

SECTION C — ALTERNATIVES FOR PROTECTION

A. CURRENT AND FUTURE THREATS TO THE SITE (NMMNH LOCALITY 846) FROM NATURAL CAUSES

Several paleontological tracksites around the world are preserved or protected (Table 4), and they all share similar problems with regard to natural processes and phenomena:

(1) Tracks occur in sedimentary rocks which are relatively soft and thus are susceptible to physical/chemical weathering and erosion if unprotected.

(2) Track-bearing rocks are usually well layered (laminated) and tend to exfoliate.

(3) For geomorphological reasons, large tracksites are often exposed in topographically low areas subject to water passage/collection (e. g., Clayton Lake, Dinosaur Valley, Lark quarry), or they are exposed on unstable slopes (e. g., Dinosaur Ridge). In either case, they are subject to elevated levels of weathering and erosion.

The Robledo tracksite has all three of these problems. In relation to natural problems, the site can be divided into two portions, the excavated area and the unexcavated area. The unexcavated area is not in danger from natural threats unless there is a major landslide or an anomalously large

Table 4. Principal paleontological tracksites with public access (from Lockley, 1986, 1991; Agnew et al., 1989 and the authors personal observations).

Name/Location	Protection Measures	Education
Dinosaur State Park, CT (Early Jurassic)	walled building over main site	full museum displays
Clayton Lake State Park, NM (Early Cretaceous)	wooden raised walkway overlook	signs
Dinosaur Ridge, CO (Early Cretaceous)	metal fence around main site	signs, brochure, guided tours
Dinosaur Valley State Park, TX (Early Cretaceous)	none	visitor center
Tuba City, AZ (Early Jurassic)	none	guides
Moab, UT (Early, Late Jurassic)	jeep trail that crossed one site redirected	signs, brochure
Samchampo, Korea (Early Cretaceous)	none	signs
Muenchehagen, Germany (Early Cretaceous)	structure over main site	signs, brochure
Barkhausen, Germany (Early Cretaceous)	fence	signs, brochure
Lark Quarry, Australia (Early Cretaceous)	structure without walls, sophisticated chemical measures (Agnew et al., 1989)	signs

flood. The excavated area exposes finely laminated siltstones and mudstones along the margin of an intermittent arroyo in a steep-walled canyon. Threats to the site from natural causes can be divided into three categories: (1) canyon walls; (2) arroyo; and (3) in situ problems. These problems can be categorized as follows:

A.1. Canyon walls

1. Water flow — canyon wall directs flow of runoff directly over tracksite
 - a. damage from water flow (erosion)
 - b. damage from transported debris (erosion)
 - c. water introduced to the tracksite enhances chemical and physical weathering.
2. Topography — erosion and weathering of canyon walls creates debris which falls onto tracksite, decreases safety and enjoyment of site by visitors and must be removed.
 - a. large debris falls and creates impact damage.
 - b. large and small debris (dust, sand) falls, covers site to some degree and impacts aesthetics and interpretive value of site.
 - c. large landslide completely buries site.
3. Shape of canyon — affects airflow and animal movement.
 - a. wind funnelled down canyon carries dust which lands on site, affecting aesthetics, visitor interpretation and comfort (blowing dust).
 - b. in the summer on still days, standing air in the canyon reaches high temperatures which can cause damage to tracksite (thermal stress causes compaction and expansion of laminated rock) and discomfort to visitors.
 - c. topography directs animal movement along bed of canyon causing damage by trampling to tracksite.

A.2. Arroyo

Intermittent water flow along the arroyo damages the tracksite.

1. Discharge — because of the canyon geometry, large discharge events will flood the tracksite, causing damage to the track surface.
 - a. damage by flowing water
 - b. damage by saltation and bed load.
2. Severity of intermittent flow retards vegetation buildup on the canyon floor that would provide stabilization and hence more channelized flow.

A.3. In situ threats

1. Physical weathering
 - a. freeze-thaw
 - b. exfoliation
 - c. heat (expansion/contraction)
2. Chemical weathering
 - a. acid rainfall/runoff (buffered to some degree by limestone in the area)

B. CURRENT AND FUTURE THREATS TO THE SITE FROM HUMAN FACTORS

Human threats to the site can be divided into several categories: (1) flagstone quarrying; (2) deliberate human threat (theft, vandalism); and (3) unintentional human threat.

B.1. Flagstone quarrying

1. The proximity of flagstone quarrying activity impacts the physical environment of the site and could even damage the site.
 - a. dust blowing into tracksite area.
 - b. noise pollution.
 - c. shockwave damage to site from possible blasting.

2. Quarrying affects aesthetic values of tracksite.
 - a. noise.
 - b. visual distraction.
 - c. dust.
3. Psychological affect to visitors/local populace when quarrying is allowed in rocks adjacent to protected area that are known to contain tracks. This may encourage deliberate human threats (see below).

B.2. Deliberate human threats

1. Theft of tracks.
 - a. for private collections or commercial sale.
 - b. tracks taken during theft of flagstone.
2. Vandalism

B.3. Unintentional human threats

1. Unintentional theft by individuals who remove tracks in the absence of knowledge that this is illegal.
2. Physical damage to site by walking on it.
3. Physical damage to site by walking in areas surrounding tracksite which facilitates erosion.
 - a. physical erosion.
 - b. destruction of erosion-retarding vegetation.

C. METHODS FOR THE PROTECTION OF THE DEPOSITS

Protection methods will to a large degree depend on the selected option for the interpretation of the site and the development of a display/interpretive facility. There are five broad options:

1. No action.
2. Interpretive signage/trails (e.g., labelled trail for self-guided tour; kiosk with brochures and displayed information).
3. Small interpretive facility (e.g., small exhibition facility, minimal staffing).
 - a. on/near site with trail to site.
 - i. no protective measures at site.
 - ii. protective measures at site.
 - b. offsite
 - i. no protective measures at site.
 - ii. protective measures at site.
4. Intermediate size facility (e.g., exhibit facility with some scientific laboratory space and a small staff that includes a technician trained in paleontology preparation/conservation).
 - a. on/near site with trail to site.
 - i. no protective measures at site.
 - ii. protective measures at site.
 - b. offsite
 - i. no protective measures at site.
 - ii. protective measures at site.
5. Large facility (e.g., exhibit facility with collection facility, research and preparation laboratories and full staff of interpretive and research personnel).
 - a. on/near site with trail to site.
 - i. no protective measures at site.
 - ii. protective measures at site.
 - b. offsite
 - i. no protective measures at site.
 - ii. protective measures at site.

Obviously the choice of one of the above options affects what protective measures need to be taken at the site. For example, problems of physical protection of the site will depend on whether or not there is a structure over the site and on the amount of human traffic. In the absence of a choice of any particular management plan we will address all the hazards that were listed in the previous section.

A variety of tracksites around the world have been protected to varying degrees (Table 4). In a broad sense, protection methodologies have been:

1. No action.
2. Physical removal of tracks to a facility (Table 5).
3. In situ protection methods.

The first option requires little further discussion. The Robledo tracksite currently is an open excavation pit and could be reclaimed by backfilling. This would obscure and insulate the site from most natural and human threats for many years.

Option 2, physical removal of the tracks, can only be a partial solution because of the huge volume of tracks at the Robledo site. Their complete excavation would be extremely expensive and might even be physically impossible as the track-bearing layers plunge under a very tall hill. A partial removal of tracks has already been carried out, and more is possible. Factors to be considered before further excavation are:

1. Will further excavation affect slope stability and erosion?
2. Will further excavation affect the aesthetics of the site?
3. Will further excavation provide new kinds of tracks or better display specimens of track types already collected?
4. The choice of facility type for interpretive purposes will affect any possible further excavation. If a display facility is to be built, then some further excavation for display purposes would be reasonable. However, if no display facility is to be built and visitation is to be encouraged or facilitated at the in situ tracksite, then further excavation should be kept to a minimum.

Assuming that further excavation will be small relative to that which has already been carried out, we will now discuss in situ protection measures from the natural and human threats to the site.

C.1. Protection from natural threats

C.1.a. Canyon walls

1. Water flow.

Water flow down the canyon walls can be redirected to avoid the site, but cannot be stopped. Reinforced channels could be constructed on the slope above the tracksite but they would:

- a. be expensive.
- b. be aesthetically unpleasing.
- c. not totally retard water flow onto the site.

2. Topography

It would be prohibitively expensive and environmentally risky to attempt to change the shape of the canyon. However, retaining walls and chain fences could retard the downslope passage of debris onto the tracksite. The Colorado Geological Survey has pioneered several such methods in conjunction with the construction of Interstate 70 through Glenwood Canyon, Colorado. Some such methods must be undertaken if the tracksite is not to be covered by debris in a relatively short time. Chemical and vegetative protection methods can hinder the movement of finer debris (Morrison and Simmons, 1977). However, the Las Cruces area climate precludes the use of soil-binding vegetation, and chemical methods would be expensive and environmentally dangerous.

3. Canyon shape.

Any measures to combat the flow of air through the canyon would be expensive and environmentally risky. Animal movement across the tracksite can easily be hindered by physical barriers (rockpiles, fencing, etc.).

Table 5. Some principal US facilities that display vertebrate tracks.

Name	Location
American Museum of Natural History	New York, NY
Appleton Cabinet	Amherst, MA
Dr. Alf's Museum	Claremont, CA
Morrison Museum of Natural History	Morrison, CO
Museum of Northern Arizona	Flagstaff, AZ
Museum of Western Colorado	Grand Junction, CO
New Mexico Museum of Natural History & Science	Albuquerque, NM
University of Eastern Utah Prehistoric Museum	Price, UT
University of California Museum of Paleontology	Berkeley, CA
Utah Field House of Natural History	Vernal, UT

C.1.b. Arroyo

The greatest natural threat to the tracksite is flooding of the arroyo. Flood control measures are difficult because of the constricted cross section of the canyon in the tracksite area. The most radical answer is to construct a deep artificial channel against the canyon wall opposite the tracksite. The channel would have to be deep to carry flood discharge and would therefore have to extend a long way down the arroyo to not effect the stream gradient. This option could be expensive, aesthetically unpleasing and might have severe ecological impacts. Lesser measures could include some deepening or/and stabilizing of the main channel or the construction of barriers or chain fences to retard the movement of large debris over the tracksite.

C.1.c. In situ threats

Both physical and chemical weathering will be affected by the nature of any protective structure that may be constructed at the site. A walled building over the site is probably impractical because of the threat of flood damage. However, such a structure would halt physical and chemical weathering if there was climate control within the building. A more likely option is a roof supported by pillars (canopy). Weathering could only be partially retarded by a canopy.

The most sophisticated weathering retardation methods that have been utilized at a tracksite are those detailed by Agnew and colleagues (Agnew and Oxnam, 1983; Agnew, 1984; Agnew et al., 1989) for the Lark Quarry site in Australia (see Appendix 4). This site has a roofed structure, guttering to retard water retention and raised walkways. In addition, chemicals have been applied to the trackway surfaces.

Various chemicals can be applied to trackway surfaces to strengthen them. Most clear varnishes produce degradation products that are harmful to the rock (Winkler, 1975; Torraca, 1982; Amoroso and Fassini, 1983). However, colorless silicon resins break down into harmless silica, carbon dioxide and small organic molecules (Mavrov, 1983; Roth, 1982). They are a feasible option for the Robledo site and are what has been used at the Lark Quarry site (Agnew et al., 1989).

Apart from the surface itself, it is important to stabilize vertical cracks in the track-bearing rocks. Agnew (1984; Agnew et al., 1989) developed an environmentally sensitive, and relatively inexpensive method to stabilize cracks in a trackway surface. He filled in cracks with flexible polyethylene foam rod which was then covered with a pigmented elastomer-sand mixture. Filling of cracks is important for several reasons: (1) to prevent breaking at the edges of cracks; (2) to stop water and dust from entering cracks; and (3) for aesthetic reasons.

It is important that individuals with strong backgrounds in geology, engineering and/or natural history conservation be involved in any conservation effort. There must be frequent continued monitoring of the stability of the site.

C. 2. Protection from human threats

C.2.a. Flagstone quarrying

It is very unfortunate that large scale flagstone quarrying has been allowed to encroach on the tracksite area, particularly in the last few years when the importance of the tracksite has been realized. The authors of this report strongly recommend all flagstone quarrying activity cease within one mile of the perimeter of the area that is to be set aside for protection. This is the only way to eliminate the threats (discussed above) that flagstone quarrying poses to the site.

C.2.b. Deliberate human threats.

An unfortunate consequence of the publicity which has been afforded the Robledo tracksite, its accessibility and the lack of protective measures, has been an increased risk of theft and vandalism. A minimum protection measure is a regular (daily) patrol by a federal ranger. The maximum protection would be the construction of a facility with quarters for staff who would be permanently present on/near site. The authors believe one of these protection measures be initiated as soon as possible to protect the area.

C.2.c. Unintentional human threats

Education is the answer to most unintentional human damage. A minimum option is the erection of signs that indicate it is illegal to collect vertebrate fossils, including tracks, in the area and what trails should be used. This, however, has the disadvantage of drawing attention to the site.

A more expensive option is to improve selected trails with sand/gravel and barriers. Other education methods will depend on which facility option is adopted (e. g., free brochures in a kiosk or a staffed interpretive center).

D. POTENTIAL FOR COOPERATIVE AGREEMENTS WITH INDIVIDUALS AND/OR INSTITUTIONS

The Robledo tracksites are of great educational significance, scientific importance and public interest. Therefore, there is considerable potential for cooperative agreements between the BLM (the agency that administers the tracksite land) with a variety of institutions and individuals. Such agreements could involve one or more of four areas: public education, tourism, exhibits and scientific research.

D.1. Public education

The Robledo tracksite is a natural outdoor laboratory for educational purposes. A possible model for its educational development is Dinosaur Ridge in Colorado, which includes a large tracksite. The Friends of Dinosaur Ridge (a nonprofit organization: see Appendix 5) runs tours for thousands of local schoolchildren every year, holds teacher orientation sessions and raises grant money from educational funds to facilitate school visitations (e. g., pay for school buses). It is likely that strong links can be forged between the Robledo tracks project and local school districts.

The possibility of establishing a locally-based, private foundation (support organization) similar to the Friends of Dinosaur Ridge for the tracksite should be investigated. Federal precedent for such support organizations already exists. The Petrified Forest Museum Association, for example, is a private foundation that supports research, education and other activities at the Petrified Forest National Park, Arizona.

D.2. Tourism

There is already strong public interest in the Robledo tracks, and further development of the site could stimulate a large visitation. As a result, the New Mexico Department of Tourism and local chambers of commerce will undoubtedly wish to become involved in the project.

D.3. Exhibits

A possible cooperative partner in the design and construction of educational exhibits that interpret the tracksite is the New Mexico Museum of Natural History and Science. This institution is locally based, heavily involved in research at the site and has an exhibits staff that has already worked with federal agencies such as the U.S. Forest Service to construct educational displays in natural history. The Museum currently has a cooperative agreement with BLM regarding repositing paleontological data from BLM-administered lands in New Mexico (**Appendix 6**).

D.4. Scientific research

Many institutions and individual scientists will be attracted by the scientific importance of the Robledo tracksites once they are more fully documented. The most obvious research partners to coordinate this research are the three institutions most involved in the initial studies, namely the Smithsonian (National Museum of Natural History), New Mexico Museum of Natural History and Science and the University of Colorado at Denver (Department of Geology, Dinosaur Trackers Research Group).