IFRAO and SIARB codes of ethics; there is also an increased awareness of the responsibility of investigators for taking part in the decisions about the administration of sites open to the public. Mexico has already started several projects to protect rock art sites, foremost in Baja California. Central America seems to lack behind, but similar processes are likely to begin soon (Künne and Strecker, 2003).

An indicator of the awareness of rock art sites as cultural heritage in Latin America is the fact that several sites have been inscribed in the list of World Heritage by UNESCO. Apart from Samaipata and Cueva de las Manos mentioned above, the following rock art sites already belong to the list: Baja California / Mexico; Nazca / Peru (geoglyphs); Sierra da Capivara, Piauí / Brazil. Others have been inscribed because of their status as natural heritage sites, but include rock art: the area of Plátano river in Honduras; La Amistad park in Panama; Ischigualasto, San Juan and Talampaya, La Rioja, Argentina; Humahuaca gorge, Jujuy, Argentina. More sites are likely to be inscribed in the near future.

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COMPUTER-ASSISTED PHOTOGRAPHIC DOCUMENTATION OF ROCK ART

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Rock art documentation usually involves four related activities: forms, maps, drawings, and photographs. A narrative description is usually accomplished with the aid of forms. Many rock art recording forms are in use, but customization is often required for particular recording projects. Site location information, and maps at regional and site scales are usually prepared. With the general use of GPS devices, accurate site locations can be obtained, but it is critical to record the datum used (e.g. WGS84 (GPS default) or NAD27 (widely used in the United States)). Sketches and/or scale drawings are usually prepared. Of particular importance is photographic documentation, aspects of which are the focus of this paper.

We are involved with the ongoing development of two digital imaging techniques. The first is the process of generating panoramas and mosaics (Mark and Billo, 1999). The second are algorithmic methods of image enhancement (Mark and Billo, 2002).

Panoramas and Mosaics

We define panoramas as the stitching together of overlapping images taken by rotating the camera about a specific point (Fig. 1a) and mosaics as the stitching together of overlapping images taken from a series of different positions (Fig. 1b).

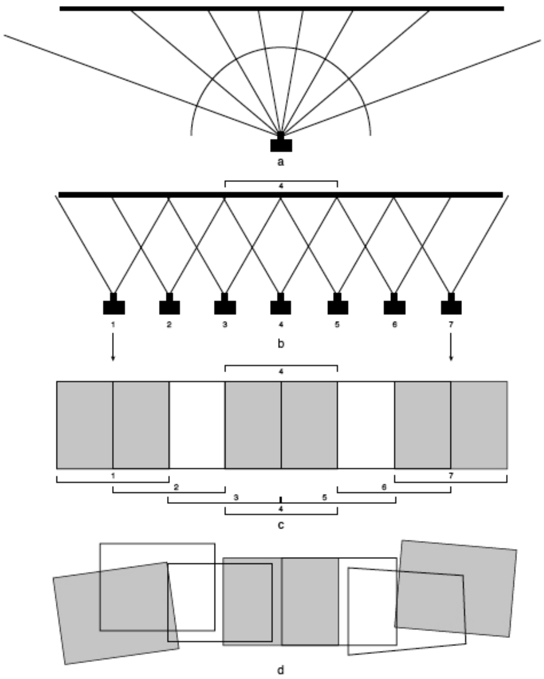

Figure 1. Camera and frame orientations for mosaic stitching. (a) Camera setup for normal panorama, with overlapping images from camera rotated about an axis perpendicular to the lens and the film, through the nodal point of the lens. The axis is normally, but not necessarily, vertical. This is the usual setup for automatic stitching. (b) Straight-on-camera setup for linear mosaic. (c) Ideal results of photography from b are best achieved if moving the camera along a fixed rail, and with image overlap of 30-50%. (d) Real-world photographs, shown as the overlapping frames would more normally appear when taken hand-held or with a movable tripod. Thus, the images have differences in scale, orientation, and skew

Panoramas are used to show rock art panels, entire alcoves, and the view outward. A full 360° panorama records the setting of a site. Close up views can be linked to a panorama. Figure 2 is an example of a panorama of a portion of a site using a spherical projection.

Images to be stitched into panoramas should be taken by rotating the camera about the point on the optic axis that produces no parallax error. This is determined by experiment and special pan heads are available to permit the rotation about one or two axes. See, for example http://www.tawbaware.com/nodalninja_review.htm

Panoramas can usually be stitched by a variety of off-the-shelf applications of varying sophistication and ease-of-use. Some stitching programs allow the user to choose a spherical as well as the standard cylindrical projection. The newest software will either render the panorama or generate a Photoshop file with each image as a separate layer with an editable layer mask. See, for example http://www.realviz.com/products/st/index.php

Mosaics are used where panoramas are inappropriate or impossible (e.g. in narrow cracks or where distant views are not possible). If all the images can be acquired from straight on with the same scale, stitching is not difficult (Fig 1c). In reality, this it rarely accomplished (Fig, 1d) and therefore stitching is usually difficult, requiring the use of rectification software of the type used for aerial photographs. Corresponding points are selected, a mathematical transformation model computed, and the process repeated for each photograph. Figure 3 is an example of a mosaic created from many photographs in a difficult setting.

Figure 2. Spherical panorama showing part of Panther Cave, Seminole Canyon State Park and Historic Site, Texas. Anthropomorphs are larger than life size

Figure 3. Mosaic stitched together from numerous photographs taken in a narrow crack. New Mexico

Digital Image Enhancement

Perhaps the most exciting contribution of computer science to rock art studies is the applications of digital image enhancement. For us, it started with a project documenting the rock art of Hueco Tanks State Historic Site near El Paso, Texas. Figure 4 was our first attempt; a successful experiment. Over the years, we developed a growing number of procedures for enhancing rock art images. These techniques, most of which use Adobe Photoshop, are based upon global algorithms (filters, histogram stretches, etc.) and do not make use of subjective applications of brushes or erasers.

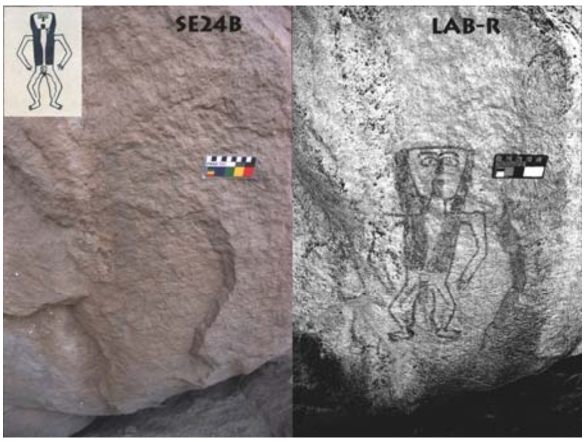

Figure 4. Panel in Hueco Tanks State Historic Site near El Paso, Texas. Left side is the original photograph; insert is an illustration made in the 1930's. The right side is a gray scale image created by enhancing the two color channels in Lab color space, then saving the RGB red channel as a gray-scale image

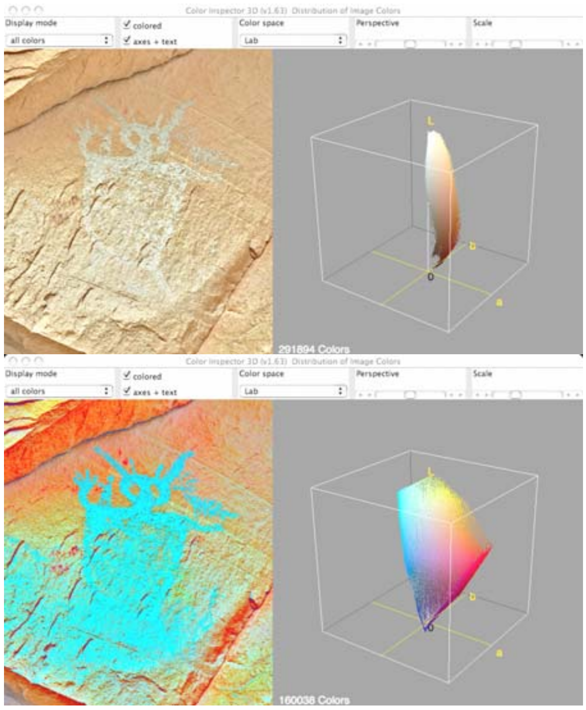

Figure 5. Image and Lab color space pixel distribution before (top) and after (bottom) histogram spread of a and b channels. Photograph by David Sucec, Utah. Images from ImageJ Color Inspector 3D plugin

In addition to the usual Photoshop tools, we make extensive use of the high pass filter, alternate color spaces (Photoshop CMYK and Lab modes), layer blending modes, and computations. The Lab color space is particularly useful, as it separates the channels into a luminosity channel (L) and two orthogonal color channels (a and b). Figure 5 shows an image and the distribution of pixels in Lab color space, before and after the spreading of the a and b channels.

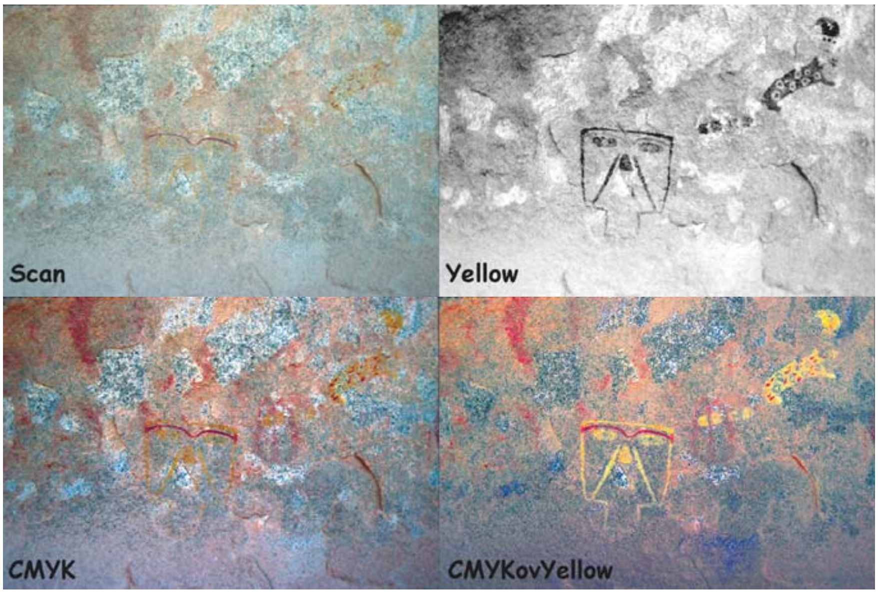

Figure 6. Upper left: Original image from Hueco Tanks State Historic Site, Texas. Upper right: enhanced Lab channel b. Lower left: enhanced C, M, Y channels. Lower right: C, M, Y, enhanced overlaid with inverted Y

Digital enhancement often involves identifying the color channels that are of interest and manipulating these to produce optimal grey-scale, intensified-color, or false color images. Sometimes good results are achieved from single color channels after application of a histogram stretch (Photoshop levels). In other cases, complex blends and computations are required. Examples are shown in Figures 6 and 7. The captions describe the general techniques used.

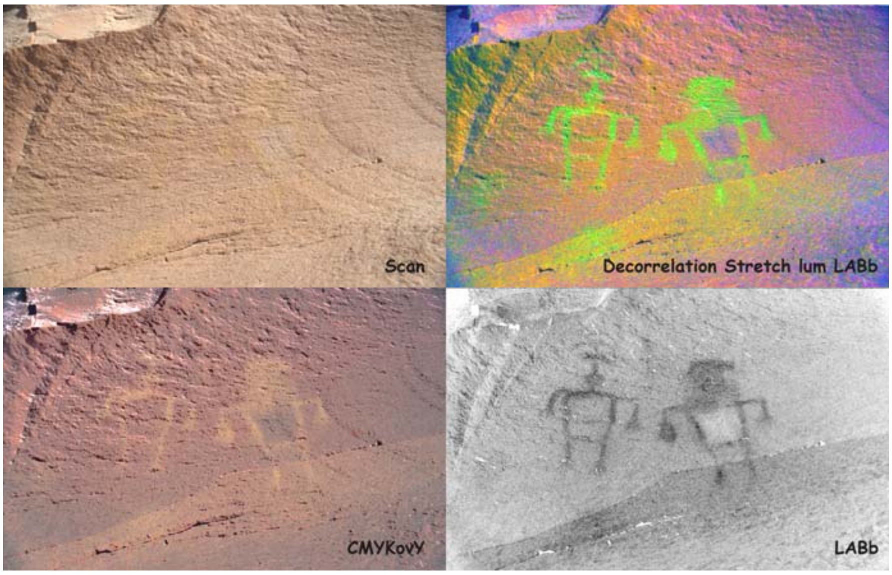

Figure 7. Upper left: original image from Arizona. Lower left: enhanced channels C, M, Y overlay with inverted Y. Lower right: enhanced Lab channel b. Upper right: color from decorrelation stretch, luminosity from inverted Lab b channel

Methods beyond those currently available in Photoshop are sometimes useful. These include the application of principal components and decorrelation stretch. We first observed the use of the decorrelation stretch algorithm on some of the Mars rover images. We collaborated with Jon Harman, PhD, to develop this tool for rock art applications (http://www.petroglyphs.us/article_using_decorrelation_stretch_to_enhance_rock_art_images.htm). The decorrelation stretch procedure involves rotating the color space to principal components axes, a histogram stretch along the independent axes to better fill the color space, and a rotation back. Figs. 8-10 show an application of this algorithm applied to the same image shown in Fig. 5.

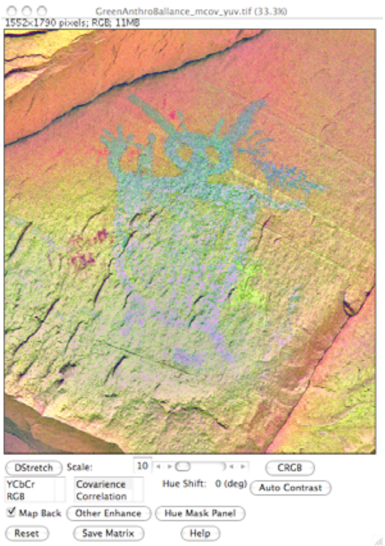

Figure 8. The ImageJ DStretch plugin window (http://www.dstretch.com/)

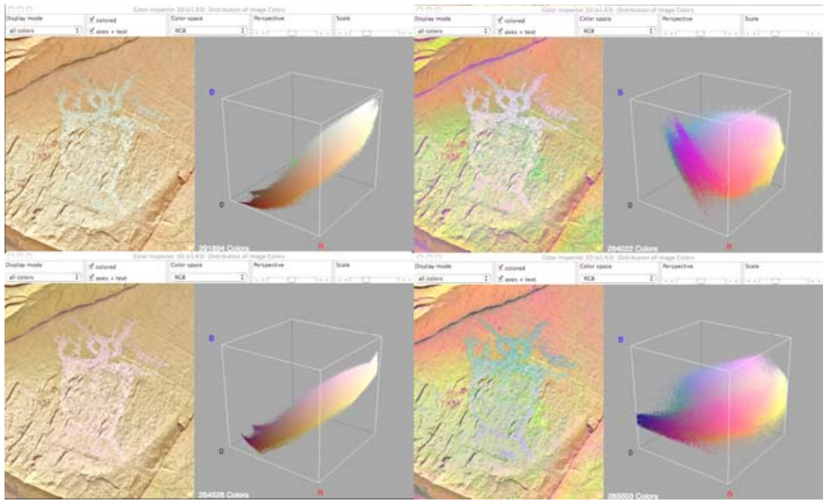

Figure 9. Application of decorrelation stretch (ImageJ using DStretch and Color Inspector 3D plugins) to image in Fig. 5. Upper left: original image. Lower left: rotation to principal components. Upper right: histogram stretch of components. Lower right: rotate color space back

In all cases, enhanced images must be so identified in the file name, the metadata, and perhaps in the image itself. Ideally when publishing, the original image should be published as a comparison with the enhanced one.

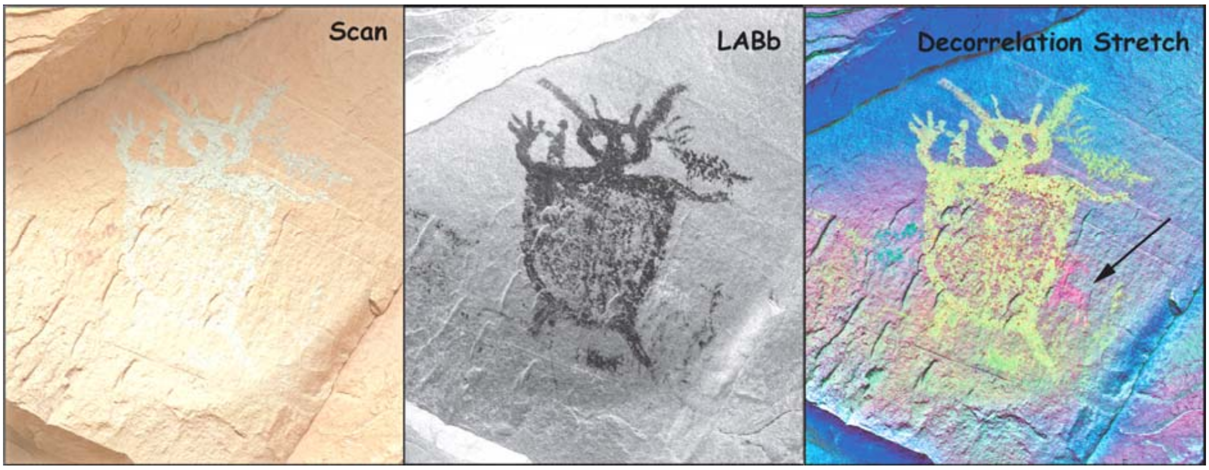

Figure 10. Fig. 5 image, as scanned, Lab stretch channel b, and decorrelation stretch image, with the color space rotated to best show the small quadruped (arrow)

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