Geobiological opportunities to learn at U.S. fossil parks

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ABSTRACT

Unlike other informal sites, fossil parks provide visitors collecting opportunities that result in ownership of a small number of fossils. In 2003, we investigated the first three identified U.S. fossil parks at Hamburg, New York; Sylvania, Ohio; and Rockford, Iowa. Case study analyses determined the opportunities to learn geobiology at each site. Data collection proceeded through lived learning experiences, and included field notes, photographic records, informal conversations with park participants, brochures, and on-site signage. Through constant comparative methods, six variable categories converged for fossil park development: (1) informative previsit Web site, (2) authentic collecting in situ, (3) authentic collecting tools, (4) accessibility, (5) fossil identification, and (6) visitor education. These variables were optimized in a model of fossil park design. In 2005, fossil parks at Sharonville, Ohio, and Fossil, Oregon, were investigated in phase 2 of our study, and in 2006, our third case study researched fossil parks in Aurora, North Carolina, and Republic, Washington. Analysis of the seven U.S. fossil park data sets resulted in the emergence of key variables that affected the visitors’ opportunities to learn geobiology concepts at fossil parks: (1) authenticity of experience, (2) age of fossils, (3) fossil-collection training and facilities, (4) availability of on-site paleontological mentors, (5) fossil identification via signage and brochures, (6) site organization and wayfinding signs, and (7) accessibility of site, including safety. The seven U.S. fossil parks were ranked against these variables according to their effectiveness as informal science education sites. We conclude that fossil parks can provide valuable informal geobiology education that can contribute to the public’s geobiological literacy.

INTRODUCTION

In 2003, the international news agency CNN reported the existence of an innovative, informal geoscience educational experience: the Fossil Park at Sylvania, Ohio (Cable News Network, 2003). Sylvania was one of three U.S. fossil parks that embraced a unique educational mission. Whereas most museums, National Parks, and other informal education sites display fossils within locked cases or exhibit them in their native strata for visitor viewing only, a fossil park is developed on the concept that visitors search for and retain the fossils they find, within the guidelines set by the park. In 2003, Sylvania was identified as one of these new, pioneering U.S. fossil parks, along with Penn-Dixie Paleontological Park (New York) and Rockford Fossil and Prairie Park (Iowa).
We began our investigation of fossil parks in 2003 (Fig. 1), when we began to research the first identified U.S. fossil parks. Our second case study in 2005 extended this research, and in 2006, we initiated a third case study with on-site investigations of two additional locations. Table 1 lists the fossil parks we investigated in our three phases of case study analysis and details the order of study and the year in which we conducted each site visit.

Beginning in 2003, we surveyed the facilities at the three originally identified fossil park locations (Penn-Dixie Paleontological Park, the Fossil Park, Rockford Fossil and Prairie Park), collected fossils at each site, observed park participants, and conversed with employees, volunteers, and visitors. Next, we coded and analyzed original field data, and key findings emerged. From our initial investigation, the data and analyses informed our development through grounded theory of an optimal fossil park design.

In 2005, our fossil park research was expanded through the identification of two additional fossil park sites: Wheeler High School Fossil Beds (Oregon), and Trammel Fossil Park (Ohio). We visited the sites, collected fossils, and interacted with the employees, volunteers, and visitors present. We analyzed data from these sites, both of which are located within small towns, against our fossil park model. Finally, we compared the fossil parks to determine their geobiological opportunities to learn as outdoor teaching laboratories, and linked our research with the findings of the National Research Council study, *America's Lab Report* (Singer et al., 2005).

The third case study in the fossil park research investigation incorporated two additional U.S. fossil parks: Aurora Fossil Museum and Park (North Carolina), and Stonerose Interpretive Center (Washington). We conducted site visits in 2006 that included fossil collecting, interviews, and observations. In 2007, we returned to our seven data sets and determined the key variables that optimized visitors’ educational experiences. We then ranked and analyzed the seven fossil parks for their opportunities to learn geobiology in the field.

![Map of U.S. fossil parks](image)

**Figure 1.** The geographic locations of the seven U.S. fossil parks involved in this longitudinal qualitative research investigation. Black stars show the sites of the first three U.S. fossil parks we investigated (Penn-Dixie Paleontological Park in New York, the Fossil Park at Sylvania in Ohio, and Rockford Fossil and Prairie Park in Iowa). White stars locate the fossil parks in phase 2 of our 2005 study (Trammel Fossil Park in Ohio, and Wheeler High School Fossil Beds in Oregon). Gray stars denote the locations of the last fossil parks investigated in phase 3 of our 2006 study (Aurora Fossil Museum in North Carolina, and Stonerose Interpretive Center in Washington).

<table>
<thead>
<tr>
<th>Fossil park name</th>
<th>Location</th>
<th>Research phase/year</th>
<th>Order of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penn-Dixie Paleontological Park</td>
<td>Hamburg, New York</td>
<td>Phase 1—2003</td>
<td>1</td>
</tr>
<tr>
<td>The Fossil Park at Sylvania</td>
<td>Sylvania, Ohio</td>
<td>Phase 1—2003</td>
<td>2</td>
</tr>
<tr>
<td>Rockford Fossil and Prairie Park</td>
<td>Rockford, Iowa</td>
<td>Phase 1—2003</td>
<td>3</td>
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<tr>
<td>Trammel Fossil Park</td>
<td>Sharonsville, Ohio</td>
<td>Phase 2—2005</td>
<td>4</td>
</tr>
<tr>
<td>Wheeler High School Fossil Beds</td>
<td>Fossil, Oregon</td>
<td>Phase 2—2005</td>
<td>5</td>
</tr>
<tr>
<td>Aurora Fossil Museum</td>
<td>Aurora, North Carolina</td>
<td>Phase 3—2006</td>
<td>6</td>
</tr>
<tr>
<td>Stonerose Interpretive Center</td>
<td>Republic, Washington</td>
<td>Phase 3—2006</td>
<td>7</td>
</tr>
</tbody>
</table>
Problem Statement

This research focused on the identification of U.S. fossil parks, a relatively new venue of paleontological informal education for the general public. The role of fossil parks within more traditional information education sites (e.g., museums, National Parks, U.S. state parks) was ascertained through both literature searches and site visits. The primary research focus was to determine the informal opportunities to learn geology at U.S. fossil parks through case study. Guiding the research investigations were the principles of active, meaningful and mindful learning, as established within the learning theory of human constructivism.

Fossil Parks as Unique Informal Learning Venues

Hose (1995, p. 16) published an early definition of geotourism as the “provision of interpretive service facilities to enable tourists to acquire knowledge and understanding of the geology and geomorphology of a site beyond the level of mere aesthetic appreciation.” By 2005, the state of Arizona was investigating geotourism as a method to sustain and enhance their region, protecting it from harmful tourist expansion (Long, 2003). Undoubtedly, geotourism is popular. In 2002, approximately one third of Americans (55 million) were interested in geotourism (Stueve et al., 2002). An especially encouraging statistic to science educators was that 53% of U.S. travelers acknowledged that learning enhances their travel expectations (Stueve et al., 2002).

However, visitors’ learning opportunities at informal educational sites vary in both quality and quantity of instructional materials and experiences. The combination of factors considered the “best practice” in interpretive design at geotourist sites has not been empirically examined (Patzak, 2000). Science centers typically depict science out of context, especially if free-standing exhibits are disconnected from the world in which they originate (Persson, 2000). Conversely, Mir (2003) noted that outdoor science parks add a dimension to informal science education and can appeal to visitors without the cultural message that buildings project.

The Conference on Earth Heritage: World Heritage in Wareham, Dorset, UK, produced interesting results and suggestions for geotourism (Larwood and Durham, 2005). Experts in informal geotourism noted that poor interpretation counteracts a geotourist site. Since fossils represent a specialized interest outside most people’s general knowledge, the interpretation of a site is crucial (Larwood and Durham, 2005). Another important factor is local community involvement in a geotourist site, which can greatly influence the site’s success (Larwood and Durham, 2005). Patzak (2000) noted that there was no demonstrable conflict between tourism promotion and geoscientific education.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) unveiled its Geopark initiative to promote a worldwide network of extraordinary examples of Earth’s geological diversity. The Geopark initiative emphasizes the use of unique geological sites in educating the general public, the use of these sites to ensure sustainable development through geotourism, and the conservation of the world’s geological heritage for the future (Patzak, 2000). Although the United States does not have a designated Geopark, the National Park System (NPS) encompasses a variety of National Parks and monuments that contain fossil remains for public informal education. The NPS published guidelines for paleontological resources, defined as including both organic and mineralized remains in body or trace fossil form, specifically requiring that the fossils be protected, preserved and managed for public education, interpretation, and scientific research (National Park Service, 1991). The National Park Service further mandates that the fossils be protected from harm, theft, or destruction. Therefore, wherever necessary, the NPS will guard locations of fossil resources it policing and removal of fossils is suspected to result from disclosed locations.

Unfortunately, the concept of “ownership” of fossils, even protected ones, has resulted in vandalism and desecration of paleontological sites. The Petrified Forest National Park in Arizona exhibits signage with “Your heritage is being vandalized every day by theft losses of petrified wood of 14 tons a year, mostly a small piece at a time.” Vandalism and collecting are not limited to easily removed bits of materials, nor are they limited to U.S. National Parks. When we conducted field research in 2005 along the Lyme Regis coast, UK, we unwittingly stumbled onto dinosaur tracks for sale. We learned later that the facility we visited was raided by authorities, and the tracks were confiscated. The tracks were illegally quarried from Beachy Head, resulting in obvious damage to a protected site in Wales (BBC News, 2006).

Fossil parks differ substantially from U.S. National Parks and protected global sites in that visitors can collect and keep the fossils they find. Therefore, the U.S. fossil parks fill a unique niche by permitting the visitor ownership of a small, limited number of personally collected fossils, for individual study and enjoyment. Notably, the U.S. fossil parks are not lagerstätten, or sites with extraordinary preservation or diversity of fossils. Fossil park sites are established in locations that are not only fossiliferous, but have been extensively researched and collected. These informal education sites serve to bridge “traditional” informal sites that only display fossils with unstructured field opportunities where visitors collect fossils without site and/or fossil education. While fossil parks expect visitors to leave with personally collected fossils, sustainability of the site is considered in the park design.

Locating the Researchers

Our backgrounds in geology, biology, and science education undoubtedly influenced the types of data we collected, as well as the analyses. As EarthScholars Research Group, we have served as consultants for signage at the Doris I. Schnuck Children’s Garden: A Missouri Adventure (Missouri Botanical Gardens, St. Louis, Missouri), and as informal education consultants and trail designers at Barton Arboretum (Burden Research Center,
Baton Rouge, Louisiana). We previously analyzed signage systems within informal education sites and designed a template for optimized science signage construction (Wandersee and Clary, 2007). Our previous research also included analysis of informal educational design (Clary et al., 2009), as well as optimized opportunities to learn in informal science field experiences (Wandersee and Clary, 2006).

Theoretical Frameworks

Learning Theory of Human Constructivism

We utilize the learning theory of human constructivism for educational research. This learning theory was originally proposed by science educator Joseph Novak (1977) and has been extensively researched and elaborated (e.g., Mintzes et al., 2000, 1998). Human constructivism is a relatively new synthesis based upon psychologist David Ausubel’s previous work (Ausubel et al., 1978; Ausubel, 1968, 1963) and developed through Novak’s (1963) pioneering work that proposed fundamental principles of research in science education. This learning theory has been advanced through research in cognitive science, epistemology, and the nature of science. Research investigations utilizing human constructivism have been reported in numerous science education venues, including the special issue of the Journal of Research in Science Teaching, devoted entirely to human constructivism-driven research (Novak and Wandersee, 1991).

Principles of Active, Meaningful, and Mindful Learning

The following theoretical principles taken from the learning theory of human constructivism are relevant to the fossil park investigation: (1) Humans seek to make meaning; (2) learning results when the meaning of experience changes; (3) knowledge is conceptual; (4) concepts are those patterns that humans identify and label; (5) concepts are used in semantic sets of propositions for thinking and expansion of learning; (6) meaningful learning occurs when new concepts are connected in a substantive, nonverbal way to prior knowledge and experiences; resulting in (7) cognitive restructuring. Therefore, the best teaching is learning-driven, and the goal of science education is to foster conceptual change. When conceptual change occurs, learners form increasingly powerful knowledge representations that reflect contemporary scientific thought.

When learners monitor and take control of their learning, meaningful learning occurs. This is identified by learners’ ability to plan, monitor, and regulate their learning, which is in turn responsible for conceptual change (Novak, 1998; Novak and Gowin, 1984). Metacognition, which can facilitate conceptual change, is the knowledge, awareness, and control of the learning process by the learner (Gunstone and Mitchell, 1998). Therefore, science education is successful when learners develop and exhibit new thoughts and feelings about the natural world. Gowin (1981) noted that successful science education scaffolds the integration of thinking, feeling, and acting within the learner.

Meaningful learning is nonverbal and nonarbitrary and results in a substantive incorporation of new knowledge within an existing conceptual framework (Ausubel et al., 1978; Ausubel, 1968, 1963). Therefore, meaningful learning will occur when learners have integrated and organized conceptual knowledge frameworks (Novak, 1998). Additionally, when learners are aware of the context of information and recognize that knowledge is not static, they can engage in mindful learning (Langer, 1997). Conversely, when learners memorize facts without context and an awareness of the changing nature of information, they have frameworks with limited uses.

DeBoer noted, “If a single word had to be chosen to describe the goals of science educators during the last 30-year period that began in the late 1950s, it would have to be inquiry” (1991, p. 206). Several research studies have affirmed the benefits of active learning (Lawrence et al., 2005; McConnell et al., 2003; Michael and Modell, 2003). Active learning can provide authentic research experiences, resulting in better learner understanding of the research process (Felszien and Cooper, 2005; Hemler and Repine, 2006). Following Gowan’s (1981) science education integration, Lord and Orkwisiewski (2006) reported increased learning alongside positive affective outcomes with inquiry-based exercises. Our previous research (Clary and Wandersee, 2008) reported significant learning outcomes with active learning investigations within informal educational sites.

Role of Informal Science Education

Informal science education and free-choice learning are well-established as important venues for learners (McComas, 2006, 1996; Wandersee and Clary, 2006). Not only does informal education provide the default learning environment for most of the adult population, but school-age students also typically engage in informal learning more often than learning in traditional environments (Falk and Dierking, 2002). Several researchers have investigated motivators, assessments, and the theoretical bases behind learning in informal environments (Anderson et al., 2003; Falk, 2001; Falk and Dierking, 2000; Meredith et al., 1997; Orion and Hofstein, 1994; Rennie and Johnston, 2004). Roy and Doss (2007) reported that informal educational programs can engage citizens in data collection, independent research, and global problems. Informal learning environments can supply an interdisciplinary science “big picture” for students (Clary and Wandersee, 2009) and provide holistic experiences that are retained (Bernstein, 2003).

METHODS

This research investigation utilized a mixed methodology design (Creswell, 1994; Tashakkori and Teddlie, 1998). However, we focus on the qualitative research aspect in this chapter. Phenomenology provides a philosophical affiliation for our ongoing research on U.S. fossil parks. With a phenomenological methodology, the research question is stated broadly (Nieswiadomy, 1993) and analysis proceeds as we examine the detailed, thick
descriptions recorded during our lived experiences at the fossil parks. Although the results from the fossil park research have been triangulated (Denzin, 1978) through several types of data, the products of our research investigations provide one rendering of the experiences available by visitors who engage these parks (Bogdan and Biklen, 1998).

We used a constant comparative method (Glaser, 1978; Glaser and Strauss, 1967; Strauss, 1987) for data generation at the first three U.S. fossil parks. Each fossil park investigation contributed data to identification and emergence of the key factors that helped to make a fossil park an effective informal educational design. As additional fossil parks were identified in 2005 (phase 2) and 2006 (phase 3), these were investigated to contribute new sources of data to the optimized model. Once we collected and analyzed data, the individual case study investigative results of fossil parks were generalized through grounded theory to optimize both fossil park designs and educational experiences for those who visited the facilities.

**Trustworthiness and Generalizability**

Our on-site visits to fossil parks were limited to short contacts within each. Therefore, our participant sample was small and should not be considered to be representative of all visitors to any of the individual U.S. fossil parks. Alternatively, the investigation of fossil parks was purposive and inclusive. We researched every informal site that we could locate that was specifically dedicated to the informal education of the visitor through the collection and retention of fossils.

Our previous experiences and backgrounds as science education researchers undoubtedly influenced our perceptions and objectivity during data generation. While complete objectivity is unattainable in qualitative research (Harper and Kuh, 2007), we utilized Lincoln and Cuba’s (1985) guidelines for establishing quality criteria, and achieved external validity through thick descriptions of our lived experiences. Denzin and Lincoln’s (2000) criteria of credibility, transferability, dependability, and confirmability helped us to establish the quality and trustworthiness of our study. We further utilized the guidelines in geoscience qualitative research, as outlined by Stokes (this volume). Qualitative triangulation (Golafshani, 2003), internal auditing (Manning, 1997), and critical subjectivity (Lincoln, 1995) helped us to meet these criteria, establish reliability and validity, and reach authentic conclusions in our analyses.

Through the analysis of our thick description, our credibility is established through the believability of our results, judged through the lens of our lived experiences at fossil parks. Because our backgrounds influenced our perspectives, and our interactions within each fossil park were limited, the transferability of this research to other informal educational settings may be restricted in its specific applicability.

While the limited hours of collecting and lived experiences, the restricted interactions with fossil parks’ visitors, and the specific days and seasons of our research visits are a small sample, we make the general assumption that our interactions were typical of visitor experiences within each fossil park. The thick descriptions gathered from each fossil park site provide an overall guideline for future researchers to replicate this research study, though undoubtedly the data collection and conclusions will not be in total agreement with our experiences and results. Thick descriptions are used to achieve dependability of our results.

It is also through thick descriptions that we achieve confirmability. Visitors’ comments and interactions, notes from our lived experiences, and data we collected via Web sites and printed material are provided to support the conclusions we made in our research, as well as manage our potential biases as science educational researchers. Our research and data also have been presented and made available to science education research communities at the International Geological Congress in Florence, Italy (2004), the American Geophysical Union (2004, 2005), the National Association for Research in Science Teaching (2005), and the Geological Society of America (2006) meetings.

Therefore, while this research is generalizable to informal educational sites in the United States that allow collection and retention of fossils, the application of our results to broader informal educational science sites or sites beyond the United States is yet to be determined.

**Investigative Techniques and Data Reduction**

In 2003, the three U.S. fossil parks that were identified by the international news agency CNN (the Fossil Park at Sylvania, Penn-Dixie Paleontological Park, Rockford Fossil and Prairie Park) were subjected to case study analysis (Yin, 2003) as the first phase of our fossil park research. Results were triangulated through multiple data-generating techniques. When additional fossil parks were identified in 2005 (phase 2, n = 2) and again in 2006 (phase 3, n = 2), we utilized case study analyses and triangulated the results.

In each of the seven fossil park investigations, we utilized naturalistic learning experiences by visiting each park and collecting fossils at each site. Our goal for each site visit was 8 h minimum of site interaction time. Rockford Fossil and Prairie Park in Iowa and Trailside Fossil Park in Ohio involved additional site hours because of limited participants. We extended our observations in order to encounter and observe more visitors/collectors at these fossil parks.

We observed visitors to ascertain the effect of the fossil park landscape and available experiences within it on participant behavior. Additionally, other participants at the site, including volunteers and employees of the fossil parks, were watched and monitored. We also engaged in informal, unstructured conversations (Wolcott, 2005) with participants where appropriate. There was no predetermined interview protocol, but conversation proceeded based on the site facilities and available collecting experiences. Because we were participating in fossil recovery alongside park visitors, our manner was unobtrusive. Our field notes on these conversations were made after the conversation concluded.
Conversations can be described as "natural," leading to the probability of low observer effect. No risks were identified for visitor participation in these on-site conversations, and we informed visitors of our fossil park investigative research and secured their permissions prior to recording their comments.

We collected literature for each fossil park, acquiring both on-site paper handouts as well as posted information on the internet. The literature was analyzed for relevance to visitors' educational experiences through coding and content analysis. Additionally, we photographed signage at each site and analyzed the contents. Our impressions of participants' behaviors and the fossil park itself (physical site, geology, facilities available, fossil-collecting experiences, paleontological mentors) were recorded as field notes with thick description. Fossil park sites also were documented through photography. However, the thick descriptions constituted the bulk of our data generation for all seven fossil park site investigations. These thick descriptions of our lived experiences at fossil parks provided data through which our findings emerged. We include narrative selections of these fossil park case studies to document our qualitative inquiry process.

For each case study investigation (phase 1: n = 3 fossil parks in 2003; phase 2: n = 2 fossil parks in 2005; phase 3: n = 2 fossil parks in 2006), we determined the categories to be examined. Field notes, photographic records, brochures, and interviews were coded and analyzed. Through the constant comparative method (Glaser, 1978; Glaser and Strauss, 1967; Strauss, 1987), data were reduced and interpreted (Marshall and Rossman, 1989). The analyses involved coding and sorting data into categories. For content analysis of brochures and signage, we utilized Neuedorf's (2002) guidelines, while for conversational, unstructured interview analysis, we employed the methods outlined by Chi (1997).

For the content analysis of published literature, Web site information, and our collected thick descriptions, we first identified the important variables for optimal learning environments at fossil parks and defined these concepts using the applicable published research literature as a guideline. We then identified the categories that would best reflect the variable parameters. Categories in our coding scheme emerged to include accessibility, biodiversity of fossils, brochures, collecting tools, data collection procedures, ease of site location, educational activities, fees, fossil density, fossil identification through charts and signage, fossil information (genus identification, characteristics), fossil preparation stations, hours of operation, museum or visitor center on-site, paleontological mentors, public awareness of site, safety, stratigraphic context, vertical relief, visitor population, and Web site information.

We coded field notes, literature, and interviews independently, and then recorded randomly selected samples of literature, researcher descriptions, and interviews. We determined the interrater reliability at 95%. Further analysis of categories resulted in the identification of themes and patterns (Marshall and Rossman, 1989), and through the themes and patterns, a consolidated model emerged for an idealized fossil park design in 2003, and for optimized visitor experiences in 2007 (Tesch, 1990).


Prior to site investigation, we researched the first three fossil parks identified by CNN, which included identifying and accessing any online materials, including advertising. In August 2003, we conducted on-site research at all three sites. Our first on-site visit was to Penn-Dixie Paleontological Park in Hamburg, New York. We proceeded next to the Fossil Park at Sylvania, Ohio, and lastly to Rockford Fossil and Prairie Park, Iowa.

Penn-Dixie Paleontological Park

Penn-Dixie Paleontological Park, once utilized as a quarry for an aggregate cement operation, was established through a partnership between the Hamburg Natural Society and the Town of Hamburg (Bastedo, 2000). This outdoor informal educational site is geologically situated within a 380-m.y.-old, highly fossiliferous exposure of the Devonian Windom Shale. Other units represented on the site include the Genundewa Limestone, North Evans Limestone, Tichenor Limestone, and Wanakah Shale. Fossils collected here attest to the paleoecology of the Devonian when warm tropical seas covered New York within 20°–30° south of the equator (Bastedo, 2000). Corals, brachiopods, bryozoans, trilobites, crinoid columnals, gastropods, bivalve mollusks, cephalopods, and fish remains have been recovered.

Although a Web site existed for Penn-Dixie, it was not fully developed. A brief description, hours, admission fees, and associated web links were included. The posted map provided good directions to the site, and we had little trouble locating the park.

We arrived at Penn-Dixie shortly after it opened for the day and paid the nominal collecting fee (US$4). Upon admission, we were provided with a fossil-collecting card with eight ink-drawing renderings of fossil corals (solitary rugose and colonial tabulate), bryozoans, trilobites (flattened and enrolled), crinoid stems (lateral and cross-section views), bivalve mollusks, brachiopods, cephalopods (coiled and straight forms), and gastropods (planispiral and trochospiral species). Additional handouts were provided that briefly described fossil formation and preservation, the Penn-Dixie quarry site schematic cross section, and a pen-and-ink paleoenvironmental reconstruction. We also received a small flyer advertising the "Dinosaur Days!" at the Science and Nature Store in Blasdell, New York. We observed no group reading any handouts at the site other than the fossil-collecting cards.

At the fee station, we were assigned to "Michael" (not his actual name), an undergraduate geology student who would serve as our paleontological mentor. Michael was enthusiastic and friendly. Although sunny and warm, we did not find the conditions overbearing and moved directly to the collecting site. Most of the old quarry site is level, although there are areas of vertical relief, naturally created through erosion and through exposure with earth-moving machinery. We first collected at one of these small vertical exposures and were allowed to use the rock
hammers and chisels we brought. There were no requirements for personal safety equipment. We retrieved partial trilobites (*Phacops rana, Greenops hornii*), brachiopods (*Macrospirifer, Athyra, and Spinocystites* species), rugose corals (*Streitina*, crinoid columnals, bryozoans, trace fossils, and a possible partial straight-chambered cephalopod (*Micheloceras*). Fossil recovery was fairly easy, and we did not utilize rock hammers often because the fossils were typically ended out of their shale matrix. During our fossil recovery, we conversed with Michael, utilizing an internal and unstructured style.

Other groups were collecting, including students participating in a summer workshop through a local college (n = 14), three solitary individuals, and a mother and son team. We observed each group and collected field notes. Additionally, we moved our personal collecting operations to within talking distance of groups and engaged in informal, unstructured conversations. Within the larger student group, we observed that students typically brought their "finds" to the adult supervisors or the paleontological mentor, or checked their identifications against four large information boards at the site (Fig. 2). We found the information boards to be helpful, but we were not brought to them by our mentor. We independently recorded that this was a missed opportunity to educate the visitor, given that the fossil descriptions on the information boards were more detailed than the handout. Another option available at the site was an open-air classroom, but it was not in use during our site visit.

After collecting, observing, and conversing with fellow collectors, we ended our site visit by returning to the admission shelter. A middle school speech teacher was one of the volunteers who collected money at the park's entrance, along with the park director, Jerry Bastardo. We explained our interest in the fossil park concept and discussed typical attendance at the Penn-Dixie park, programs within the park, and their perceptions of park activities.

Other pamphlets were available at the admissions area. The Penn-Dixie Paleontological and Outdoor Education Center trifold brochure incorporated information on fossil collecting, astronomy, ornithology, and the future of the Hamburg Natural History Society (HNHS). This brochure included a membership application to the HNHS. Other literature available at the station included flyers on the Saturday evening astronomy programs (two flyers), information on special occasion outings and groups (birthday parties, graduations), a Halloween special event at the park, and Western New York Earth Science Day. Some copies of the *Penn-Dixie Chronicle*, a monthly newsletter for the HNHS, were available at the station as well. We collected and reviewed five newsletters (April through May 2003), which primarily contained information on upcoming events, park updates, and membership.

**Fossil Park at Sylvania**

Our next stop in our first phase of fossil park case study was the Fossil Park at Sylvania, Ohio, which was the fossil park featured in CNN's 2003 article on the new fossil park concept. Although our methods for on-site study were similar to those we utilized at Penn-Dixie Paleontological Park, our visit to Penn-Dixie undoubtedly influenced our examination of Sylvania in that it helped to provide a focus and define the boundaries and variables for our on-site fossil park investigations. Following our Penn-Dixie site research, we discussed our perceptions of the benefits of collecting fossils from areas with topographic relief, the helpfulness of the site mentor, and the organization and information contained on the display boards for fossil identification at the site. We also noted the fairly long walk between some fossil-collecting areas and the display board and felt that this distance could deter visitors from accurately identifying their fossils as they recovered them. Therefore, in our future fossil park investigations, we searched for these helpful elements (topographic relief, on-site mentor, identification boards) and hindering factors (distance between fossil identification information and collecting sites).

The Fossil Park at Sylvania was developed on an abandoned quarry site. Encompassing only 5 acres (1.6 square hectares), it is much smaller than the Penn-Dixie site in New York. The Fossil Park is geologically situated upon the bottom of the Devonian Silica Formation with the Dundee Limestone exposed at the upper quarry ledges. Within the 375-m.y.-old Silica Formation, over 200 species of fossils have been recovered, including rugose corals, bryozoans, brachiopods, bivalve mollusks, echinoids, echinodermasteroids, fish, and trilobites (Stoll, 2001). Fossils collected from the Silica Formation comprise the major portion of the Devonian collection at the Smithsonian Institution, and they are representative of a marine environment. The formation is known to paleontologists and amateur collectors around the world for its excellent preservation of Devonian invertebrates.

Fossil collecting at the fossil park is not done in situ. The Hanson Aggregate Midwest mining company approached the local

![Figure 2. Penn-Dixie Paleontological Park has several large information signs at the collecting site, including this board on brachiopods. Collecting groups were situated at a distance from these signs, but younger visitors often returned to the figures to check their fossil identifications against the diagrams.](image-url)
park system with an idea of creating a fossil park situated away from their main quarry. For safety reasons, visitors are not allowed to collect on-site in the active quarry, although Hanson Aggregate reported that numerous requests were made each year. The Fossil Park at Sylvania, managed by the Olander Park System (TOPS), opened in 2001 as the result of the quarry and park partnership. Visitors are provided spoil piles on two concrete pads at the bottom of the abandoned 25-ft-deep (7.6 m) quarry, through which they may hunt for fossil treasures.

We did not uncover a lot of information about the park prior to our arrival, although the CNN (2003) article and a visitor’s guide (Ohio.com) were posted online. Both sources were descriptive and weighted toward tourism. The Fossil Park at Sylvania did not have a Web site, and the map we found posted for the fossil park proved very confusing. When we stopped for directions, the local residents could not direct us to the park location. We resorted to another map and eventually found our way to the site.

Upon arrival, we found the park had not yet opened. This gave us an opportunity to investigate the surrounding area before a potential crowd arrived. When “Andy,” the resident naturalist, opened the site, we quickly drove to the parking lot. The facility was new and had access for wheelchair users. There was no admission fee, although plans for the park’s future included a nominal fee (Downing, 2003).

We walked down the ramp from the parking lot into the abandoned quarry. There, water-saturated shale spoil piles awaited the geotourists on their concrete pads (Fig. 3). Covered tables were available for examining fossils, along with large plastic wash stations for cleaning the sticky weathered shale residue from the fossils collected. No tools were allowed for collecting, and hammers, chisels, shovels, and screwdrivers were banned at the site. Although the wash station provided the means with which to remove the mud from the fossils, it was underutilized. We observed children playing with the water and in the mud pile at the station’s base.

Upon our arrival, we signed the guest book and were given a handout. One side of the handout listed the fossil park policies that no tools were allowed for safety reasons, and fossil hunting was restricted to the enclosed areas. On the reverse side of the handout were some diagrams featuring a trilobite, brachiopod, horn coral, crinoid, and bryozoans. Very basic descriptions of these invertebrates accompanied the figures as the “Commonly Found Devonian Fossils.” We did not observe anyone on-site utilizing this identification handout.

The shale of the Silica Formation, referred to as paper shale, was soft and very easy to break apart. However, we found that the spoil piles were well collected, and even after an hour of collecting, the EarthScholars team could only claim one decent, small Phacops trilobite. After several hours of collecting, we were able to procure a few trilobite portions, primarily the thorax portions of individuals or molts, and a few bryozoans, but the fossils were extremely small. The spoil piles were slippery, and suspected fossils were encased in mud.

We collected elbow-to-elbow with other visitors. No organized school or club groups were present, but several families and extended families visited the site. We counted a total of 71 visitors. Where appropriate, we engaged visitors in informal, unstructured conversation. We observed that within family units, children turned to adults for guidance in what they were uncovering. Often, the object in question was not a fossil. When adults could not answer questions or suspected a fossil find, they typically sent their children to the on-site naturalist for further identification.

We observed some groups collecting on the side of the quarry near the naturalist’s station. We then moved to the naturalist’s station and spoke with him about the park. During our conversation, several children came to ask about the fossils they uncovered. The best specimen we observed was a 3 cm brachiopod collected by an 8-yr-old boy. Although Andy had reference notebooks available to him, there were no additional copies or posted identification diagrams within the naturalist’s area.

Within the naturalist’s area, there was a kiosk with a wall devoted to “Fossil Finders” with photographs of particularly good fossil finds at the park. Another wall was devoted to “Fossil Facts,” but specific taxonomic genera were not identified. Instead basic invertebrate groups were described, similar to the handout we received upon entry. A “Tourist ? Info” wall had plastic containers for trifold brochures, but it was empty at the time of our visit. We found that the most interesting side of the kiosk featured an interactive fossil quiz. The “Fossil Challenge” posed 15 questions for visitors. The answers were obtained by lifting the hinged wooden doors.

We retrieved an additional pamphlet for the Fossil Park at Sylvania from the naturalist’s station. This trifold brochure included basic descriptive information about the fossil park. A general description, safety features and handicap amenities, and

![Figure 3. The Fossil Park at Sylvania in Ohio did not offer fossil-collecting opportunities within strata. Instead, spoil piles were available on two concrete pads. The facility accommodated handicapped visitors, and tables were available for sorting fossils.](attachment:image)
brief descriptions of the partners (TOPS and Hanson Aggregates Midwest) were included, but fossil types were absent.

**Rockford Fossil and Prairie Park**

Our final stop in phase 1 of the fossil park research was Rockford Fossil and Prairie Park in Iowa. We approached this fossil park in a similar manner to the other two U.S. fossil parks we previously investigated, but our iterative process and earlier experiences influenced our perceptions of this final site. The Fossil and Prairie Park is a 490-acre site (162 square hectares) that became public land in 1990. A new visitor center opened in 2001. The site encompasses a wetlands area and native prairie in addition to the fossil-collecting quarry. The area was originally the quarry site of the Rockford Brick and Tile Company.

The Lime Creek Formation was deposited in a shelf-margin, shallow-marine setting and is 385–375 m.y. old (Frasnian). The park interpreted the palaeoenvironment of the area to be subtropical deltic and estuarine during the Late Devonian. At the Fossil and Prairie Park, the Cerro Gordo Member of the Lime Creek is exposed. It is exceptionally fossiliferous and consists of fossiliferous calcareous shales, argillaceous limestones, and bedded argillaceous limestones (Drewes, 2005; Anderson, 1998). Several species of brachiopods, bivalves, gastropods, rugose and tabulate corals, and bryozoans are common, with cephalopods less common (Anderson, 1998). During the first geological survey of Iowa, spirifer brachiopods were collected in the area (Drewes, 2005). Their identifications and illustrations were included in the 1858 geological survey of Iowa (Anderson, 1998).

We obtained initial information from the Iowa Community Web site prior to our arrival. Although the fossil beds were briefly mentioned, only the minimum directions to the site were provided. We accessed the information that the park was open from “sunrise to sunset.” Unknown to us, this did not include the visitor center hours, which were not posted. We found within a Fossil and Prairie Park Web site a general map of the collecting area. The Web site (www.fossilcenter.com) featured more information on the Prairie Heritage Days than any other topic.

We drove from Rochester, Minnesota, to access the site. The trip took longer than we anticipated, and we first accessed the site on a warm summer August afternoon. No fees were required to enter the park, and no park personnel were present. This fossil park was the most remote of the three initially investigated in phase 1 of our research.

We proceeded to the quarry, which offered an authentic in situ collecting environment with fossils similar to the Penn-Dixie Paleontological Park experience. Unlike Penn-Dixie, the site was not primarily used but offered collecting along fairly steep walls of the abandoned quarry (Fig. 4). There was no handicap access available to the quarry’s edge. Only one other group was present, a local father and son team.

Although the Web site noted that tools were not required, we found that our rock hammers were appropriate with some of the harder matrices. Fossils were plentiful. Some were weathered from the strata, and others were easily visible within the calcareous shale. We collected multiple crinoid stems, bryozoans, brachiopods (spirifers, _Artryso, Dicesina, Eryina_), gastropod molds (both trochospiral and planospiral forms), rugose corals, and bivalve mollusks. The limiting factor to collection were the slope of the quarry walls and loose material, but not the number of fossils available.

We observed the other group collecting fossils. They worked in a systematic manner and moved over part of the quarry slope in a slow, deliberate fashion, stopping every few minutes to pick up an object of interest. They did not consult a fossil manual, nor did they return to the posted information boards at the top of the quarry for identifications. We moved near their collecting area and engaged them in informal, unstructured conversation.

At the top of the quarry, we observed a basic, unlabeled map of the site, a fossil washing station, and posted material for fossil identification. The identifications provided basic descriptions of the types of invertebrates that could be recovered from the site, but genera were not identified. Typical specimens of the invertebrates were included alongside the descriptions.

We walked the entire Fossil Park and Prairie site, investigating the reconstructed sod house and the native prairie environment. Historic bee hive kilns were also present. We were disappointed to find that the Fossil and Prairie Center was not open. We walked around the building and glanced into the facility through the windows. We spotted several hands-on exhibits with animals’ antlers and skins, and identification posters of what appeared to be native birds and insects. We did not see any fossil exhibits in the center, but we were not able to view all of the interior facilities through the windows.

Because no park personnel were available, we could not retrieve any pamphlets or additional handouts that might have...
been present in the visitor center. We attempted to follow up with the facility for handouts but did not receive any information. Because we had engaged only one group, we returned the following day in an attempt to observe more visitors. We were unsuccessful, and after spending the second day at the fossil site, we concluded our 2003 fossil park investigation, or phase 1 of our research.

Phase 2: Case Studies of Two Additional U.S. Fossil Parks (2005)

Following the phase 1 one case study investigation of the first three U.S. fossil parks and the subsequent development of an optimized fossil park model through our identified key categories, we expanded our research in 2005 (phase 2) to include two additional U.S. fossil parks that we located: Trammel Fossil Park (Sharonville, Ohio) and Wheeler High School Fossil Beds (Fossil, Oregon). Prior to our on-site research, we investigated each site and accessed information about the fossil parks. In August and September of 2005, we visited both sites. We searched for fossils as part of an authentic fossil park experience, photographed the signage at the site, collected available literature, and interacted with the fossil park visitors and personnel. Our previous research contributed to the site visits of these new parks, and we evaluated them within our optimal fossil park model. We also performed a comparative analysis between these two new fossil parks as geotourist sites within small communities.

Trammel Fossil Park

The first stop for our phase 2 case study of fossil parks was Trammel Fossil Park in Sharonville, Ohio. The fossil park was established through a gift of the R.L. Trammel family to the City of Sharonville, to be developed as an educational site where school children and fossil hunters could explore and collect. This 10 acre site (4 square hectometers) includes a kiosk in the shape of an edrioasteroid, the fossil logo of the park.

Trammel Fossil Park rocks were deposited in the Late Ordovician and are of the Cincinnati Series. There are four formations exposed at Trammel: Fairview (interbedded limestones and shales, with some ripple marks and annelid burrows), Miami (shales), Bellevue (fine-layered limestone), and the lower Corryville (shales). Marine fossils attest to a paleoenvironment in which the state was 20° from the equator, situated in warm, tropical seas. Some of the 445-m.y.-old fossils that are found here include brachiopods, bryozoans, crinoids, gastropods, bivalve mollusks, edrioasteroids, and trilobites.

A Web site provided basic information on the founding of Trammel Fossil Park as well as directions to the site. We also accessed basic geology site information on the University of Northern Kentucky Geology Department’s Web site (2004).

We arrived on a warm August day in 2005 using the posted directions on the Web site as our guide. However, there was absolutely no signage leading up to the park. On the day of our visit, it was sunny with no breeze, and temperatures rose to 96 °F (35.6 °C). No park personnel or other collecting groups were present. The facilities were newly developed, which we described as in perfect shape. There were brightly painted benches, kiosks, a wash station, a huge parking lot, bathrooms, and interpretive signs. The kiosk area was shaped like an edrioasteroid (Fig. 5), and each of the four formations was described within the “ambulacrum.” Not only were the formations’ characteristics listed, but the types of fossils that each formation yielded were included with genera identified. Photographs accompanied the descriptions.

Each formation was identified by a fossil symbol as well as a different color. Whereas the Fairview was represented by a red background and a Rajinhesquana brachiopod, the Miamitown was a blue edrioasteroid, the Bellevue was a turquoise Herbertella brachiopod, and the Corryville was an orange trilobite. This was extremely helpful for visitors as each formation was identified through signage displaying the characteristic color and fossil. Any visitor could quickly locate himself or herself within the formation containing the fossil assemblage that he or she desired. Even the contacts between formations were labeled.

In addition to the formation and fossil information, signage also explained the dedication of the park, the characteristics and sources for limestone and shale, geologic time with the placement of the Cincinnati rocks within the time scale, and the Ordovician Period events. We did not find any paper handouts at the park.

We collected within each formation and quickly retrieved more fossils than we had from any of the first three U.S. fossil parks we visited during phase 1 of our research. Many fossils were small and fairly easy to recover within the shale, although we did use our rock hammers and assorted tools. We found fossil retrieval from the Bellevue Limestone to be more difficult, however. We recovered some varied invertebrate assemblages,
and collected Rajinesquia, Domaintella, and Herbeetella brachiope pods, bryozoans, crinoid columnals and holdfasts, and the gastropod Cyclonema.

Wheeler High School Fossil Beds

Our second fossil park investigation in phase 2 of our 2005 case study research was Wheeler High School Fossil Beds within the small community of Fossil, Oregon. Although the area behind the high school has been accessible to fossil collectors for many years, a small interpretive center opened in April 2005, and the park began to charge a nominal admission fee (US$3). With the $3 fee, visitors are allowed to find and keep three personal fossils.

The Wheeler High School Fossil Beds feature the 33-m.y.-old Bridge Creek Flora within the John Day Formation. These Oligocene shales record a paleoenvironment indicative of a temperate deciduous forest. Leaves, twigs, and an occasional fish and salamander were preserved in a lake bed within volcanic sediments (Meyer and Manchester, 1997). The Bridge Creek Flora at Wheeler High School Fossil Beds is also present at John Day Fossil Beds National Monument, but collecting fossils at the national monument is strictly prohibited.

We accessed some information on the Web sites prior to our arrival at Wheeler High School Fossil Beds. Information about the geology of the area was available also on the John Day Fossil Beds National Monument Web site. The Oregon Paleo Lands Institute Web site provided an online overview of the area, including some photographs of fossil plant material that could be recovered there.

We arrived at Wheeler High School Fossil Beds in the early afternoon of a pleasant September day of the Labor Day holiday. The town of Fossil is small, and we encountered no unusual difficulties in finding the site. As the name implies, the fossil beds are located behind the school, and visitors were required to check in at the interpreter’s station and pay the required fee. At our arrival, we observed several families and extended family groups digging for fossils within the weathered shale.

We moved to the hillside and began our own search. Collecting tools were allowed, including rock hammers, shovels, and picks. It was fairly easy to dig into the weathered shales, and we were able to retrieve fossils fairly easily at the collecting site. However, the fossil density was not as great as that at Tramceal Fossil Park. We uncovered mostly fossil leaves and sticks of plants and identified our collected specimens as Metasequoia, Sequoia, Quercus, and Acer.

There were multiple family groups on the hillside, but no school or club groups were present. We counted a total of 64 visitors in the field and engaged groups in informal conversations. Most groups were focused upon collecting, although children occasionally investigated other aspects of the area, or ran up the hill. We engaged the other visitors in informal conversation and asked them which fossil they felt was their most interesting find. We identified most of the fossils being recovered by other visitors as Dawn Redwood or Metasequoia.

While a few visitors consulted personal fossil identification guides they brought to the site, several visitors converged at the station where Karen Mazzu of served as the paleontological mentor. There was also a canvas-covered area with a table by some bleachers that could also serve as an interpreter’s station. Additional facilities included a very small gift shop. The only signage at the site was on the board at the site’s entrance, which explained the basic plant fossils that could be recovered. This board provided good pictures as well as the genus names of the common fossils. A mural, painted on the side of a building, provided a stratigraphic context for the John Day Group (Fig. 6).

We left at the end of the day when the park closed, but returned the following morning to interact with additional visitors and the on-site interpreter, repeating the general routine for data collection.

Phase 3: Case Study of Two Additional Fossil Parks (2006)

In 2006, we uncovered two additional parks that fit into our definition of a fossil park. While neither Aurora Fossil Museum in North Carolina nor Slone’s Interpretive Center in Washington referred to itself as a fossil park, visitors were allowed to search for and keep fossils within the informal education sites. Although both sites were in existence in 2003 during our initial fossil park case study research, neither was initially identified in our exploratory research or by international news agencies. Therefore, we planned on-site visits to add data from these two facilities to our fossil park research data set. Our prior research and analysis influenced our perception of the final two fossil parks. Our optimized model for fossil park design provided guiding parameters, as opposed to the raw emergence of variables that we experienced in phase 1 of our 2003 fossil park investigation. We also used the National Research Council study.

Figure 6. This mural depicts the stratigraphy of the area through the John Day Group and the underlying Clarion Group. Fossil plants at the Wheeler High School Fossil Beds are from the John Day Group.
America's Lab Report (Singer et al., 2005) in our analysis of the previous fossil parks in phase 2, in 2005. This report's content influenced our focus upon the new fossil parks' educational potential as outdoor laboratories.

Aurora Fossil Museum

Aurora Fossil Museum was established in 1976 as a non-profit informal education venue highlighting the geology and paleontology of North Carolina. The town of Aurora, North Carolina, partnered with phosphate mines, government institutions, including East Carolina University, fossil clubs, and interested individuals to open the museum in 1978 as part of a program to bring tourism to the area.

Potash Corporation of Saskatchewan (PCS) currently operates a phosphate mine in the vicinity. During the retrieval of phosphate nodules, PCS encounters some intercalated fossiliferous layers and provides this material for the spoil pile at Aurora Fossil Museum. Called the Pit of the Pungo, the spoil pile is located outside the museum building across the street. Visitors can search through the spoil pile for shark's teeth and other fossils from sunup to sundown. There is no charge to access the site.

The Miocene-aged Pungo River Formation is composed of interbedded phosphatic sands, limestones, dolostones, and diatomaceous clays (Gilmore, 2006). During the Miocene, this area was part of the Abermarle Embayment and is interpreted as an outer continental shelf environment. In addition to 15-m.y.-old shark teeth, other fossils include early whale and teleost fish remains. Invertebrates are represented by barnacles, corals, echinoids, bivalve mollusks, and gastropods.

We accessed information online prior to our visit in June 2006. There were several Web sites with material posted about the Pungo River Formation, and a Web site devoted to the Aurora Fossil Museum. The map proved accurate, and we encountered no difficulty in finding the site.

We arrived at Aurora Fossil Museum on a pleasant but overcast day. The museum was open and housed local specimens. In addition to the Miocene material of the Pungo River Formation, Pleistocene fossils and archaeological artifacts were on display. However, since our primary research focus was the fossil spoil pile, we moved our attention outside.

There were several family and extended family groups collecting in the spoil pile on the day of our visit (Fig. 7). While we were collecting within the spoil pile, we counted 23 other individuals at the site. The material, similar to the spoil piles at the Fossil Park at Sylvanil, was without stratigraphic context. There was no fossil identification signage at the site and only one sign posted at one end of the collecting area with the “Park Rules.” We sorted through the material and collected several species of sharks’ teeth, corals, and broken bivalve shells.

We observed the other collectors and engaged them in informal unstructured conversation. The visitors' fossil searches were focused upon finding sharks' teeth, particularly teeth from the extinct giant *Carcharocles megalodon*. On the day of our visit, none of the collectors was successful at finding a *C. megalodon* tooth, but groups did retrieve several small sharks' teeth. No one focused upon the invertebrate fauna.

Stonerose Interpretive Center

The Stonerose Center and Interpretive site was established in Republic, Washington, in 1989. The Boot Hill Fossil site was discovered in 1977 by Kirk Johnson, paleontologist, and Wesley Wehr, artist. Wehr collaborated with Republic City Councilman Bert Chadick to purchase a house within walking distance of the fossil site. This was transformed into the Stonerose Interpretive Center. Both sites—the interpretive center and the fossil-collecting hill—are owned by the nonprofit Friends of Stonerose Fossils.

Boot Hill Fossil Site preserves Eocene tuffaceous shales within the Klondike Mountain Formation. Fifty million years ago, the Republic, Washington, area was the site of a lake in a temperate highland region. Volcanic sediments trapped and entombed a variety of plant material, as well as insects, fish, and even bird feathers. The site's logo is *Florissantia gilchrenesis*, a flower that resembles a rose but is an extinct relative of cocoa plants. However, the Stonerose site is famous for the earliest rose and maple fossils (Wehr, 2008). We accessed information prior to our visit, including a feature on the Stonerose fossil logo within National Geographic Magazine (Klesius, 2002).

We arrived at Stonerose Interpretive Center on a sunny day in August 2006. We did not have great difficulty in finding the site. With our admission (US$3), we had access to the Boot Hill Fossil site. Visitors are allowed to search for and retrieve up to three fossils each day. Visitors may also rent tools or bring their own to the site. Chisels are allowed, but hammers are only allowed to hit

Figure 7. Visitors at Aurora Fossil Museum may collect fossils in the outdoor collecting area across the street. The spoil piles come from the local phosphate mine. Fossils recovered are without stratigraphic context.
the chisel handle and not for splitting rocks. All fossil finds must be shown to the Stonerose staff.

On display at the Stonerose Interpretive Center, there are three glass cases with "conifer," "leaves," and "unique finds" fossils. We walked to Boot Hill Fossil site to experience the collecting opportunities ourselves (Fig. 8). Boot Hill Fossil site is accessible during normal operating hours, but the site is closed one hour earlier than the Stonerose Interpretive Center.

Collecting at the site was in situ and fairly easy. However, similar to the Wheeler High School Fossil beds, fossils here were not as prolific, and the visitor success rate for fossil recovery was not as high as those fossil park sites with marine strata. We collected several bits of Dawn redwood twigs and some unidentified plant stem material.

At the site, we observed two other groups collecting. One group was a local mother and daughter team, while the other was a group of local young adults. We engaged the groups in informal, unstructured conversation. There was only one sign available at the Boot Hill Fossil site, and this provided basic information about the site's ownership and collecting policies. No information was posted for easy identification of fossils.

RESULTS AND DISCUSSION

For content analysis, we utilized the methodology outlined by Neuendorf (2002), while for conversational, unstructured interview analysis, we employed Chi's (1997) guidelines. Through all three phases of case study investigations, we explored the educational opportunities available at fossil parks, and uncovered via grounded theory and data comparisons the most effective methods for meaningful informal learning at fossil park sites.

Figure 8. At the Boot Hill Fossil site, visitors may search through the siliceousshales for Eocene fossils. The most common fossils are plant stems and leaves. Only the collecting rules are posted at the site. No identification charts or geological information signage were posted.

Phase 1: The First Three Investigated U.S. Fossil Parks

Conversations with Penn-Dixie volunteers revealed that most of their visitor attendance is a local population, although they remembered visitors from Canada, Japan, and Lebanon. The primary visitor population results from school groups. The teacher volunteer reported that the New York high school curriculum required a mandatory earth science course in grade 9. Volunteers estimated 30-40 individuals typically visit the site for fossil collection on a daily basis, while the Saturday night astronomy programs can result in attendance of over 600 individuals.

The site has hosted "science camp" as well. There were plans for ongoing development, including interdisciplinary science (climatology, ornithology, astronomy) and additional signage, which was described as a "painstaking process." The site relies heavily on its volunteers, which at the time of our visit were estimated to number between 175 and 200.

Experiences at the Penn-Dixie site could vary, based on our volunteers' responses. When large school groups visit the area, most of the larger specimens are removed, resulting in a diminished collecting experience for later groups. For our site visit, there was a large acreage exposed for the productivity we encountered. Exposure of the site through earth-moving processes was not conducted on a regular, scheduled basis. A volunteer remarked that the "kids get bored easily" without positive feedback from regular fossil recovery. The same volunteer noted that the smaller kids "collected fossils, played in the mud, and then wanted to go home."

In Ohio, the Fossil Park at Sylvania also noted plans for expansion, including interpretive signage and running water at the site. The Ouander Park System hopes that a Fossil Interpretation Center will bring national and international recognition to the geotourist site. Until 2004, the park reported an annual visitor count of ~20,000, in addition to 2000 annual students and scout groups (Jones, 2004). The on-site naturalist mentioned that a visitor count averaged 250-500 per day. On the day of our visit, we determined that most of the visitors were from local family units based on our informal conversations. We did not encounter the family from Nevada at the fossil park site though they signed the first visitor entry for the day.

The naturalist claimed that 90% of visitors were from out of state. This is a very different visitor composition from Penn-Dixie Paleontological Park. The out-of-state population may be partially attributed to CNN's international news article that featured the park earlier that summer. The naturalist at the site expressed disappointment with the CNN news article's wording, noting that "bucketfuls" of trilobites were an exaggeration. He further stated that 1 out of 100 visitors will find a complete trilobite.

When we visited the site, it had been approximately 3 wk since the last load of materials was deposited. This did not make for authentic or rewarding collecting. We observed that visitors had a very low success rate, and there were very few fossil treasures in the spoil piles. The spoil piles consisted primarily of slippery mounds of weathered shale. Additionally, the site was crowded.
Collecting at the Fossil Park at Sylvania was not done in situ and was without stratigraphic context. Authentic collecting tools were not allowed. Although we noticed brushes in a bucket at the naturalist’s station, they were never offered to the visitors. However, the handout was correct in acknowledging that the shale was easy to break apart without tools.

We observed children playing in the mud as often as we spotted them searching for fossils. Some adults appeared to be struggling to find a “fossil.” The kiosk and handouts did not describe the different species, and no explanations for evolution, geologic time, or biodiversity were offered in any format. Collecting within the weathered spoil piles can best be described as a “trial-and-error” process.

In the most remote fossil park, located in Iowa, attendance records for 2002 to 2003 documented visitors from 35 states, 6 countries, and 160 cities within the state. School groups from Iowa (21) and Minnesota (2) visited the park, contributing to the recorded annual visitation of 6400 people (Fossil and Prairie Center Foundation, 2003). However, it is highly probable that more visitors experienced the site without registering, as we did. There are special events at the fossil park, including the Rockford Fossil Days, an annual event held during the Labor Day weekend.

We could not retrieve any information from volunteers or park personnel at Rockford Fossil and Prairie Park, because no one was present when we visited. However, we can attest to the authentic collecting experience at the park. The procurement of fossils at Rockford Fossil and Prairie Park was the most realistic experience and most like a paleontological field excursion of the three U.S. fossil parks. With the quarry exposures, however, came a higher field risk. There were no fences or warning signs keeping visitors off the slopes, and even though we have experience and wore proper field boots, we found the site more difficult to navigate than other public informal sites we investigated. While the density of fossils and the large collecting site were positive attributes, we discussed the safety issues and wondered how safe a fossil experience would be for families with younger children.

There were no brochures available for visitors at the quarry site, although the identification boards were helpful in offering descriptions as well as specimen examples. However, with the size of the quarry, it would be unrealistic for a fossil hunter to trek back and forth to the sign to identify the retrieved specimens.

**Content Analysis Key Findings**

We analyzed each fossil park site for the geobiological opportunities to learn. Through content analysis of the coded field notes, on-site signage and brochures, and unstructured conversations of the first three U.S. fossil parks, three key findings emerged: (1) Fossils presented and recovered without stratigraphic context can hinder paleontological understanding; (2) on-site geological mentors can facilitate an authentic geological collecting experience; and (3) a fragile balance exists between safety considerations and adventure during field experiences. We diagram some of the characteristics of the first three U.S. fossil parks that contributed to these key findings in Figure 9.

Although the paper shales at the Fossil Park in Sylvania facilitated easy collection of fossils, the spoil piles at the bottom of the quarry were without geological context. The concepts of geologic time, biodiversity, extinction, evolution, and paleoenvironments were not visible to the average visitor. It was easier for a park to convey stratigraphic context in situ. When visitors can retrieve fossils within vertical exposures, the principle of superposition is more apparent. Furthermore, the retrieval of fossils within the strata makes apparent the original deposition of the organism. One man within a family unit at the Fossil Park at Sylvania noted that the fossils were laid down during a “great flood,” and the jumbled nature of the spoil pile did not easily counteract that misconception.

The paleontological mentor was an important resource at both Penn-Dixie Paleontological Park and the Fossil Park at Sylvania. At Sylvania, the on-site naturalist resided in a station within relatively close access to the collecting piles. This was a feasible arrangement because the site was relatively small, and children were often at the station with their latest find for identification. At Penn-Dixie, the mentor was assigned to our collecting group, and after leaving us, traversed the field site to see whether other collecting visitors had questions. A central site at Penn-Dixie, stationed with a mentor, might not have worked as well as it did at Sylvania because of the size of the Penn-Dixie site. At both locations, however, the mentor was a primary source of fossil information for collectors. Although identification boards and handouts were available, our notes detailed how visitors approached the
mentor for fossil identification and information much more often than they referenced other sources of fossil information.

Although we initially questioned the number of rules and the absence of tools at the Fossil Park in Sylvania, we experienced the other extreme in conditions with Rockford Fossil and Prairie Park. We are familiar with general field protocols, but we found ourselves slipping within the quarry on several occasions. The quarry site at Rockford provided a grand adventure for the collector, but safety considerations for young children or novices were not apparent.

**Fossil Park Design Model**

Following the first case study of the original three U.S. fossil parks in phase 1, we compared data from the three site visits. Broad groups of similar concepts emerged. These formed the basis of six categories: informative previsit Web site, authentic in situ collection, authentic collection tools, accessibility, fossil identification, and visitor education. These categories, along with their variables, were analyzed. Our optimal fossil park design model emerged through grounded theory. This design model incorporated superior features of each category, as determined through the researchers' participation in the fossil park collection experiences and observation of participants at the fossil parks.

**Informative previsit Web site.** In addition to providing a basic overview of a fossil park facility, a Web site should have accurate directions for the visitor to quickly access the facility without the need to ask further directions from the local residents. The Web site can also serve as a form of wide-range advertising. In order to attract geoscientists to a fossil park, the general public must be aware its existence.

**Authentic in situ collection.** A fossil park site should be large enough to accommodate the projected number of visitors without crowding of participants. Sites should be conducive to fossil recovery with a visitor success rate at least moderate in scope. This applies to both the number of fossils specimens to be collected as well as variety. If earth-moving machinery is required to expose new strata, the facility should ensure that this is done on a periodic basis to maximize visitor collecting experiences. Collecting in authentic sites, whether done within abandoned quarries, natural exposures, or road cuts, is preferable to spoil piles. Vertical relief provides a stratigraphic context and contributes to the opportunities to learn at the park.

**Authentic collection tools.** Authentic collection tools enriched the experience for the visitor. However, ifrock hammers, chisels, and screwdrivers are allowed, or even supplied at the site, the fossil park should also provide guidance and instruction on safe fossil-collecting techniques. Recommended personal safety equipment may include goggles, and visitors should be encouraged to wear sturdy, closed-toe shoes. Supporting facilities also enhance a fossil-collecting experience. Wash stations for cleaning recovered specimens and tables to sort the collected items assist the visitor in identifying his or her retrieved specimens.

**Accessibility.** A public fossil park should be accessible to all visitors. Therefore, handicapped access, including a paved trail and ramps, are required at the site. Daily hours should be maintained by the park, for both weekday and weekend fossil excursions. Although a fee may be charged for entrance, it should be nominal and reasonable. Detailed, accurate directions to the site should be readily available.

**Fossil identification.** Instead of brochures for fossil identification, we recommend semipermanent signage that can be accessed, hands-free. Because signage should be available at the collection sites, portable signs provide a good option. A high density of signs at the eighth-grade reading level is recommended (Wandersee and Clary, 2007).

**Visitor education.** For meaningful learning experiences, visitors should be exposed to learning opportunities with an integrative geology and biology field. The signage and site interpretation should emphasize evolution, biodiversity, and geologic time. Interactive quizzes provide good opportunities for self-testing. A paleontologist mentor should be available for assisting in fossil identification as well as scientific understanding of the site. A training program for these individuals would ensure the continuation of the mentor program. Visitor centers and museums within a fossil park site can provide additional learning opportunities of geobiology through free-choice, self-paced learning. Exceptional specimens of fossils recovered from the site can be displayed.

Public safety considerations are important, and visitors should be apprised of safety risks and protective measures. If a site possesses different slopes and/or levels of difficulty, coded levels of collecting access can quickly communicate associated complexities through signage. In order for a fossil park to improve its presentation and learning experiences for the visitor, it should keep records on visitors' origin, usage, and fossil success rate. Additionally, methods should be in place for feedback from visitors.

**Phase 2: Comparisons and Geobiological Opportunities of Two Additional Fossil Parks (2005)**

The hot August day we visited Trammel Fossil Park in Sharonville, Ohio, may have kept local families away. However, schools, families, and geology clubs appear to make regular trips to the site. The local fourth-grade classes also travel regularly to the site. Trammel Fossil Park reported school visitors from as far away as New York. Without park personnel, volunteers, or guest books, accurate visitor counts are problematic.

Trammel Fossil Park was not staffed and is continuously open. However, we observed zero vandalism at the site. Although no park personnel were present, workers from a small factory alongside the park took their work breaks on picnic benches and seemed to keep an eye on the park. The park is handicap accessible, and there is adequate parking.

Information on geologic history of the site, biodiversity, and fossil identification was available at the kiosk. We noted that the fossil density and diversity were good when compared with other fossil sites we visited; this led to a good fossil-collecting experience. Extraction of the fossils from limestone was difficult, and
even the shale extraction resulted in bits of rock flying from our rock hammer. Some visitors would probably benefit from personal protective equipment.

Conversely, Wheeler High School Fossil Beds (Fossil, Oregon) had numerous visitors, but this may be as a result of our site visit over the Labor Day weekend. The majority of the population appeared local, based on our informal conversations. However, the facility has the potential to attract other visitors, especially those who are interested in John Day National Monument and who would like to procure similar fossils plants for themselves. We could not access any data on visitor populations because the park had only been open for 4 mo.

Because Wheeler High School Fossil Beds charges an admission and relies upon an on-site interpreter for geobiological education and fossil interpretation, the site is open from 9 a.m. to 5 p.m., Tuesdays through Sundays. This fossil park is in its early stages of development, and the interpreter’s station and guest shop were quickly constructed. Handicap access was not fully developed at the site.

Basic information on geologic formation was available on the entrance board, but the site relied primarily on the interpreter for fossil identification. Although our collecting experiences did not result in the same number of fossils that we recovered at Trammel, this is not inconsistent with plant fossil collection and the nature of the organisms’ paleodeposition. We did not have trouble collecting fossils, and most of the groups we observed at the site were engaged in collecting processes.

Key Comparisons

Both Trammel Fossil Park and Wheeler High School Fossil Beds are located in small towns: Sharonville, Ohio, had a population of 13,000, while the population of Fossil, Oregon, was 430. Each town developed a collaborative, partnership-driven, pedagogically innovative field-based geotourism venue. While Trammel Fossil Park’s educational partnership included R.L. Trammel, the University of Cincinnati, and the City of Sharonville, Wheeler High School Fossil Beds’ collaboration involved town, county, state, federal, and foundation-based economic development and a field-based paleontology education program. Following the collapse of the timber industry, the economic recovery plan for Fossil, Oregon, is predicated on geotourism and geoscience education activities centered upon its fossil park as part of a rural renewal. In 2005, the Wheeler High School Fossil Beds only received 2% of Oregon’s tourism dollars. In Sharonville, Ohio, Trammel Fossil Park has become an enticing geoscience education leader of the town’s park system.

Both parks had future plans for expansion. While Trammel Fossil Park’s plans included a future college dormitory on-site, Wheeler High School Fossil Beds anticipated a future Paleo Learning Center and on-site short courses.

The parks differed in several variables. While Trammel Fossil Park’s collecting opportunities were from Ordovician-age marine strata, the Wheeler High School Fossil Beds provided collecting in an Oligocene-age lake bed and featured the state fossil of Oregon (*Metasequoia*) and the Bridge Creek Flora. The Trammel Fossil Park’s site was small, with room for ∼150 collectors at a time. Conversely, the Oregon Paleo Lands Institute addressed a 10,000 square mile area (26,000 km²) radiating from Fossil, Oregon. The Wheeler High School Fossil Beds site could accommodate ∼200 collectors comfortably.

The two parks were much in contrast by the way each provided fossil identifications and on-site assistance. Trammel Fossil Park utilized an effective, centralized interpretive signage system that aims to be self-teaching. Conversely, Wheeler High School Fossil Beds employed a helpful on-site geological interpreter.

**Fossil Parks as Outdoor Geobiology Laboratories**

Both Trammel Fossil Park and Wheeler High School Fossil Beds were noteworthy in specific ways for their geoscience education potential as outdoor teaching laboratories. The Trammel Fossil Park excelled in its focus of geological time and the fossil identification via the interpretive signage system designed by a university geology department. Wheeler High School Fossil Beds is slated to be the focus of a large paleontology education effort and will integrate on-site short courses as part of its paleontology education activities. While Trammel Fossil Park was guided by the City of Progress model, Wheeler High School Fossil Beds was guided by a 50-page *Master Plan for Learning* designed by the Oregon Paleo Lands Institute (2005).

We linked the findings of the two new fossil parks case study investigations, along with our results from our original three U.S. fossil park case study in phase 1, to the National Research Council (NRC) study, *America’s Lab Report: Investigations in High School Science* (Singer et al., 2005). Specifically, we correlated the missions of the fossil parks as informal geoscience education venues that provided an outdoor geobiology laboratory setting. The NRC study did not exclude outdoor experiences from their definition of laboratory, but instead noted that their definition included student research and observation in outdoor settings including “nearby geological formations” (Singer et al., 2005, p. 35). The NRC study concurred that field work is an effective way to provide alternative learning experiences to laboratory research. We found it disappointing that ∼50% of teachers reported that they never take their classes on field trips (Singer et al., 2005). Singer et al. (2005) concluded that teachers should conduct open-ended field research in order to better understand inquiry. Data can originate from either the laboratory or the field.

Geologists often rally around the slogan that “geology is best taught in the field.” Notably, the National Research Council concurred. Their report affirmed that there is no equivalent technological substitute for direct interaction with the real world. We propose that fossil parks can serve as authentic field sites and outdoor laboratories to address fossilization processes, biodiversity, evolution, geologic time, biostratigraphic correlation, and environmental change over time. Furthermore, fossil parks can offer scientific experiences to the public that contribute to the nation’s scientific literacy. Through public understanding of past environmental changes, including numerous transgressions
and regressions of the sea, glaciations, and past warming events, modern issues such as ozone depletion and climate change are provided an Earth context. Fossil parks can successfully convey Earth’s past environmental changes through effective geology education at their sites.

**Phase 3: Case Study of Additional Fossil Parks (2006)**

We discovered at Aurora Fossil Museum that one reason we did not identify the site sooner was because of its organization: Aurora Fossil Museum is an *indoor* informal education site that has a complementary spoil pile for visitors to search for fossils they may keep. Unlike the previous fossil parks identified, the museum was not built to support a fossil park, but the fossil “park” (spoil pile) was added as a hands-on exhibit to the museum.

The collecting opportunities at the spoil pile were without context. Family groups who were collecting the day of our visit were not focused upon identification of fossils, nor did they perceive the geological context of the fossils’ deposition. Younger visitors were intent on finding the “big shark’s teeth” (*Carcharocles megalodon*). Although other fauna were present in the spoil pile, none of the fossils were identified at the site. Visitors could identify their fossils by comparing them to the displayed specimens in the museum, but we did not observe any visitors doing this.

Similar to the Fossil Park at Sylvania, the collecting experience of a group can vary greatly depending upon when the latest material was added to the spoil pile. Although the site was not completely picked over, we did not observe anyone collecting large fossil items.

Stonerose Interpretive Center may have also escaped our early identification as a fossil park because of the separation of the interpretive center and the fossil-collecting site: Stonerose Interpretive Center is located away from Rock Hill Fossil Site, although it is within walking distance and owned by the same nonprofit group. Unlike Aurora Fossil Museum, collection at the Eocene outcrop is in situ. However, quick identification of fossils at the collecting site is not facilitated. The only signage posted rules for fossil recovery, but no helpful pictures and descriptions of the common fossils retrieved at the site were available. Visitors must return to the Stonerose Interpretive Center to show their fossil finds to a staff member before claiming them, and at the center they may seek identification assistance from the staff, or use the posted specimens for comparison. However, we think that this delay works against the educational potential of the fossil-collecting experience.

**Resultant Rankings on Key Variables (2007)**

After our final on-site fossil park case study at Stonerose Interpretive Center, we returned to our field data of lived learning experiences for all seven identified U.S. fossil parks. Our data sources included field notes, photographs, visitors’ comments, and park documents. Our focus was not upon an optimized fossil park model as it had been in 2003, but on our interpretation of how each of the seven U.S. fossil parks ranked as informal learning facilities of geological and biological concepts.

We searched our data for meaning and understanding as to how a fossil park could best offer informal geoscience education experiences to a visitor. Our data were filtered through the learning theory of human constructivism, particularly the principles of meaningful, mindful, and active learning. Through years of fossil park investigations and data sources, seven variable categories emerged through grounded theory. Our focus was upon these variables that we interpreted through our authentic collecting experiences that contributed to the fossil park visitor’s overall learning experience of biodiversity, geologic time, evolution, and environmental change. These variable categories included (1) the authenticity of the outdoor experience with genuine collecting tools and in situ fossil recovery; (2) the geological age of the strata and ease of fossil retrieval; (3) fossil-collection training and facilities for the novice; (4) the availability of an on-site paleontological mentor; (5) the availability of signage and brochures to aid in the visitor’s fossil identification; (6) the fossil park’s organization and wayfinding signage; and (7) accessibility, including fossil park awareness through publicity and posted directions to the site, as well as visitor safety considerations. We ranked the seven U.S. fossil parks on a scale from 1 (best) to 7 (worst) in each category.

Whereas we were on complete agreement with our independent rankings for the fossil park sites for the quality of the mentor (4), fossil identification (5), site organization (6), and safety and accessibility (7), we encountered differences in rankings for authenticity (1), age (2), and training (3). We resolved these issues by thoroughly defining “authenticity,” and removing safety considerations from the category. We also compromised on geologic age rankings by scoring sites with similar-aged fossils identical. However, we agreed on the exception of the Fossil Park at Sylvania, which had excellent preservation of fossils that were easily extracted from the shale matrix. Therefore, we categorized Sylvania’s fossils as equivalent in desirability with the upper-aged fossils at Tramml Fossil Park (Sharonville, Ohio). Finally, we resolved our researcher disparities by defining “training” (3) to include the total training experience of the visitor through brochures, signage, and a fossil mentor. Even before compromise, we were in agreement on the two U.S. fossil park sites as well as the two lowest ranked fossil park sites (Table 2).

**Authenticity of site and collection tools.** When we considered the seven U.S. fossil parks on their authenticity of field experience, the two fossil parks were Tramml Fossil Park in Ohio, and Penn-Dixie Paleontological Park in New York. Both sites offered collecting in situ with more than one formation at the park site. The Tramml Fossil Park site labeled the different formations through signage that was color-coded, for superior, directed collecting opportunities. It also had good outcrop exposure. Both fossil parks allowed visitors to utilize authentic collecting tools.

Rockford Fossil and Prairie Park offered stratigraphic context and collecting in situ, but the large exposed area without
TABLE 2. FOSSIL PARK RANKINGS

<table>
<thead>
<tr>
<th></th>
<th>Hamburg, New York</th>
<th>Sharonville, Ohio</th>
<th>Fossil, Oregon</th>
<th>Sylvania, Ohio</th>
<th>Republic, Washington</th>
<th>Aurora, North Carolina</th>
<th>Rockford, Iowa</th>
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<tr>
<td>Authenticity</td>
<td>2</td>
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<td>5</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Age</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>6</td>
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<td>3</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Mentor</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Fossil ID</td>
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<td>1</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>7</td>
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<td>3</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Accessibility</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Overall score</td>
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<td>2.3</td>
<td>3.9</td>
<td>4.3</td>
<td>4.6</td>
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<td>5.6</td>
</tr>
<tr>
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<td>2nd</td>
<td>3rd</td>
<td>4th</td>
<td>5th</td>
<td>6th</td>
<td>7th</td>
</tr>
</tbody>
</table>

Notes: Parks were ranked from 1 through 7 in the following categories, with 1 being the best rating a fossil park could achieve, and 7 being the rate in most need of improvement: authenticity of the outdoor experience; age of fossils at the site; fossil-collection training and facilities; availability of on-site paleontological mentor; signage and brochures to aid in fossil identification; site organization and wayfinding signs; and accessibility through public directions and safety features.

signage and safety considerations detracted from the experience. The lowest-scoring U.S. fossil parks for authenticity were the Fossil Park at Sylvania and Aurora Fossil Museum, both of which utilized spoil piles instead of in-situ collecting.

Age of strata and ease of fossil retrieval. We observed that visitors enjoy collecting the specimens that are the oldest and the most distant from present-day organisms. Our notes detailed greater excitement and exuberance from visitors when they found fossil specimens (such as trilobites) that are markedly different from modern life forms. Visitor responses were more subdued when they recovered specimens that more closely resembled modern organisms (such as leaves and smaller sharks' teeth). Therefore, we identified the age of fossils that could be collected at each site and ranked them accordingly. Trammel Fossil Park, Penn-Dixie Paleontological Park, the Fossil Park at Sylvania, and Rockford Fossil and Prairie Park are situated on Paleozoic sites. All of these fossil parks showcase Devonian fossils for Trammel, which features Ordovician fossils; the younger Cenozoic sites are Aurora Fossil Museum (Miocene Epoch), Wheeler High School Fossil Beds (Oligocene Epoch), and Stonerose Interpretive Center (Eocene Epoch).

Fossil-collection training and facilities. The complete program offered by Penn-Dixie Paleontological Park earned it the best marks for fossil park training through signage and on-site assistance. Although Trammel Fossil Park did not have an on-site paleontological mentor, the content of the on-site signage provided good instructions for fossil retrieval for the novice visitor and specifically noted where various fossil types would be located on the site. Additionally, Trammel provided a wash station. The lowest ranked U.S. fossil parks in fossil-collection training and facilities were the Rockford Fossil and Prairie Park and the Aurora Fossil Museum. The Rockford site had a wash station, but it was inadequate given the area of the quarry. Additionally, we encountered no signage on how to collect at the site. The Fossil and Prairie Center may provide some assistance and training, but it was removed from the collecting area and was not open when we visited. Aurora Fossil Museum received a low score in this category as well. The spoil pile was a distance from the museum and visitors simply searched for fossils without instruction.

Availability of on-site paleontological mentor. Volunteers or park personnel who are knowledgeable with a fossil site can make a large impact on visitor success and satisfaction. The Penn-Dixie Paleontological Park provided a college student as a paleontological mentor and also had volunteers manning the entrance station. The Wheeler High School Fossil Beds had a knowledgeable mentor at the booth. At Stonerose Interpretive Center, personnel were available for assistance, although no one was at the Boot Hill Fossil site. The lowest ranked fossil parks in this category were Trammel Fossil Park and Rockford Fossil and Prairie Park, which had no personnel or volunteers at the site to offer visitor assistance.

Availability of signage and brochures for fossil identification. Signage and brochures are especially important if a paleontological mentor is not available. The best signage system we encountered at the U.S. fossil parks was undoubtedly at Trammel Fossil Park. Not only was it scientifically correct, but it was placed within easy visitor access. Coded signage also marked the various formations at the site. Penn-Dixie Paleontological Park scored second on signage. The signage was removed from the collecting areas of several groups, but it was scientifically correct and informative. Penn-Dixie also provided a fossil identification card to each visitor group. Ranking the lowest in signage and fossil identification were Aurora Fossil Museum and Rockford Fossil and Prairie Park. Aurora’s signage and information were in the museum and not at the spoil pile, while Rockford Fossil and Prairie Park had too little signage for such a large quarry area.

Fossil park organization and wayfinding signage. The organization of the site was extremely important for enjoyable fossil-collecting experiences and informal science education opportunities. When sites were large, collecting areas were at a distance from park personnel or signage. Additionally, some sites did not provide signs within the outcrop, and we anticipated that some small visitors may easily become distracted and disoriented. For this reason, Rockford Fossil and Prairie Park scored worst in this category. The distance from the Stonerose Interpretive Center to the collecting site at Boot Hill Fossil site also earned low marks. The best site organization was displayed by Trammel, which had a well-organized site that could accommodate
collectors without crowding, but which maintained a reasonable
distance from the centralized signage to the outcrops. Likewise,
Penn-Dixie Paleontological Park was well-organized.

Accessibility: Park awareness and visitor safety considerations.
Our final variable category considered the accessibility of
the fossil park. Visitors should know about the park's existence,
find the fossil park easily, and interact with the site in a safe fash-
on. Penn-Dixie Paleontological Park scored highest in this cat-
gory, followed by the Aurora Fossil Museum site. Our on-site
experience with Rockford Fossil and Prairie Park resulted in our
questioning the safety of the site, especially with younger visitors
or guests who may underestimate the difficulty of accessing fos-
sils on the quarry slopes.

Overall fossil park rankings. By taking an average of the
fossil park's rating in each of the seven categories, we determined
a numerical value for each of the 7 U.S. fossil parks. In first place
was Penn-Dixie Paleontological Park, which we determined pro-
vided the best visitor experience and the greatest opportunities to
learn geobiological concepts in an informal fossil park environ-
ment. In second place was Trammel Fossil Park. Although this
site did not have any fossil park personnel present or a paleont-
ological mentor to aid in fossil identification, the superior signage
system, authentic collecting experiences, and site organization
contributed to a fossil park site that facilitated geobiology educa-
tion for the visitor.

Identification of Geobiological Ideas That Personal Fossils
Can Teach.
Throughout our case study research investigations, we sought
to determine the opportunities to learn geology and biology within
U.S. fossil parks. At the conclusion of our final case study inves-
tigation at the Aurora Fossil Museum and Stonerose Interpretive
Center sites, we determined some of the important geobiological
categories that personal fossils, collected at the U.S. fossil parks,
can teach. The outdoor collecting experience and the ownership
of fossils can serve as the platform from which to address the
gologic age of Earth, evolution, how environments change over
time, and biostratigraphic correlation. Because the fossils recovered
at any of the U.S. fossil park sites are millions of years old, the
fossils' ages facilitate the visitor's comprehension of the enorm-
ity of geologic time and the way in which this relates to our own
historical time frame. In addition, the fossils collected were often
from extinct organisms, such as trilobites, rugose corals, and
some extinct species of plants and sharks. Fossil ownership of
these extinct organisms provides a springboard to origin, ex-
ination, and evolution of life forms over Earth's history.

Fossils provide information for reconstructing past envi-
enments and are the only direct evidence of past life on Earth.
Marine fossils can be retrieved from live of the U.S. fossil parks.
These collecting sites are terrestrial today, and can serve to initi-
ate a discussion on how environments change over time, the rela-
tive amounts of time required for these environmental changes in
the fossil record, and how the human-induced climate changes of
the present fit into an Earth framework. Biostratigraphy, utilized
for correlating rock units of the same age over wide areas, was
first used in the early 1800s. Fossil succession is an important
tool utilized for relative age dating and can be more specific than
radiometric techniques. Additionally, the other principles utilized
in relative age dating—including superposition and lateral con-
finuity—can be introduced in the field in many fossil parks.

IMPLICATIONS FOR GEOSCIENCE EDUCATION

Our longitudinal case study research of U.S. fossil parks
demonstrated that fossil parks can serve as informal education
sites for meaningful science learning experiences. However,
through constant comparison, our research revealed that the U.S.
fossil parks differ in their authenticity, collecting experiences,
and visitor education programs. Our optimized model for fos-
sil park design provides guidelines for others contemplating the
establishment or instructional use of fossil parks. Similarly, our
ranking of the seven U.S. fossil parks researched in our longitudi-
nal investigation revealed individual parks' strengths and weak-
nesses. Our assessment of the opportunities to learn geobiology
at fossil parks can serve as a guideline for teachers or others
planning a trip to one of these sites. Using the identified
weaknesses, future visitors can better prepare their excursions
and optimize the opportunities to learn within this unique
informal venue. Furthermore, previous research has indicated
that directed field excursions can be more conducive to learning
because some students can have difficulties focusing upon indi-
vidual exhibits or activities within a large informal site (Clary
and Wanderee, 2009). The fossil park rankings on the seven key
variables should be helpful for planning a directed informal
science field experience.

We utilized lived learning experiences, observation of vis-
itors, and casual informal conversations with visitors, volunteers,
and park staff during our case study investigations. However, we
were unable to interact with visitors at each site, and many of our
conversations were brief. Therefore, future qualitative investiga-
tions should sample learner impact of fossil park signage, bro-
chures, collecting methods, and on-site mentors. More intensive
ethnographic studies at each park site will generate additional
data through more in-depth interviews and multiple observa-
tions of park participants, volunteers, and personnel over longer
periods of time and through seasonal variations. While our thick
descriptions and lived learning experiences testify to the authen-
ticity of our research, our optimized fossil park design model and
the key variables we designated for ranking fossil parks may not be
similarity weighted by other researchers, park personnel, or
visitors. Additional qualitative investigations can determine the
reception of our optimized fossil park model, and whether differ-
ent groups of people value different key variables for fossil park
learning opportunities. Furthermore, future research investiga-
tions may determine that key variables at one fossil park site may
not be transferable to all U.S. fossil park sites.

Therefore, our research investigation into the quality of
informal education offered by U.S. fossil parks is ongoing. More
research is needed to fully elucidate the effects of the fossil parks’ signage systems, on-site mentors, and fossil-collecting opportunities on informal geoscience education, and the ways in which informal learning experiences at fossil park sites can be optimized for the visitor.

CONCLUSIONS

For all seven on-site case study investigations of U.S. fossil parks, our focus was to identify the opportunities to learn and the features available to learn geobiology via active learning experiences for both students and families, and to identify those that subsequently led to a sound informal geoscience education program. The original data in phase 1 of our research investigations were collected at the first identified three U.S. fossil park sites through lived learning experiences. Through grounded theory, our research progressed toward the development of an optimal fossil park design, a tool that can be used in the development or improvement of a fossil park and the optimization of instruction within these outdoor learning venues.

Following the model development, we identified and investigated four other informal education sites (phases 2 and 3) that allowed the collection and retention of personal fossils, and that considered their primary mission to be advancing geoscience education. Comparative investigation of these additional fossil parks through the lens of the optimal fossil park design resulted in the identification of the available opportunities for visitors to learn important concepts in geobiology in outdoor settings. We affirm that fossil parks can serve as outdoor teaching laboratories to address geologic time, fossilization, evolution, biostratigraphy, biodiversity, and environmental change (Singer et al., 2005).

Our 7 yr qualitative research study concludes that fossil parks can offer scientific experiences to the public that contribute to geoscience literacy, although the individual effectiveness of each park is dependent upon key variables. There is no equivalent virtual substitute for direct interaction with Earth, and fossil ownership sparks thought about deep time, evolution of life forms, and environmental change over geologic time.

We caution that our interpretation is unique and reflects investigations of fossil park facilities and their analyses over a 4 yr period. Undoubtedly, some of the fossil parks may have since modified their designs, signage, and facilities resulting in improved geobiological education opportunities for the visitor. Our qualitative work does not aim to describe all parks in which fossils are displayed, but rather provides an illuminating flavor of the U.S. informal sites we identified that permit fossil collection and retention. We acknowledge that our comparative ranking of the seven U.S. fossil parks may or may not be the same if we visited each site again. Replication of this study may be affected by the season in which investigations are conducted, the economic conditions of the area, and the conditions of the site. Our interpretation and research serve as a snapshot analysis in time.

Multiple data sources were utilized in all of our case studies, including posted materials, brochures, and on-site signage. Additional data sources included unstructured informal conversations with fossil park personnel and visitors, and field notes from our lived learning experiences. Inter-rater reliability was good and was established within 95% agreement. Therefore, the internal validity of the research investigations was established through verification.

Our lived learning experiences at the seven U.S. fossil parks were unique, and therefore the external validity and the generalizability of our research to other informal educational sites outside of the fossil park realm are limited. However, we confirmed that the optimal fossil park design that emerged from the initial case study of the first three U.S. fossil parks (phase 1) had application and relevance to the subsequent four fossil park sites we researched in phase 2 (2005) and phase 3 (2006).

We note that our findings are in concordance with the principles of active, meaningful, and mindful learning and the learning theory of human constructivism. Visitors to fossil parks can have optimized geobiology education experiences when they are actively engaged in fossil collecting with awareness of both the purpose and context of collecting, when the geobiological information presented at the site accesses the learner’s existing knowledge framework, and when information and experiences at the fossil park have a context to the learner. The successful fossil park designs provide the context of geologic time, biodiversity, and environmental change through signage or a helpful paleontological mentor, and aid in the construction of visitors’ geological knowledge by scaffolding upon experiences and general knowledge.

We continue to search for additional U.S. fossil parks that offer informal geoscience education to the visitor and that fill a gap between the U.S. National Park System and undeveloped field experiences.

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