Runaway Dinosaur Tracks: Cooperative Efforts to Preserve Fossil Resources at Two National Natural Landmark Sites

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Long-term preservation of fossil resources has unique challenges, given that the natural preservation state for these resources is to be buried. Intentional or non-intentional excavation are the means by which we are made aware of paleontological resources. Once exposed, they become available for scientific discovery, study, and interpretation; however, they also become susceptible to weathering, erosion, and collection. Thus landowners of lands containing fossil resources, who are either charged with conservation by law, policy or organizational mission, or voluntarily elect to conserve fossil resources, face a variety of challenges and key decision points. This paper explores the methods undertaken and partnerships employed for long-term preservation of dinosaur track resources at two National Natural Landmark (NNL) sites. The Morrison Fossil Area in Colorado and Dinosaur Valley in Texas are designated NNL sites in recognition of their significant paleontological resources and both are actively addressing the issues associated with long-term preservation of such heritage resources.

The National Natural Landmarks Program was established by the Secretary of the Interior in 1962, under authority of the Historic Sites Act. Administered by the National Park Service (NPS), the primary program objectives are to identify, recognize and encourage the preservation of sites containing the best remaining examples of biological and geological features that illustrate our nation's natural heritage. With designation occurring on lands of any ownership, the NNL Program is the only natural areas program of national scope that recognizes outstanding examples of biological and geological features in both public and private ownership. To date, 586 sites in 48 states, 3 territories, and the Commonwealth of Puerto Rico have been designated as NNLs.

Landmark designation is not a land withdrawal, does not change ownership of the site, does not require public access, and does not dictate use nor impose any land use activities. It is a recognition program highlighting and raising public awareness of significant natural resources. Landmark designation also creates a partnership between the National Park Service and the landowner, such that the NPS can be an advocate for and assist in the conservation of significant natural resources.

Based on NNL significance criteria of illustrative character, present condition, rarity, diversity and value for science and education, NNL resources are considered to be some of the best examples of those biological or geological features within a bio-physiographic province. Potential NNL sites go through an in-depth evaluation by a qualified scientist(s) to

determine the fit of the potential site as it relates to these national significance criteria and in comparison to other sites with similar resources. Evaluation reports go through internal and external review and designation is ultimately conferred by the Secretary of the Interior, with owner consent. More information on the NNL Program can be found at www.nature.-nps.gov/nnl.

The Morrison Fossil Area (locally known as Dinosaur Ridge, see www.dinoridge.org), located approximately 35 miles west of Denver, Colorado, was designated a NNL in 1973. The site is significant as the site of the first major discovery of giant dinosaur fossil bones in North America. In the late 1800's, fossils from nine different species of dinosaur were recovered, seven of which were newly discovered species. The site also contains a dinosaur trackway with over 300 dinosaur tracks that were made by three types of dinosaurs and one crocodile.

The tracksite is located in the South Platte Formation, which is composed primarily of thin to massive sandstone units with thin shale interbeds, and has a slope of 37–38 degrees (77%). The site is also open and exposed to the outdoors and thus is susceptible to weathering (Figure 1).

Natural erosional processes have taken a toll on the tracksite over the years resulting in the loss of tracks. This has typically occurred in the form of small rocks slides. The interbedded shale begins to crumble after being compromised by water seepage and freeze-thaw cycles. This in turn results in the overlying track-bearing sandstone layer breaking up, and sliding down the face of the tracksite.

In April 2006, a sandstone slab containing several tracks sloughed off the main trackway and slid to the bottom of the hill. As previously discussed, this has been the natural progression of erosion at the site. Piecemeal solutions, including wire-mesh and shotcrete, a concrete diversion structure, rebar pins and metal strapping, have been implemented over the years in an attempt to arrest the erosion. However, these are typically short-term, band-aid repairs, versus substantial protection measures.

The Friends of Dinosaur Ridge (FODR), the non-profit managing entity at the site, was founded in 1989 to preserve the fossils on the ridge and to educate the public. Approximately 100,000 visitors, including 10,000 school children visit the site each year. In addition to its national significance and scientific value, the site's proximity to a large metropolitan area and

Figure 1. Main tracksite at Morrison Fossil Area National Natural Landmark (Dinosaur Ridge) in Lakewood, Colorado. Dinosaur tracks located in sandstone along the Dakota Hogback, tilted at a 37–38 degree slope. Photo by S. Hutchison.

easy access to viewing such dramatic evidence of life from millions of years ago, makes this site a favorite among locals. Given the site's significance, the mission of the FODR, and the continued loss of the resource from erosion, investigations into longer-term preservation options became imperative.

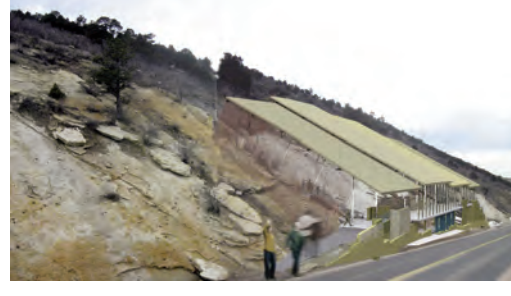
Using the partnership in place through the NNL designation, the expertise of two National Park Service Geologists were employed to provide an overall assessment of the condition of the tracksite and to offer short- and long-term management recommendations. They determined that if no action was taken, more tracks would continue to be lost and that over time, perhaps over several decades to a century, the entire tracksite is in jeopardy of being lost completely to a progression of slides. The FODR have also sought consultation and input from the State Historical Society, paleontologists, architects, and engineers, and have since determined that a structure over the tracksite is the alternative that would best provide for the long-term preservation of the track resources, thereby ensuring its continued presence for future generations.

The past couple of years have been spent designing a structure for the tracksite that will meet long-term resource preservation needs, provide viewing and educational opportunities, as well as meet aesthetic requirements. Situated on the side of a wide valley, the main tracksite at the Morrison Fossil Area can be seen for quite some distance. Thus in addition to the challenges associated with the steep setting of the tracksite, the view of Dinosaur Ridge has also been an important consideration in the structure's design. After much research, many versions, and passionate discussion, final renderings have recently been completed (Figure 2).

The proposed structure, which will include a solid foundation wall and perimeter drain at the top to divert water away, will protect the tracksite from the erosional effects of freeze-thaw cycles. Additionally, it will include a translucent roof to produce the flat natural lighting for best viewing, new interpretive exhibits on the second floor, and elevated walkways up either side of the trackway to provide for more public educational opportunities and new ways to view and experience the resources. A major fundraising campaign has recently been undertaken to help raise the money needed for construction (tracksite cover, $2 million dollars; a child in awe over dinosaur tracks for generations to come, priceless).

The second NNL site experiencing runaway dinosaur tracks is Dinosaur Valley. This NNL is located within Dinosaur Valley State Park just outside Glen Rose in the central hills of Texas (see www.tpwd.state.tx.us/spdest/findadest/parks/dinosaur_valley). Dinosaur Valley was designated a National Natural Landmark in 1968 in recognition of the series of trackways that contain some of the best preserved Sauropod and Theropod footprints. The site contains the first discovered and identified Sauropod trackways, and they are designated

Figure 2. Computer generated rendering of proposed tracksite cover for main tracksite at Morrison Fossil Area National Natural Landmark.



as the type specimen for that species. Additionally, one of the park's Theropod tracks was designated as the type specimen for Acrocanthosaurus. The tracks also provide evidence related to the herding, habits and locomotion methods of Sauropods and their interaction with Theropod carnosaurs. The Theropod tracks are a good source of information regarding the maximum speed of bipedal Theropods.

The dinosaur tracks at Dinosaur Valley are preserved primarily in limestone within the bed of the Paluxy River and tributary creeks (Figure 3). Therefore, as with the fossil resources at Morrison Fossil Area, the track resources at Dinosaur Valley are also susceptible to the natural effects of weathering. However, given the extent of the resources and their riverine location, building a structure to cover the track sites is not a viable management action; continued erosion and loss of tracks at this site are inevitable. Therefore, an important aspect of managing and preserving these important resources is having a thorough inventory of the track resources and ideally having those data digitally stored for easy retrieval and long-term, archival storage.

Figure 3. Theropod tracks preserved in the limestone bed of the Paluxy River at Dinosaur Valley National Natural Landmark, which is located within Dinosaur Valley State Park, near Glen Rose, Texas. Photo by M. O'Brien.

It was estimated that about 80% of the known track sites have been mapped at the park. The first maps were made in the late 1930's and mapping continued through the 1990's. However, these maps were recorded on paper using measuring tape, triangulation and a compass. These maps have not been gathered into a single geo-referenced map using modern GIS technology, thus the risk remains that the maps, which represent the park's primary documentation, are subject to loss. Additionally, as most of the tracks are located within the bed of the river, many of the tracks documented over the past 70 years are gone or are disappearing due to natural streambed erosion. Thus, there was a critical need for complete and digital documentation of the park's track resources.

The NNL status at the site made it eligible for funding through the NPS Challenge Cost Share Program (CCSP). CCSP funding was applied for to help address this need, and funding was awarded for 2008–2009. Project partners include the National Park Service, Texas Parks and Wildlife Department, Indiana-Purdue University, a volunteer paleontologist who has been involved with mapping at the park for the past 28 years, and the Friends of Dinosaur Valley. The overall goal for the project was to bring together the work of the past 70 years of track documentation into a long-term, geo-referenced digital format using GIS, to make the data accessible for future study and to guide in management decisions and preservation efforts, and to create a fully interactive map of the park's track sites to serve as an educational resource for park visitors.

A major effort to collect data took place during the summer and fall of 2008. Data were collected at most of the known track sites with one new site discovered along the way. Some of the park's trackways, at any given time are either above or below water. Dry track sites were gridded with chalk in one meter cells and oriented to magnetic north. These track sites were hand drawn, and where available, compared with earlier maps. In several instances tracks

were visible today that were not visible when the maps were drawn 10 or 30 years earlier and vice versa; tracks appearing in older maps are no longer visible at the track sites today. Thus, the value of previous map documentation can not be overstated. Moreover, using earlier maps in conjunction with existing maps provides a more complete picture of the tracksites. Another technique employed at some of the sites where dry tracks were accessible, was to hand-trace individual tracks onto large sheets of Mylar. These data are used for later refinement of the digital data.

The second step in the field involved digital documentation through the collection of photographs and GPS data. A 17-foot metal deer stand was used as the platform from which to take close range aerial photographs. Digital photographs were taken at the four cardinal directions and the center of each deer stand location, which was moved along the grid until the entire track site was photographed. This resulted in several hundred individual photographs that are now in the process of being painstakingly merged to create a photo mosaic of the entire site (Figure 4).

Sub-foot accuracy GPS points were also collected at the center point of each deer stand location and on individual tracks, data that continue to be collected. These data, when combined with digitized versions of the hand-drawn maps, result in fully geo-referenced versions of each track site.

After all the post-field data processing has occurred, Dinosaur Valley will have a fully geo-referenced digital record, in a long-term, archival format, of all known tracks within the park. Data have been captured down to the individual track level such that single tracks can be measured for length and width, and distances between tracks can be measured. Digital databases will be created to provide for easy access to information for park managers and for future scientific study and education. And finally, an interactive map will be created that will aid park visitors with identification and location of tracks.

While each fossil resource conservation situation has its own unique set of challenges, as can be seen with the two examples in this paper, some commonalities exist. First, it is important to explore and understand the range of alternatives available to best meet the preservation needs at hand. Whether its collecting data to capture the history or whether its capturing the resource itself, look at the variety of options available, explore what has been done in similar situations elsewhere, and look for new methods and technologies. What is available today is certainly different than what was available 20–30 years ago.

Second, utilize partners. Solicit the involvement of a variety of partners to provide different perspectives, expertise, and experience. This often assists in identification of alternatives, adds credibility, promotes collaboration, and enhances opportunities for cost-sharing.

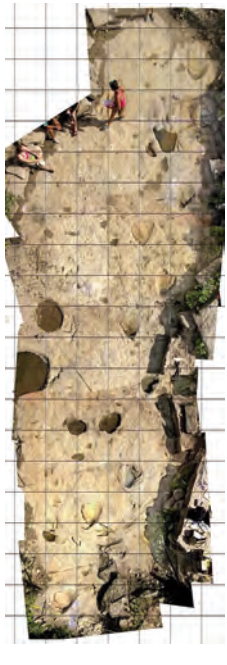


Figure 4. Photo mosaic of a dinosaur trackway at Dinosaur Valley National Natural Landmark.

Finally, engage the public. People are fascinated by dinosaurs and fossil resources. Get the public involved at whatever stages are appropriate. Find new ways to show them the resources and opportunities to learn and gain appreciation. Long-term preservation of all resources depends on a people who understand the value of their natural heritage.