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HIGH RESOLUTION THREE-DIMENSIONAL LASER-SCANNING OF THE TYPE SPECIMEN OF *EUBRONTES* (?) *GLENROSENSIS* SHULER, 1935, FROM THE COMANCHEAN (LOWER CRETACEOUS) OF TEXAS: IMPLICATIONS FOR DIGITAL ARCHIVING AND PRESERVATION

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ABSTRACT

The lower member of the Glen Rose Formation (Albian, Lower Cretaceous) in what is now Dinosaur Valley State Park preserves dinosaur trackways of theropods and sauropods. An excavated theropod track was built into the wall of the bandstand at the Somervell County Courthouse by the citizens of Glen Rose, Texas, in 1933 and later designated as the type specimen of the ichnospecies *Eubrontes* (?) *glenrosensis*. To this day, this unique paleontological and cultural resource attracts visitors. Over the past 74 years, exposure to the elements has caused erosional loss, altering the shape of the track impression, but to an unknown degree. In order to preserve the current state of the type specimen and provide a baseline for future analyses, 3D laser scanning was employed to perform *in situ* digitization of the track. The scans were post-processed to generate a high-resolution 3D digital model of the track. The model was rendered in various media formats for viewing, publication, and archival purposes. Raw scan data and industry-standard 3D object files formats are available for download. Portable 3D laser scanners capture original fossil morphology and texture, thus providing a low cost, high fidelity alternative to traditional molding and casting. The results demonstrate the advantages of using portable laser scanners to capture field data and create high-resolution, interactive models that can be digitally archived and made accessible via the worldwide web for research and education.

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INTRODUCTION

The Glen Rose Formation represents the transgression phase of a transgressive-regressive sequence within the Lower Cretaceous Trinity Group (Upper Aptian – Lower Albian) of Central Texas (Jacobs and Winkler 1998). The Glen Rose Formation, and indeed the entire Trinity Group, preserves a diverse vertebrate fauna represented by body fossils (Winkler et al. 1990). At the type locality in Somervell County, Texas, the Glen Rose Formation is approximately 75 m thick and is considered earliest Albian in age (Rodgers 1967, Young 1967, Perkins 1987, Winkler et al., 1989, Jacobs and Winkler 1998). The Glen Rose Formation is subdivided into three members. The upper member consists of alternating limestones and marls. The middle member is the most extensive unit, consisting of lime mudstones, wackestones, and calcarenites. The lower member consists of alternating arenaceous limestones and mudstones (Winkler et al. 1989). Sediments in the lower member formed on shallow subtidal to tidal flats (Hawthorne 1990), preserving extensive tracks of theropods and sauropods, as well as rare ornithopod tracks (Farlow 1987, Pittman 1989, Hawthorne 1990).

Since their discovery in the early part of the 20th Century, dinosaur tracks have been an integral part of the human as well as geological history of North Central Texas (Bird 1985, Jacobs 1997, Jasinski 2008). In 1935, Shuler formally described the large theropod track embedded in the stone wall of the bandstand in the Somervell County Courthouse square in Glen Rose, Texas. Shuler (1935) tentatively assigned it to the ichnogenus *Eubrontes* (?) as a new ichnospecies *Eubrontes* (?) glenrosensis (Figure 1.1, Shuler 1935, Albritton 1942, Langston 1974, Farlow 1987). The specimen was originally from the “fourth crossing” (Hendrix-Ramfield crossing) of the Paluxy River, that now lies in Dinosaur Valley State Park, approximately 6 miles west of the town of Glen Rose (Shuler 1935, Jasinski 2008). As a type specimen, conservation is important, but in this case less than optimum. The footprint, preserved as an impression in limestone (Figure 1.2), is exposed to weather and has suffered visible erosion. However, given the cultural and historical significance of the specimen, removal to an institutional collection is not feasible. Therefore, our goals were to: (1) preserve the current state of the track surface as a 3D facsimile for archive and conservation, (2) provide a baseline for study of future erosional damage, and (3) provide a low cost, accessible method of distribution for study and outreach.

METHODS

Producing casts by traditional techniques, such as rubber or silicon molds, were rejected due to cost of material, labor, limited life span, storage issues, and potential damage to the track. Although casts have been used successfully for replication and distribution of fossils, including tracks, recent advances in 3D digitizing technology provide a high fidelity, low cost means of producing facsimiles that can be used in a variety of ways.

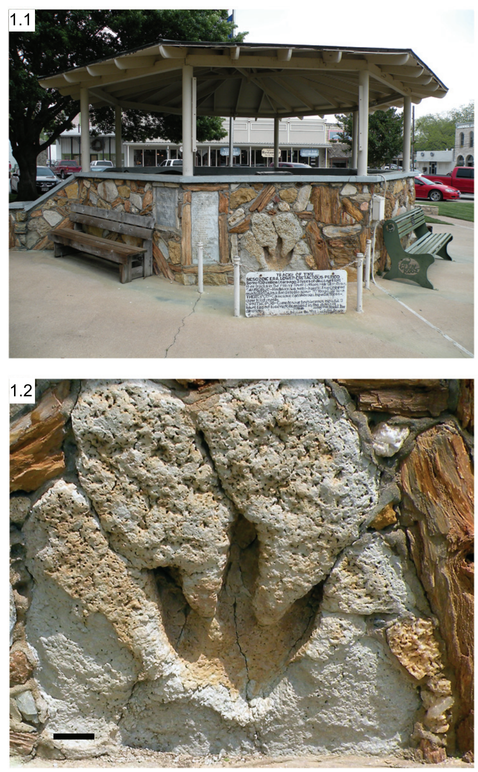

FIGURE 1. The type specimen of the ichnospecies *Eubrontes* (?) *glenrosensis*. **1.1** Track embedded in the stone wall of the bandstand in the Somervell County Courthouse square in Glen Rose, Texas; **1.2** Close up view of the type specimen. Notice eroded lower section of the track. Fossil wood is from the Paluxy Formation, which overlies the Glen Rose Formation. Scale bar equals 100 millimeters.

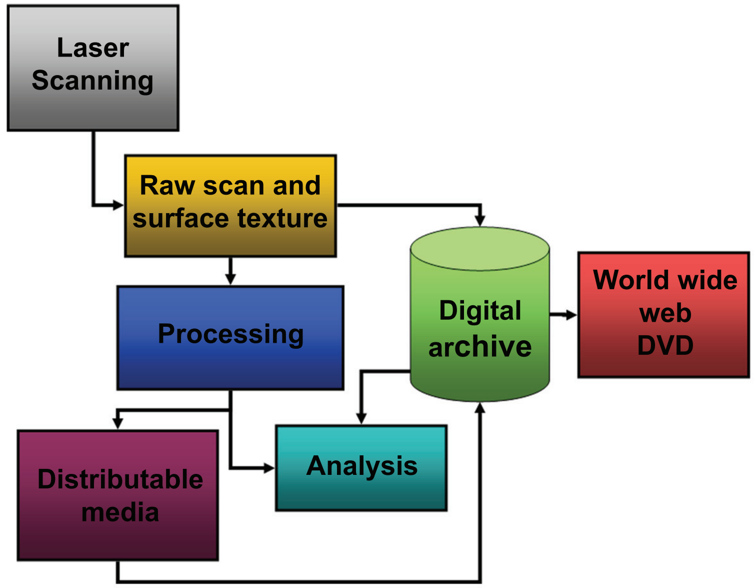

FIGURE 2. Schematic flow chart illustrating the 3D digitizing process.

Figure 2 provides an overview of the process employed to achieve our aforementioned goals.

Data Acquisition

We employed a NextEngine™ HD Desktop 3D scanner and ScanStudio™ HD PRO software (NextEngine™ 2008, Figure 3.1) running on a standard Windows XP 32 laptop. The scanner and pc were powered from outlets available on the bandstand. A tent was required to control lighting and maximize laser contrast (Figure 3.2). Based on the large size of the track (640 mm x 430 mm), precision was set to wide mode for single scans, capturing a view approximately 250 by 330 mm. The optimum recording distance from the scanner to the footprint was between 400 mm to 480 mm, measured before each scan. To ensure the greatest resolution, the NextEngine™ was set to HD (high definition), a tolerance of 0.13 mm, and a smoothing level of one. A surface attributes setting (light - dark) of 60% and matte surface were determine experimentally to give optimum color fidelity and surface capture. Data capture was focused primarily on the track impression and not on the peripheral surface of the limestone block. Multiple scan angles were required to capture all internal track surfaces and minimize occluded surfaces. Scans were rough aligned within ScanStudio™. Fifty-two overlapping scans (~2.0 GB in size) were saved. The scanner captured both point cloud data and RGB color textures during the scanning process, removing the need to integrate scan data with secondary surface images to create a photorealistic model. Other scanner technologies may require this additional step.

Data Processing and Archiving

Raw scans were imported into Rapidform® XOR2™ Redesign (INUS 2009) to align and merge them into a single 3D model. The final 3D model was exported in Wavefront OBJ (Rose and Ramey 1993) format that includes mesh, material, and texture files (*.obj, *.mtl, *.jpg). LightWave 3D® version 9.3 software (NewTek 2007) was used to render the 3D object into common web accessible media file formats (Figures 4, 5, Appendix 1). Raw ScanStudio™ files, processed 3D object file (Appendix 2), and additional media formats were archived within the Shuler Museum of Paleontology at Southern Methodist University, Texas.

Erosional Analysis

Visual inspection reveals that the track-bearing limestone surface has undergone deterioration since its mounting in 1933 (Figure 1.2), but to an unknown degree. Although theoretically possible, we made no attempt to quantify the morphology present at the time of Shuler's publication. Shuler (1935, figures 2, 3) did make clay molds and plaster casts of the bandstand track; however, those and his original photographs and notes are now lost; therefore, quantitative comparisons with first generation facsimiles was not possible. To qualitatively assess erosional loss, we made visual com-

FIGURE 3. NextEngine™ HD Desktop 3D scanner. **3.1** Type specimen *Eubrontes* (?) *glenrosensis* in the process of being laser scanned. Scanner size is 223.5 mm x 91.4 mm x 276.9 mm; **3.2** Tent to minimize sunlight on the footprint and scanner.

parisons with figure 1 from Shuler's original 1935 publication (Figure 6.1).

The 3D digital model provides a baseline to monitor future erosion using quantitative digital techniques. To demonstrate the potential of erosional monitoring, we modified the mesh of the 3D facsimile. Using Rapidform® XOR2™ Redesign's mesh tools, randomly chosen surface areas along the outer edges of the track impression were altered (Figure 7.1 - 7.2). Within Rapidform® XOV2™ verifier software (INUS 2009), the modified scan model was compared to the baseline model to calculate the amount of deviation. Whole deviation analysis of XOV2™ aligns and compares spatial coordinates of the vertices, or points, in the new scan model to those of the baseline model, and calculates the gaps between points that depart, generating various reports that quantify the area and degree of divergence (Figure 7.3).

Renderings of Digital Model

A two-dimensional image of the color mapped 3D model was rendered in Lightwave 3D (Newtek) to replicate a similar camera view and shadowing to what is seen in Shuler's (1935) figure 1 (Figure 6.2). The camera view and light origin were visually approximated based on shadows in Shuler's (1935) figure 1, and we made no assumptions as to camera type, lens, or distortion introduced by either. A second false color image of the 3D model was rendered to illustrate the relief of the impression, with cool colors indicating the deeper areas of the track (Figure 6.3). The render was done from the same perspective but with self-lighted surface attribute (luminosity = 100%) to eliminate shadows.

RESULTS

The full resolution 3D digital model is comprised of more than 1,000,000 poly-faces and over 500,000 vertices with a resolution (inter-vertex spacing) of 1.2 mm, and stored in Wavefront format (*.obj), which retains color surface mapping and the underlying mesh. The model in this format is approximately 145 MB (Appendix 2).

Comparison of Shuler's (1935) figure 1 with the 3D model provides a relative assessment of shape change in the track impression and indicates some erosion has occurred (Figure 6.1–6.3). In particular, Shuler (1935, p. 10, figures 1, 2) described the bottom contour of the track [the heel of the track] as having a ~10 cm wide projection. Today the "projection" is eroded; leaving a more rounded posterior edge, which is now approximately 15 cm wide (Figures 5, 6.2–6.3, Appendix 1). In addition, outer surface areas posterior to this edge have apparently fractured and fallen away (Figure 1.2).

The results of digital comparison of the 3D model with a synthetically altered version, demonstrates how weathering may be quantified in the future when a new set of scans are taken after the occurrence of natural erosion. The result of the deviation analysis (Figure 7.3) displays areas with zero deviation as yellow or cyan on the color map, while areas that vary from the baseline model appear as cool colors (negative deviations). Using commonly available software tools such as Rapidform, boolean subtraction of new scans from the baseline model yields volumes that can be used to quantify total volume loss, and point samples can be used to calculate the gap distance along nor-

FIGURE 4. Scanned images of the type specimen *Eubrontes* (?) *glenrosensis* shown in stereo pairs. Scale bar equals 100 mm.

mals between the two scan models (measurements in red boxes). In our example, the total volume change is 6,152.9 mm^3 (Figure 7.3). The volume of loss can be produced as a 3D mesh and used to construct physical 3D models of "lost" volumes for restoration purposes.

DISCUSSION

The application of computed tomography (CT) and 3D laser scanners has become widespread, producing high quality 3D digital models used in accurate fossil restorations, mass estimations, biomechanical studies, and finite element analysis (Lyons et al. 2000, Motani 2005, Rayfield 2005, Polcyn et al. 2005, Boyd and Motani 2008, Smith and Strait 2008, Rybczynski et al. 2008, Falkingham et al. 2009). In paleoichnology, LIDAR (Light Detection and Ranging remote sensing system used to collect topographic data) and photogrammetry have been incorporated to capture high-resolution images from remote localities and sites with large concentrations of dinosaur footprints (Breithaupt et al. 2004, Bates et al. 2008).

This paper demonstrates the feasibility of using portable 3D laser scanners to capture field data and create high-resolution, interactive 3D models of at-risk natural history resources. A portable 3D laser scanner can be used as a method of capturing data while visiting institutions and collections, as well as producing facsimiles of material that is normally inaccessible, too large, or too fragile to mold and cast. Laser scanning is non-invasive, whereas in many molding and casting procedures, the molding material may damage specimens.

Dinosaur tracks and other trace fossils are geologic features and as such are subject to the same natural processes as other rock formations. Weathering and other geological processes can alter the track both after its initial formation and during its subsequent surface exposure as a trace fossil. In addition, the vertical placement of the type specimen of *Eubrontes* (?) *glenrosensis* Shuler (1935) in the bandstand wall introduces the effects of gravity to the weathering process. Chemical stabilizers applied to the surface of footprints can temporarily halt erosion; however, this typically consolidates only the outer surface layer of rock, causing spalling (the flaking of material) and accelerated erosion.

Using a high-resolution 3D model of an at risk specimens, erosional rates can be monitored to provide the needed information for future planning and conservation. By creating an accurate 3D digital model, the current condition of the type specimen of *Eubrontes* (?) *glenrosensis* Shuler (1935) can now be used as a baseline to monitor future erosion. Using established protocols, 3D scanning can be repeated periodically to quantify and graphically display track erosion (Figure 7.3).

Apart from removing the bandstand track from public display, the loss of this culturally and scientifically important fossil is inevitable, emphasizing a greater need for long-term preservation of the type specimen. 3D laser scanning, or digitizing by CT, allows for the creation of a digital equivalent of a plastotype (any artificial specimen molded and casted directly from the primary type, Morningstar 1924). We propose the term "digitype" to refer to this particular use of digital facsimile. Plastotypes are not currently recognized by the ICZN (Interna-

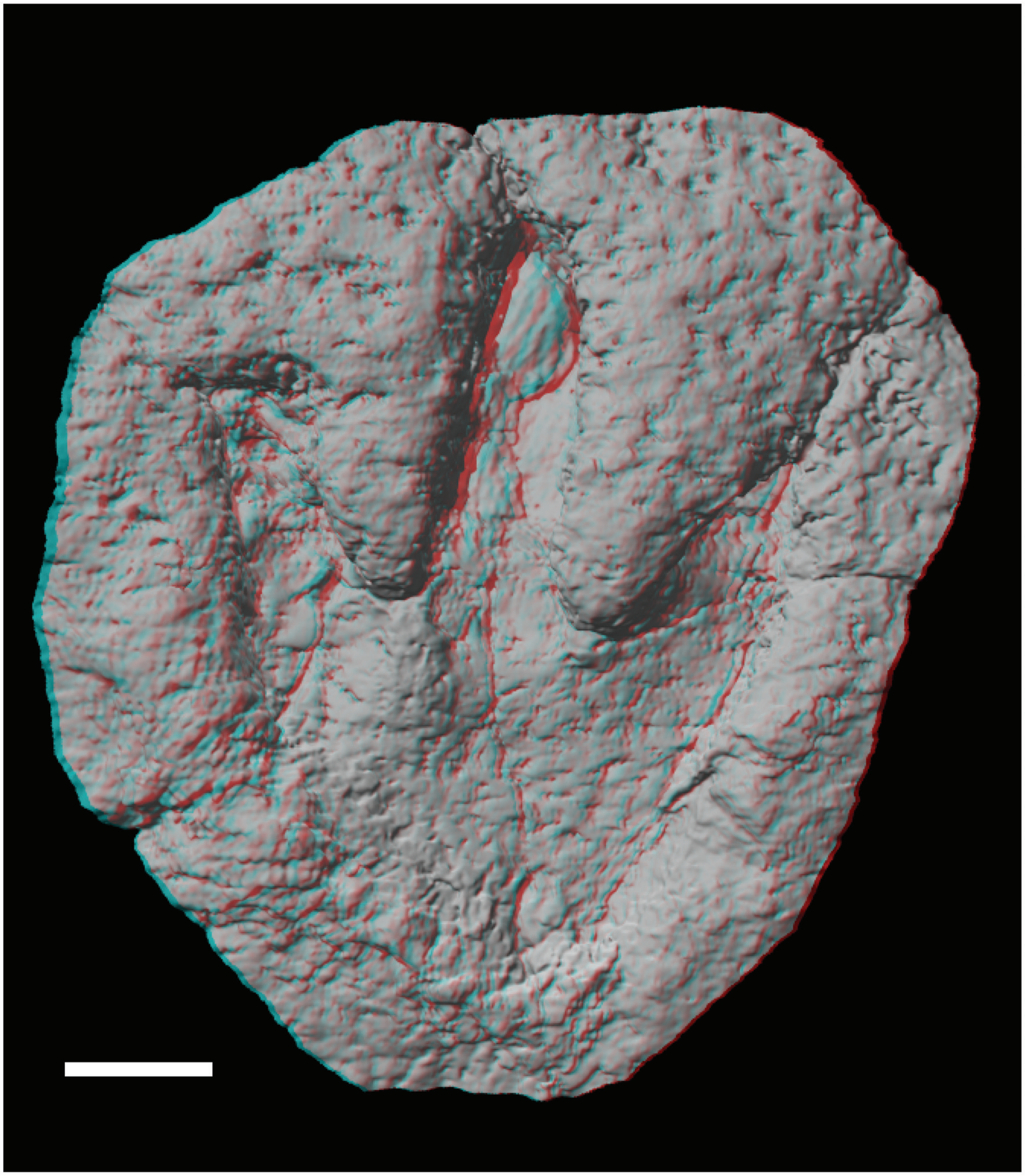

FIGURE 5. Image of the type specimen *Eubrontes* (?) *glenrosensis* shown as an anaglyph. Scale bar equals 100 mm.

tional Commission on Zoological Nomenclature) and currently could not replace the actual specimen as an official representation of that taxon. However, illustration or description of a syntype as a lectotype can be treated as designation of the specimen, whether the specimen exists or not (ICZN. 1999, Article 74.4). In our opinion, this policy reflects a somewhat dated view; given the fidelity of current CT and laser scanning technology, digital vouchers should enjoy the same status.

As the technology to capture 3D data has become more commonplace, digital archives and online museums have become an important way for researchers to distribute data to peers, educators, and the public (Smith and Strait 2008). Database management and digital archives require long-term storage and means of retrieval of digital

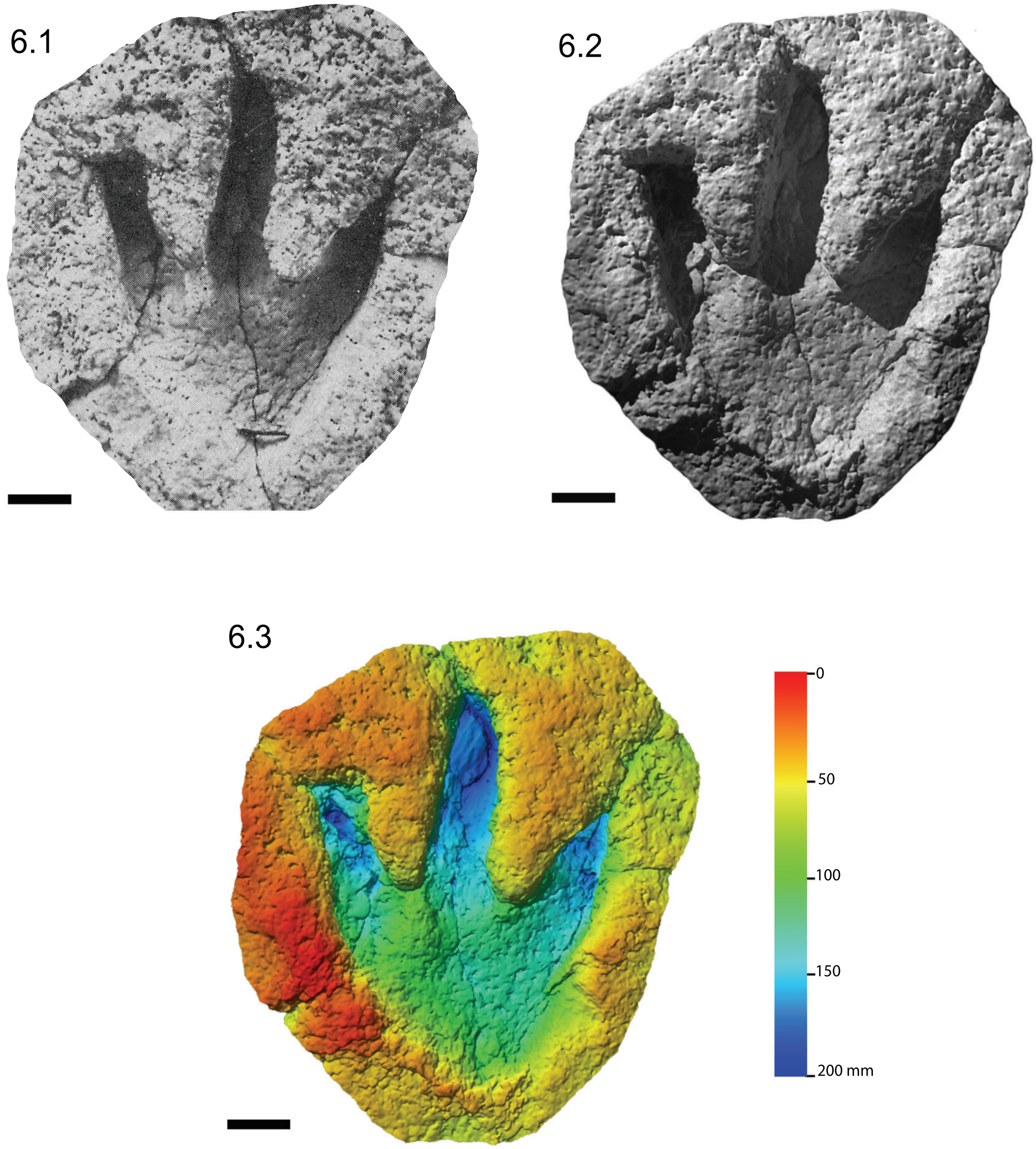

FIGURE 6. Image comparrisons of the type specimen *Eubrontes* (?) *glenrosensis*. **6.1** Shuler's (1935) Figure 1 used to evaluate the amount of erosional loss. Note the pen knife resting in the bottom of impression; **6.2** 2D image of the 3D digital model of *E*. (?) *glenrosensis*, rendered to replicate the same camera view and shadowing as in Shuler's (1935) Figure 1; **6.3** 2D image of 3D model color-coded to indicate relief; Scale bar equals 100 mm.

information (Chen 2001). As a result, the preservation of digital information has become increasingly more important as we expand our technical resources. Unlike physical specimens and casts, digital facsimiles demand periodic attention to handle rapid technical advances in media formats. Preservation becomes more then just the product of a program, but process as well (Chen 2001). In addition, technical advances demonstrate the need to develop standard formats to ensure data accessibility. Currently there is no single 3D format that is universally portable and accepted by all software manufacturers and researchers. Until there is, researchers can take advantage of commonly used file formats, such as Wavefront OBJ (Rose and Ramey 1993) and Stanford PLY Polygon (Turk 1998) formats, both which provide the ability to move 3D data between application, and allow dis-

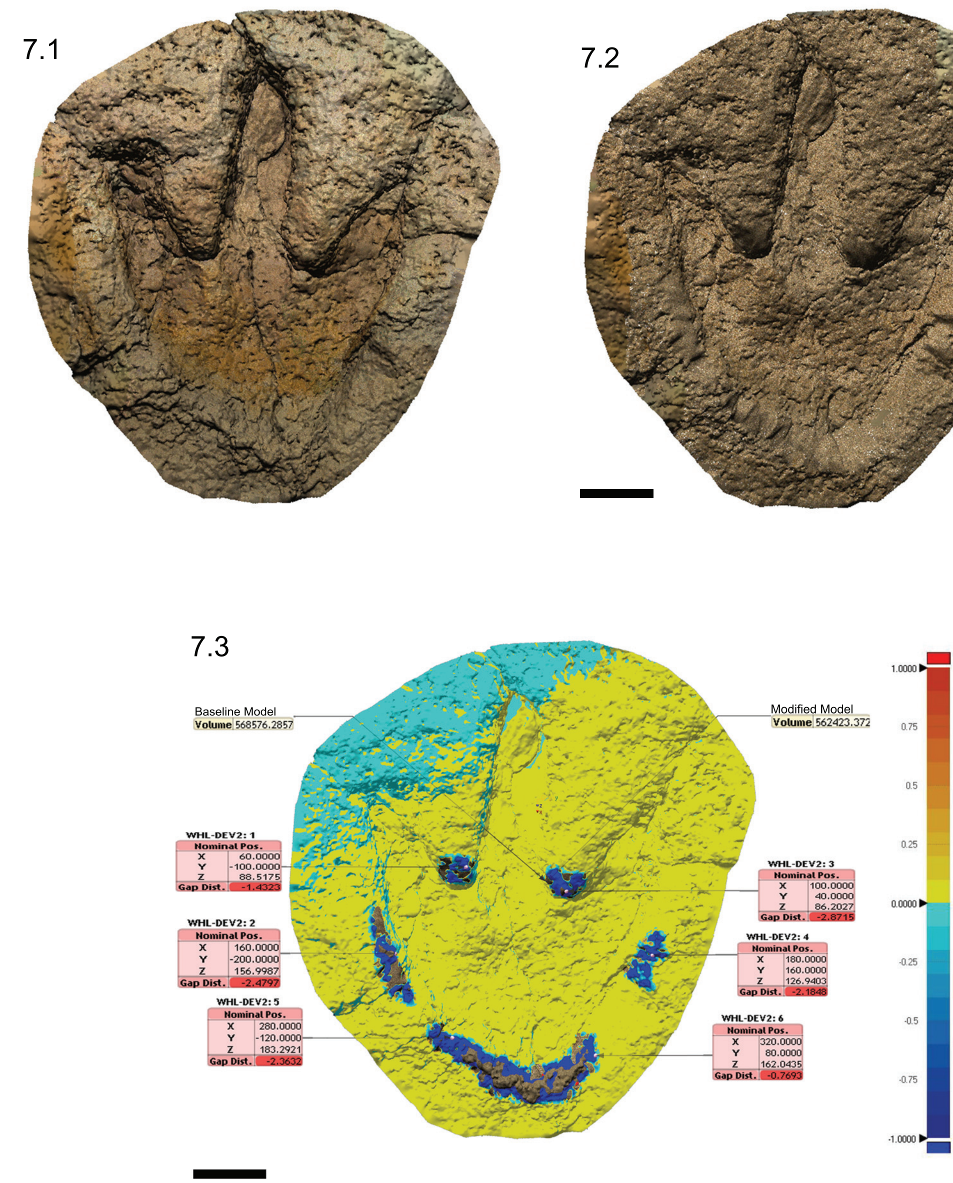

FIGURE 7. Demonstration of erosional monitoring of the type specimen *Eubrontes* (?) *glenrosensis*. **7.1** 2D image of the 3D digital model of *E*. (?) *glenrosensis* used as the baseline to evaluate future erosional loss; **7.2** Modified 3D model; **7.3** Color map of whole deviation analysis, see text for results. Yellow or cyan = zero deviation, warm colors = positive deviation, and cool colors = negative deviation. Scale bar equals 100 mm.

semination of 3D data through the worldwide web, CD-ROMs, and DVD (McHenry and Bajcsy 2008).

CONCLUSION

The type specimen of *Eubrontes* (?) *glenrosensis* Shuler (1935) represents a unique cultural and scientific heritage for Texas. Its placement in the bandstand in the Somervell County Courthouse square in Glen Rose, Texas, has given it a place of honor that to this day still attracts visitors from all over. However, continual exposure to the elements means that eventually this footprint will be lost to erosion. In this paper, we have demonstrated that with the use of a 3D laser scanner, the type specimen can be preserved as a baseline, to allow quantification of future erosion, and provide high-resolution 3D digital models necessary for scientific research and distribution.

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We dedicate this work to Billy Paul Baker, late Superintendant of Dinosaur Valley State Park.

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APPENDIX 1.

QuickTime Virtual Reality Object (QTVR), allowing 3D manipulation and viewing of the type specimen *Eubrontes* (?) *glenrosensis*. After selecting the object below, and allowing time for download, place the cursor in the window, press the left mouse button and drag the object to the desired viewing angle. You can also use the toolbar under the QTVR to zoom and pan the object. File size is ~ 98 MB. QuickTime is required and available for download from Apple.

APPENDIX 2.

Interactive 3D model in Wavefront (*obj.) and Stanford PLY Polygon (*ply.) format that includes mesh, material, and texture file. If you currently have a program/viewer that will open *obj. or *ply. formats, simply download the model and open within the program. File size is ~145 MB.
To the right - still image from animation.

APPENDIX 3.

PDF of Shuler, E.W. 1935. Dinosaur tracks mounted in the bandstand at Glen Rose, Texas. *Field and Laboratory*, 9:9-13.

EDITORIAL NOTE

For any of these appendix files, please see palaeo-electronica.org/2010_3/226/index.html.