may be historically, postindustrial landscapes do not typically attract a wide audience appreciative of their heritage value (Storm 2014). The remnants are often abandoned, decaying, and structurally unsound, and pose real or imagined risks to human health, safety, and welfare. Yet despite these factors, many buildings, structures, and sites remain in the postindustrial landscape.

How do we account for their persistence? Others have tackled this question broadly, and describe analogue remnants as having been preserved “by neglect” (Blasius 2016), as the subjects of “passive preservation” (Francaviglia 2000), or, in acknowledging their unclear fate, as “undefined” (Storm 2014). This dissertation uses Michigan’s Copper Country as a case study to ask: what mechanisms have preserved a model postindustrial landscape? It is clearly not official historic preservation, which is a highly regulated approach to protecting heritage properties that depends on the involvement of experts trained in its contributing disciplines. Instead, the bulk of what remains in the postindustrial landscape has been preserved by a pragmatic, locally-responsive process of unofficial rehabilitation, what I am here calling *vernacular preservation*.

The concept of vernacular preservation follows and extends the work of Francaviglia and Storm on the subject. Properties that have been preserved by the informal processes of vernacular preservation are characterized by several attributes. First, and most importantly, these are places that have not taken advantage of any of the tools or incentives offered by traditional, or formal, historic preservation, including trained expertise or financial incentives. Second, the material protection of these buildings and other structures is related primarily to their practical use and re-use, not to conserving the integrity of historic fabric or character. And finally, the products of vernacular preservation are maintained over time in a state of dynamic equilibrium by these same processes, neither falling to ruin nor being fixed by the mechanisms of formal preservation.

The second objective of this dissertation is to understand how heritage professionals can manage and interpret this vast, complex landscape using 21^{st}-century spatial and digital tools. The sheer scale of historical industry, connected by and incorporated into the underlying landforms, is difficult to comprehend. Furthermore, much of the original industrial fabric is often missing—demolished, burned, or scrapped. This pair of factors makes it very challenging to assemble a coherent understanding of the historic whole, a prerequisite for both management and interpretation.

How do we model such a vast and shattered heritage landscape? To do this, I am borrowing techniques from geography and GIS (Geographic Information Systems), retooled to meet the particular spatiotemporal demands of the Keweenaw's postindustrial landscape. Under the direction of Dr. Don Lafreniere, as a co-principal investigator in the Historical Environments Spatial Analytics (HESA) Lab at Michigan Tech, I worked with an interdisciplinary team to develop the Copper Country Historical Spatial Data Infrastructure (CC-HSDI). The CC-HSDI is comprised of a series of high-resolution, longitudinally-linked datasets that are built on the frameworks pioneered by Lafreniere and Gilliland (2015). This HSDI is designed to track the past century of change in the social, economic, and built environments in Michigan's Copper Country (the Keweenaw Peninsula). The CC-HSDI is the digital foundation for the heritage management and interpretation work in this dissertation.

Virtually reconstructing a historical cultural landscape has, until recently, been beyond the reach of most researchers. The considerable challenges of modeling at this scale have been moderated in recent years by progress in computing power (Dell'Unto et al. 2016), but the question of manpower remains: is there an efficient way to accurately model the thousands of individual buildings, and hundreds of roadways, present at any historical period of time? The recent development of commercially available procedural modeling software provided an excellent opportunity to take advantage of the CC-HSDI's rapidly growing database of historical building information.

Procedural modeling iteratively applies rulesets to refine a basic shape with increasing detail. This computing technique has been used for recreating a single historical building (Danielová et al. 2016), for generating a model of a historical city center as it is today (Rodrigues et al. 2016), for modeling a select area of a city at a historical time period (Dylla et al. 2008). Procedural modeling has also been used for modeling the historical city, both for testing alternative reconstructions for a given time period (Saldaña and Johanson 2013) and for modeling the built environment of a city center at two discrete time periods (Botica et al 2015). In this dissertation, I build on this earlier work by applying procedural modeling for purposes of visualizing the evolving industrial landscape of the Keweenaw Peninsula, using data recorded in the CC-HSDI.

The proof-of-concept virtual reconstruction of the historical industrial landscape presented here outlines the potential of using a fully developed model to address the immediate management and interpretation needs facing many postindustrial landscapes, beginning with their lack of recognized heritage value (Storm 2014; Baeten, Langston, and Lafreniere 2016, 2017). Indeed, cultural landscapes of all stripes present preservation challenges generally (Alanen and Melnick 2000; King 2013). The Copper Country is, in some respects, an outstanding exception, in that it has been federally recognized as Keweenaw National Historical Park (See 2013). While its creation was certainly a watershed moment, its management and interpretation are ongoing, and often challenging, tasks: what can be done presently with the CC-HSDI to advance its heritage goals?

Traditional GIS has found wide use in heritage management, from the relatively simple survey and inventory of historic properties (Husseini and Bali 2015; Shah 2015) to planning large-scale energy production facilities in heritage landscapes (Latinopoulos and Kechagia 2015; Sánchez-Lozano et al. 2013; Watson and Hudson 2015). An historical GIS (HGIS), such as that which forms the basis of our CC-HSDI, expands on this concept by creating geospatial datasets that are linked through time. In this dissertation I present a series of case studies demonstrating the utility of the CC-HSDI to heritage management in the Keweenaw in terms of enhanced efficiency, robustness, and flexibility.

Equally important, though more widely visible, are the heritage interpretation roles that the CC-HSDI can play in postindustrial landscape preservation. These unique cultural landscapes face particular preservation challenges, many of which arise from an incomplete recognition of their heritage value. In this dissertation, I describe our work in communicating the deep and rich historical spatial context of the contemporary landscape, using the public engagement face of the CC-HSDI, known as the Keweenaw Time Traveler. Here, I illustrate this approach with case studies that demonstrate its usefulness for both guided field interpretation and stationary heritage research.

A NOTE ON THEMES

As this is an integrated article dissertation, the following two sections ("Perspectives on the Past" and "Reading the Postindustrial Landscape") are not written as comprehensive literature reviews but rather introductory overviews of a number of key themes that together undergird the dissertation as a whole. These themes are more fully developed in the individual papers that follow, as are their explored literatures.

PERSPECTIVES ON THE PAST

The body of rules and recommendations that constitutes normal preservation activity, and the cultural milieu that supports and structures it, are not inviolate but subjective and political constructs. In this research, these perspectives on the past help to illuminate the complexities tethering the activities of the past to their interpretation in the present.

Heritage And Preservation

Heritage, conceptually speaking, is not bound to a material presence, though its communication does benefit from such a connection. Janet Blake articulates this idea clearly in her writing, pointing out that it is manifestations of cultural heritage that are moderated through the built environment; “the physical elements of cultural heritage—that which has traditionally been viewed as comprising it—are in fact the vehicles by which cultural heritage…is mediated to us” (2000, 74). The activation of heritage takes place via mechanisms of preservation; that is, heritage is crafted in the present through the physical conservation of material artifacts of the past (Ashworth 1997; Harrison 2010; Lowenthal 1979; Lowenthal 1985; Riesenweber 2008; Smith 2006). This construction of heritage from history is an active and engaged undertaking, and is not uniformly applied to all vestiges of the past; indeed, the heritage appropriation of the past is selective and subjective (Carman 2009; Harvey 2001; Lowenthal 1985; Smith 2004; Smith 2006). Elements of this parsed history, plucked from the past, are shaped and presented in accordance with current demands (Lowenthal 1985, 348). This captured and represented past “ is used both to legitimate and to understand the present” (Smith 2004, 2). Just as heritage provides a selected subset of history for consumption in the present, preservation works to communicate that heritage materially.

Ashworth makes a definitional distinction between preservation and heritage management philosophies that differ in objectives, process, and strategy: the former offers simply material protection, while the latter indicates the contemporary usage of the vestiges of the past. The heritagization of selected historical residues is, like the selection process itself, a conscious enterprise. Writes Smith, "heritage is heritage because it is subjected to the management and preservation/conservation process, not because it simply 'is'" (2006, 3). The preservation of heritage "constructs a story of the past through the lens of the present" (Riesenweber 2008, 32). Lowenthal, too, is acutely aware of the malleability of perceptions of the past through its contemporary acknowledgement and appreciation, writing that "when we identify, preserve, enhance, or commemorate surviving artifacts and landscapes, we affect the very nature of the past, altering its meaning and significance for every generation in every place," concluding that "even to appreciate the past is to transform it" (1979, 124).

In all preservation work, there is the opportunity to revise, enhance, and edit the past through the selective presentation of heritage as representative (Harrison 2010; Lowenthal 1998). Legal scholar Janet Blake echoes these considerations that cultural heritage is not absolute: it is selected, it is social, and it is political; the continuity—the inheritance—is deliberate and desired, not automatic or even necessary (2000, 74); Blake writes succinctly, "the identification of cultural heritage is itself a political act" (2000, 68). Virtually all that follows the initial act of recognition is similarly political, even if not overtly so. The heritagization of the past is largely reliant upon preservation activities, some practitioners of which are acutely aware of its crucial political role. Daniel Bluestone opines that preservation is "fundamentally about constituting a politics of place and a place-centered citizenship in which buildings and landscapes provide the grounds for us to critically understand and thoughtfully negotiate the relationship between the past and the future." (Bluestone 2011, 17). The selective retention and presentation of elements of the historical built environment through the mechanics of historic preservation relies on the experience and training of a diversity of professionals, including historians, architects, craftspersons, and others. This broad swath of activities collected under the rubric of *historic preservation* constitute a formalized, official undertaking, legislated by the National Historic Preservation Act of 1966 and its revisions.

READING THE POSTINDUSTRIAL LANDSCAPE

A close reading of the subjects of history, heritage, and preservation establishes their deep conceptual ties and illuminates the subjective and political nature of heritagization and preservation activities. This emergent understanding is, in broad terms, applicable to a range of things and places of history. Curated historical collections of all sorts, from pictures at an exhibition to national parklands share the commonalities of selection and presentation. In this dissertation, additional intellectual tools need to be employed to focus more clearly on one specific subset of historical remnants. This exploration of the living postindustrial landscape is situated at the intersection of the study of cultural landscapes, vernacular architecture, and industrial archaeology. Industry in general, and early industrial activity in particular, exhibits a deep integration of site and function. Successful industrial enterprises are located to optimize access to a number of critical variables, including raw materials, energy sources, and markets; these rich cultural landscapes often evolve substantially over time, in concert with changes to the panoply of factors contributing to any industrial process. Just as the active industrial landscape is very clearly a system made of parts, so is the postindustrial landscape a relic of that system—a product of processes that intimately tethered humans and their enterprise to the natural world.

Cultural Landscapes

"Technology," writes James Williams, "serves as the junction between humankind and nature" (Williams 2010, 9). This consideration, that there is an area of interface between ourselves and our environment that we term *technology*, clarifies the construction of cultural landscapes from natural landscapes. Cultural landscapes are landscapes that have been created through this dynamic engagement, through the "intersecting and overlapping natural and human-built systems," in the words of Thomas Hughes (2004, 154). There is a spectrum of landscapes so created, ranging from virtually untouched areas that may be officially designated as "wilderness," through the heavily constructed landscapes of industry, to a neglected and decayed postindustrial state. A cultural landscape, writes Longstreth, has no inherent status; unlike a designated historic district, for example, "any part of the land can be seen as a cultural landscape" (2008, 2). The conceptual flexibility of cultural landscapes is further extended through its willing embrace of change over time, as even changes "that have eroded the historical value of a place may nonetheless be important contributors to a cultural landscape" (Longstreth 2008, 2). The landscape, in fact, "is both artifact and system; in other words, it is a product and a process" (Alanen 2000, 16). Cultural landscapes are not static, nor sacred, but evolve over time; this mundane yet fluid view is grounded in the physical world (Alanen 2000; Longstreth 2008).

Furthermore, a landscape-scale perspective affords one the ability to understand connections between a diversity of otherwise disparate components, tethering them together spatially and functionally to generate meaning. Particularly relevant to this dissertation is the importance of spatiotemporal context; "considering buildings, structures, or objects within a given spatial and physical setting…endows them with historical significance and context that would be absent if viewed individually" (Andrzejewski 1998, 181). These attributes of cultural landscapes—that they are composed of both natural and artificial elements, that they are often wholly familiar, that they readily incorporate change over time, and that they are often composed of independently unremarkable components, all contribute to an almost unavoidable invisibility; cultural landscapes, broadly, are our natural habitat (Groth 1997). These same attributes make cultural landscapes exceptionally well suited as a model for the study of the postindustrial landscape: the deep integration of site and process, the mundane ubiquity of material remnants, and their evolutionary nature, are all hallmarks of these remnants of industrialization.

Vernacular Architecture

The postindustrial landscape is scattered with the remnants of pathways, sites, buildings, and other structures that once served living industry. While some key buildings were architecturally designed, the vast majority were engineered and built to simply shelter the many tasks of daily work. These pragmatic and unadorned industrial constructs fall well within the parameters of what Bernard Rudofsky has broadly termed *non-pedigreed architecture*: the informal, unclassified architecture variously referred to as anonymous, spontaneous, indigenous, rural or vernacular (1964). Vernacular, writes Stewart Brand, may be summarized as "everything not designed by professional architects—in other words, most of the world's buildings" (1994, 132). Vernacular buildings are without a doubt *common* buildings, and, in Brand's view, this means common "in all the senses of the word—'widespread,' ' ordinary,' and 'beneath notice'" (1994, 132). Thomas Carter agrees that "vernacular architecture is simply common architecture—what most people build and what they use," but carefully eschews qualitative overtones, instead restricting its use solely to the quantitative sense of common (2005, 8). Arnold Alanen contributes "typical" and "everyday" to the definitional pool, and clarifies with comparison that vernacular "is often contrasted with academic, high style, and formal expressions" (2000, 112).

The predominance of common buildings in a cultural landscape is due to several closely related factors. J.B. Jackson writes that the vernacular "is built with local techniques, local materials, and with the local environment in mind: its climate, its traditions, its economy" (1984, 85). That is to say, vernacular buildings can exhibit a native and regional meaning common "to a particular region or community" (Carter 1997, 3; Carter and Cromley 2005). The term *vernacular* was borrowed by architectural historians from linguists (Brand 1994, 132), and like vernacular speech, in vernacular architecture "there is a strong community content that is manifest in distinctive qualities and results in recognized patterns of everyday building" (Carter and Cromley 2005, 8). Vernacular, in other words, is local, and is so because it is traditional and evolutionary (Brand 1994, 132). It is important to recognize that vernacular architecture does not represent static conclusions to fixed design problems; indeed, "far from being 'timeless' and determined by ancient archetypes," any vernacular architecture has "undergone a long and complicated evolution" (Jackson 1984, 85). The evolved and evolving forms of a region's vernacular architecture are responsive to local constraints and opportunities, as are the traditions that built them.

The perspective offered through the lens of vernacular architecture is liberating. This approach to architectural study incorporates the widest possible range of buildings, including both endpoints of the economic spectrum and everything in between (Carter 1997, 4). The study of vernacular architecture offers a singularly inclusive approach to the built world, one that "favors completeness, recognizes diversity, and seeks ways to use buildings as evidence in order to tell better versions of the human story" (Glassie 2000, 21). The study of vernacular architecture is not merely the study of the buildings themselves, but the study of the people who made them, and what they made them for—these lived-in artifacts are historical evidence that "encode in tangible form deeply held and often otherwise unstated cultural, social, and economic values" (Carter 1997, 4). As a core component of cultural landscapes, vernacular architecture is often similarly invisible for its mundane ubiquity. Vernacular architecture, then, in addition to describing buildings that are intimately and evolutionarily related to their immediate environmental context, serves in many respects as a catch-all term for those buildings that don't fit comfortably within the traditional purview of architectural historians.

The buildings populating the postindustrial landscape are clearly vernacular: non-pedigreed, widespread, informal, and evolutionary; in this dissertation, I am borrowing the term and using it as a modifier, in these same senses, of *preservation*. The nature of the practical transformations that so often befall elements of the postindustrial landscape are themselves vernacular: new uses for a historical property are pragmatically driven, locally responsive, and informal, and, I posit, are so common that they pass virtually unnoticed, little discussed, and under-theorized.

Industrial Heritage & Archaeology

The academic discipline of archaeology is familiar to most people as the scientific study of human culture through material remains; industrial archaeology, however, is less so. "Industrial" is not solely an adjective describing a subdiscipline—the term *industrial archaeology* captures more than the archaeology of industry, as a diversity of academic, professional, and avocational interests and activities are gathered together in the field under the perhaps overly reductionist but steadfast moniker. Scholars Marilyn Palmer and Peter Neaverson introduce industrial archaeology in their textbook of the same name as "the systematic study of structures and artefacts as a means of enlarging our understanding of the industrial past" (1998, 1) that is "enhanced by the use of a variety of other sources" (1998, 15). The authors emphasize that "the essence of industrial archaeology is the interrelationship between [evidence from the field] and the evidence from written sources" (1998, 105), and the continuing importance of a strictly archaeological perspective is illuminated by Martin (2013).

The meaning and scope of industrial archaeology has been a subject of academic discussion, sometimes pointed, for decades (Foley 1968; Vogel 1969; Clark 1987; Palmer and Neaverson 1987; Palmer 1990). In recent years, however, consensus has generally coalesced around two points: "industrial archaeology…is not a homogenous discipline but has two main meanings"; in addition to the archaeological work of interpreting material remains to understand the past, industrial archaeology is also a conservation undertaking interested in actually preserving these material remains (Palmer 2005, 59). The close coupling of these two functions may be at once the most consistently recognized and singular attribute of industrial archaeology (Martin 2009; Palmer 2010; Palmer 2012). Kate Clark reflects this in acknowledging that "if material evidence is important, it is also worth keeping," a sentiment that clearly draws a bridge between the two aspects of the discipline: "it is thus a short step from industrial archaeology to what we conserve and why we conserve it" (Clark 2005, 116) or, in other words, "industrial archeology and industrial heritage are mutually reinforcing" (Seely and Martin 2006, 72).

Reflecting these integrative philosophies, industrial archaeology is a truly interdisciplinary undertaking, and includes a range of practitioners including museum professionals, historical archaeologists, historic preservationists, and architects, as well as historians of technology and architecture (Gordon and Malone 1994; Palmer and Neaverson 1998; Seely and Martin 2006). The nature of industry is such that the physical residues available for interrogation by industrial archaeologists include not only individual structures and buildings, but physical plants, transportation corridors, and industrial landscapes (Bergeron 2012; Gordon and Malone 1994; Palmer and Neaverson 1998; Trinder 1982). Industrial archaeologists Robert Gordon and Patrick Malone clearly articulate the importance of this environmental understanding, while grounding it firmly within the rubric of conventional artifactual research, noting that "artifacts studied as isolated objects may be misinterpreted if we do not also look at the context in which they were made and used…[and] part of the context of any device involved in manufacturing is the flow of materials to and from it (1994, 20). Landscapes, to put it succinctly, "comprehend much more than machines and buildings" (Trinder 1982, 3).

This broad perspective is particularly useful to the comprehension of the residues of industrial operations in the postindustrial landscape, as in many cases little remains of original physical plants themselves, while evidence persists in the overall landscape as town names, ancillary businesses, railway tracks, and slag and tailings piles (Gohman 2013; Quivik 2007). The material focus of industrial archaeology and its capacity to operate at a macroscopic scale of analysis provides a critical perspective to this dissertation; many, if not most, of the material remnants to be found in the postindustrial landscape are widely dispersed across a broad area of terrain, where their interconnectedness is not immediately apparent, and their individual insignificance is often paralleled by a deficiency of historical documentation. Understanding the meaning of the postindustrial landscape—and its continuing use—is reliant upon the close coupling of a practical understanding of material remains to a historical understanding of industrial systems.

GEOGRAPHIC CONTEXT

The cultural landscape of Michigan's Copper Country has been indelibly shaped by the combined efforts of many thousands of workers, laboring over more than a century in industrialized copper production. This complex imprint, challenging to untangle, continues to assert its influence today. Beginning in the 1840s with a mine rush to the north end of the Keweenaw Peninsula, the mining, milling, and smelting operations concluded in 1967 with the closure of the last mine at its south. Across the intervening years, various mining operations worked the landforms, reading geological clues, in seeking clues about the quality and extent of ore bodies still hidden in the earth below. But certainty develops only after initial, cautious, explorations; the aboveground development at a mine site not only echoes the successes found below, but serves as an indicator of a company's confidence it its future, a bellwether of things to come.

The development of a mine site proceeds as an iterative process. The initial prospecting stage of an operation might be a dozen men living in tents, surrounded by wilderness. If encouraging deposits were found, the camp would expand, hosting upwards of 200 men. This is something of an inflection point in the course of the exploratory operations. To continue requires additional workers and added infrastructure, which could well be worth the investment if the lode is good—or a waste of capital, labor, and time if it is not.

If the operation moved into full production, the wilderness camp would evolve quickly into what is known as a *mine location*. In a short period of time, hundreds more workers arrive at the site and proper houses are built to house the workers. Some mine locations proved particularly rich, and grew yet again into true, platted, townsites; more housing was built, and hospitals, churches and schools were added in short order. These communities, while planned and built by the mining companies, were never really "company towns"; by and large they were absent any real commercial districts, which were built up independently by outside interests. These communities were viewed by the companies as little more than a necessity—the mines needed workers, and the workers needed housing, churches, schools, and hospitals.

At first, extracted ore was milled near the mines, using retained water at ponds supplied by nearby streams. Within years, the mines' productivity was surpassing the milling capacity possible at these relatively meager water sources, and the companies constructed stamp mills along nearby lake shores. In addition to supplying water used in sluicing the milled ore, these lakes provided another crucial service to the companies in serving as the repositories for the millions of tons of tailings, or stamp sands, produced by the process of milling. Towns were platted at mill sites, and as production continued to grow, still other towns were built to accompany newly-constructed copper smelters. Connected by rail and seasonal waterways, the Keweenaw Peninsula was interwoven into a vast network of people and places in the active industrial landscape.

Over the next half-century, the companies navigated a fluctuating and oftentimes challenging market: wars brought demand for copper, but took away able men; wars ended and the stockpiled surplus deflated the market. A low market price demanded more production, and at ever-lower costs; efficiencies cost workers jobs, and fueled strikes. New mines opened up in the western states, and Ford made enticing offers from Detroit; workers went where they could make a living. Profitably extractable copper was running out, even as new tools, new technologies, and new processes extended operations.

These waves of profit and loss shaped the communities of the Copper Country. Companies built new neighborhoods when times were rich, added amenities when workers grew restless, and expressed corporate pride when the future looked especially bright. These successive pulses of growth are recorded in the built environment like strand lines at the sea; even as receding profits demanded corporate contractions, the remnants of industry and their supporting communities persist in the postindustrial landscape, bearing witness to the vagaries of fortune.

Today, the population of the Keweenaw is less than 40% of its 1910 peak of nearly 100,000. The many municipalities and communities of the Copper Country, while dramatically diminished in population and economic vitality, retain a strong sense of their historical character. In conjunction with the surrounding terrain, today's Copper Country is an exceptional recording of an early twentieth century industrial landscape of national importance. This, as noted above, has been recognized formally with the formation of Keweenaw National Historical Park and its 21 associated Heritage Sites, county historical societies, and community-based interest groups. It is my hope that the ideas, tools, processes, and case studies presented here will serve the people and places of this living postindustrial landscape as it continues to evolve, keeping a keen eye on its heritage.

THE COPPER COUNTRY HISTORICAL SPATIAL DATA INFRASTRUCTURE

The first phase of the Copper Country Historical Spatial Data Infrastructure (CC-HSDI) CC-HSDI, which is being used in this dissertation, started in 2015 with initial seed funding from MTU and in 2016 expanded with the support of a Humanities Collections and Reference Resources Grant from the National Endowment for the Humanities

Our HSDI is comprised of a series of high-resolution, longitudinally-linked geospatial datasets recording information on the social, economic, and built environments of Michigan's "Copper Country" in decadal intervals from the late nineteenth century to the middle of the twentieth. These data are tethered to a Historical GIS (HGIS), composed of over 1,300 scanned and georeferenced Sanborn fire insurance maps of the area, with individual record linkages made to over 120,000 digitized building footprints. The project was designed to be able to readily accommodate continual and long-term growth of its database, and to date has ingested census and city directory data, with company employee records and area school records in queue for incorporation in the near future. The HGIS component will additionally include historic roads and railways, public utilities, and other infrastructural elements, all of which will in turn receive linked datasets. The continually-growing CC-HSDI will ultimately be a publicly-available, map-driven historical database, useful to anyone researching or exploring the region's rich history.

However helpful it may be, recording, organizing, and making data available to others is not an end in itself. That is to say, even a perfect representation of the historical and contemporary industrial landscape, while resulting from a serious intellectual and academic undertaking, is still itself data. Studying, and sharing the results of, such massive datasets again demands novel tools and techniques. Visualization of even a fraction of the data that has been accumulated so far is a monumental undertaking, and one that lends itself well to the application of another existing tool, in a new and previously untested way.

For this I used a second proprietary software package, ESRI's procedural modeling software CityEngine. CityEngine is traditionally used by architects, planners, and animators to quickly create highly detailed 3D digital models of buildings and various landscape features by the application of coded rulesets to 2D spatial data. In building the original HSDI, several key characteristics of each geolocated building footprint were recorded directly from the historical maps, including number of stories, exterior cladding, and building use. The CC-HSDI datasets are extraordinarily well positioned to evaluate the ability of CityEngine to rapidly evolve high-resolution, data-driven, spatiotemporally representative models of the Copper Country's industrial communities.

Drawing upon a select subset of the vast dataset, I ingested nearly 48,000 building footprints, and their recorded map data, from the CC-HSDI into CityEngine. These data were drawn upon to generate a comparative set of 3D cultural landscape models of the Village of Calumet, using data transcribed directly from historical maps. This proof-of-concept visualization demonstrated the viability of CityEngine as a heritage tool to quickly process and display in a easily comprehensible fashion huge historical datasets about the built environment. As the CC-HSDI grows, so too will the possibilities for data visualization using this powerful digital tool.

Finally, even meticulously recorded, carefully indexed, and beautifully visualized data must have a purpose to be useful. To this end, the CC-HSDI datasets are being applied to heritage management and interpretation of the postindustrial landscape. The public face of this HSDI has been branded by the HESA Lab as the *Keweenaw Time Traveler*, and is actively being used to share the Copper Country's history geospatially. My primary focus within this larger project relates to the conservation of the postindustrial landscape itself, and public education and engagement that forwards this goal. Rather than simplifying the area's rich and complex mining history, the Time Traveler employs techniques of data consolidation and graphical, map-based representation—that is, it brings a diversity of historical information together, and provides familiar (if newly digital) interfaces to communicate the industrial heritage.

Michigan's Copper Country is the beneficiary of broad public interest and support. With leadership provided by Keweenaw National Historical Park (KNHP), a diversity of interest groups including numerous local historical societies, governmental agencies, and 21 KNHP-allied Heritage Sites oversee the management and public engagement with the area's history. Here, I illustrate the usefulness of the big data CC-HSDI for both heritage management and public interpretation with a series of case studies demonstrating some realized roles of the Keweenaw Time Traveler in heritage planning, administration, community engagement, interpretation, and education in the postindustrial landscape.

My three heritage management case studies presented here include a schematic rehabilitation plan for Quincy Smelting Works the last remaining Great Lakes region copper smelter; a conceptual preservation plan for Calumet's historic industrial corridor; and the construction of an online, GIS-based, building inventory for the Village of Calumet Civic and Commercial Historic District. In the future, as the CC-HSDI continues to grow, so will the usefulness of its database. I conclude with recent examples of the role of the Time Traveler in heritage interpretation. First, using the Time Traveler in a "fieldwork" mode, exploring a Lake Linden Village park with local youth, outfitted with GPS-enabled 4G iPads pulling that superimpose their present location on historical maps; and second, using the Time Traveler in a "research" mode, pursuing answers to longstanding historical questions with an older generation of visitors using stationary, large-format touchscreen kiosks.

The many novel challenges presented by postindustrial landscape heritage study can be understood as stemming from their singular typology, vast scale, and often much-evolved forms. New approaches to thinking about the nature and goals of historic preservation, coupled to new tools for consolidating, comprehending, and representing these unique places advances these goals considerably.

STRUCTURE OF THE DISSERTATION

This dissertation follows an integrated article format. This introduction is followed by three chapters (1–3) that have been prepared for publication in peer-reviewed academic journals, followed by a conclusion that includes a discussion and suggestions for future research.

The first article (Chapter 1), "The Persistence Of Time: Vernacular Preservation of the Postindustrial Landscape," is in press in *Change Over Time: An International Journal of Conservation and the Built Environment,* and presents a theoretical framework for thinking about the common but neglected informal processes of preservation that are prevalent in the postindustrial landscape of Michigan's Copper Country.

The second article (Chapter 2), "Creating a Longitudinal, Data-Driven 3D Model of Change Over Time in a Postindustrial Landscape Using GIS and CityEngine" is in press in *Journal of Cultural Heritage Management and Sustainable Development,* and details a study that harnesses procedural modeling software to the big historical spatiotemporal datasets of the Copper Country Historical Spatial Data Infrastructure (CC-HSDI) for cultural heritage management.

The third article (Chapter 3), "Historical GIS in Industrial Heritage Landscape Management and Interpretation" is in review at *Heritage & Society*, and describes a series of case studies that applies the CC-HSDI to heritage management and heritage interpretation in and around Keweenaw National Historical Park.

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THE PERSISTENCE OF TIME:
VERNACULAR PRESERVATION OF THE POSTINDUSTRIAL LANDSCAPE

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ABSTRACT

Formal historic preservation is a professional and sanctioned approach to the conservation of our historically significant built cultural heritage. Postindustrial landscapes are, by definition, functionally and materially obsolete, and in many cases derelict and decaying. While they hold historical significance these sites are often not widely perceived as valuable contributors to our heritage. Yet these landscapes persist. We argue that the material persistence of these features is the result of generally unrecognized processes of informal material conservation.

In this paper, we outline a new framework, vernacular preservation, an ontology for heritage professionals to use in considering how to approach and recognize nonformal interventions that result in the protection of heritage resources. Here, we use the postindustrial landscape of Michigan's Keweenaw Peninsula—a former copper-mining district—to illustrate how vernacular preservation differs from formal historic preservation, reviewing the process of vernacular preservation and how it is activated in practice.

Vernacular preservation constitutes perhaps the most traditional, common, and widespread mechanism of material conservation of the historical built environment yet has been largely invisible, little discussed, and undertheorized by the heritage preservation community. Understanding this preservation process begins by acknowledging its existence and by extending the heritage dialogue to include these underrepresented historical properties and their important role in defining postindustrial

landscapes. We conclude the paper with a discussion on how this novel approach to thinking about preservation extends broadly to the field and should be given greater attention.

INTRODUCTION

Contemporary historic preservation practice in the United States follows a rigorous and bureaucratic approach to the protection of select historic resources and is ultimately reliant on the expertise of architects, historians, planners, and others. This preservation methodology, conducted by professionals working within strict regulatory parameters, ensures high minimum standards for the conservation of the built cultural heritage. This process and act of conservation is known commonly as "historic preservation." Here, we refer to historic preservation as formal historic preservation to emphasize its basis in a formal protocol, guided by policy and legislation. In this paper, we outline an alternative mechanism that similarly results in the material conservation of the historical built environment, *vernacular preservation*.

Vernacular preservation is a pragmatically driven, locally responsive, and informal process that, despite its nonexpert and unofficial nature, contributes consequentially to the legibility and meaning of the historic landscapes. It is important to note here that it is the *process* of preservation that is vernacular, rather than the subjects, that is, vernacularly preserved buildings, structures, and sites are properties that have been repurposed in a manner that is inconsistent with their original, specific functions and that is often wholly incompatible with the Secretary of the Interior's Standards for Rehabilitation. By formal standards, these properties have been rendered ineligible for historic preservation designation and are often overlooked or even dismissed by preservation professionals. This oversight is a missed opportunity for preservationists; we aim to begin the conversation in this paper.

Few buildings, structures, and sites (herein referred to as “sites”) from our past are significant in and of themselves. Furthermore, both normal maintenance and dereliction obscure whatever significance they may have once held. There are also many historical properties that persist without the benefit of formal conservation and official heritage designation. Often, these properties do not readily conform to the established criteria of heritage significance and integrity.

In this paper, we outline a new framework for heritage professionals to use in considering unofficial interventions that result in the protection of heritage resources. To illustrate how vernacular preservation differs from formal historic preservation, we examine current and past practices in the postindustrial landscape of Michigan’s Keweenaw Peninsula—a former copper-mining district. We conclude the paper with a discussion on how this novel approach to thinking about preservation extends broadly to the field and should be given greater attention.

The Particular Case of Postindustrial Landscapes

Postindustrial landscapes, or those historical landscapes shaped and evolved by the workings of now-absent industry, are notably underrepresented as subjects of formal historic preservation—yet many historical industrial sites persevere. In this paper, we argue that the persistence of these features results from generally unrecognized processes of informal conservation, which we have termed “vernacular preservation.” This unofficial but highly effective approach to preservation, despite its nonexpert and unofficial nature, contributes significantly to the conservation of a breadth of cultural landscapes that change over time. This process is particularly well represented in postindustrial landscapes, as will be demonstrated here with examples from the once-vital landscape of extraction found in Michigan's "Copper Country," the Keweenaw Peninsula.

While commonplace in the postindustrial landscape, these apparently inconsequential and often heavily modified historical properties have received comparatively little attention from preservation professionals. Acknowledgement of these places, when it does occur, often regards their state as a temporary condition that precedes either abandonment and eventual ruin or resurrection through formal historic preservation. Here, we propose that many sites in the postindustrial landscape persist in a quasi-stable state perpetuated through pragmatic, locally responsive, and informal reuse; that is, through vernacular preservation.

The pressures facing rural postindustrial sites are different than those in the more familiar urban postindustrial sites such as Detroit or Pittsburgh. Those caring for the industrial heritage sites of North American postindustrial cities regularly face population pressure–induced challenges such as redevelopment, gentrification, and "not-in-my-backyard" responses to the size, appearance, and legacy toxins that are commonplace in former industrial sites.[1] In contrast, many rural postindustrial sites, our case study included, have experienced only a decline in population since peak industrial activity. With abundant land and no significant population or development pressure, many industrial vestiges remain.

There are several interrelated attributes of historical industrial sites that make them particularly strong candidates for vernacular preservation and, as such, that serve as an excellent case study. There are obvious physical qualities that facilitate a variety of reuse activities: industrial buildings, for example, are often capacious, exceptionally robust, and spatially flexible, as demonstrated by the familiar repurposing of historical brick warehouses to serve as offices, loft apartments, or shops. In addition to these physical attributes, however, industrial landscapes—in particular extractive landscapes—are fundamentally unlike nonindustrial landscapes. In many cases, remnants that appear to be individual features (viewed in the context of the contemporary postindustrial state) are actually interdependent components of once-vital industrial systems so vast that their historical connections are obscured by time.

Two key insights follow this understanding. First, any isolable part of an industrial system is unlikely to be individually significant and, second, virtually all sites comprising the postindustrial landscape experienced—even over their productive lifetimes—continual material, if not functional, evolution. That is to say, many, if not most, of these properties are without significance or integrity and simply do not qualify for formal historic preservation. Pragmatically speaking, this is just as well; there is no feasible way to formally protect an entire postindustrial landscape—there are simply too many parts, spread over too great an area of land, often under separate ownerships or even jurisdictions without sufficient resources for formal historic preservation. It is not necessarily meaningful to privilege one iteration of an industrial landscape over others, even those that occurred after the original function of the site was lost or had ended. The heritagization of the postindustrial landscape is ultimately reliant on a network of complex systems and cannot be understood on the basis of any one, or even any few, individual components.

Formal Historical Preservation

Professional historic preservation activities follow highly structured and regulated procedures. Architects, historians, craftspersons, preservationists, and other professionals operate under federal, state, and local legislation and are guided by a coherent body of standards that collectively trace their lineage to the National Historic Preservation Act of 1966. *Historic Preservation*, in common usage, refers to a suite of official and prescribed policies and practices designed to protect and prolong the life of heritage sites. To differentiate these sanctioned preservation efforts from other mechanisms that also result in the physical conservation of the built world, we consider the activities of professional preservationists as comprising *formal historic preservation*.

Implementation and Application

The institutional origins of contemporary historic preservation in the United States can be traced to popular reaction against the widespread destruction of historic sites that accompanied mid-twentieth-century urban renewal and the construction of the Interstate Highway System.[2] The National Historic Preservation Act of 1966 (NHPA) established a suite of regulations primarily intended to slow the dramatic and alarmingly rapid loss of historic sites at the hand of these developmental threats. Formal historic preservation has evolved significantly since then, and today the field is able to draw on a robust body of procedure operating at multiple levels of government.[3] The heart of this body is the National Register of Historic Places (NRHP), assembled and administered by the National Park Service (NPS) in accordance with the NHPA. Historic preservation, as defined by the act, is concerned with the "identification, evaluation, recordation, documentation, curation, acquisition, protection, management, rehabilitation, restoration, stabilization, maintenance, research, interpretation, and conservation" of historic properties;[4] "historic properties" as defined in this legislation are limited to those resources eligible for or listed on the National Register of Historic Places.[5]

Listing on the NRHP is a complex, closely controlled, and official process, wherein eligibility is conclusively determined by a professional assessment of the *significance* and *integrity* of an historic resource as evaluated in accordance with established criteria. The preparation of a nomination to the National Register demands substantial sustained effort and, while not technically required, benefits from experienced or professional guidance to construct a thorough historical narrative and to convincingly demonstrate the significance and integrity of a proposed historic property. A submission is reviewed at the state level and, if approved, is forwarded to federal review for consideration. If accepted by the Keeper of the National Register of Historic Places, the property is inscribed on the Register Listing, [6] or (since 1972) the determination of eligibility for listing, is the crucial step for a property's formal historic preservation, as official designation opens the doors to legal and financial obligations and opportunities.[7]

Once listed, a historic property may be subject to one of four approved *treatments* as detailed in the Secretary of the Interior's Standards for the Treatment of Historic Properties: preservation, rehabilitation, restoration, or reconstruction. While these standards are advisory for preservation, restoration, and reconstruction work, they are regulatory for rehabilitation, the treatment that is most closely aligned with vernacular preservation. Rehabilitation is the process of "making necessary changes while retaining the characteristics that make the place important" and is considered to be the most influential of the four treatments, given the availability of tax credits for a successful, approved project.[8]

The standards for rehabilitation are regulatory and subject to enforcement, a process that is necessarily subjective, at least to some degree: the application of any set of uniform rules, such as the standards, requires the expertise and judgment of experienced practitioners. Generally speaking, preservation of existing features, especially those that have significance to adjacent historic sites and are visible to the public, are prioritized.[9] Rehabilitation work also requires a thorough and nuanced understanding of other treatments, notably preservation and restoration. While the specifics must always be evaluated on a case-by-case basis, retention of historic fabric is a hallmark of formal historic preservation.[10]

The Challenges of Applying Formal Historic Preservation Principles to the Postindustrial Landscape

The rules, regulations, and recommendations that guide formal historic preservation work are not static. The kinds of sites eligible for formal recognition as having historic and interpretive value for the present have increased dramatically in the past half century.[11] However, despite the accommodating nature of the perennially evolving field, it is important to emphasize that preservation professionals remain beholden to definitions and statutes—even as they change over time.

Recall that a *historic property* as defined in the NHPA must be a historic resource (district, site, building, structure, or object) included on, or eligible for inclusion on, the National Register of Historic Places.[12] This statutory definition means that if a resource is deemed ineligible for listing in the National Register, it is not technically a historic property and therefore not, strictly speaking, subject to the purview of the professional preservationist.[13] This means that there is a vast swath of the historical built environment that is largely overlooked by preservationists in their professional practice, even though these buildings may be valuable in other ways.

In spite of the expansion of historic preservation's scope, industrial heritage remains insufficiently considered in official preservation thinking.[14] This concern was recently highlighted by the 2016 *U.S. World Heritage Gap Study Report*, which states that "sites of invention, industrial heritage, and technological evolution are . . . very under-represented on the U.S. World Heritage List."[15] This lack of official endorsement is certainly not due to a shortage of potential sites, but rather to the challenges in making them formally recognized under current standards. And while numerous professional associations (including the Vernacular Architecture Forum, the Society for Industrial Archeology, and the Alliance for Historic Landscape Preservation) have for decades focused on establishing best practices for the preservation, interpretation, and policy protection for a variety of sites such as those discussed here, there remain significant challenges to their long-term formal protection.

As opposed to house museums, for example, landscapes are composed of features that are constantly changing, making the very means of their preservation more difficult than the more traditional, fixed, preservation modes that may be imposed on any individual building or structure.[16] Compounding the challenge, "culturally significant landscapes . . . don't fit very readily into the well-understood taxonomy of 'building, site, district, structure, and object' used by the National Register."[17]

The vernacular nature of these landscapes only compounds the challenge of constructing compelling arguments for their preservation within the current preservation system; because they often encompass the histories of numerous owners and users over time, and may represent the values of diverse cultural groups, vernacular landscapes are especially difficult to address within established historic preservation guidelines.[18] Of the many obstacles facing postindustrial landscape preservation, one of the greatest is neither mechanical nor procedural, but *perceptual*. Postindustrial landscapes imply a functional obsolescence and, in many cases, are derelict and decaying. Despite their past significance, these sites are often not widely perceived as valuable contributors to our heritage. There is a sense that the postindustrial landscape is, as Anna Storm describes, often too ruined, modified, or complex to be easily recognized from a heritage perspective.[19]

Postindustrial landscapes are among the most illustrative examples of cultural landscapes, as—due to the very nature of industrial activities—the resultant topographies can simultaneously exhibit multiple layers of time with particular clarity, and each presents a place-specific intersection of nature and culture.[20] An additional element of industrial sites that has only recently begun to be considered as an integral component of their heritage value is the waste material produced during their operation. Historian Fredric Quivik argues convincingly that "wastes from the mining industry are more than just visual, physical, or chemical presences on the landscape; they embody powerful and important cultural meanings as well."[21] Although concerns for human and environmental health and safety are paramount, approaches to remediation often neglect the historic and interpretive value of industrial sites.[22] The acknowledgement of the heritage value of waste only underscores the importance of preserving and interpreting historic industrial sites holistically; for any given postindustrial landscape to communicate its history meaningfully, preservation efforts should not be limited to its most important or iconic buildings or factories, but must extend to include a diversity of elements, including perhaps its waste. That is, components of the industrial past can communicate their heritage value in the present with the greatest resonance when they are preserved and interpreted as constituents of a greater landscape.[23] Vernacular preservation is itself a function of the evolving cultural landscape and is a process that contributes meaningfully to deeper understandings of heritage.

Vernacular Preservation

Although postindustrial sites seldom qualify for official recognition, many of them persist as active components of the living postindustrial landscape. This nonprofessional or *vernacular preservation*, as we outline here, is the result of informal conservation, driven by pragmatic local needs and activated by practical attributes of postindustrial resources—in particular, those that leverage their latent value toward reuse, rather than neglect or abandonment.

Vernacular Preservation, Neglect, and Abandonment

The National Register of Historic Places lists more than ninety thousand properties, a figure that includes around 1.4 million individual resources (including sites, districts, buildings, structures, and objects), found in virtually every county in the United States.[24] While impressive, this inventory includes only a tiny fraction of the historical resources woven into the fabric of the national cultural landscape. Postindustrial sites of historical significance that are not included are usually regarded as inhabiting an unstable state of being—that is, their status is a temporary condition that necessarily precedes the more widely acknowledged states of ruin or resurrection.[25] However, if this were true, the historical built environment would be comprised solely of the products of official conservation and ruins—or resources en route to one or the other. Clearly, this is not the case, as we conduct our lives surrounded by the material residues of our past, and few could be uncomfortably worked into one of these classes. This state must, therefore, be less transitory than suggested, stabilized by forces that have not been adequately addressed by heritage professionals. The missing agent, we argue, is the pragmatic, local, informal—in other words, *vernacular*—preservation of historical sites. The gap in existing preservation thinking filled by this factor is bracketed by a number of established concepts that are related to, yet distinct from, vernacular preservation: *ruin*, *abandonment*, and *preservation by neglect* are all familiar, if peripheral, terms used to describe the state of extant heritage resources that have not been the subjects of formal historic preservation efforts.

Abandoned resources require little by way of description. Without care or maintenance of any sort, a property is subject to the natural processes of weathering and decay. In the common sense of the term, particularly when applied to buildings, the state of abandonment represents the antithesis of preservation; the process is neither active nor intentional and ultimately may result in total loss. The National Register has long maintained that "the present use of a building does not affect its eligibility for listing." This claim does not, however, extend to cases of disuse (such as vacancy or abandonment), as structural deterioration may compromise eligibility, as outlined in the statement that a "building [may be] beyond the point of rehabilitation and therefore beyond the point of making a lasting contribution to the community, State or Nation."[26] Examples of such ruinous sites that nonetheless have received designation include Bodie State Historic Park, comprised of the preserved ruins of a nineteenth-century gold-mining camp in California that is maintained in a state of "arrested decay," or the remains of a fourteenth-century Hohokam compound in Arizona today known as Casa Grande Ruins National Monument. This strangely divergent perspective, in which a ruinous state can either disqualify a site on the basis of insufficient integrity or serve as the basis for interest in the site, is limited to the evaluation of *buildings*, however, and is directly contradicted by the allowances afforded to *sites*: "a site is the location of a significant event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself possesses historic, cultural, or archeological value regardless of the value of any existing structure."[27] While it is clearly important to carefully select the appropriate category when writing a nomination, the crucial point here is that the NRHP is not categorically opposed to listing abandoned and ruined buildings, if strong justifications can be made for their historic significance and integrity.[28] Despite being bypassed by the demands of the Secretary of the Interior's Standards for the Treatment of Historic Properties, both ruins and abandoned buildings can have a presence and standing within the purview of professional preservation.

Defined by exclusion more than by any real commonality, those places described as the unwitting beneficiaries of "preservation by neglect" make a mixed bag; the phrase itself is not a legal or academic term, and its definition is more inductive than deductive.

There are but a handful of published papers that employ the term in any capacity, all of which merely reference the phrase in passing; further, none of these papers define the expression, suggesting that it has sufficient common currency to obviate the need. This possibility is supported by the term's ubiquity in Weblogs and online newspaper articles, with a simple Google search returning hundreds of unique hits. One blogger describes a "large square old farmhouse that has not been updated" as benefiting from "preservation by neglect," while another writes, "because there's no reason to tear down a building if there's nothing to replace it, Buffalo has benefited from 'preservation by neglect.'"[29] One author acknowledges the need for such a term in his description of the historic mansions of Cuba, explaining that "they're not being torn down, though a lot are dilapidated and falling down. . . . I call it preservation by neglect."[30] Finally, an architectural historian provides a definition on her blog: "'preservation by neglect,' is a term used to describe the way an old building is preserved by disrepair, thus [conserving] the building's original or historic features."[31] What these brief and representative quotations make clear is that while it is a term that is used casually, it is also used consistently and meaningfully, including by historians and preservationists. This idea, that historical sites may be preserved passively, by default, simply by virtue of being unmolested over time, is an important argument for this paper. However, unlike these passive and unplanned preservation accidents, vernacular preservation is *not* "preservation by neglect": it is an active and engaged undertaking that results, almost unavoidably, in the material conservation of the industrial heritage.

The Stabilizing Forces of Vernacular Preservation

Historical resources that are the beneficiaries of vernacular preservation are typified by a lack of perceived heritage value. They persist through time as a result of their continued usefulness rather than efforts designed to preserve their historical meaning. Vernacular preservation does not meet the high bar set by the Secretary of the Interior's Standards for an approved rehabilitation treatment; rather, the sites are beneficiaries of a kind of practical preservation, and their persistence is a function of their continued utility.

The term *vernacular preservation* bridges a conceptual void and provides an explanation for the kind of temporal endurance of heritage resources that have traditionally been considered to be typologically unstable—on the edge of ruin or resurrection. In his essay on the pragmatics of historic preservation, Richard Francaviglia employs the term *active preservation* to describe those heritage resources conserved through the familiar processes of formal historic preservation and introduces the term *passive preservation* to denote the state of remote, economically stagnant historic landscapes that have been overlooked by progress.[32] Francaviglia recognizes the preservation validity of simple persistence over time (akin to "preservation by neglect"), but writes that passively preserved landscapes exist in a sort of limbo, ultimately subject to one of two fates: either disappearing if the economy worsens or being "transformed by progress" if the economy improves.[33] Both of these trajectories, it seems, draw a landscape toward one extreme or another: either toward oblivion, by demolition or the natural processes of unmediated decay, or toward preservation by rehabilitation. Francaviglia notes, "only if sentiment or economic incentives are strong enough will they be actively preserved."[34] This suggestion that all paths forward for passively preserved landscapes result in loss—through acute neglect, demolition, or metamorphosis—does not examine closely the stabilizing forces of ongoing use. That is to say, while they exist, historical resources are maintained by *something*. Most of the historical built world dwells in this unexplored gap, filled, we argue, by vernacular preservation.

Neatly intersecting with Francaviglia's passively preserved landscapes (and by extension those that have been "preserved by neglect") are those categorized by Anna Storm as *ruined*, a term she uses to describe abandoned and decaying industrial sites in remote or rural areas that are not subjected to pressures of development.[35] In the same work, Storm introduces the term *reused* to describe the rehabilitation of redundant industrial sites.[36] These reused sites correlate to Francaviglia's actively preserved sites and are what we describe as the subjects of formal historic preservation. There is, however, a distinction to be made. Rather than suggesting that passively preserved landscapes exist in an unstable limbo, Storm proposes a third class of postindustrial landscape, the *undefined*, to describe "places and processes that are not acknowledged as important from a memory or heritage perspective . . . [and that are] left outside the arena of contemporary heritage recognition." She notes that these sites "are marked by a lack of identity and an integral potential to gravitate toward one or both of the other two categories." That is, they are in neither a reused nor a ruined state.[37]

Still, neither of these taxonomies has a place for vernacular preservation. While Francaviglia's passive preservation acknowledges that the absence of attention may allow a building to persist over time in its (more or less) original form, it stops short of incorporating a discussion of factors that may perpetuate this state, instead characterized solely as a transitory state. Conversely, Francaviglia's concept of active preservation is limited to the processes of incentivized conversion, discounting wholesale those historical sites that have been informally altered to serve new purposes. If active preservation is predicated on financial or sentimental value and leads to a stable state, while passive preservation describes an uncertain and temporary state that precedes only ruin or rebirth, then persistent resources that fit neither class soon simply fall out of the conversation altogether.

Similarly, Storm's reused buildings are often gentrified by their new uses and new tenants, and their industrial heritage reduced to aesthetics.[38] Almost unavoidably, Storm's perspective favors professional efforts and requires a significant amount of capital investment—again excluding vernacular preservation from the conversation. Further, despite introducing the previously invisible category that she refers to as *undefined* to the ongoing heritage discourse, and noting its ambivalent destinies, Storm does not grant this category a stable status; these undefined sites, she writes, evolve either toward formal reuse or to ruins.[39] Again, there is no place here for the ongoing informal use of the postindustrial landscape. Simple abandonment only partially accounts for the persistence of the past in the present. To understand the overwhelming majority of what remains, it is important to examine the role of additional, unexplored forces at work stabilizing these landscapes, and their product: vernacular preservation.

Case Study: Vernacular Preservation in a Landscape of Extraction

Michigan's Copper Country was historically a vibrant industrial landscape comprised of interconnected sites; today, its postindustrial shadow offers evidence of those extensive networks only as isolated nodes and broken paths, apparently devoid of significance and lacking integrity. The remaining scattered remnants are, however, significant elements of an otherwise largely vanished historical landscape. Many of the redundant industrial buildings, structures, and paths are often modified to accept new uses. The physical changes affecting many historical industrial remnants are a testament to the value these buildings and sites have as active elements of the living postindustrial landscape. Here, we present three case studies of sites located in the postindustrial landscape of Michigan's Copper Country to illustrate the process of vernacular preservation.

Figure 1. Calumet & Hecla industrial core, circa 1910, Calumet, Mich. (Michigan Tech Archives)

Historical Context

The Keweenaw Peninsula's 1992 designation as a National Historical Park recognized the site's natural and cultural significance and its role in American industrial history. Early explorations of the area by Euro-Americans found evidence of what proved to be the largest deposit of unalloyed, native copper in the world. Industrialized copper mining began in the 1840s as thousands arrived to seek their fortunes. Unlike gold, however, copper can only be a profitable enterprise when mined at a large scale—a risky, and costly, undertaking virtually requiring corporate investment and oversight. Soon, rail and waterways were constructed to connect the mines, mills, smelters, and towns; this infrastructure wove an intricate network of interconnected people and places, leading the area to become the epicenter of Michigan's Copper Country (fig. 1).

Over the next century, the copper industries were required to continually shift in response to changing market conditions, profitability, and labor disputes. Companies built new neighborhoods when more workers were needed, added amenities when workers grew restless, and constructed expressions of corporate pride when times were especially prosperous. While copper operations in the Keweenaw ultimately ceased in the late 1960s, the landscape continued to evolve. The successive pulses of growth are evident in the landscape, and this complex imprint continues to assert its influence today, thanks largely to the effects of vernacular preservation—and to the factors that lead to it.

Critical Variables for Vernacular Preservation

Buildings that benefit from vernacular preservation are largely characterized by their continued usefulness in the postindustrial landscape. We conducted archival research and interviews with property owners in the Keewenaw Peninsula to understand the factors that contributed to the persistence and continued usefulness of various buildings. We discovered continuous usefulness is contingent on three key characteristics or variables: *situation*, *space*, and *construction*.

Situation is more complex than the location of a building and includes the important connections, both historical and contemporary, to other places and the relationships between them. These connections dictate to a large degree the flow of ideas, materials, people, and products between places. Given the diversity of uses that redundant industrial buildings are put to, there can be no single situation that serves all equally well. While a property's situation is often considered to be the primary determinant of its desirability, this can only be meaningfully evaluated in the context of the building's potential use. Different functions have different ideal situations that, importantly, change over time: many once-central industrial buildings now are remotely situated in today's postindustrial landscape. For others, postindustrial urban development such as highways, suburban sprawl, and energy infrastructure may place the building in a prime situation to increase its likelihood of vernacular preservation.

Space, or more broadly, a building's spatial attributes including footprint, useable area, and enclosed volume, largely circumscribe the possibilities for its use and reuse. As with *situation*, different uses require different spaces but generally speaking, a building must be large enough to accommodate its intended functions, while small enough to afford manageable operation and upkeep. Industrial buildings in particular possess a positive spatial quality that encourages vernacular preservation, as technological shifts in extraction and production drove the design of spaces that were flexible in form and function. This spatial adaptability is associated with expansive, uninterrupted volumes, as well as the large building envelope penetrations required by industrial processes to admit light, machinery, or materials.

The remaining critical variable identified here is that of a building's *construction*. For most contemporary uses, a building's construction is not a priority, as long as the enclosed space can be adequately controlled to meet programmatic requirements, such as providing adequate light and air, thermal comfort, and energy efficiency. The owners and users of most new buildings care only that these needs are met, while the underlying (and often invisible) building construction is not a consideration. For a postindustrial building to provide the utility that endears it to the processes of vernacular preservation, however, the original fabric of the building itself may be a crucial variable; the evolving uses of a building may highly value or even rely on the retention of the building's construction.

The Powerhouse

In 2001, Michigan Technological University partnered with the cities of Houghton and Hancock to create the Michigan Tech Enterprise SmartZone, a collaborative business incubator designed to foster the commercialization of emerging technologies. One of the first tasks was to find an appropriate workspace that would attract and retain identity-conscious tenants who demand an excellent *situation*. The optimal site would command a prominent location, provide impressive views of its surroundings, and be within walking distance of the university district and urban amenities. This ideal was met by a former electrical powerhouse, a beautiful sandstone building just a mile from campus overlooking the downtown core and offering splendid views to (and highly visible from) the iconic bridge connecting the region's primary population centers (fig. 2).

Erected in 1890, the coal-fired electric power plant was enlarged several times over the decades to meet the needs of a growing local population before it was ultimately taken offline and vacated in the early 1960s. Around that time, a number of related buildings and rail sidings on the site were removed. Today the SmartZone Powerhouse Building is the sole remnant of what had been a far larger complex. Spared the destruction that befell its less-useful neighbors, the large masonry building was eventually purchased and stabilized by a local contractor, who conducted extensive exterior renovations before making it available for purchase in 2003.

While the building's *situation* may have been the first consideration of its new owners, it was not their only concern. The opportunity to build out unfinished *space* to meet new specifications is a valued attribute to any new occupant. Its original design as a powerhouse featured a three-story open plan devoid of columns. The cavernous volume offered astonishing spatial flexibility. In terms of *construction*, the original, locally sourced sandstone shell exhibits an undeniable and uncommon beauty that demonstrates regional pride and a refined appreciation for aesthetics; an overhead gantry crane retained at the second level hints that there is some value attached to the material historicity of this iconic building. All of this together has produced one of the "nicest office buildings within 100 miles."[40]

Figure 2. The Powerhouse, Houghton, Mich. (Photo by John Arnold)

While the building is currently called The Powerhouse, the salable product was never its heritage, but rather its *situation*, *space*, and *construction*. The contractor who renovated the building demonstrated no interest in pursuing formal designation or enlisting the assistance of preservation professionals, and there was no perceived advantage to following approved rehabilitation guidelines. The Powerhouse owes its persistence to its inherent ability to meet the key factors necessary to its continued utility, and hence, to its vernacular preservation.

Rockwood Concepts

Rockwood Concepts is a multifaceted company whose properties include a rustic furniture manufactory, log-home sales center, natural-stone distributor, and shingle recycling site. These diverse subsidiaries are collectively housed in a pair of connected buildings. One building is an enormous trussed concrete box and the other is an even larger brick-infill steel-frame structure. Together these are well suited to accommodate change over time, not only in terms of their *space*, which features open plans and high ceilings, but also in terms of their *construction*, as visible structural systems makes modification both easier to plan and to execute (fig. 3).

These two buildings, a dry house and a hoist house, were originally components of the Ahmeek Mining Company's surface operations for its number three and number four shafts, first opened in 1908 and in operation until 1968. Shortly after their closure, the site was bisected by the rerouting of a nearby freeway. At that time, a number of steel buildings on the site were demolished.

In 2004 the property was purchased by a new owner who removed the infill brickwork from the highly visible street façade of the hoist house, revealing an elevated concrete deck and eight bays delineated by the intricate steel structural frame. The building soon found new purpose as a loading dock for the sale of landscaping material, and shortly thereafter consigned a bay to serve as a collection point for used asphalt shingle recycling. The simple and inexpensive modification, while irreconcilable with traditional preservation principles, actually increased the property's immediate utility and economic viability, and by so doing ensured that the buildings—albeit greatly modified—would continue to exist. This fairly dramatic alteration to the appearance of these historical buildings were sure to be noticed by passing motorists, as the site's *situation* was the third critical criterion considered in its selection for continued use. As the main thoroughfare between population centers to the south and prime vacation properties to the north, Rockwood Concepts is seen by thousands of potential customers a day. Furthermore, as this highway is also the largest and most direct route along the spine of the Keweenaw Peninsula, the site is exceptionally well positioned to accept bulk deliveries of heavy materials and arrange for their redistribution.

Figure 3. Rockwood Concepts, Mohawk, Mich. (Photo by John Arnold)

The owner cultivates an abiding interest in the history of the property and is eager to share his knowledge of it. However, very much like the contractor involved with the renovation of The Powerhouse, he is very wary of the costs and perceived restrictions associated with formal historic preservation, reporting that while he had been approached in the past, to him, “it just didn't seem viable,” in context of the information presented, which to the owner sounded very much like, “well, you’ve got to come up with $200,000 first, and we *might* reimburse you.” He continued by describing his reluctance to conform, in that he would “have to bring it up to such standards, and you can’t deviate.”[41] He greatly values the independence and the programmatic and physical flexibility afforded by these redundant industrial buildings and can see no benefit in their inscription to the National Register. Instead, it is this pragmatic approach toward the malleability of the *space* defined by the shells of these postindustrial buildings that holds the key to their ongoing usability and, therefore, their vernacular preservation.

The Copper Country Curling Club

First formed in 1993, the Copper Country Curling Club spent its first two decades renting rink space at several regional venues. However, each place ultimately fell short of consistently providing the high quality ice conditions that curling requires. In 2005, the club made the decision to secure a facility that could meet its specific needs. The programmatic requirements were quite clear: any potential building must be large enough to house the regulation curling sheet, as well as a small gathering area for players. Spatially, these are not difficult demands to meet; the real challenge is that the playing surface is, of course, ice. As a small club of sixty members, operating expenses needed to be minimized, and constructing and operating a refrigeration plant was simply not financially viable. A cost-effective alternative is the use of "natural ice," if it can be maintained in appropriate and relatively constant interior environmental conditions. A redundant industrial building provided an elegant solution, the *construction* of which was critical to its selection for use.

Like most of the area's industrial buildings, the Calumet & Hecla drill shop is constructed of so-called "poor rock," a local name for the material extracted from the earth but discarded before milling due to its low copper content (fig. 4). This waste rock is composed of extremely robust basalt and is an excellent building stone for projects that don't require finely dressed masonry. As its name suggests, the c.1885 building was originally used for repairing mining drills, but it was vacated in 1968. Like so many disused industrial buildings in the area, it soon found use as a storage facility. Unlike others, however, this building was owned by a local municipality. When its tenant ceased making payments for its use, the stored contents were auctioned off and the building made available to new uses.

Figure 4. The Copper Country Curling Club, Calumet, Mich. (Photo by John Arnold)

The two-foot-thick stone walls of the drill shop were never insulated, and the building was not well sealed against air exchange. Instead, workers relied on cheap and abundant steam heat, amply provided by the nearby industrial boilers powering the mining operations. When the mines shut down, so did the heat. The Curling Club inherited the use of a cold, rough building, replete with unfinished dark stone and underlain by an earthen floor. Many potential users would balk at the prospect of resurrecting such an edifice, but for the purposes of the Curling Club, it was extremely well suited by virtue of its *construction*. The dirt floor readily received a level concrete topping slab, poured up to and meeting the poor rock walls. In December, this slab is flooded with two inches of water and dammed against exfiltration by packed snow thresholds; in May, the ice thaws and seeps harmlessly away. The club is proud to host what is surely the most environmentally friendly regulation ice, thanks to "a very unique interior that isn't matched anywhere" in the United States; "those walls, being solid rock, have fantastic thermal mass," and virtually ensure four months of continuous use, as the thermal mass of the stone buffers against several days' of above-freezing temperatures.[42] This clever reuse leverages the robust and raw *construction* of this redundant industrial building to wonderful advantage.

Unsurprisingly, there are numerous other underutilized industrial buildings in the Copper Country that are constructed of similar materials and in a similar fashion; again, it was the additional considerations of *space* and *situation* that led to the selection of the drill shop from the available candidates. The plan dimensions of the building are nearly perfect to house two adjacent regulation sheets of ice, with space remaining for a seating area for spectators, an enclosed clubhouse, locker rooms, and a storage area (fig. 5).

Despite its active and ongoing employment, the use of this historical industrial building as a natural ice rink for curling does not meet (or even approach) the high standards of formal historic preservation. Indeed, it is largely due to the lack of competing pressures from formal historic preservation interests that the Curling Club has been able to embrace and inhabit the drill shop. This practical perspective on a historical building's capacity to accommodate change over time in the living postindustrial landscape is the heart of vernacular preservation.

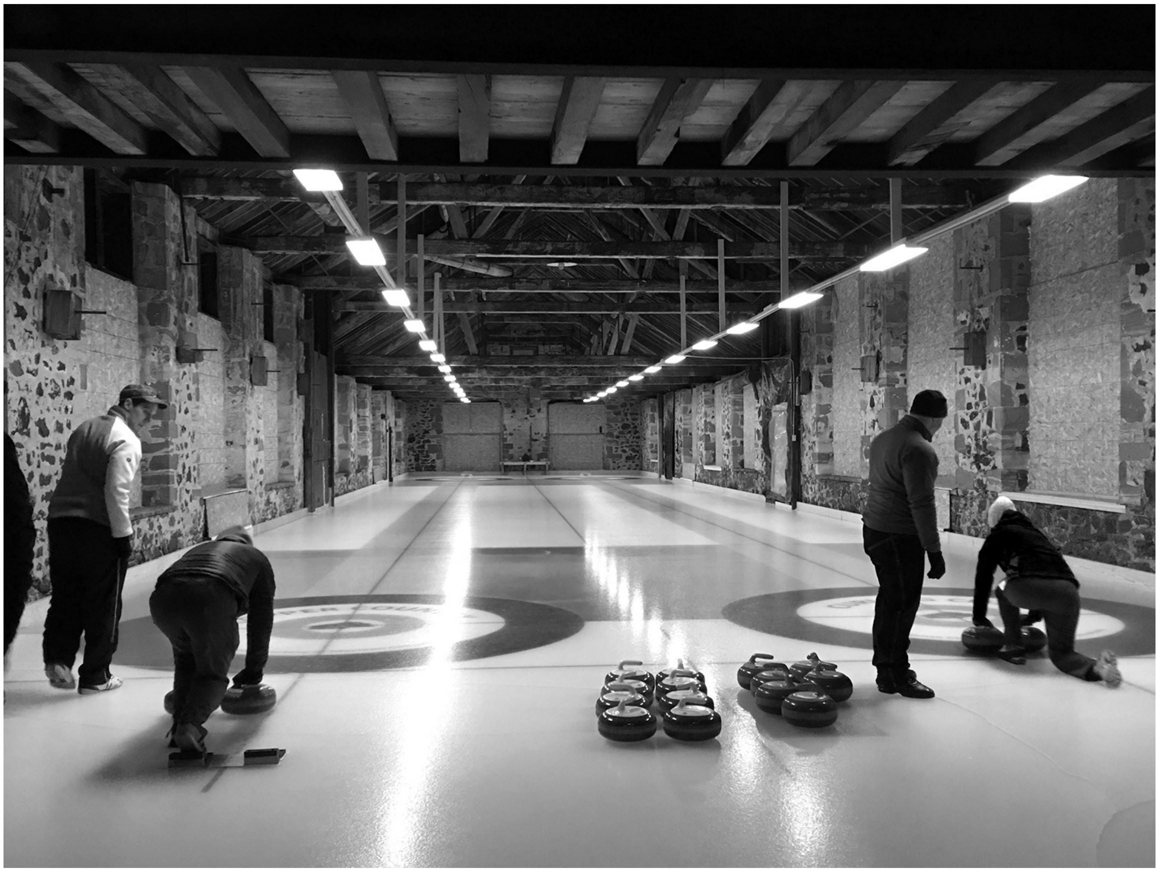

Figure 5. Vernacular preservation in action. (Photo by Emily Rogers, published with permission)

Conclusion

The innumerable remnants of the human-built world are found virtually everywhere; historical cultural landscapes are extensive and pervasive in the United States, even in many areas that may initially appear to be untouched wildernesses. Only a tiny minority of the countless resources occupying these landscapes—including those formally classified as buildings, structures, objects, sites, and districts—are listed on the National Register. The overwhelming majority of these places have not been altered or maintained with even a remote awareness of the Secretary of the Interior's Standards, nor even formally recognized at a state or local level.

The established system of formal historic preservation deserves abundant credit for its demonstrated capacity to change over time. However, despite its expanding purview, academic and professional conversations regarding the nature of preservation itself remain generally limited by the parameters established by the criteria and standards initiated by, and legislated in, the NHPA of 1966 and its subsequent iterations. The field of historic preservation is understandably reluctant to investigate—without significant external influence—the innumerable properties considered to be ineligible for listing vis-à-vis the national standards of significance and integrity; there are likely many thousands of properties that may in fact be historically consequential but fail to meet the established thresholds that would garner them notice by heritage professionals. Such places, including the numerous otherwise overlooked components of postindustrial landscapes, are as a matter of course bypassed entirely by the existing formal system.

Individual insignificance and lost integrity are not relevant considerations when seeking to understand deeply interwoven industrial landscape systems. Indeed, the physical evolution of many obsolete industrial resources is a testament to the value these buildings and sites have as active components of the living postindustrial landscape. The legibility and meaning of the postindustrial landscape relies on the continued presence of even scattered remains to bear witness to the astonishing scale and extent of the historical industrial enterprises that profoundly shaped and continue to influence today's postindustrial landscape.

Unburdened by adherence to the regulations of formal historic preservation, including those that guide rehabilitation for adaptive use, innumerable historical sites persist as components of continually evolving cultural landscapes across the United States. Many of the myriad sites of the postindustrial landscape that initially served specific industrial functions have been repurposed in a manner inconsistent with the role for which they were originally designed. These places are neither ruins nor abandoned, and while these places in no way follow official standards for material conservation, they are hardly neglected. In an important sense, significant preservation is taking place, albeit in an unofficial fashion that is not currently professionally recognized. These crucial contributors to the cultural landscape have been subjected to the pragmatic, local, and informal processes of vernacular preservation and deserve the closest consideration of heritage professionals, not only in their own right, but as candidate recipients of meaningful material support and protections.

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CREATING A LONGITUDINAL, DATA-DRIVEN 3D MODEL OF CHANGE OVER TIME IN A POSTINDUSTRIAL LANDSCAPE USING GIS AND CITYENGINE

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ABSTRACT

Purpose:

The purpose of this paper is to create a longitudinal data-driven model of change over time in a postindustrial landscape, using the "Copper Country" of Michigan's Upper Peninsula as a case study. The models resulting from this project will support the heritage management and public education goals of the contemporary communities and Keweenaw National Historical Park that administer this nationally significant mining region through accessible, engaging, and interpretable digital heritage.

Design/Methodology/Approach:

The paper applies Esri's CityEngine procedural modeling software to an existing historical big dataset. The Copper Country Historical Spatial Data Infrastructure, previously created by the HESA lab, contains over 120,000 spatiotemporally-specific building footprints and other built environment variables. This project constructed a pair of 3D digital landscapes comparing the built environments of 1917 and 1949, reflecting the formal and functional evolution of several of the most important copper mining, milling, and smelting districts of Michigan's Keweenaw Peninsula.

Findings:

This research discovered that CityEngine, while intended for rapid 3D modeling of the contemporary urban landscape, was sufficiently robust and flexible to be applied to modeling serial historic industrial landscapes. While this novel application required some additional coding and finish work, by harnessing this software to existing big datasets,

48,000 individual buildings were rapidly visualized using several key variables.

Originality/Value:

This paper presents a new and useful application of an existing 3D modeling software, helping to further illuminate and inform the management and conservation of the rich heritage of this still-evolving postindustrial landscape.

Key Words: Industrial Heritage, CityEngine, Historical GIS, Historical Spatial Data Infrastructure, 3D Modeling

INTRODUCTION

This study integrates a high-resolution, big-data, historical geographic information system (HGIS) (known herein as the Copper Country Historical Spatial Data Infrastructure, CC-HSDI) with procedural modeling to recreate a pair of temporally-comparative 3D models of an entire industrial landscape.

Background

The use of 3D digital modeling technologies today is widespread in the design and analysis of new buildings (Eleftheriadis *et al*., 2017; Szalapai, 2014) and in the study of contemporary cities for land use planning and management (Billen *et al*., 2014; Miller and Tolle, 2016), and a variety of archaeological undertakings (Biljecki *et al*., 2015; Meyer *et al*., 2016). Furthermore, the role of computer graphics extends beyond the needs of designers, planners, and managers, and has secured a role in the study of cultural heritage (Arnold, 2014). In particular, the use of Building Information Modeling (BIM) has expanded greatly from its original application as a design tool, and is being increasingly employed in the study of historical buildings as Heritage Building Information Modeling, or HBIM, (Arayici *et al*., 2017), often employing data procured by laser scanning and photogrammetry (Dore and Murphy, 2015) to recreate digital emulations of historic buildings. Others have built on this approach, semantically enriching an HBIM by coupling it to a database of non-architectural attributes including landscape information by using GIS both broadly (Yang *et al*., 2016) and to investigate in depth a single building at a particular point in time (Baik *et al*., 2015). In particular, such

3D digital models have a particular utility to an evolutionary study of historic buildings (Casu and Pisu, 2015).

Only recently have the significant time and computational challenges of modeling at the city scale been somewhat diminished with technological progress in data capture and processing power (Dell'Unto *et al*., 2016). A further advancement has been the advent of commercially available procedural modeling software. Unlike traditional 3D digital modeling in which individual building volumes must be independently modeled, procedural modeling, a computing technique for creating models from sets of rules, can quickly and easily be deployed for the creation of entire cityscapes through the application of rule-based code to simple, pre-existing, geometries. Procedural modeling has been used for digitally replicating a single historical building (Danielová *et al*., 2016), for modeling a historical city center in its current state (Almeida *et al*., 2016), for the virtual reconstruction of several buildings (Rodrigues *et al*., 2014) or a portion of a city at a selected time period in the past (Dylla *et al*., 2008), and as a tool for research and data recording in an active archaeological site (Piccoli, 2015). Procedural modeling has additionally been demonstrated to be valuable for testing alternative architectural reconstructions of past built environments, both in examining various interpretations of a single time period (Saldaña and Johanson, 2013) and directly modeling different time periods in a discrete location (Botica *et al*., 2015). However, the power of procedural modeling has yet to be applied to a wide, near-complete representation of a built environment, over time.

This paper unites the limited existing scholarship in procedural modeling with recent developments in the field of historical GIS that has demonstrated the ability to model historical environments using longitudinally-linked high-resolution ‘big data’ spatiotemporal datasets (Lafreniere and Gilliland, 2015) and ‘deep mapping’ (Ridge *et al*., 2013) to recreate historically representative 3D models for an entire industrial landscape over time.

METHODOLOGY

Case Study

The case study selected for this project is a 130-square-mile area that encompasses the present-day Michigan communities of Houghton, Hancock, Calumet, Laurium, Lake Linden, Hubbell, and Dollar Bay, in addition to numerous small, scattered settlements. Located in the Keweenaw Peninsula, these towns and villages of the historic “Copper Country” comprise a nationally-recognized example of the profound and lasting effects of industrialization in a semi-rural landscape. Industrialized copper mining of the region began in the 1840s, and ultimately ceased in the late 1960s. While the area’s population today is only 40% of its peak (38,784 in 2010 and 95,254 in 1910), the living postindustrial landscape continues to evolve.

Keweenaw National Historical Park (KNHP), established in 1994, is charged with the preservation and interpretation of resources that relate the area’s nationally significant story of copper. In addition to the work of KNHP, the Copper Country benefits from the attention of numerous local heritage sites, historical societies, and governing agencies, including Isle Royale National Park. Further, there is an astonishing depth and richness of historical documentary evidence in the care of two archival collections, the KNHP

Archives and Michigan Technological University Archives. Despite the widespread involvement of an engaged and caring populace, much of the remaining historic fabric is highly endangered due to ongoing depopulation and divestment, and very limited local financial capacity to stabilize or reverse the trend of deindustrialization, blight, and property loss. Furthermore, the area has neither an indexed historical building inventory nor a consolidated repository of historical building data, both of which would serve local and regional heritage conservation and interpretation efforts. This study attempts to digitally preserve a record of the industrial past as well as serve as a tool for the use of local preservation professionals in managing today's cultural landscape.

Copper Country Historical Spatial Data Infrastructure

We began construction of the Copper Country Historical Spatial Data Infrastructure (CC-HSDI) in 2015. The CC-HSDI applies the concepts of the contemporary SDI to the creation of a big historical dataset for use in an HGIS. Using an approach pioneered by Lafreniere and Gilliland in 2015, the CC-HSDI consists of a series of high-resolution, longitudinally-linked datasets that tracks changes in the social, economic, and built environments of Michigan's Copper Country, from the middle of the nineteenth century to the recent past.

The HSDI incorporates a range of data on the historical built environment, and is designed to ultimately serve as the basis for a publicly-accessible clearinghouse of the vast but currently physically dispersed stores of Copper Country historical spatial data. The CC-HSDI presently contains more than 120,000 digitized building footprints, traced to over 1300 scanned and georeferenced historical maps of the region. This paper employs a select subset of this HSDI, working with a total of over 48,000 buildings across two years (1917 and 1949) for this longitudinal comparison.

CityEngine

Our HSDI datasets are exceptionally well suited to test the capacity of Esri's 3D modeling software *CityEngine* to create high-resolution, data-driven, temporally and spatially accurate models of the industrial mining communities in Michigan's Copper Country. This software is available as a free trial, and both single-use and educational site licenses can be purchased. We used a PC with a quad-core processor running at a clock speed of 4.4Ghz and a dedicated graphics processing unit to run CityEngine, which exceeds recommended requirements but resulted in extremely rapid modeling—averaging around a 20-second refresh time for a fully-rendered landscape of 48,000 structures. Numerous characteristics for each building are recorded in the CC-HSDI, including spatial location, building footprints, civic addressing information, number of stories, exterior finish, and building use.

CityEngine is designed to quickly transform 2D GIS data into 3D models by employing procedural modeling to rapidly generate buildings and landscape features through the implementation of coded rulesets to predefined geometries. The software features dedicated tools for the import of polygonal tax lot or building GIS shapefiles created in ArcMap which are often made available by the local municipalities. We utilize linear roads and pathways from OpenStreetMap (OSM), and digital elevation models (DEMs) from the U.S. Geological Survey (USGS) to provide the needed topography for our industrial landscape model. The user interface is clear and legible, and the importation of the various datasets is straightforward, as is the application of predefined

CGA rulesets. Indeed, learning the basics of CityEngine and its overall functionality is not particularly difficult when hewing closely to Esri's own tutorials, employing associated datasets and rulesets as provided. Furthermore, making parametric changes to model primitives is easy via user-friendly selection palettes that feature drop-down menus of available settings. For our project however, few presets proved directly applicable as most presets are for modern cities rather than the historical industrial environments we aimed to model.

Data Import

Virtually every stock step outlined above required some degree of modification to meet our demands in modeling historic industrial landscapes, from the generation of the underlying terrain, to working with existing street networks, to the writing of historically accurate rulesets. This process required significant iterative learning but did result in a viable product that met our requirements and, while challenging to this novice CGA coder, did not overtax the capacity of the (very flexible) software itself.

Although we are modeling historical data, contemporary digital data could serve the project well as a basis for the construction of our historical datasets, either through simple comparison or more directly through modification. However, the small municipalities (most with less than 1000 residents) within our semi-rural case study do not have the capacity to produce GIS-ready tax lot or building footprint shapefiles, requiring our team to build the spatial data from scratch. Procuring, scanning, georeferencing, and digitizing many hundreds of historical maps was itself a significant task.

As noted earlier, CityEngine has a specific and user-friendly interface for the importation of third-party terrain data. For this project, we outlined an area slightly larger than that required to encompass the communities selected for modeling, and downloaded and imported a texture-mapped DEM and contemporary street network of our case study site with just a few clicks. Although we are working with a postindustrial extractive landscape, due to the scale of our subject site we did not elect to modify the DEM for this project. However, because we are modeling historical data specifically, using either the provided contemporary cartography or the high-resolution orthoimagery as a texture for the terrain would invite unnecessary inaccuracy into the model. Instead, we duplicated the grayscale heightmap provided with the DEM download, posterized and colorized it in Adobe Photoshop, and applied this new texture to the DEM as a gestural topographic overlay emulating a familiar elevation color ramp.

Similarly, the street network imported from OSM is contemporary, not historical. CityEngine again provides easy-to-use tools for the direct creation, deletion, and modification of linear elements that are modeled as roadways when an appropriate CGA ruleset is applied. We did correct the imported street network to more closely approximate historical conditions. Because we built our own historically accurate feature classes for our HSDI, no further modifications to building footprint polygons were required within CityEngine. Both were imported into CityEngine and automatically fitted to the previously-imported DEM (Figure 1).

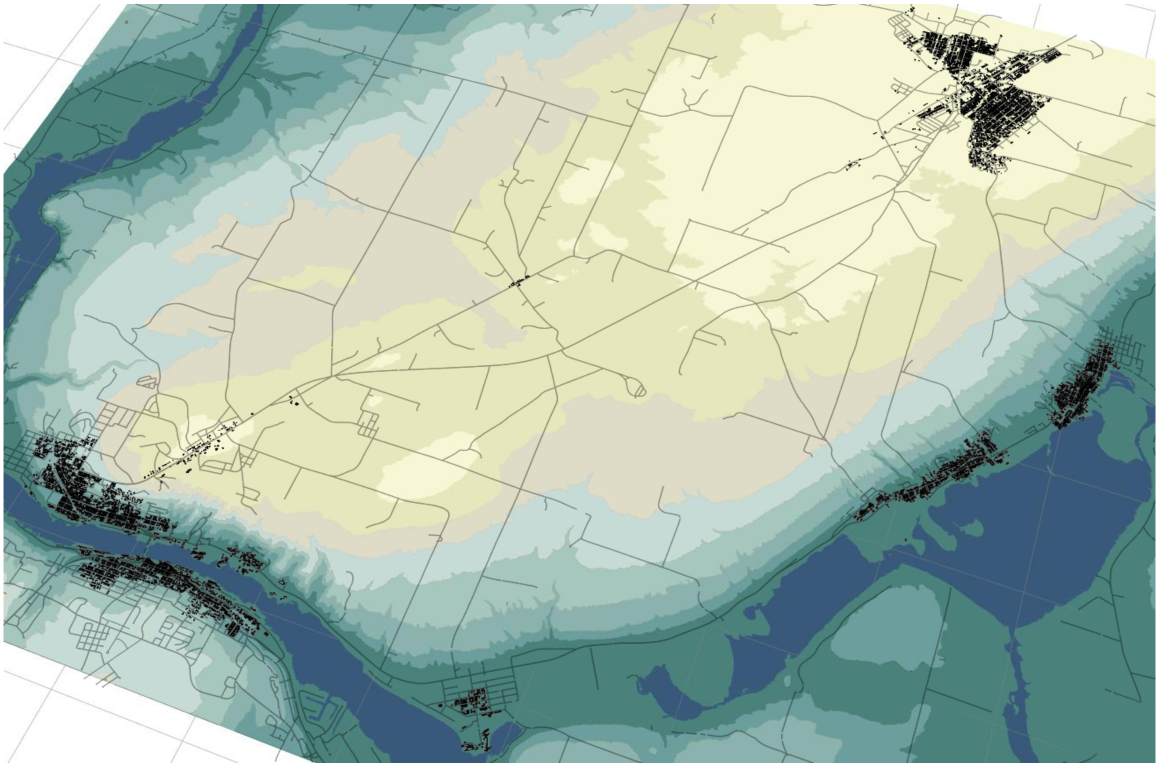

Figure 1. 24,000 imported building footprints and contemporary roadways aligned to our customized DEM for 1949.

Rulesets

The power of procedural modeling lies in its capacity to very quickly generate a large and complex 3D model from a relatively small and simple set of easily modifiable rules. For this project, we required four rulesets: one each for buildings and for roadways, for each study year (1917 and 1949). Each object (polygon or line segment, respectively) is associated through a relational database to key attributes that are called by the CGA coding for 3D expression.

While we began our research by attempting to modify existing rulesets created by others, we soon determined that writing new CGA script from scratch would result in cleaner, more legible, code and better satisfy our unique demands for a comparative virtual reproduction of the postindustrial landscape of the Copper Country at two points in time. It was our goal to write the script in a fluid manner, with the code designed to readily accommodate predicted modifications. This structuring would allow us to replicate and reuse portions of the code as similar subroutines in the same script (e.g., the code for "lower front wall" is very similar to the code for "upper rear wall"), as well as to duplicate the entire script used to generate one year (1949) for modification and application to our comparative year (1917).

To reiterate, when we created the building footprint shapefiles in ArcMap, we assigned three key variables to each polygon in the attribute table: the building's height, material, and use, as determined from the underlying historical fire insurance plans. *Height* is a value, recorded as number of stories, and may include a decimal fraction; *material* is a text string, recorded as either wood, brick, stone, iron, 'special', or a combination thereof. Building *use*, also text, is recorded as dwelling, porch, garage, store, public, or industrial. We designed our buildings ruleset in CityEngine to incorporate all three of these variables in producing the 3D model, using facade material and roof type to illustrate various typologies, and volume—derived from the building footprint and a vertical height extrusion—to indicate massing. Because the few 'iron' and 'special' buildings present were a fairly even mix of just two (industrial and public) building types, we were able to consolidate these two materials categories and narrow our scope to just 18 combinations requiring CGA scripting (Figure 2).

	wood	brick	stone	iron	special
dwelling	✔	✔	✔		
auto	✔	✔	✔		
store	✔	✔	✔		
industrial	✔	✔	✔		
public	✔	✔	✔		
porch	✔				
all types				✔	✔

Figure 2. The eighteen material-use combinations that we wrote CGA script for.

In general terms, our buildings CGA script extrudes a footprint vertically in accordance with its height attribute, decomposes the volume into faces, and subdivides the faces into stories. The CGA script then pulls an appropriate texture map from a collection we have assembled (e.g. brick, shiplap siding, and so on) in response to the facade material recorded for that polygon, and applies it to the extruded volume's walls. CityEngine can automatically model a number of familiar roof types (shed, hip, gable, etc.), and our script tops the textured volume with a roof type based on the original polygon's designated use-type. The resulting 3D digital buildings immediately communicate the values of their three key variables clearly and directly (Figure 3).

The imported Open Street Map data retains the attributes of its components; in this project, the crucial variable is the *class* of roadway assigned to each segment and node. CityEngine recognizes ten different classes by default, but for this project we limited the possibilities to just three: residential, secondary, and primary roads. After CityEngine automatically generates road and sidewalk widths based on this attribute, our roadways

CGA script—again, as directed by class—extrudes sidewalk height, decomposes the street assembly into faces, and applies appropriate texture maps to each surface.

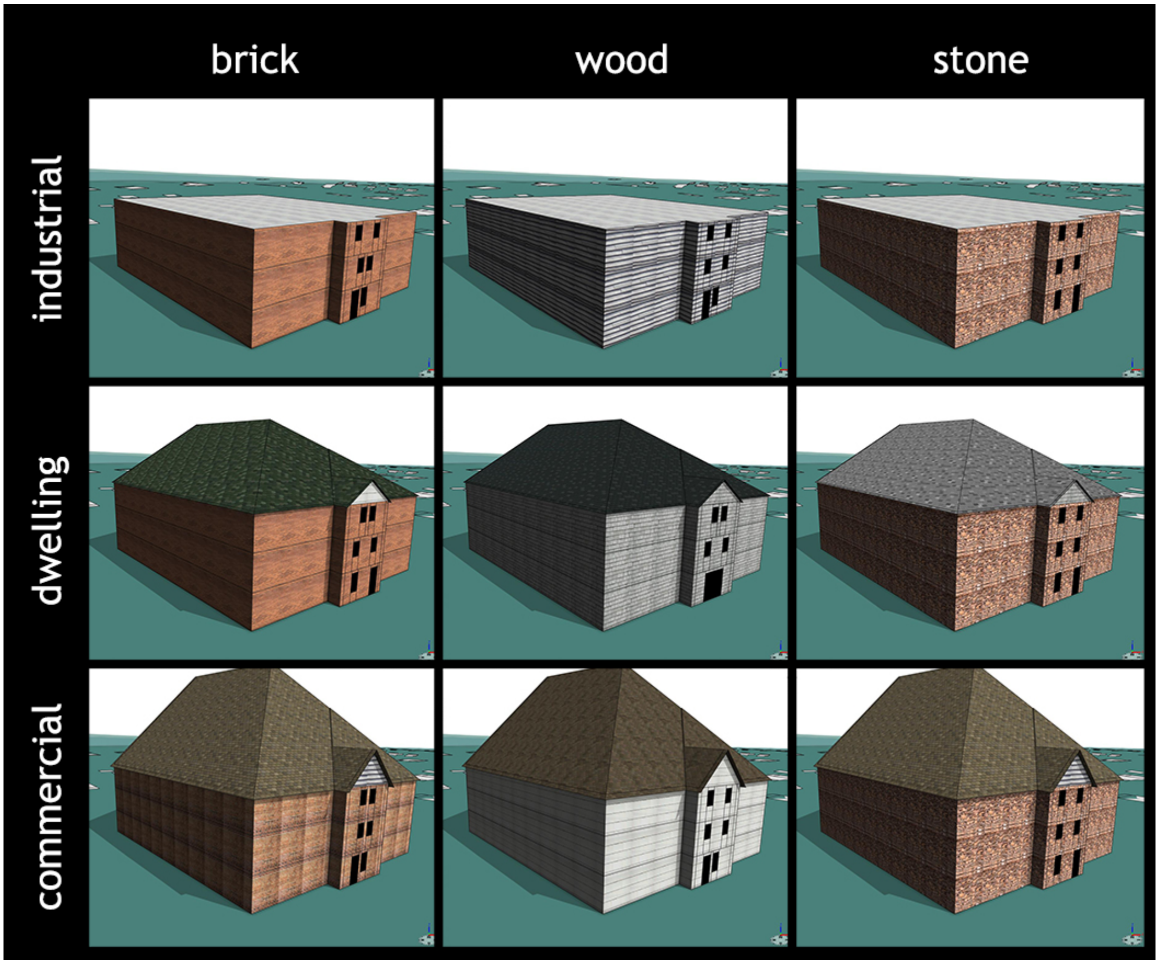

Figure 3. Nine examples of the three key variable combinations, modeled on the same building footprint.

1917	Curb Texture	Street Texture	Street Lights	Street Trees
Primary Streets	50% concrete 50% sandstone	50% concrete 40% brick 10% wood block	80% acorn style 20% early globe	10% young maple 10% young oak
Secondary Streets	70% concrete 30% sandstone	30% concrete 50% brick 20% wood block	30% acorn style	30% young maple 30% young oak
Residential Streets	10% concrete 90% no curbs	100% earth	50% acorn style	45% young maple 45% young oak 5% mature maple 5% mature oak
1949	**Curb Texture**	**Street Texture**	**Street Lights**	**Street Trees**
Primary Streets	90% concrete 10% sandstone	80% concrete 20% brick	10% acorn style 10% early globe 60% late globe 20% mast arm	10% young maple 10% young oak 10% mature maple 10% mature oak
Secondary Streets	70% concrete 30% sandstone	50% concrete 50% brick	30% acorn style 30% late globe 20% mast arm	20% young maple 20% young oak 30% mature maple 30% mature oak
Residential Streets	60% concrete 40% no curbs	45% concrete 45% asphalt 10% earth	10% acord style 40% late globe 30% mast arm	5% young maple 5% young oak 45% mature maple 45% mature oak

Figure 4. Textures and objects referenced by our 1949 roadways CGA script.

However, because these subtle differences are difficult to discern visually from a distance, we evolved our roadway modeling to an additional level by introducing object (.obj) files representing plantings and streetlights (downloaded and exported with Trimble Inc.'s SketchUp Pro modeling software) to more clearly articulate street classes. In addition to the surficial texture maps, we employed four lamp types and four planting types to describe the three different classes of roadway in our models (Figure 4).

We initially wrote both of our CGA scripts (buildings and roadways) to visualize a representative historic streetscape of the Copper Country, as it appeared in 1949. Again, we intentionally wrote our code to be easily modified to model other data years from our HSDI. This provided us the ability to copy the script wholesale, and simply make adjustments to key variables to illustrate our comparative study year, 1917. For both buildings and roadways, we drew upon different sets of surface textures (including the siding of wood buildings and paving patterns) and applied them in different proportions to ensure that we were creating a model that was a better representative of the earlier time period. For the roadways CGA, we called additional object files that were more accurate to 1917, including earlier-style street lights and young street trees; since the entire region was heavily deforested at settlement, any street trees were still small, having just been planted in the early 20th century (Figure 5).

Figure 5. The CGA scripting provides a clear and meaningful visual distinction between the 1917 and 1949 roadways.

DISCUSSION

Opportunities

Esri's CityEngine presents a highly useable interface for architects, planners, designers, and researchers to apply the power of procedural modeling to the built environment, and to quickly do so at a truly remarkable scale. For comparison purposes, creating simple 3D models of 48,000 imported building polygons using Trimble Inc.'s SketchUp, working at an average rate of 45 seconds per footprint, would take 600 hours; that's 15 weeks of full-time work at an uncomfortably relentless pace. For this proof-of-concept project, we taught ourselves the software and CGA scripting, and built the finished comparative models with a much higher historical accuracy and precision than would a simple SketchUp model in just under 200 hours. The functional and transferrable product can be applied to the other 60,000+ building polygons in our HSDI requiring only minimal additional scripting time to adjust the CGA to reflect temporal differences. Procedural modeling in general, and CityEngine in particular, provides an unparalleled opportunity to quickly and easily visualize big GIS datasets as part of a complete 3D landscape over time.

However, 200 hours is still a considerable commitment to make, and it must be noted here that this requirement would be substantially decreased were we simply creating a single, contemporary city model rather than a pair of historical models of an entire postindustrial landscape. Working with CityEngine on this historical project required the development of a moderately robust understanding of CGA scripting, as the code that was available for our training (and potential use as the basis for subsequent modification) was highly developed for present-day urban applications. However, because of CityEngine's heavy reliance on CGA scripting to produce useful and meaningful output—rather than limiting user-initiated changes to existing preset values, toolsets, and menu options, for example—we were able to adapt the software to meet most of our needs fairly readily.

The degree of customization made possible by writing our own script meant that we were able to employ data directly from our HSDI's building shapefile attribute table, completed long before we had developed an understanding of the working parameters of CityEngine. Writing our own buildings CGA script also meant that we could choose precisely how to combine these data for modeling and display; in particular, to model just 18 of the 30 possible combinations of material and use-type, and to specify graphical distinctions between lower and upper stories and between street facade and other building faces. The benefits of creating our own CGA script was similarly apparent in writing the streetscape rulesets; we selectively incorporated an existing segment of code (to randomize the location of objects) into an otherwise uncomplicated script whose simplicity allowed us to emphasize just those few variables we wished to demonstrate. The inherent flexibility of custom CGA scripting is CityEngine's strongest feature, and offers tremendous opportunities for the 3D visualization and presentation of built environment data.

Challenges

Despite CityEngine's power and adaptability, we did encounter several important challenges in modeling historical landscapes. As noted earlier, there are complexities of representing historical space that are entirely independent of CityEngine, such as procuring or producing accurate historical building footprints, street networks, textures, and objects. Yet the software itself, designed as it is for modeling contemporary urban settings, necessarily makes assumptions that advance efficient user progress towards that goal.

Rule-based modeling such as CityEngine's CGA is applied iteratively to generate successively less symmetrical forms. For example, our buildings CGA script first extrudes a 2D polygon into a 3D massing, which establishes a top side and a bottom side. Second, it divides this volume into stories, and differentiates between the ground floor and any upper floors. Third, our script recognizes the distinction between the front facade and the other faces of these stories. These three rules, applied in order, transform a directionless plane into a three-dimensionally oriented volume that may be textured as (say) a first-floor storefront with walkup apartments above. The crucial step in this triad is nearly invisible, and is the one that bedeviled us in our work: automated recognition of the front facade.

The front of an extruded volume in CityEngine is defined by the "first edge" of its generating polygon; by default, this first edge is the first segment that was originally drawn in ArcMap. Since we created our shapefiles with no forethought of this possibility, the first edges are essentially random—meaning our rendered buildings would have no coherent orientation. The first edge of each polygon can be reset manually without difficulty, but doing so would obviously be extremely time-consuming. Because this is a predictably common possibility for shapefile imports, CityEngine provides a dedicated tool that automatically reassigns the first edge as that edge closest to the nearest street (Figure 6).

While this automated command can save quite a lot of time, it is designed to work with single-polygon buildings with a primary street face—which the contemporary urban landscape largely consists of. However, in following our research design in creating the HSDI, we had drafted our historical building footprints as multiple polygons, subdividing a single building into its varied parts for the purposes of documenting substantial additions or modifications to buildings over time (i.e., the enclosure of porches or the additions of garages or workspaces). Furthermore, much of our built historical landscape is simply not oriented toward a common roadway; many industrial buildings are sited facing waterways or railroads, and the rapidly-established and densely inhabited residential areas frequently contain numerous small dwellings that are approached not by the main road but by alleyways or even footpaths.

Figure 6. Note the randomized entry façade orientation before and after executing automated alignment.

The second of these two challenges can be most directly addressed by faithfully recreating the critical elements of the historical transportation network (including railways, alleys, and pedestrian paths) before its import into CityEngine; the automated first edge reassignment would be more accurate, and the rendered volumes require less subsequent manual correction. While this solution also provides the added benefit of resulting in an even more detailed and accurate recreation of the historical industrial landscape, it does not solve the first problem—our use of multiple polygons to represent a single building. Many of the buildings in our case study site feature multiple additions, a common practice in rapidly changing localities, such as rapidly industrializing landscapes. CityEngine automatically models shed roofs with the low eave at the first edge, and gable roofs with the ridge parallel the longest axis of the root polygon (Figure 7). Again, while these assumptions may work quite well in for single-polygon building footprints in a contemporary urban setting with a strong primary axis, they result in pronounced modeling errors for clusters of polygons representing historic building elements that serve a diversity of orientations.

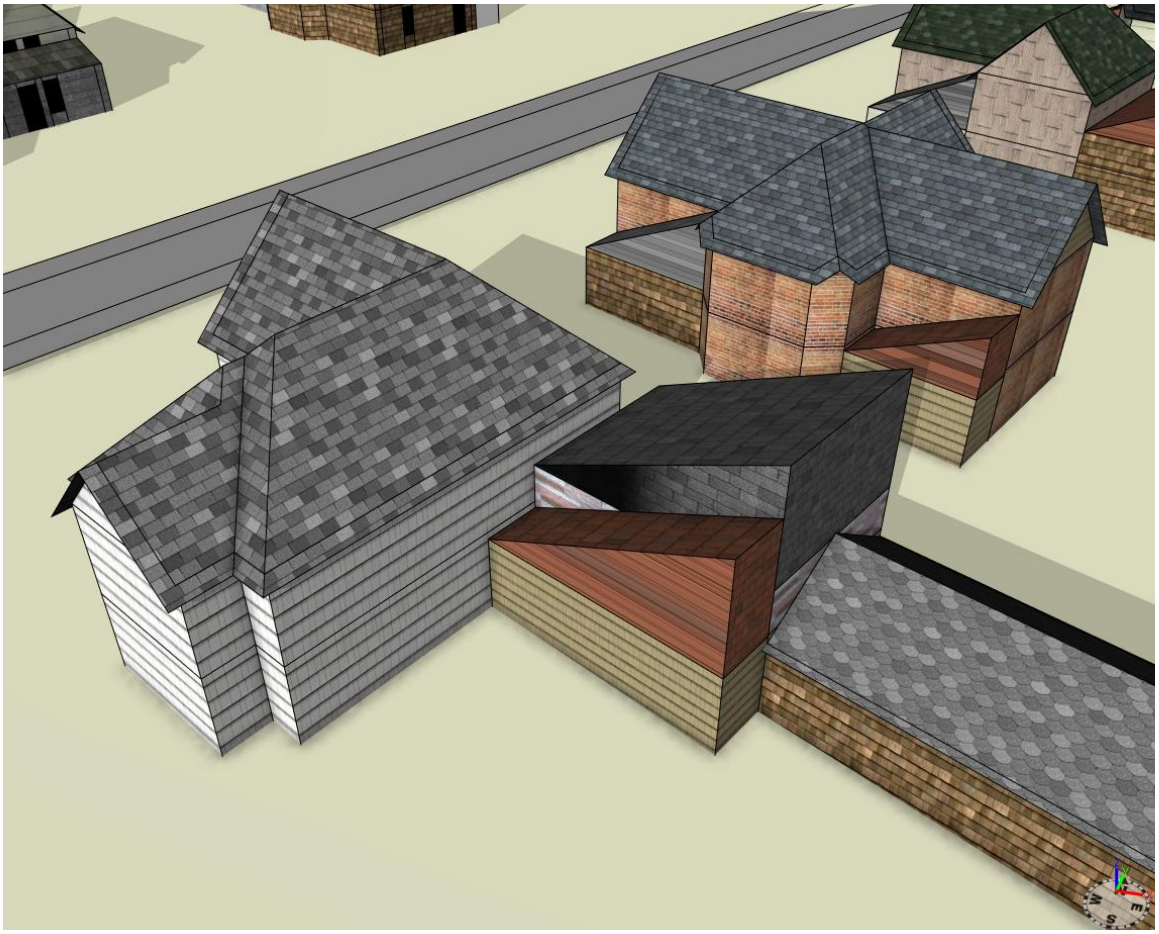

Figure 7. Automated roof development modeling errors. Stock CGA script orients sheds from the primary face as described by street proximity.

Of course, these challenges can be surmounted through fine-grained, manual modification, and doing so would not be an inappropriate part of final model cleanup of even a few hundred building footprints. However, doing so mitigates much of the efficiencies of this procedural modeling approach. CityEngine, as its name clearly suggests, preferences the automated modeling of the urban landscape, not the rural industrial landscape; it relies heavily, and stubbornly, on the presence of road networks to determine building orientation. Finally, like all evolving digital technologies, the ongoing usability of the code written today depends on maintenance and adjustment for it to continue to be useful tomorrow. Despite these challenges, the power of CityEngine and the flexibility of CGA scripting offers new and unparalleled opportunities for heritage management and interpretation.

CityEngine for Heritage Management

Harnessing CityEngine to HESA Lab's CC-HSDI datasets holds great promise for advancing the public education and preservation goals of the many local heritage sites, historical societies, municipalities, and governing agencies engaged in the conservation and interpretation of the Keweenaw Peninsula's historic industrial landscape. Historically, this industrial landscape was woven together in a vast network of functionally interconnected buildings, structures, and sites. Much of the earliest activity on the historic industrial landscape been superseded by more recent construction, and much else has fallen to decay or been deliberately removed; today's landscape retains evidence of those systems largely as little more than isolated nodes and broken paths. Still, even remnants of this history confer meaning to the contemporary postindustrial landscape, if their message can be heard.

While the sparse historic remains scattered across today's descendant landscape may be understandably overlooked by heritage professionals seeking to relate a compact and coherent story, they are nevertheless significant. These vernacularly preserved remnants were once vital components of now largely vanished landscape-scale industrial mechanisms for the extraction, refinement, and movement of copper; furthermore, many of these vestiges have compelling stories to tell about their material and functional evolution over time (Arnold and Lafreniere, 2017). Importantly, neither component significance nor evolutionary significance are necessarily visible at the scale of any single building or at any single time period. To understand the historical meaning of those remnants populating today's postindustrial landscape, it is crucial to situate them within their greater spatiotemporal context. The perspective provided by a longitudinal landscape study such as this provides a useful and much-needed viewpoint for historians, planners, and preservationists to evaluate and prioritize historical properties for the targeted application of always-limited human and financial resources for historic preservation.

Whatever significance or value may be ascribed to the remnants of the Copper Country's industrial past, it is simply not feasible—and perhaps not even desirable—to physically preserve everything. It is, however, possible to do so digitally, in a manner of speaking. That is, while digital recreations of historical buildings or past environments cannot replace the original material evidence, they can supplement and expand upon that which remains, both over space and across time. Working at a landscape scale means that we exchange a focus on individual character and fine-grained architectural detail for an aggregate perspective and a broad and collective overview of spatial relationships that integrate the built world and the natural. Working on a timeline spanning a century means that we trade daily narratives of work and rest for generational transformations of space and place. CityEngine provides the opportunity to do both well, to the ultimate benefit of the people and heritage of Michigan's Copper Country.

Future Applications and Next Steps

All additives to the CityEngine model can be refined independently: the terrain, the roadways, the buildings shapefile and its associated attribute table, and of course the rulesets themselves. This structural autonomy means that the overall model can be evolved iteratively, as more or better data is developed or discovered. In a real and important sense, the 3D model is nothing more than data visualization—this visible output is the product of its constituents, and a better model can be produced by the improvement any of its factors.

Conceptually, it is critical to consider CityEngine not as recreating a replica of the historic industrial landscape, but rather producing a useful abstraction: in essence, a 3D, data-rich map. In the present study, we are visualizing historical map data of our subject area at two points in time, displayed as moderately realistic texture-mapped volumes that express our selected attributes. CityEngine's CGA scripting can easily be written to produce output at various levels of detail (LODs) depending on the purpose, audience, and the way that users will access the model.

In the future, there will be opportunities to use CityEngine to graphically represent aspects of our ever-growing HSDI that are not actually manifest in the built world, while retaining the spatial relationships established therein. For example, using employment data records and the decennial census linked to building footprints, we will be able to visualize non-architectural social attributes in a three-dimensional landscape, similar to how cartographers use proportional symbology in 2D maps. Imagine that a building's height represents the level of income or wealth of the homeowner, while the envelope texture could indicate ethnicity, and the roof color the housing tenure status (rent vs.

own). This technique was suggested by Lafreniere and Gilliland (2015) to model the social environment of a nineteenth century journey to work. Furthermore, the software holds promise for spatiotemporal data visualization of even more abstract paradata, which could act as a kind of primitive or introductory version of the "Complex Object" as detailed by Bonnett *et al*. (2016). The whole of the Copper Country's population for which we have employment data might be displayed, across a century of continuous and sometimes dramatic social change.

Currently, there are a number of refinements that can be made to our current models. Our terrain, while a fair approximation of the historical landscape, is not truly accurate to either the 1917 or the 1949 landscape. The waterways in particular were demonstrably altered by the addition of millions of cubic meters of mine waste over the decades, and the DEM will be adjusted to demonstrate this. Similarly, our texture map for the terrain graphically illustrates elevation change, but the color fields do not tightly correspond to numerically meaningful contour lines; we will soon create a more accurate and useful cartographic overlay for our terrain model.

Furthermore, as we continue to grow our HSDI and incorporate new information from additional sources, we will extend and rework the CGA scripting to take advantage of the increasing abundance of our available datasets. For example, while we can currently model with confidence the location and basic massing of various tracts of worker housing, the assigned roof types are merely approximate. However, once we ingest mining company housing data into the HSDI, we will likely learn the actual roof types, original finish siding, and paint colors used, and edit our script to increase the visual accuracy of our model. This iterative refinement of the model can be continued indefinitely, bounded only by available data and time.

Conclusions

We will continue to model our high-resolution spatiotemporal datasets as they evolve over time. Historical GIS generally, and our HSDI specifically, offers an unparalleled opportunity to consolidate historical information spatially, and CityEngine provides a currently underutilized capacity to visualize these big historical datasets. Landscape visualization at the scales we are exploring—both spatial and temporal—can benefit not only academics and researchers, but to the public as well, presenting high quality historical geographical interpretive and educational opportunities.

The historic industrial landscape of Michigan's Keweenaw Peninsula has been studied extensively (Gohman, 2013; Hoagland, 2010; Lankton, 2010; Martin, 1999; Quivik, 2007; Scarlett, 2014) and much of it is the fortunate ward of numerous local heritage sites, historical societies, and administrative entities working to protect and share its rich history (Liesch 2014; See, 2013). Many of these studies and those in other, similarly dynamic historic landscapes would benefit from the addition of 3D data visualizations; the robust and flexible CGA code developed here is modifiable and applicable to a diversity of historic landscapes. Much of what remains of the industrial past in the Copper Country is only coherent at the landscape scale, and is only significant when understood as evolutionary phases of a great historical narrative.

It should be emphasized that CityEngine, as a sophisticated and highly customizable software package, requires dedicated and focused commitment to master. It requires a high level of computer literacy and experience with basic programming to implement as demonstrated in this paper, and the licensing fees are not inconsequential. However, given its power and versatility, it is well worth these costs, especially for planning organizations responsible for heritage landscapes, districts, or any site where the focus is expanded beyond a single resource. When working at these large scales, fostering a holistic understanding of a historical resource's temporospatial context can assist in the often-difficult processes of evaluating the National Register qualities of significance and integrity of remnant buildings, structures, and sites, and how to best allocate always-limited human and capital resources.

The broad spatiotemporal overview provided by this longitudinal landscape study offers an additional evaluative tool for heritage professionals, including historians, planners, and preservationists to study the changing industrial landscape and assist in informed, prioritized decision-making. Understanding the industrial vestiges as remnants of once-vast and vital industrial networks—of materials, of people, of energy, and of waste—will further illuminate the meaning and importance of that which remains. Authorship of National Register nominations for a variety of features in the contemporary postindustrial landscape would be directly served by these 3D data visualizations, both in terms of demonstrating the association of a property with significant historical events, as well as investigating and communicating its integrity of setting. The exploration and interpretation of these important places is strengthened through the use of CityEngine and 3D spatiotemporal data visualization, and will benefit both the people and places of the historic industrial landscape that has evolved into today's Copper Country well into the future.

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HISTORICAL GIS IN INDUSTRIAL HERITAGE LANDSCAPE MANAGEMENT AND INTERPRETATION

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ABSTRACT

In this paper, we demonstrate the value of using a big-data, longitudinally-linked Historical GIS, the Copper Country Historical Spatial Data Infrastructure (CC-HSDI). The CC-HSDI is an important regional infrastructure used in the management and, in its public engagement format, interpretation of a significant postindustrial landscape overseen by Keweenaw National Historical Park. Due to their expansive spatial interconnectivity and evolutionary nature, industrial heritage landscapes are often incomprehensible from the perspective of any single location at any given point in time. Active public heritage interpretation strategies that emphasize the historic spatial and temporal contexts are central to cultivating deep and broad understandings. We have found that these important contexts can be communicated more clearly and to a wide audience using digitized historical maps and linked datasets. This paper presents a series of case studies to illustrate its use in heritage management and interpretation.

Keywords

Historical GIS, Industrial Heritage, Industrial Landscape, Heritage Management, Heritage Interpretation, Historical Spatial Data Infrastructure

Introduction

While historians may intuitively understand the value of cultural landscapes in general, and even postindustrial landscapes in particular, their interpretation and management pose unique challenges. Unlike the traditional subjects of architectural historians and historic preservationists, cultural landscapes are, by their very nature, astonishingly inclusive (Longstreth 2008, 2). Geographer Carl Sauer first, and very broadly, defined cultural landscapes in 1925 as those places "fashioned from a natural landscape by a culture group" wherein "culture is the agent, the natural area is the medium, and the cultural landscape the result" (1925, 46). This rather uncomplicated statement has evolved over the past near-century, and today we view the nature of cultural landscape not as simply the fixed product of human inscription on nature's *tabula rasa* but rather as the malleable and socially-constructed intersection of humans and nature. Consider the now-familiar distinction made between space and place wherein impersonal, undifferentiated space becomes social place through our experiences (Tuan 1977). And yet place is more than that, as Cresswell explores in his book dedicated to this subject. At once both "familiar" and because of that, "slippery," *place* further expands to, and includes, the crucial contemporary importance of virtual place (2014). While cultural landscapes themselves are accessible and can be immersive, they are particularly difficult to manage and interpret, especially when they are spatially discontinuous or when a temporally-rich view adds important perspectives on how landscape change impacts contemporary issues such as environmental legacies of industry, social segregation, or post-industrial economic decline.

Still greater challenges accompany those cultural landscapes forged by industrial processes. In addition to familiar population pressures such as redevelopment and gentrification, postindustrial sites face unique threats (Sadler and Lafreniere 2017). Preservation opponents cite the scale, size, appearance, and health risks associated with keeping even remnants of postindustrial sites in place; compounding the challenge, postindustrial landscapes are very often abandoned, hazardous, and even toxic; even though these places may be important historically, they are not widely appreciated for their heritage value (Storm 2014; Baeten, Langston, and Lafreniere 2016, 2017). Furthermore, these are truly enormous landscapes, often retaining only scattered remnants, unevenly distributed across many square miles, under multiple ownerships. Here, our case studies all draw from properties associated with Keweenaw National Historical Park (KNHP), a nationally-recognized example of a successful, community-driven effort to honor and protect our industrial heritage through the creation of a federally-recognized, protected postindustrial landscape (See 2013). Passing enabling legislation, however difficult, is at least a discrete task; management and interpretation are on-going enterprises. These challenges are not unique to KNHP, but shared across the breadth of protected industrial sites, from the long-established and successful model of Lowell National Historical Park (1978) to the recently created Pullman National Monument (2015).

Bearing on all of these places are two closely allied perspectives: subjective, place-based valuation and objective, systems-based thinking. Both are useful and even needed, and there is an intriguing tension created by this dichotomy that is made manifest by preservation efforts; the very notion of "preserving" a living, changing landscape is a more challenging concept than the traditional, concrete conservation modalities that may be applied to any single heritage building (Arnold and Lafreniere 2017; Alanen and Melnick 2000; King 2013). This second perspective in particular, in seeking an intellectual understanding of the evolution of the landscape through a close study of its historical systems, benefits from the development of an external system for studying, collating, and representing the functional attributes of the postindustrial landscape. It is crucial to integrate such an understanding spatially and temporally in terms of its own internal systems, and also to situate it within a greater sociocultural context.

GIS for Heritage Management & Heritage Interpretation

Given the multiple barriers to their appreciation and understanding, it may indeed be that the greatest impediments to postindustrial landscape preservation are not technical at all, but perceptual. The clear communication of a postindustrial landscape's historic spatiotemporal context is key to fostering a recognition of its value. Practically, of course, it is not possible to preserve what amounts to thousands of individual industrial remnants scattered across hundreds of square miles, representing a century or more of technological and social change. Using a historical GIS, however, it is possible for heritage professionals to document, enrich, and classify these historical remains, and for public historians to use these data in interpretation, education, and engagement.

The overarching importance of spatial data to archeologists made them among the earliest adopters of emerging GIS technologies. The first, and most obvious, use for GIS within archeology was in the simple inventory work of location marking and map making. These capabilities, for visualization and in the management of cultural resources, have traditionally comprised the majority of archeological GIS work, while the more sophisticated capabilities of GIS in analysis have been underemployed. One early archaeological project that did tap its analytical capacity praised its ability to simultaneously consider numerous factors in an analysis (in this example, multiple influences on human settlement patterns), but lamented the lack of both the temporal dimension and a third spatial dimension; archeologists are as interested in change over time as much as change over space, extending to and including three-dimensional locations of discovered artifacts and their context (Ebert 2004).

Nearly a decade later, the use of 2D GIS in archeological spatial analysis and predictive modeling has become commonplace, and fast and cheap 3D data capture and representation has been realized (Arnold and Lafreniere 2017). As earlier, however, much of the capability is focused on creating visualization models (including virtual reality), rather than on data analysis. While these representations can certainly help with holistic comprehension of collected data, little of it is truly analytic. Most needed, however, is the ability to assign a temporal component to whatever data is collected and represented in the GIS: a true, 4D GIS (De Roo, Bourgeois, and De Maeyer 2013).

A less academic, more publicly-engaged future for archeological GIS extends the current trajectory of 3D visualization towards a fully-immersive experience—one featuring computer simulations and recreations of past environments, and one that invites public participation in representing multiple narratives of a shared past (Richardson 2014) In the past 20 years, GIS has become a tool of central importance in historical archaeology, both in the analysis and comparison of complex datasets, in addition to its earlier roles in archaeological inventory, geospatial database management, and cartography (González-Tennant 2016).

The management of heritage properties follows this model in many respects. The critical first step underpinning any heritage management undertaking is compiling an inventory of subject properties. While many traditional and time-tested survey methodologies persist, the simple address catalog and printed map has largely been supplanted by GIS-based inventory systems (Husseini and Bali 2015; Shah 2015). There are numerous advantages to using GIS as the basis for heritage management, including the consolidation of a diversity of geographically referenced information into a single, readily shareable database, and the capacity to engage spatial data across a range of scales, incorporating regional context in the assessment and interpretation of individual heritage sites or buildings (Boz et al. 2014; He et al. 2015).

Moving beyond simple inventory, the role of geospatially-enabled information systems in mapping has found wide acceptance in heritage management activities across a breadth of subject typologies and topographies. At one end of this spectrum are highly localized and inwardly-focused studies that track heritage data geographically. A sampling of this type of application includes a study of the influence of the location of Civil War commemorative markers on the creation of social memory, a visualization of the impact of traffic noise on heritage tourism along a popular pedestrian route in Macao, and tracking the work of a citizen-scientist program monitoring changes to Scottish coastal heritage (Hanna and Hodder 2015; Sheng and Tang 2015; Dawson 2016).

At the other end of the spectrum of projects that use GIS to bring a spatial data perspective to heritage concerns are regional-scale comparative landscape analyses, where historic sites are considered in conjunction with potential planning conflicts at a scale larger than individual buildings. This kind of study uses heritage geodatasets as a value-rich component of the topography against which possible planning solutions are set. Clear examples of this use of GIS includes the siting of large-scale energy production facilities within heritage landscapes, including wind farms in Greece, solar farms in Spain, and a combination wind-and-solar farm in England (Latinopoulos and Kechagia 2015; Sánchez-Lozano et al. 2013; Watson and Hudson 2015). The expansive range of examples, ranging from individual investigation to landscape planning is suggestive, and in many ways representative, of the diversity of project types that harness the spatial data capabilities of GIS towards heritage management goals.

A still more sophisticated approach to heritage management uses GIS to better understand future risk, mitigate damage, and prioritize preservation efforts. By ingesting multiple spatially overlapping geodatasets into a GIS, heritage managers are able to evaluate weighted parameters impacting heritage preservation interventions. Combining regional heritage geodatabases with specific risk assessment maps for location-specific endangerment factors assists in the allocation of always-limited human and financial resources to be targeted to specific properties, prioritized by heritage value and assessed degree of endangerment. A few of the many examples of heritage risks include flooding in Taiwan, foundation-damaging persistent soils moisture in Seville, a multiplicity of anthropogenic hazards on Cyprus, and a range of building-specific pathologies in Greece and Russia (Wang 2015; Ortiz et al. 2016; Lysandrou et al. 2015; Chatzigrigoriou 2016; Sheina and Babenko 2014). The management of these examples benefits from an increased ability to understand the differential risks to heritage properties at the landscape scale at some time in the future. However, none of the projects enumerated above seeks to document the complex narrative that wrought heritage from history. In this paper, we present several case studies that build on and extend these examples, expanding the place of GIS in heritage management beyond examinations of the present to embrace the past and seek to understand patterns as they change over time.

In our heritage interpretation component, we follow the lead of influential early work by Summerby-Murray (2001) in which he created an integrated GIS that fulfills multiple useful roles in teaching historical geography, wrestling with the messy reality of historical documentary evidence, while addressing real-world, local heritage management needs. We are also following related work by Mostern and Gainor (2013) in which students were taught to use Google Earth to create digital historical atlases; select approaches and standards explored in the classroom were then available to subsequent development by professional spatial historians. In both of these projects, an engaged public works closely with academic geographers in building highly developed, map-based datasets that articulate with existing heritage goals. Our projects presented here similarly work towards community-engaged heritage projects using a publicly accessible spatial data infrastructure.

Copper Country Historical Spatial Data Infrastructure

The Copper Country Historical Spatial Data Infrastructure (CC-HSDI) follows and expands upon a demonstrated methodology in extending a contemporary SDI longitudinally (Lafreniere and Gilland 2015; Ridge, Lafreniere, and Nesbit 2013). The CC-HSDI is comprised of longitudinally-linked geospatial datasets of Michigan's historical "Copper Country," a mining region near Lake Superior that operated for about 100 years starting in the 1850s. The CC-HSDI incorporates information on the social, economic, and built environments that changed dramatically over a century of industrialization, stasis, and decline. This HSDI has been designed to be able to readily ingest a wealth of historical environmental information, and is the digital backbone of our public engagement enterprise known as the Keweenaw Time Traveler, presented below in greater detail.

This continually-growing geodataset consolidates the cartographic holdings of two area archives, georeferences nearly 900 maps, and over 130,000 building footprints have been digitized and linked through time from 1880-1950. In turn, these building footprints have been linked to census and city directory information, and are currently being linked to other big datasets including company employee records and regional school records. Moving forward, the CC-HSDI will incorporate historic roads, railways, public utilities and other key components of the area infrastructure.

Case Studies in HSDIs for Heritage Management

It was the fantastically rich deposits of native copper in Michigan's historic Keweenaw Peninsula that drove its intensive industrialization for over a century. Beginning in the 1840s, the mining, milling, and smelting operations in the "Copper Country" dramatically shaped the area's land and waterways, and left a deep and lasting legacy written in the landscape. Our university, Michigan Tech, was founded in Houghton in 1885 as a school for training mining engineers. Today's postindustrial landscape enjoys wide public interest and support. Its stewardship is led by two units of Keweenaw National Historical Park (KNHP) and its 21 allied Heritage Sites, in addition to numerous regional and local historical societies, administrative authorities, and civic groups. In our case studies, we work with this diversity of interest groups.

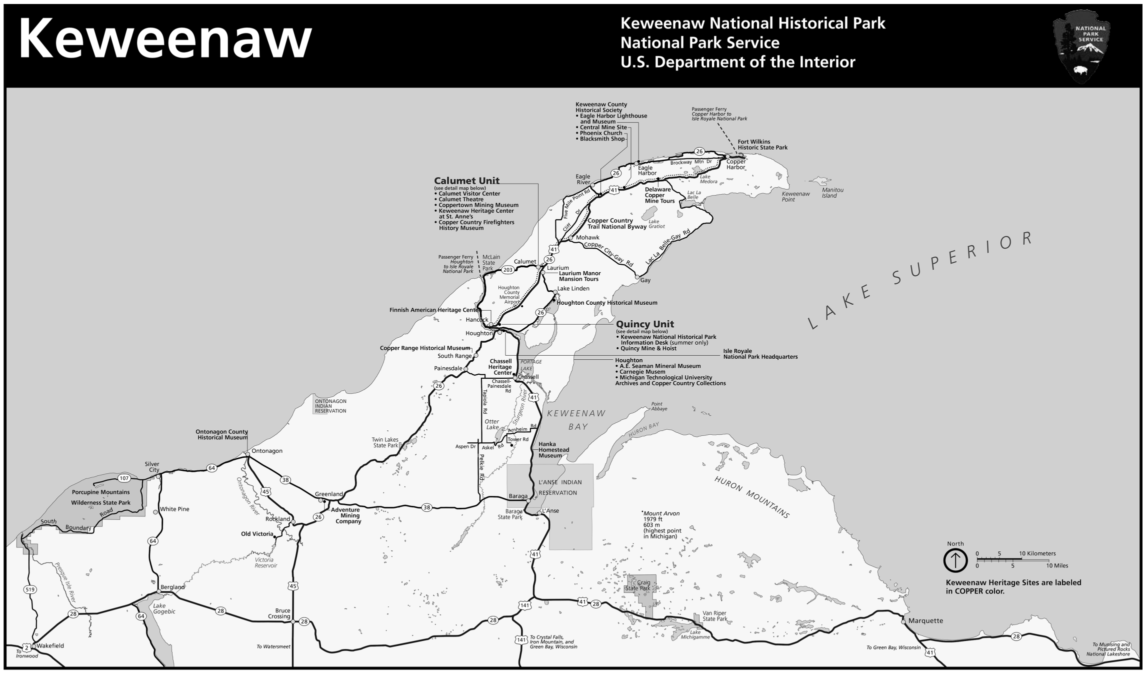

Figure 1. Map of Keweenaw Heritage Sites. (NPS / Keweenaw National Historical Park)

The first case study, a schematic rehabilitation plan for the historic Quincy Smelting Works in the community of Ripley, was completed while the CC-HSDI was still in its planning phases, and so wasn't able to benefit from the multiple efficiencies that our public-interface HSDI would have provided. The second case study, a conceptual preservation plan for Calumet's historic industrial corridor, was embarked upon as the CC-HSDI was in its early development. Our third and final case study presented here was the construction of an online, GIS-based, building inventory for the Village of Calumet Civic and Commercial Historic District—a contemporary spatial data infrastructure (SDI) that ties directly into, and draws from, our Historic SDI. More than a simple proof-of-concept, this building inventory system is actively used by the Historic District Commission (HDC) to quickly research historical data on included properties and to monitor and track their contemporary preservation and rehabilitation work.

Efficient: Quincy Smelting Works

Of the six historic copper smelters that Keweenaw mining once supported, only the remnants of the 1898 Quincy Smelting Works remain—representing, in fact, the only remaining copper smelter in the whole of the Lake Superior mining region to survive relatively intact. As part of the vast Quincy Mining Company holdings, the smelter was documented by the Historic American Engineering Record (HAER) program in 1978, and nominated to the National Register of Historic Places as part of the Quincy Mining Company Historic District (a National Historic Landmark) in 1989, and is within the bounds of the Quincy Unit of KNHP created in 1992. The smelter closed in 1971, and nearly three decades passed before Franklin Township took ownership of the property (in 1999) with modest aims of building stabilization and site preservation. Most recently, the smelter was acquired in 2012 by the KNHP's Advisory Commission, which is authorized to purchase property that advances the goals of the Park's enabling act.

The perennial question faced by virtually all obsolete industrial properties is, essentially: now what? Finding and funding meaningful contemporary uses for these often long-neglected and decaying historical places of work is a continual preservation challenge. Following years of false starts, a recent proposed solution for the Quincy Smelter looked very promising: adaptively reuse the site to host the headquarters and ferry dock of Isle Royale National Park (ISRO), currently housed in less-than-proud accommodations on the opposite shore of the narrow waterway separating Ripley from Houghton. As early conversations of the move evolved into a planning phase, the need arose for visualization aids of the early schematic designs for the site and buildings.

The Advisory Commission sought multiple illustrative views of the site, in both the proposed design and its current state for comparison. As is often the case when developing a proposal of any sort, the methodology was driven by a close consideration of time and budget; there was precious little of either to be spent conducting background research. The solution here was to create a simple digital model using Trimble SketchUp Pro 3D modeling software, relying on contemporary aerial photos of the site to locate buildings and referencing HAER drawings to approximate their massing. While this degree of detail is largely sufficient for an isolated schematic design, developing a meaningful and informed management plan—one that incorporates, and even invites, the possibility of adaptive reuse of such a heritage site—demands much more.

While this project did result in a useful set of planning documents, its production would have benefitted from the availability of and integration with the CC-HSDI. Addressing the preservation challenges of any postindustrial site in a historically sensitive fashion requires a studied understanding of its spatiotemporal context and evolution. Generally speaking, this is a tall order. Sourcing and consolidating relevant historical documents such as maps, site plans, blueprints, photographs, company registers and ledgers, and perhaps even personal recollections and narratives, is itself a significant research project. This is precisely the role that the Copper Country HSDI can fill as a contributor to the management of historic sites.

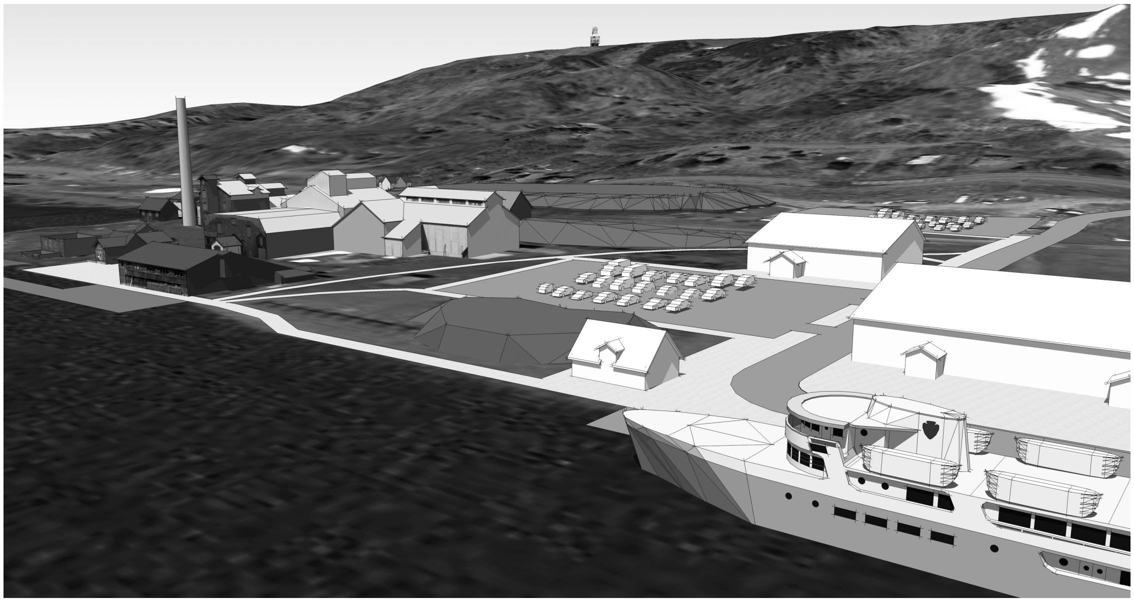

Figure 2. A proposed reuse of the Quincy Smelter site. (John Arnold)

This project in particular would have benefitted not only from ready access to historical information to aid in the virtual reconstruction of the site, but also to assist in making decisions regarding the relative historical value of alternate possible locations for the ISRO headquarters and dock across the reach of the site.

By serving as a clearinghouse for a diversity of collected historical data, the CC-HSDI makes geographically referenced, historical resources freely available to researchers and the general public alike, thereby greatly increasing the efficiency of a range of crucial variables on undertakings such as this—efficiency of time, energy, research, and, of course, funding. The CC-HSDI provides heritage professionals and others responsible for making informed decisions regarding the future of fallow industrial sites, such as the Quincy Smelter, with a wealth of information about their past: the evolution of the physical plant in terms of material and work flows, product distribution, and waste disposal can all be studied spatially, resulting in an informed spatiotemporal understanding to advise management in the present and planning for its future.

Robust: Industrial Calumet Preservation Plan

As is true for the Quincy Smelter site, the Village of Calumet has been repeatedly recognized for its national significance; National Register listings include the Calumet and Hecla Industrial District (1974), the Calumet Downtown Historic District (1974), the Calumet Historic District (a National Historic Landmark District, 1989), in addition to its central role in the second of the two discrete units of KNHP (1992). While the Quincy Unit focuses primarily on the preservation and interpretation of processes and technologies of copper extraction and processing, the Calumet Unit emphasizes the manifold social, ethnic, and commercial facets of the former mining community that is today's Calumet Village. However, the Village also retains ample evidence of its industrial origins, with disused structures and buildings of the once-powerful Calumet & Hecla Mining Company, strung along the aptly-named Mine Street corridor. While obvious landscape features, these historic remains receive only minimal centralized management.

Virtually all property within the Park's two units is privately owned. Within the 750-acre boundary of the Calumet Unit, the National Park Service owns fewer than ten acres. The remnant sites and structures along Mine Street fall under both public and private ownership, and most are in various stages of disrepair and endangerment. The mixed holding of these properties only compounds the complexity of their preservation; many of the most visible and potentially viable subjects for rehabilitation are owned neither by the Village nor the Park, but by Calumet Township, a governing agency whose resources are already stretched thin by a severely dwindling tax base coupled to an ever-growing backlog of maintenance and repair work.

This is the context within which the KNHP Advisory Commission determined that the Calumet Unit would benefit from a preservation plan to explore the capacity of these heritage resources to serve new functions, while contributing to the full story of the Calumet Unit. As the Park's enabling legislation mandates that the general management plan "shall interpret the technological and social history of the area, and the industrial complexes of the Calumet and Hecla, and Quincy Mining Companies, with equal emphasis," the study described here directly helped to satisfy an important Park mandate.

The preservation plan was assembled in three, closely interrelated, stages of research and planning. Phase I (Identification & Assessment) established baseline property data, while Phase II (Ideas & Precedents) drew on examples from across the United States to produce a collection of creative solutions for the adaptive reuse of underutilized industrial buildings. Phase III (Preservation Planning) integrated the results of these two sections, applying both the categorical and specific case studies, identified in Phase II, as potential reuse solutions to the prioritized resources of industrial Calumet. Since this preservation plan was initiated just as the CC-HSDI project was beginning, the workflows of the Calumet-based steps of this project (Phases I and III) were used to test prototype functionality of this novel HSDI, specifically, the ease of comparing building metadata for a single location, over time. Doing so provided valuable feedback for its early development, in addition to directly benefitting the advancement of the preservation plan itself.

Figure 3. Calumet's Mine Street corridor, facing north. (John Arnold)

Given the overtly spatiotemporal nature of this preservation plan, we made extensive use of ESRI's ArcMap GIS software in recording the locations and relationships of all existing and former industrial buildings and corridors in the Calumet area. In Phase I, archival research was aided by informal interviews with area experts; this work, coupled with a series of investigative site surveys, produced an initial inventory of existing candidate properties. Next, we needed to determine which of the many identified properties to focus on in the remainder of the study; to do this, we created evaluative rubrics to selectively include those historic remnants that met a number of key criteria Phase II data were not recorded geospatially. In Phase III, we referenced contemporary aerial photos and high-resolution historical maps to generate a series of digital overlays to illustrate the spatial relationships of the remaining industrial buildings in their historical context. These strategies prioritized both spatial and temporal understanding that would help advise our development of conceptual plans and guide specific recommendations for the reuse of individual buildings.

All of the crucial steps of these bookending phases—mapping the locations of the preliminary pool of candidate properties, generating and applying our evaluative rubrics, and developing the resulting schematic site plan and proposed reuse strategies—were ideally suited to test the capacity and possibilities of an easily-accessible, data-rich, historical GIS for heritage management. This project served as a pilot for what would later become the Copper Country HSDI, but was far more limited in spatiotemporal ambition and scope, encompassing but one small area and only two time periods, compared to the 160+ square miles and nearly 100-year coverage now available within the CC-HSDI.

While the tangible product of this project was a set of deliverables useful to the Advisory Commission in their planning for future preservation activities, the intangible—and fully transferable—outcome was the development of a key understanding of the value of creating a *robust* geospatial database. By robust, we mean an HGIS that it not limited to performing a single function, but rather has a wide range of capabilities, both potential and realized. Any future work for similar projects will be able to draw upon the longitudinally-linked big datasets of the CC-HSDI for planning and management of a diversity of regional heritage sites. Substantial time and effort was required up-front to construct the digital maps and associated databases for this project, and future projects will benefit greatly from the established structure provided by the CC-HSDI.

Flexible: Village of Calumet Civic and Commercial Historic District

Nested within the several nationally-recognized districts already noted lies the Village of Calumet Civic and Commercial Historic District. The five-member, all volunteer, Calumet Village Historic District Commission (HDC) administers the Historic District ordinance, reviews and approves proposed work within the District, and, "maintains a system for the survey and inventory of historic and architectural resources in coordination with the survey work of the State". However, similar to most organizations in severely depopulated postindustrial communities, the HDC's mandate to survey and inventory the historic and architectural resources of the community has been severely hampered by the lack of human, technical, and especially financial resources.

The Historic District encompasses roughly twenty blocks and includes around 170 properties; nearly two decades of carefully filed written records attest to the work done in the District since its inception, and a large printed map outlining its borders graces the Village office wall. What has been missing, however, was an ability to link the written records to the map. That is, while there was a tremendous written record of these historical resources, they were difficult to use and largely inaccessible except for those with the institutional knowledge of building change over time. Conventionally, locating property records required non-cartographic data, such as address, owner, or building name. As with the previous two examples, this case study employs historical spatial data in its pursuit of heritage management solutions in the present. A number of discussions with the Commission helped us to understand not only what the HDC needed to digitally consolidate and organize their data, but, as importantly, what the Commissioners wanted.

At root, the HDC needed a simple way to coordinate the numerous variables it uses in District management and planning. We were provided a long list of attributes of interest to the Commission, ranging from simple identification (tax ID, owner, address, plat-block- lot) to material qualities (year built, construction type, building height and use), to property status (contributing or not, occupied or vacant, availability for rent/lease/sale) and—in many ways most crucially—an assessment of building condition (stable, neglected, vulnerable, or endangered). While even this range of information could be managed with a relatively simple spreadsheet, the HDC was interested in developing some kind of map-based digital tool that would link these data directly to its buildings. Clearly, a contemporary GIS would admirably meet the administrative needs of the HDC as a buildings inventory.

However, what the Commissioners were actually envisioning was something more than a simple GIS. Unsurprisingly, the ability to record and research change over time was high on their list of desired attributes; what the HDC really wanted was something similar to the Historical GIS that we had produced for the industrial Calumet project—but amplified. Timescales range from organizing monthly work permits for District buildings or visually tracking year-over-year changes to street facades, to the decadal townscape shifts that are reflected in historic maps. By simply extending the requisite contemporary GIS longitudinally, we were able to create a much more useful, and more powerful, HGIS. Crucially for this project, however, we were able to take it one step beyond; construction of our HSDI was already underway, and this project presented a perfect opportunity to tap into its burgeoning dataset for purposes of heritage management.

Working under our supervision and as part of our initiatives in community-engaged teaching with HGIS, students in a GIS for Social Sciences class adopted the project. Students using ArcGIS's Collector App ground-truthed an existing but outdated dataset for the Historic District, and mapped building footprints, captured contemporary photographs, recorded street addresses, façade elements, devised and implemented a condition ranking, determined occupancy, and documented the number of stories for each structure in the district. Over the course of the term, and advised by a series of meetings with local officials including the Chair of the HDC, the Village Comptroller, and the Historical Architect for KNHP, the students and faculty built a web-based GIS of the Historic District, which they launched at term's end as a public beta version at monthly HDC meeting. In the following months, improvements were made to the WebApp's interface in response to user feedback, and today the it is integrated with the CC-HSDI—a data linkage that vastly expands its spatiotemporal dataset and its utility.

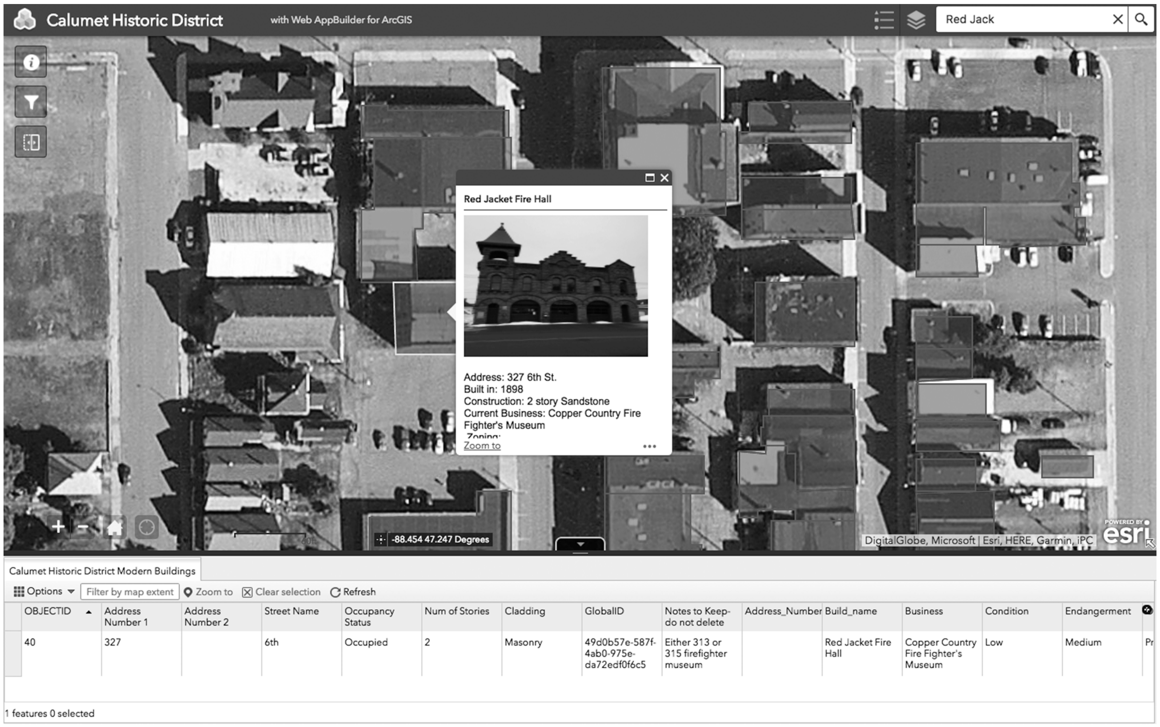

Figure 4. Calumet Historic District Commission (HDC) Web App interface. (Don Lafreniere)

In its first year of service, the HDC Buildings Inventory WebApp has been used extensively by the HDC for management and planning, just as anticipated. While this demonstrated utility has certainly been rewarding to us, it was also entirely expected; as is so often the case with the adoption of novel technologies, it is the unexpected uses that are most illuminating. Soon after its launch, the Village of Calumet, in conjunction with its Main Street program and the local economic development authority, utilized the WebApp as a promotion tool to encourage and provide information to redevelopment projects and used the GIS to provide critical baseline data for major grant proposals to the State of Michigan for funds to stabilize and remediate several key heritage properties.

Tying the WebApp to Copper Country HSDI greatly enhanced its flexibility—its broad utility was quickly recognized beyond the HDC. Users can explore the spatial context beyond the District to over a century of material evolution thanks to recent new longitudinally linked datasets loaded in the CC-HSDI. As data access is controlled by user group, the WebApp is useful both for internal HDC uses, such as management and planning of properties in the District, as well as public sharing and engagement in an accessible and engaging way. This connectivity additionally provides the capacity to spatiotemporally link historical photographs and narratives relating to the Historic District and beyond, vastly enriching the geodataset and opening the HDC Building Inventory WebApp to still more new and unanticipated uses. As the now fully-operational CC-HSDI continues to grow, it also grows in its utility, as its inherent flexibility allows its adoption by a diverse set of interested parties, and application to a range of heritage management, planning, and development goals.

HDSIs for Heritage Interpretation: The Keweenaw Time Traveler

The public face of the CC-HSDI is known as the Keweenaw Time Traveler (KeTT). The Time Traveler is an online interface that empowers the public to engage with the spatio-temporally linked datasets in a map-based, user-friendly way. 'Citizen Historians' are encouraged to classify building materials, identify building use, and transcribe hand written text about the inner workings of substantial industrial and commercial sites, and map notations about other elements of the built environment. Another interface with KeTT affords users an opportunity to link or geotag their own collections of historic photos, newspaper articles, and personal papers to temporally-specific recreations of past environments represented on historical maps. Contributors are encouraged to tell stories or memories about the people, places, and environments by placing points directly atop historical maps, making immediate contributions to the spatiotemporally-linked big datasets. Search tools also allow users to find past populations, places, and businesses, while the map interface moves and loads digital, historically accurate, representations of the environs where people lived, worked, and went to school. In this paper, we demonstrate the utility of big-data historical GIS for both heritage management and public history, through a series of case studies illustrating the creation and deployment of the CC-HSDI and Keweenaw Time Traveler that demonstrate applications in heritage planning, administration, community-engagement, interpretation, and education in the postindustrial landscape.

Heritage interpretation facilitates and fosters the public support necessary for the perpetuation of heritage management—people want to keep what they care about. However frequently cited, Freeman Tilden's oft-repeated quotation (1957) bears inclusion here: "Through interpretation, understanding; through understanding, appreciation; through appreciation, protection." Indeed, without interpretation, there would likely be little to manage at all; a key role of interpretation is to help make meaningful connections to heritage places. In recent years, rapid technological development has produced a variety of digital tools to help make these connections in new and potentially effective ways.

In a wide-ranging and insightful investigation, Laura King seeks to address the actualization of this potential directly by asking if heritage professionals are actually taking advantage of those emerging technologies that have been much discussed in the academic literature. The satisfying conclusion of her paper is that, yes, "a wide range of new and increasingly refined digital tools are being mobilized in order to increase the value of digital, virtual, and remote offerings for public audiences," outpacing the literature, no less; as it is, "the cutting edge of exploring digital possibilities in heritage is now firmly in the realm of practice" (King, Stark, and Cooke 2016). This is encouraging, as preservation action is realized most directly at the interface between heritage professionals (both public and private) and user groups; furthermore, if the available literature on the subject offers any sort of index, heritage professionals are moving ahead.

While still generally unfamiliar to the general public, augmented reality (AR) is an emerging technology that holds great promise in heritage interpretation. Using mobile phones and tablets, AR "enables an enriched perspective of the real or physical world by superimposing virtual digital objects in real time" (Casella and Coelho 2013). Although its utility may be limited by unfamiliarity among novice users (Chung et al. 2015), AR can be an enjoyable way to connect with and learn about heritage places (Chang et al. 2015). Because this innovative technology is not limited to providing interpretation for what is present, it lends itself well to visualizations of elements that may be hidden or invisible, such as historic infrastructure in a cityscape (Marques et al. 2017), and to the enhanced engagement with historical artifacts through experientially immersive VR "re-animation" museum tours (Pedersen et al. 2017). While engaging, AR is typically done at the building or street scale because of the intense resources needed to create historically accurate models and the computing power and bandwidth to provide large AR projects to a wide audience. Additionally, AR does not currently have the capacity to harness longitudinal and spatially-linked datasets the way an HSDI can, though important work is underway to overcome these limitations (Bonnett et al. 2016).

Less exotic spatial technologies currently used in heritage interpretation include harnessing the time-tested data tracking and cartographic functions of GIS to produce targeted (yet static) heritage tourism maps (Leanza et al. 2016) and the creation of "digital guides," or GPS-enabled smartphone apps that deliver relevant, and even customized, place-based content to visitors (Bohlin and Brandt 2014). Our project, the Keweenaw Time Traveler, dwells at the intersection of these two functions, combining the familiar appearance of the printed map with spatially-tethered and longitudinally-linked historical data through a web-based interface. Presenting historical data in a familiar and comfortable format presents few challenges to even a novice user, but is particularly exciting in its lack of restrictions—users are not limited to exploring their own, present location at any particular point in time; rather, anyone, anywhere, can investigate any of the places that have been georeferenced and digitized, at any time in history for which data has been collected and incorporated into the Time Traveler. This time- and space-independent approach to historical exploration is well suited for interpreting the postindustrial landscape.

Recall that the preservation of the postindustrial landscape faces numerous challenges: landscapes in general are living, changing entities; cultural landscapes are abundantly inclusive; historical industrial landscapes often feature hazardous, toxic, and dilapidated remnants, scattered across vast swaths of terrain and nearly devoid of contextual meaning. Much of what remains has been materially and functionally repurposed—or vernacularly preserved—in ways that may be incompatible with traditional, or formal, preservation (Arnold and Lafreniere 2017). Constructing strong and convincing arguments for significance and integrity of those scraps littering today's postindustrial landscape is a necessary precursor their National Register-listing and eventual formal preservation. Unlike many subjects of historic preservation, their meaning is necessarily spatiotemporally contextual (Arnold and Lafreniere 2017). In other words, the challenges of preserving an industrial landscape are preceded by parallel challenges in interpretation. Conveying the historical importance of these isolated vestiges of once-integrated industrial systems calls for tools equal to the task—in essence, demonstrating a place's importance by recreating its evolution. In our case studies, Keweenaw National Historical Park faces additional, specific challenges. The extent of the formal spatial boundaries of the park are not uniformly understood, even by locals (Liesch 2014). As a partnership park, the goals of the multiple public and private owners of contributing "Heritage Sites" are not necessarily aligned (Liesch 2011), and it is a persistent challenge for these sites to present themselves as parts of a coherent interpretive plan (See 2013). As we will show with the following examples, the Keweenaw Time Traveler is as well-suited to helping with the complex tasks of interpretation as it is for the preservation of the numerous disjointed elements that together constitute its postindustrial landscape.

Interpreting Historical Spatial Data with the Keweenaw Time Traveler

Thanks to its easily navigable, web-based interface, users can access the Keweenaw Time Traveler from virtually anywhere, at any time. As a key component of the project's rollout and development, however, HESA Lab hosted a series of sponsored engagement events at numerous area historical sites and cultural events to solicit user input and provide guided, interpretive, exploration opportunities to the public. At these events, the interested user accesses the Time Traveler with a custom touch-screen kiosk presenting high-resolution historical maps and data-rich linked location markers in the cultural landscape. Under the direction of an interpretive guide (one of the 12 or so members of the HESA Lab present at any given event), these engagement events offer an unparalleled opportunity to explore our historical big datasets via a large format, user-friendly series of georeferenced historical maps.

The benefits of georeferenced cartographic collections have been previously realized by several successful online historical map projects, including David Rumsey's Map Collection, the Old Maps Online project, and the efforts of The British Library and the New York Public Library.[1] Fleet and Pridal (2012) write that georeferencing allows visualization in a more useful and flexible way, in that historical georeferenced maps can be viewed alongside or overlaid upon other maps, enabling comparison of maps over time, research into landscape change, urban morphology, and the development of places; furthermore, when linked to other historical sources, as we are doing, it allows for spatial and textual searches of linked data and metadata across the time periods represented. In other words, the Keweenaw Time Traveler organizes even non-cartographic archival information geospatially into an interactive, searchable digital historical atlas. The wealth of data, coupled to an intuitive, familiar, and engaging interface has generated considerable interest as a research tool for those interested in studying the region's heritage.

[1] See: www.davidrumsey.com; www.oldmapsonline.org; www.bl.uk/maps/georeferencingmap.html; maps.nypl.org/warper/

Figure 6. Keweenaw Time Traveler kiosk in use at Quincy Mine open house. (Sarah Scarlett)

Since the public launch of the Time Traveler in June 2017, our lab has presented numerous public engagement events across the region, including several hosted by KNHP partner Heritage Sites, namely the Carnegie Museum of the Keweenaw, the Quincy Mine Hoist Association, and the Keweenaw County Historical Society. The support of these established and respected local heritage organizations is not only a welcome endorsement of our work, but the events were well-attended by their existing memberships—an ideal demographic for trying out the research capabilities of the Time Traveler.

At our engagement events, visitors are invited to access our “research” WebApp via one of our lab’s custom mobile kiosks, each housing a 27” HD multitouch display all-in-one PC. As with the "field" App, users are presented with the opportunity to explore any of the historic maps we have scanned, georeferenced, and digitized. Unlike the "field" App, however, users have access to all of the 11 towns and villages in our geodatabase, across each of six decades from just before 1890 up to 1950. Through the highly-responsive touch screen interface, participants are able to rapidly pan across maps, zoom scales, and even cross-fade two maps to compare years for a selected location. A series of innovative "search" boxes allow users to search the historical documentation by people, address, and even user-contributed stories, and to be immediately positioned at the corresponding geotagged location. For users familiar with the region and its history, the depth of coherently organized information available, accessed through a familiar and intuitive interface, provides an unparalleled spatiotemporal navigation tool that can help answer longstanding questions of personal interest.

As a point of methodologically, it is important to note that we have not yet conducted systematic testing or formal user surveys on the impacts of the Keweenaw Time Traveler's public engagement components. The narrative descriptions of questions, perceptions, and experiences that follow are based on our preliminary and subjective impressions of users' experiences with the Time Traveler. Nearly everyone begins their explorations by finding their own home on the most recent historic map: what did my house used to look like? my street? my neighborhood? As so much of the housing stock in our area is historic, most investigators are able to retrace the material evolution of their homes—watching recent additions disappear and long-since demolished outbuildings reappear, and today's detached garages replace alley stables, as they search back through time. As the historical geographic context comes into sharper focus, visitor's questions expand, and spatially driven and grounded memories and recollections become explorable, such as the ability to retrace their work commute, to remember the character of past neighborhoods, or to find lost public spaces. They also recall landscape features for which the environment itself provides no immediate answers: why is there an old stone warehouse in the woods? Is this pond natural or man-made? Did this old railway trail end up somewhere important?

Users of the Time Traveler kiosks are able to pursue the answers to these kinds of historical questions for themselves, with minimal oversight and guidance, learning more along the way than if they had been simply delivered an answer. Rather like thumbing through a dictionary to confirm a spelling and coming away with three new words, or browsing a library for a specific title only to walk out with an unanticipated armful of books, using HGIS in heritage interpretation is an embrace of the unknown. If this is true of work undertaken in a controlled, indoors setting, it is even more true in the field.

Guided Field Interpretation with the Keweenaw Time Traveler

In daily life, moving through the world is largely a matter of wending one's way through the present, with an eye on the near future; for many people, there is little practical need to understand the past, however strongly it may have influenced the current state of things. The practice of heritage interpretation understands that there is a real value to knowing the past, one that is not driven by strict pragmatism—a central goal of interpretation is to foster meaningful engagement with the past and its role in the present (Thomson and Humes 2000). Building on accepted tools and technologies is a welcoming way to help advance this goal.

Printed maps are common, familiar tools used in navigating and exploring our contemporary world; in recent years, access to digital maps on handheld, internet-connected devices has become virtually ubiquitous. The field-ready interpretive functions of the Keweenaw Time Traveler harness and extend this familiar mobile technology by adding two novel elements: georeferenced historical overlay maps, and digitized building footprints tethered to a high-resolution historical geodatabase. Equipped with GPS- and 4G-enabled iPads connected to dedicated, place-based GIS Web Apps, visitors to one of our selected historical areas can physically explore the site in real time while simultaneously tracking their location in the past by watching their "blue dot" traverse an historical overlay map on their handheld device. Buildings or structures shown on the historical map—even if they are no longer present in the landscape—can be selected in the App, which quickly displays linked information from our source geodatabase for the interested user.

There are two crucial aspects to this strategy of heritage interpretation: it engages the user directly with real heritage landscapes augmented with historical information, and it can be a wholly self-directed undertaking, if desired. Together, these features foster the independent generation of novel questions about the nature of the landscape and its change over time. Rather than being "talked at," this model encourages users to ask and seek answers to their own, internally-generated questions. If guided to explore within a context of heritage preservation, these questions may include critical inquiries about why

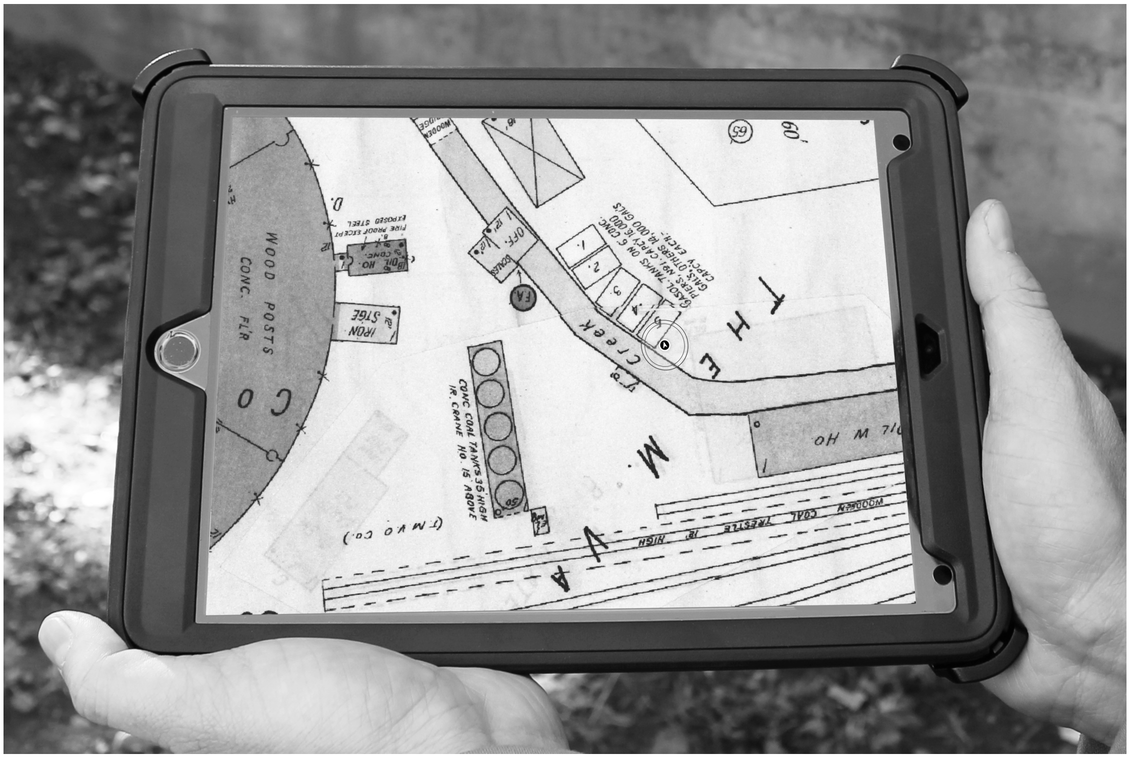

Figure 7. The Keweenaw Time Traveler Web App’s layered interface. (Don Lafreniere)

Figure 8. The field location of the Keweenaw Time Traveler in use. (Don Lafreniere)

we bother to preserve, manage, and interpret heritage landscapes at all— and why some buildings, structures, and sites may be preferred over others. In the example below, the subject participants were local youth; this proved an excellent demographic to test the capacity of our Web Apps to provide the kind of wide-ranging, exploratory engagement that invites novel inquiry from an audience new to thinking historically about the landscape around them.

The Village of Lake Linden, at the end of the nineteenth century a noisy and smoky copper milling town boasting 2,600 residents, is today a quiet, clean, and pretty historic town on the shores of Torch Lake, with less than half its peak population. It retains much of its original housing stock, as well as a number of architecturally significant civic and commercial structures, many of which are listed among the 69 contributing properties in the National Register-listed Lake Linden Historic District. Missing, however, is virtually any trace of the industry that built the town: the once-obtrusive stamp mills, powerhouses, smoke stacks, railways, trestles, and launders have all been removed due to cleanup efforts as part of the area's designation under the EPA Superfund program. Even most footprints have been obliterated by environmental remediation undertakings that capped polluted soils and industrial detritus with a foot of soil, planted with stabilizing grasses. These sites today play host to a popular area park featuring playgrounds, ballfields, and a summer weekend farmer's market.

The dramatic changes that this place has been subjected to made it an excellent candidate location for field-testing the Time Traveler. We accompanied a group of 15 local high school students outfitted with iPads on a walking tour of this familiar park, and

Figure 9. Exploring Lake Linden with the Keweenaw Time Traveler on iPads. (Sarah Scarlett)

participated in an experience all too rare for this age group—the wonder of genuine discovery. As the students meandered the grounds, they were able to flip through the digital historical maps, marked with their continually-updating location, to see what they would have been walking on 80 or 100 or 120 years ago. Prior to this experience, these students had no real sense of what had been here before their neighborhood park, having only heard talk of "the mills" from grandparents.

These students were inspired to ask new questions by being presented with an unfamiliar but intriguing historical context for their daily lives—a context that includes important contemporary environmental effects that are relics of the milling era. What was here before the park, and what is it actually built on? Why can't we eat the fish from

Torch Lake? Why does the lakeshore erode so much black sand after every storm? And, most critically: how are these questions related to one another, and this place, as it has changed over time? Conducting historical spatial research with the Keweenaw Time Traveler engages an interested public with a welcoming interface to investigate historical spatial data that may be freely explored, independent of any strict research program, or really any plan at all beyond a curiosity to discover what is around the next spatiotemporal corner.

Conclusion

The management and interpretation of historical industrial landscapes is rife with challenges not presented by the traditional subjects of historic preservation efforts, which tend to be small, independent, and relatively static buildings. Postindustrial landscapes, on the other hand, are spatially vast, deeply interconnected, and highly changeable over time—and often retain only isolated remnants of what once were vital and dynamic industrial systems. These can be places that are difficult to understand or appreciate without a broad, spatiotemporal context. Developing this contextual understanding is a primary role of heritage interpretation, itself a necessary prerequisite for heritage management. Our research demonstrates that digital historical maps, coupled to geospatial datasets, linked through time, comprise a useful new tool that is particularly well-suited to the management and interpretation of postindustrial landscapes: our big-data HGIS, the Keweenaw Time Traveler.

Research supporting a simple digital model of the Quincy Smelter Works, the development of a preservation plan for Calumet's remaining industrial buildings, and the creation of an online, publicly-accessible, building inventory for the Village of Calumet's Civic and Commercial Historic District are three examples of how the Time Traveler can assist local stakeholders by increasing the efficiency, robustness, and flexibility of heritage management projects. Taking the Time Traveler into the field as an augmented reality location overlay on historical georeferenced maps, as we did with high school students in Lake Linden, and using the Time Traveler as a stationary research kiosk for local history enthusiasts at a series of engagement events at KNHP partner Heritage Sites, are all examples of its expansive utility to heritage interpretation.

More broadly, beyond demonstrating the utility of the Keweenaw Time Traveler as an effective heritage tool, it is important to emphasize that all of our Apps are simply different presentations of the same underlying spatial data infrastructure—they all draw on the same big dataset. Successful heritage work requires the engaged participation of a spectrum of participants, with differing interests, desires, and demands; specific goals will vary by project, as will relevant historical information. In some cases, only subtle shifts are required to reposition the data more meaningfully to a target audience and task: while it is interpretation to explore postindustrial Lake Linden with local high school students, it could have just as readily been employed for management if undertaken with, for example, professionals from the EPA. By drawing from a single consolidated dataset, and selectively curating the data and its interface to particular user groups and aims, it is possible to harness the HSDI to perform work across a gradient of heritage tasks, from interpretation through administration, planning, and management.

These digital technologies and their underlying ideas are all readily transferrable to other established parks and preserves. Their applicability easily extends to include such non-industrial cultural landscapes as historic farmlands, as at Ebey's Landing National Historical Reserve; Civil War sites, such as Manassas National Battlefield; or westward emigration along the Oregon National Historic Trail, as it passes through six states. Again, though, it is the dispersed yet interwoven remnants populating vast historical industrial landscapes that may most benefit from this application of historical GIS.

There are numerous National Heritage Areas (NHA) that could benefit from the development and deployment of HSDIs. The Ohio & Erie Canalway National Heritage Corridor is a 110-mile long heritage area connecting a canal route and a historic railroad to a national park; the Blackstone River Valley National Heritage Corridor encompasses 24 towns in Massachusetts and Rhode Island related to the American industrial revolution; the 165-mile long Delaware and Lehigh National Heritage Corridor, a multi-use trail that conserves and interprets natural and historical sites; the Hudson River Valley National Heritage Area includes a network of over 100 designated Heritage Sites situated along a 150-mile long valley running from Albany to Yonkers; these examples represent just a sampling of the 49 NHAs that bear direct comparison to our historical Copper Country, as collected and connected in the Keweenaw Time Traveler.

The demonstrated utility of our current HSDI invites the prospect of future projects to expand its horizons, incorporating spatiotemporal information of even less centralized historical processes. It is not difficult to envision an HSDI interface mapping historical data of nineteenth-century industrial whaling, accessed through a touch-screen kiosk in New Bedford Whaling National Historical Park, or tracing the paths and activities of the turn of the century fortune-seekers from Seattle to Skagway and into the gold fields, and (hopefully) home again, all from the comfort of the visitor center at Klondike Gold Rush

National Historical Park; these are well within the realm of possibility, and would be great projects to work on. But working from what we have already built, it is an even shorter stretch of the imagination to consider digitally connecting the villages, towns, and mining locations of the Copper Country with roads and railways, digitizing docks and shipping corridors, and selectively expanding our map to include the origins and destinations of people and products: Chicago, Detroit, Boston. The historical spatiotemporal connections are all already there. It is up to us to find and convey their meanings, and to ensure their shareability into the future; historical GIS is a tool that can help get us there.

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CONCLUSION

The postindustrial landscape of Michigan's Keweenaw Peninsula is rich to with the vestiges of its copper mining history. The preservation, management, and interpretation of this singular cultural landscape pose numerous challenges to traditional historic preservation thinking and practice, and invite the development of novel perspectives, tools, and techniques suited to its unique conditions and requirements.

There are three interrelated attributes of the postindustrial landscape that, taken together, distinguish it from other preservation subjects and demonstrate the importance of alternative methodologies for their conservation as heritage. First, the historical industrial landscape is discontinuous today; much of its original fabric, both places and pathways, are no longer. Second, much of that which does remain lacks *integrity*, or the ability of a property to convey its *significance*; retaining integrity is crucial to listing in the National Register of Historic Places. Third, of those scattered remnants that do possess integrity (of location, design, setting, materials, workmanship, feeling, and association), most are unlikely to have any significance (for their association with important events or people, design or construction, or archaeological potential) to convey at all.

The traditional mechanisms used by heritage professionals to initiate historic preservation efforts are confounded by the very structure established to aid in the determination of a historical property's eligibility for National Register listing and ultimate material conservation. By these traditional criteria, most of the Copper Country is simply ineligible for any sort of formal historic preservation recognition; as a corollary, much is overlooked, or even dismissed, by heritage professionals, further contributing to their already marginalized heritage status.

However, this familiar preservation rubric of significance-and-integrity is poorly suited to evaluating historical industrial properties in this postindustrial landscape. Most of the remaining sandstone, brick, and poor rock industrial buildings in the Keweenaw were *never* significant by themselves. Many were accessory buildings for mining, milling, and smelting operations; if anything, these places have an identity of *in*significance. Others were more central, but only a very few could be considered significant by traditional criteria—and these, largely, have been so considered, and formally recognized for it. What is needed is a deep and thorough recognition of very real value that the hundreds of other, insignificant, properties together contribute to demonstrating the context and extent of the enormous industrial processes that contributed to the nationally significant history of Keweenaw copper.

Similarly, the concept of a fixed historical integrity has little meaning in an ever-changing industrial landscape. Ordinary industrial buildings and places are continually reinvented, even over the course of their original services. They are, after all, *tools*: built and reshaped, extended or retracted, demolished and repaired and rebuilt. Their sites evolve, their context changes, and they themselves are disassembled and moved and reassembled. Marked more by flux than stasis, these places are mutable by nature, and by design. These places have an identity not of integrity, but of perpetual incompleteness.

The third distinguishing characteristic of the postindustrial landscape noted earlier, spatial discontinuity, amplifies and exacerbates the historic preservation challenges presented by insignificance and absence of integrity. It is difficult to accurately communicate the historical reach and intensity of industrialization in the Copper Country, using only those remnants visible in today's descendant landscape; this is a point that will be returned to in more detail, below. At this juncture, it is sufficient to envision a vast, wooded, terrain, sparsely dotted with small stone buildings in various stages of ruin and resurrection.

The remnants in this imperfect, beautiful, broken historical landscape have been preserved not by formal historic preservation, but rather by the informal mechanisms of vernacular preservation. Vernacular preservation is a pragmatic, local, responsive process of material conservation and modification; buildings are repurposed in any number of ways, few of which would receive any sort of official endorsement by heritage professionals, but all of which result in its continued presence in the landscape persistence. Taken together, vernacular preservation provides a substantial force that contributes consequentially to the historical meaning of the Copper Country—a force that deserves acknowledgement.

The selfsame attributes that ensnarl traditional historic preservation thinking also complicate efforts at heritage interpretation and management, for similar reasons. The remaining historical fabric is an irregular patchwork of adapted and transformed remnant buildings, structures, sites, and pathways that may not have even been considered important at the height of their capacity, much less today. Interpreting the history and managing the heritage of this postindustrial landscape is made still more difficult by one final factor: it is *big*. A single mining-milling-smelting operation may stretch across 6 to 12 square miles; the Keweenaw Peninsula is roughly 1,500. Even if all the historical fabric were intact, the scale alone makes it extremely difficult to succinctly interpret or effectively manage the heritage landscape for visitors.

Clearly, however, this postindustrial landscape is not intact, and its fragmentary nature only adds to the difficulty of clearly communicating its historical importance and heritage value. Most of the scattered remnants of the Copper Country's industrial past are simply not consequential independent of their spatiotemporal context. Their meaning only really emerges when understood as remnant components of a vast, much changed, and now mostly missing industrial complex. The obstacles to heritage management and interpretation inherent in this incomplete landscape can be mitigated with digital tools appropriate to the task.

A big data geospatial approach is particularly well-suited for reconstructing the critical spatiotemporal context required for comprehending and making decisions about the postindustrial landscape. The Copper Country Historical Spatial Data Infrastructure (CC-HSDI) consolidates historical spatial data of over 120,000 building footprints, drawn from nearly 1,300 historical maps, documenting nearly a century of change at high resolution. The virtual reconstruction of the built environment in this way provides the opportunity to study the evolution of this industrial landscape in a holistic fashion. Thus contextualized, the surviving remnants, persisting in the descendant landscape by either formal or vernacular preservation, are transformed from mere *memento mori* into real-world touchstones to the past.

This big dataset was harnessed in several ways in this dissertation. The first primary role of the CC-HSDI came with using ESRI's *CityEngine* procedural modeling software to create a diachronic pair of virtual 3D landscapes, comparing the built environment within a 130-square mile area in 1949 to its 1917 antecedent. Encompassing Houghton, Hancock, Calumet, Laurium, and the communities along Torch Lake, this proof-of-concept study enlisted three key variables (building height, material, and use) from the CC-HSDI to model materially representative digital reconstructions of these important historic communities. Visualizing historic landscapes at this spatial scale and over this span of time is beneficial not only to academics, but to heritage professionals charged with its ongoing interpretation and management. By situating the lasting remains within their greater spatiotemporal context—that is, as component parts of a giant, defunct machine—this research project provides a useful historical narrative for prioritizing the allocation of limited preservation resources, and for sharing the meaning and importance of these industrial remnants.

The second primary role of the CC-HSDI was in providing the big dataset for a publicly accessible interface referred to as the *Keweenaw Time Traveler* (KeTT). This novel tool for heritage management and interpretation provides for easy, public access to the georeferenced and digitized historical maps of the CC-HSDI, and importantly, all their associated data. KeTT has been used for advancing local heritage management goals by increasing the efficiency, robustness, and flexibility as demonstrated here in a series of advancing case studies, culminating in the creation of a WebApp for the use of the Village of Calumet Civic and Commercial Historic District. Through a series of public engagement events, KeTT has also been deployed as an effective heritage interpretation tool, both in the field on iPads for exploring location-based historical spatial data, and in targeted heritage sites as a stationary research kiosk.

Central to the above research, in addition to demonstrating the broad utility of CityEngine and the Keweenaw Time Traveler to heritage management and interpretation, it is crucial to highlight that all of these various applications are simply different manifestations of the same data, the CC-HSDI. There is a great range of heritage work, and each project has its own set of stakeholders, interests, and goals. By embracing a big data geospatial approach, a single, consolidated dataset can serve multiple preservation projects simultaneously, requiring only the selective presentation of relevant data through a digital interface appropriate to the task. As the dataset is grown over time, so too can the output be iteratively updated and refined to meet new goals in preserving the vernacular postindustrial landscape.

There are, of course, parameters to the applicability of these perspectives, tools, and techniques, developed, as they were, within a postindustrial landscape milieu. The concept of vernacular preservation appears at first blush to be little different than the time-honored traditions of simple reuse of historical buildings. The key distinction is, in fact, philosophical, rather than mechanical: these adaptively reused buildings are distinguished by the fact that they are not rehabilitated in alignment with formal preservation criteria, and may in fact be historically compromised or even materially damaged by their reuse. For most buildings, this sort of detrimental reworking of historical fabric undeniably results in the loss of those qualities that endeared it to preservation in the first place. However, in a postindustrial landscape, populated with individually insignificant buildings and structures designed to change over time to suit evolving functional demands, it doesn't matter: vernacular preservation is a viable, if unorthodox, preservation modality.

Further, there is an intriguing kind of self-limiting paradox to vernacular preservation. That is to say, if a vernacularly preserved building were to be formally recognized, it would be eligible for the benefits that such recognition brings—including a greater degree of scrutiny and involvement on the part of heritage professionals, trained in the traditions of the craft. This proposition, of course, risks trading the living vernacular for a more self-reflective, and familiar, form of historic preservation. The consequences of acknowledging the value of the vernacularly preserved postindustrial landscape is an aspect of this dissertation clearly deserving of future study.

While the philosophical perspective of vernacular preservation may have limited applicability beyond postindustrial landscape study, without significant manipulation, the digital tools and techniques here developed in the same context are more readily transferrable. As noted previously, our HSDI is a single, albeit very large, database from which a variety of projects can draw; collecting and organizing the data is a significant task in and of itself. However, reframing any select subset of the data for a particular audience and task is less onerous, once the tools and their applications are understood. The same dataset can be harnessed to a variety of heritage goals, including interpretation, administration, planning, and management. Heritage landscapes everywhere could benefit from developing their own HSDIs, modeling their work on the Time Traveler and building on the work presented in this dissertation.

The CC-HSDI itself will most certainly benefit from ongoing expansion in coming years. Numerous historical maps have been scanned and are queued for georeferencing, including Sanborn maps of many of the smaller communities and mining sites around the region. Once digitized, these places will be available to help relate a still fuller history of the deeply interwoven history of people and place in the Copper Country. Of course, the history of Keweenaw copper does not end at the edge of Lake Superior or begin at the coal docks of Hubbell. Digital heritage studies in general and GIS in particular offer unparalleled opportunities to weave in spatially distant elements of historical narratives. The CC-HSDI, for example, will ultimately incorporate local and regional railways, waterways, and Great Lakes shipping channels, connecting the mines and people of the Keweenaw to the origins, and destinations, of much of the region's wealth.

Similarly, the work in this dissertation demonstrates the potential of CityEngine to rapidly model big historical landscape data for heritage interpretation and management. Any cultural heritage landscape that has an established HSDI would be able to harness this powerful tool for historical spatial data visualization. Critically for future research, these visualizations are in no way limited to the material characteristics of historical buildings or structures or sites—in fact, it may very well be that the most powerful application of CityEngine is as a tool for the spatial visualization of immaterial characteristics, or intangible culture heritage, and their association with populations and their spatiotemporal evolution.

It is important to conclude with a caveat for the future. As digital tools such as GIS and CityEngine, and even 3D digital modeling more broadly, become ever more inexpensive, accessible, and powerful, it is tempting to consider the digital emulation of heritage resources as "preservation" in some meaningful sense. It is, in my considered opinion, not. These compelling technologies can produce convincing simulations, or even persuasive virtual reconstructions, of buildings and places of the past, but there is a danger in confusing records or recollections of a resource with the resource itself. It is hoped that the novel tools, techniques, and structuring philosophies explored in this dissertation will be commonplace in twenty years, and the value of these big data geospatial approaches will be demonstrated in service to preserving the vernacular postindustrial landscape.