

Use of Radiance Scaling to Enhance Visibility of Petroglyphs from 3D Models

Robert Mark and Evelyn Billo

When documenting rock art sites Rupestrian CyberServices often utilizes many digital images taken from various perspectives to create high-quality Structure from Motion (SfM) 3D models. When these models accurately capture the geometry of the rock surface, they can be further processed using the Radiance Scaling shader in Meshlab (free at <https://www.meshlab.net/#download>) and then Adobe Photoshop. Photoshop is used to blend (overlay, soft light, or hard light) the red or blue channel from the color curvature map with the original image or a shaded one that can also be generated in Radiance Scaling. The results enhance the visibility of petroglyphs that are otherwise difficult to see. Radiance scaling was introduced by Vergne et. al. (2010) and has been used by researchers since (cf. Peña-Villasenín 2019). It is not our intention to review this literature, but rather to present a new procedure in enough detail to make it accessible to readers using photogrammetry.

Many rock art locations contain petroglyphs that, for various reasons, are difficult to discern. Sometimes color- or luminosity-based enhancement of images (eg. Photoshop or DStretch) can help, but too often there is no useful contrast available for those techniques to work. Rupestrian CyberServices (RCS) has been developing simple methods to produce enhanced images from high-quality 3D models. The first method utilized the surface relief (Mark 2017). The method that is described in this paper is based upon curvature mapping of photogrammetric models (cf. Hixon et al. 2018). It has proved to be helpful in revealing hidden glyphs (Berrier and Mark 2020). Figure 1 shows a model of a boulder with petroglyphs prior to and then after Radiance Scaling enhancement, where additional glyph patterns and cupules can be seen.

Illustrating the Method

To provide details of the process we show a photogrammetric model of petroglyphs on a boulder from Scotland (Figure 2a) that does not need enhancement. However, it does have significant relief (depth) of its petroglyphs

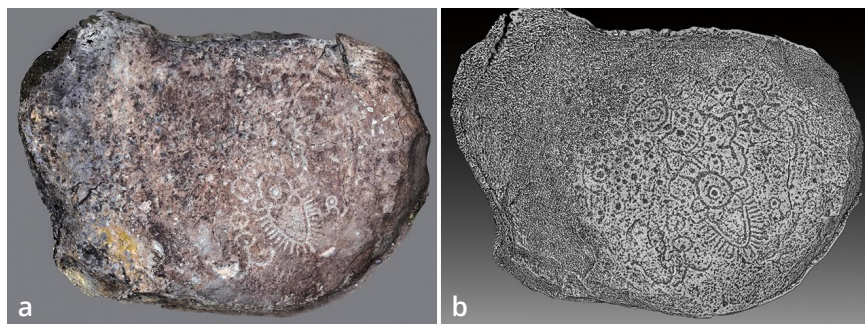


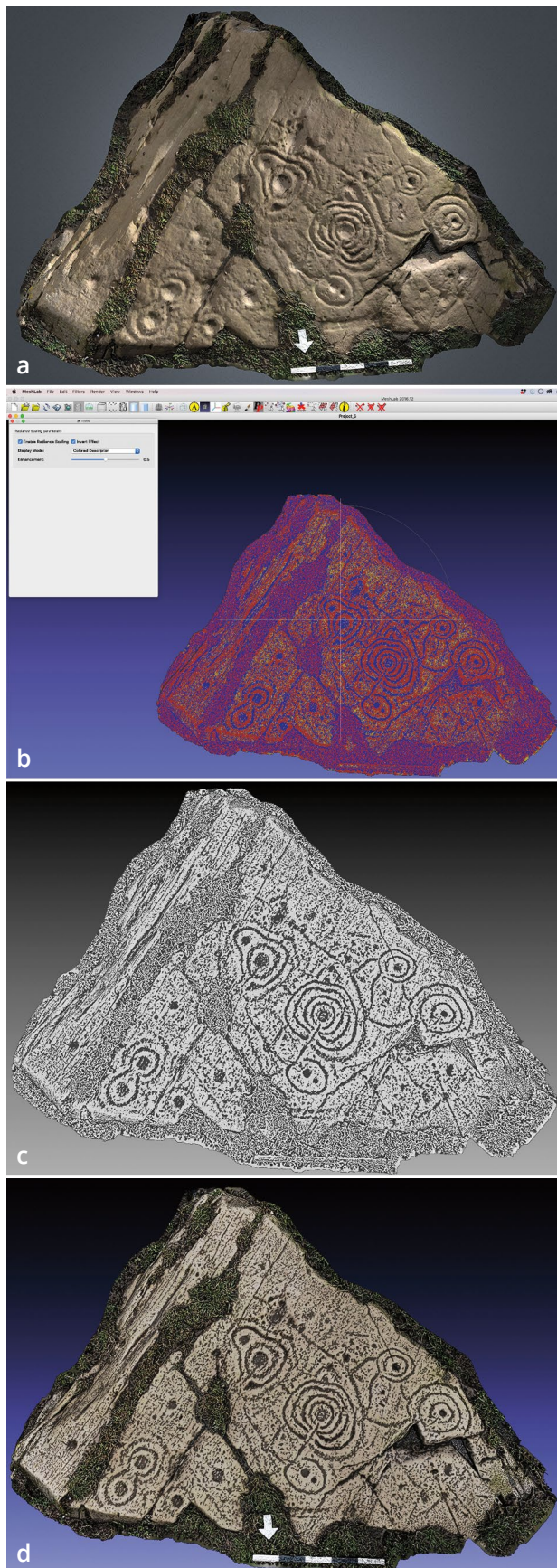
Figure 1. Cove Palisades Boulder, Oregon. Image from model and result of radiance scaling enhancement (curvature map, red channel), created using 49 images (slides and digital).

Robert Mark

Rupestrian CyberServices,
Flagstaff, Arizona

Evelyn Billo

Rupestrian CyberServices,
Flagstaff, Arizona



that make this model well suited to illustrate radiance enhancement and color curvature map. Scotland's Rock Art Project (copyright Historic Environment Scotland) kindly gave permission to use their model for this paper.

The first step is to obtain a set of high-quality images that provide the needed geometry of the object's surface to create a 3D photogrammetric model. This process has been described elsewhere so will not be repeated here. For guidance on generating high quality photogrammetric models, see Cultural Heritage Imaging 2020. Once the model is created, the high-quality mesh is imported into Meshlab. Select Render, then Shaders → Radiance Scaling. The Color Descriptor provides a curvature map. This image can be captured as shown in Figure 2b.

Tilting the curvature map shows how the convex and concave features are colored. Figure 3 illustrates the concave cupules shown in red and the convex raised circular patterns in blue.

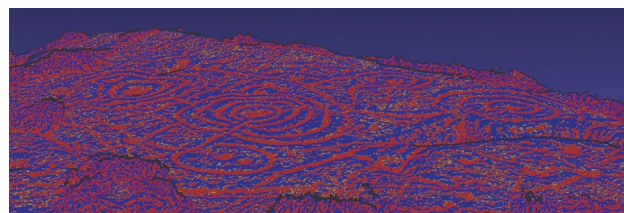


Figure 3. Oblique view of the curvature map. In this image red is concave, blue is convex.

Next the image of the curvature map is opened in Photoshop where the red and blue channels are viewed, and whichever of the two gray scale images works best is selected. Figure 2c provides a gray scale image of the red channel of the colored curvature map of the Scottish petroglyph panel.

This image can be saved, or can be blended (blend modes overlay, soft light, or hard light) with the original image or with a shaded-relief image. The final enhanced image, shown in Figure 2d, used the red channel over the shaded-relief (Lambertian Radiance Scaling option 7) image.

Figure 2. Townhead 1A, Dumfries and Galloways, Scotland.

- (a) The 3D photogrammetric model can be found online on Sketchfab (Scotland's Rock Art Project 2020).
- (b) Screen capture of Meshlab, showing the Radiance Scaling dialog box. Since invert is selected, red depicts convex areas and blue concave ones.
- (c) Red channel of colored curvature map. Dark is concave.
- (d) Radiance scaled enhancement of the Scotland boulder achieved by an overlay blend of red channel over shaded-relief image.

Radiance Scaling Procedure in Detail

1. Create a high-quality 3D model that captures the surface geometry, using a program such as Agisoft Metashape.
2. Export the model.
3. Import the mesh into Meshlab.
4. Select Render → Shaders → Radiance Scaling.
5. Select Color Descriptor. Adjust and use Invert Effect as appropriate.
6. Use Save Snapshot tool to capture the curvature map.
7. Optionally, use Render → Radiance Shader → Lambertian Radiance Scaling to capture a base image.
8. Open the image(s) in Photoshop.
9. Open the curvature map in the image Channels Panel; select and save the Red, Green, or Blue channel as appropriate. These channels can be saved as gray scale images or copied and blended with a base image.
10. Optionally, paste the selected channel over the base image and choose a blending mode (overlay, soft light, or hard light). Flatten and save.

Numerous digital processes can result in various scaling enhancements for there is no one-way path through the steps of the procedure. Experiment with various techniques and paths within these powerful software applications. There may be surprises, and whenever possible, results should be field checked. The Scottish petroglyph model example that did not need enhancing, illustrates the procedure, while Figure 4 provides a different example of the technique used on a sandstone-slab petroglyph panel that is not very visible. The slab's model, curvature map, red channel, and resulting blended enhancement are shown. Additional examples of the usefulness of radiance scaling are presented next in the case study from Costa Rica.

Costa Rica Case Study: Enhancing Visibility Using Radiance Scaling

In 2019 the authors visited several petroglyph sites in the province of Cartago, Costa Rica, near the city of Turrialba, including the Guayabo National Monument and the Tropical Agricultural Research and Higher Ed-

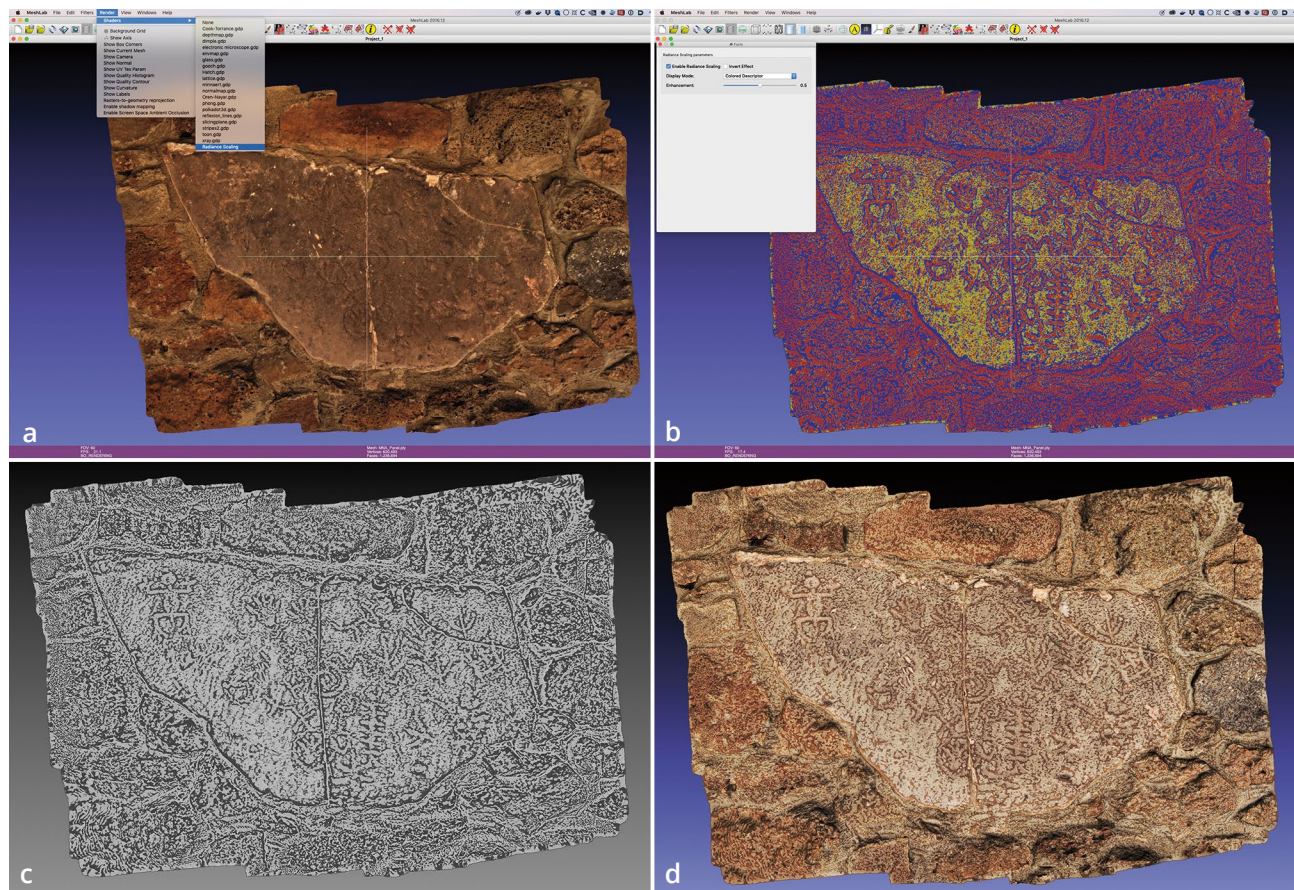


Figure 4. Sandstone slab with petroglyphs that was used in constructing a wall of a courtyard at the Museum of Northern Arizona early in the last century (which would of course not be done today). (a) Model image in Meshlab. (b) Curvature map in Meshlab. (c) Red channel of curvature map. (d) Photoshop overlay blend of red channel over image from model.

ucation Center. Lush vegetation of the tropics can and does hide many petroglyphs that might otherwise be visible to the naked eye. Figure 5 shows the lichen- and moss-covered boulder on the grounds of the Research Center. One of its very weathered interpretive signs mentions that, “The whole upper surface of the rock is covered with spirals, now mostly worn away.” The radi-



Figure 5. Lichen-covered boulder with weathered interpretive signage at the Tropical Agricultural Research and Higher Education Center near Turrialba, Costa Rica.

ance scaling image shown in Figure 6 was created from a 3D model that used 160 overlapping photographs. It dramatically revealed portions of a complex curvilinear abstract design that includes spirals and it also gives a hint as to possible remnant designs in the portions of the upper surface that were described as worn away. This enhancement includes details of the row of faces that was partially visible in the field. Another sign at the Research Center states that, “The carved head, eyes, and snout of the primeval alligator can be seen clearly here.” However, that design was not visible until much later after postprocessing images back at the office. Figure 6c is a detail from the radiance scaling image highlighted to show what may be the depiction of the alligator head. Its shape compares favorably with the head of a petroglyph from Guayabo National Monument, which lies about 10 km north of the Research Center site. This petroglyph (Figure 7) is one side of a boulder with two carvings described in the interpretive sign as follows: “It features a mammal and a reptile or amphibian on opposite sides of the stone. The relationship of the two animals has been construed to mean a symbolic alliance of peoples, groups, or high-ranking persons interacting in the Guayabo region and surroundings.” For more information on the Figure 7 petroglyph and Costa Rican archaeology see Turnbull-Houde and Houde 2015.

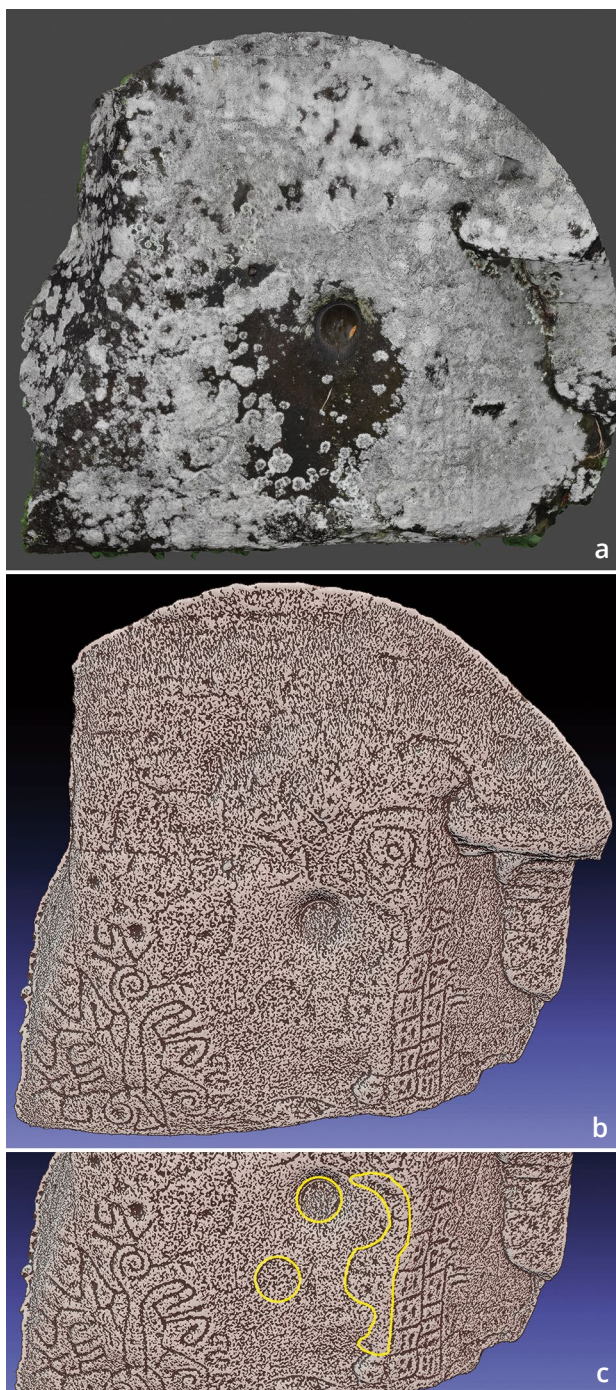


Figure 6. Top of boulder shown in Figure 8. (a) Screen capture image from 3D model; (b) result of the radiance scaling enhancement; (c) detail of enhancement with suggested outline that may be the “primeval alligator” mentioned on the signage at the Research Center.

Guayabo National Monument was established in 1973 to protect the largest archaeological site in Costa Rica that may date back to more than 3000 years. It is of interest to compare the sheltered boulder shown in Figure 7 with the relatively small and well-camouflaged



Figure 7. Petroglyph boulder from Guayabo National Monument described on separate signs as an alligator, a lizard, or a reptile. For a 3D model of the Guayabo boulder see Mark 2019.

moss-covered petroglyph boulder shown in Figure 8. It is not known (by us) if the sheltered one was extracted during excavations and/or was cleaned of vegetation before it was displayed. An interpretive sign said there



Figure 8. Guayabo National Monument archaeologist located the petroglyph for which we were searching near the trail and partially hidden by lush vegetation.

were 36 petroglyphs found at the site but that most were moved to the Museum in Santa Cruz. Luckily, the archaeologist on site was willing to show us the location of one that remained (Figure 8), which is printed in a photo on a park sign. Figure 9 contrasts that photo with the RCS model of its current condition and the radiance scaling enhancement.

Applications of Radiance Scaling

The radiance scaled enhanced images from 3D models of the petroglyph sites presented in this paper introduce a new procedure for using this tool for documenting petroglyphs. The improved understanding of petroglyph imagery can be useful for further analysis of motifs and stylistic variations in rock art imagery. It has potential to reveal details left by the creators of the glyphs that may help archaeologists, indigenous descendants, and rock art researchers with documentation or interpretation.



Figure 9. A small boulder (about 30 cm diameter) at Guayabo National Monument. (a) Photo (date unknown) posted on one of the monument's interpretive signs; (b) the 3D model of its condition in 2019; (c) result of the radiance scaling enhancement.

Acknowledgments. We thank Scotland's Rock Art Project for the use of their model, Cultural Resource Imaging of San Francisco, California, for their excellent photogrammetry course, and reviewers who helped with presentation and improved clarity. We also thank our anonymous reviewers for their helpful suggestions.

References Cited

- Berrier, Margaret, and Robert Mark
2020 Taking Some Guesswork Out of Sketch Work. *La Pintura* 46(2):6–9.
- Cultural Heritage Imaging
2020 Photogrammetry. Electronic document, <http://cultural-heritageimaging.org/Technologies/Photogrammetry/>, accessed July 13, 2020.
- Hixon, Sean W., Carl P. Lipo, Terry L. Hunt, and Christopher Lee
2018 Using Structure from Motion Mapping to Record and Analyze Details of the Colossal Hats (Pukao) of Monumental Statues on Rapa Nui (Easter Island). *Advances in Archaeological Practice* 6(1):42–57. doi:10.1017/aap.2017.28.
- Mark, Robert
2017 Creating a Digital Rubbing from a 3D Model of Petroglyphs. *Rock Art Research* 34(2):215–217.
- 2019 Jaguar & Alligator Monolith (3D Model). Sketchfab.com (online). Electronic document, <https://skfb.ly/6TMQ9>, accessed July 18, 2020.

Peña-Villasenín, Simón, Ma L. Gil, and Juan Ortiz

2019 Professional SfM and TLS vs a simple SfM photogrammetry for 3D modelling of rock art and radiance scaling shading in engraving detection. *Journal of Cultural Heritage* 37:238–246.

Scotland's Rock Art Project

2020 Townhead 1, Dumfries and Galloway (3D Model). Sketchfab.com (online). Electronic document, <https://skfb.ly/6Rn7X>, accessed July 18, 2020.

Turnbull-Houde, Jennifer, and Matthew Houde

2015 Guayabo National Monument: An Ancient Pre-Columbian City. Two Weeks in Costa Rica (website). Electronic document, <https://www.twoweeksincostarica.com/guayabo-national-monument/>, accessed July 13, 2020.

Vergne, R., R. Pacanowski, P. Barla, X. Granier, and C. Schlick

2010 Radiance scaling for versatile Surface Enhancement. *Proceedings of the 2010 ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games*, pp. 143–150.