gecko est couvert de brillantes taches colorées et on voit sur la peinture, également, des points placés au hasard sur le corps.

Les reliefs apparemment mammaires de la peinture, interprétés comme la crinière hirsute de l'animal, se trouvent légèrement vers sa partie antérieure, comme pour des seins humains. De même, les reliefs de l'animal plus petit apparaissent haut sur l'abdomen, près de la poitrine.

Conclusions

En conclusion, il est peu probable que l'interprétation de cette image en tant que celle d'un tapir marsupial éteint, Palorchestes, soit correcte. Elle représente plus probablement une créature mythique incorporant des attributs de reptile, de marsupial et d'animaux placentaires. Elle est significative en tant que représentation ancienne des créatures mythiques des légendes aborigènes en Australie. La plus connue est celle du *bunyip* dans le sud-est du pays : il s'agit d'une créature indescriptible que l'on craint et qui se cache dans marais et cours d'eau.

L'artiste australien qui créa jadis cette peinture s'inspira non de la vision du Palorchestes ou de tout autre animal éteint, mais de son imagination et de la notion qu'il pouvait créer son propre *bunyip*, cette créature fantastique, mystérieuse et indescriptible.

gecko is covered in brightly-coloured spots, and similarly the painting has areas with randomly-placed dots.

The breast-like protrusions on the painting, believed to be the shaggy mane of the animal, are placed slightly towards its anterior, analogous to human breasts. Similarly, the protrusions on the smaller animal are positioned high on the abdomen, approaching the chest.

Conclusions

In conclusion, the interpretation of this painting as the representation of an extinct marsupial tapir, Palorchestes, is unlikely to be correct. Instead, it represents a mythical creature incorporating the features of reptile, marsupial and placental animals. The painting is significant as an early representation of the mythical creatures featuring in Australian Aboriginal legends. The best known of these is the bunyip *in the south-east of the country. This is a feared and indescribable creature that lurks in swamps and waterways.*

The early Australian artist who created this painting was inspired, not by the vision of Palorchestes or any other extinct animal, but by his imagination and the notion he could create his own bunyip*, a fantastic, mysterious, indescribable creature.*

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USING DSTRETCH FOR ROCK ART RECORDING

DStretch is an image enhancement program that makes faint rock art visible. Fig. 1 gives an example of the usefulness of this program for recording pictographs. In many cases rock art that cannot be seen due to weathering or lighting conditions can be made visible with this program. Even if rock art panels may be visible by a human observer they often do not photograph well. DStretch can make the art visible for more accurate recording and allows it to be more clearly seen in a publication.

DStretch is easy to use :

It works with color digital images from consumer cameras.

Its interface consists of a set of buttons, one for each enhancement. The enhancements are given 3 or 4 letter names (YRE is used in Fig. 1).

Expertise in digital imaging tools is not needed. A long

series of arcane enhancement steps need not be documented.

Specifying just the enhancement name allows others to reproduce the results.

DStretch is a plugin to the freely available ImageJ program developed at NIH. It is written in Java and is available for both Macs and PC's. It does not run on Android or iOS devices. It is free, but a small donation is requested from professionals who find it useful. See DStretch.com for information.

Algorithm Background

DStretch uses the decorrelation stretch algorithm to create enhancements of digital images. This algorithm was developed in 1978 at the Jet Propulsion Laboratory (JPL), Pasadena, CA, where it was used for contrast enhancement of Landsat multispectral scanning imag-
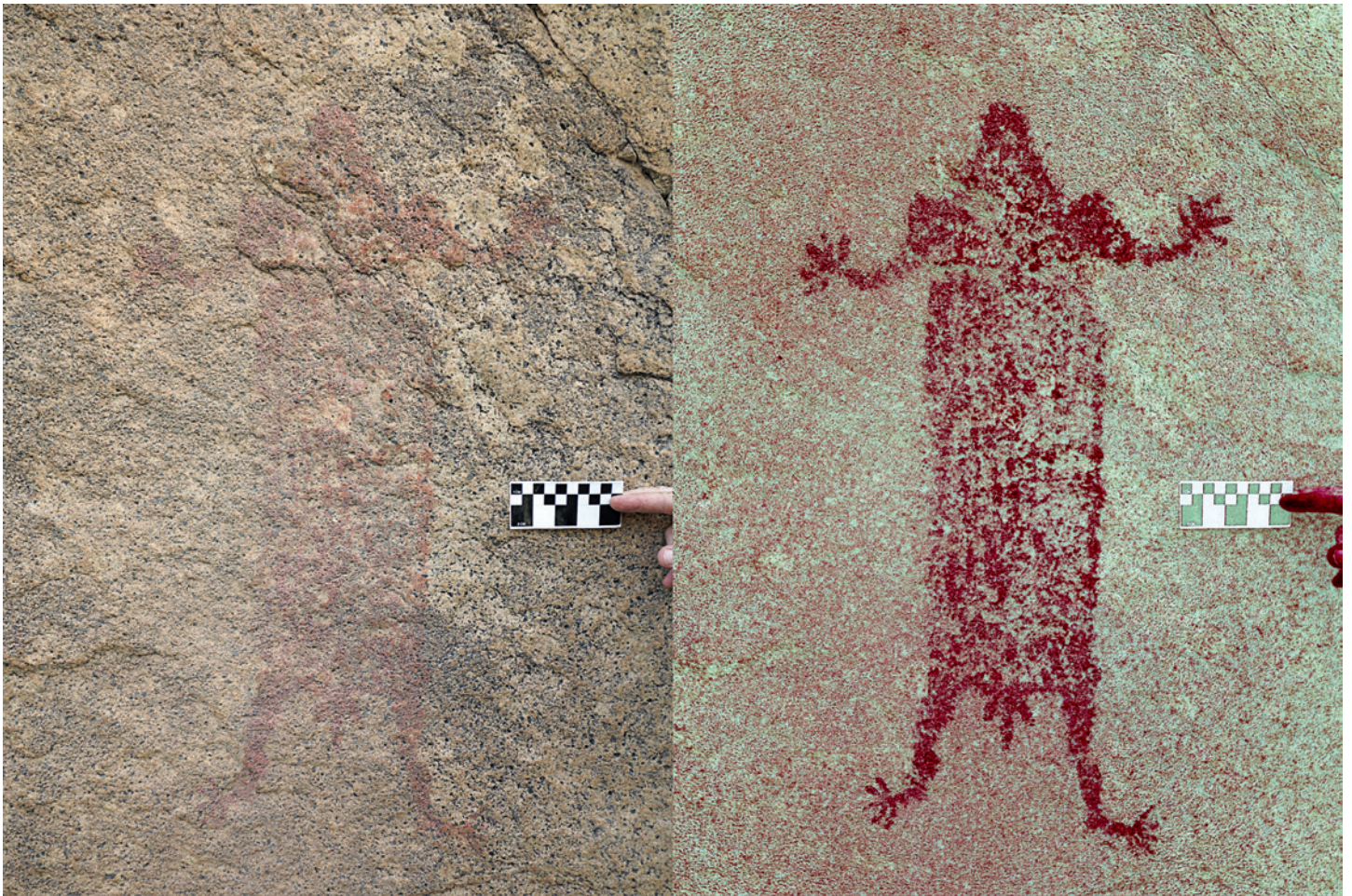
Fig. 1. Baja California pictograph from the Sierra de San Borja – left: without DStretch enhancement; right: DStretch YRE enhancement.

ery (Soha and Schwartz 1979). It was later used in ASTER (Advanced Spaceborne Thermal Emission and Reflectance Radiometer), and an algorithm description was then published (Alley 1996).

DStretch applies this algorithm to digital images. Each pixel in a digital image contains three numbers that specify the color that should be displayed at that point. The three numbers can be considered a point in a three dimensional space, called the color space. A common color space is RGB in which the three numbers quantify the amount of red, green and blue in the color. There are many other color spaces in use, for instance hue saturation and brightness (HSB) and the YUV color space that was developed for television. The color space provides a means for specifying colors and the same color is specified by different sets of numbers in different color spaces. For a discussion of color spaces see (Color space 2015.) The decorrelation stretch algorithm produces different results in different color spaces.

Early in the development of DStretch it was realized that the color space could be manipulated to give better enhancements for particular pigment colors. Several different color spaces were created and given three letter names. These fall into two groups; those beginning with a Y (examples: YBK, YYE, YRE) which were derived from the YUV color space, and those beginning with an L (examples: LDS, LRE, LBK) which were derived from the LAB color space. After much experience with rock art worldwide several color spaces have proved to have general usefulness. They will be described later in this article. Decorrelation stretch analysis as used in remote sensing uses the RGB color space. This color space is available in DStretch but has not shown much utility for rock art.

The decorrelation stretch analysis produces a 3x3 numeric matrix as an end result that specifies the color transformation to be performed. In DStretch this result can be stored and reused on other images, skipping the decorrelation stretch analysis. Some matrices have turned out to be generally useful and have been built into the program. They are given 4 letter names (examples: CRGB, RGB0, LABI.)

Limitations of DStretch

DStretch works by enhancing the colors in an image. For it to work there needs to be a color difference. For this reason it does not do as well on petroglyphs as on pictographs. It can work well on some petroglyph panels if there is a color difference between the rock patina and the pecked area. DStretch produces a false color image. Some enhancements produce very saturated vivid colors. The vivid colors are a result of the decorrelation stretch algorithm. The colors in the enhancement are characteristic of the color space. Usually one can look at an enhancement and know which color space was used. DStretch contains tools that can reduce the saturation of the colors.

Obtaining DStretch

DStretch is a plugin to the program ImageJ, a public domain, Java-based image processing program developed at the National Institutes of Health (Rasband, 1997-2014). To obtain DStretch request the plugin from the email address given at DStretch.com. The email containing the plugin gives installation instructions.

Digital Photography Tips

The DStretch enhancement process is sensitive to noise and to color compression in the file (typically a jpeg
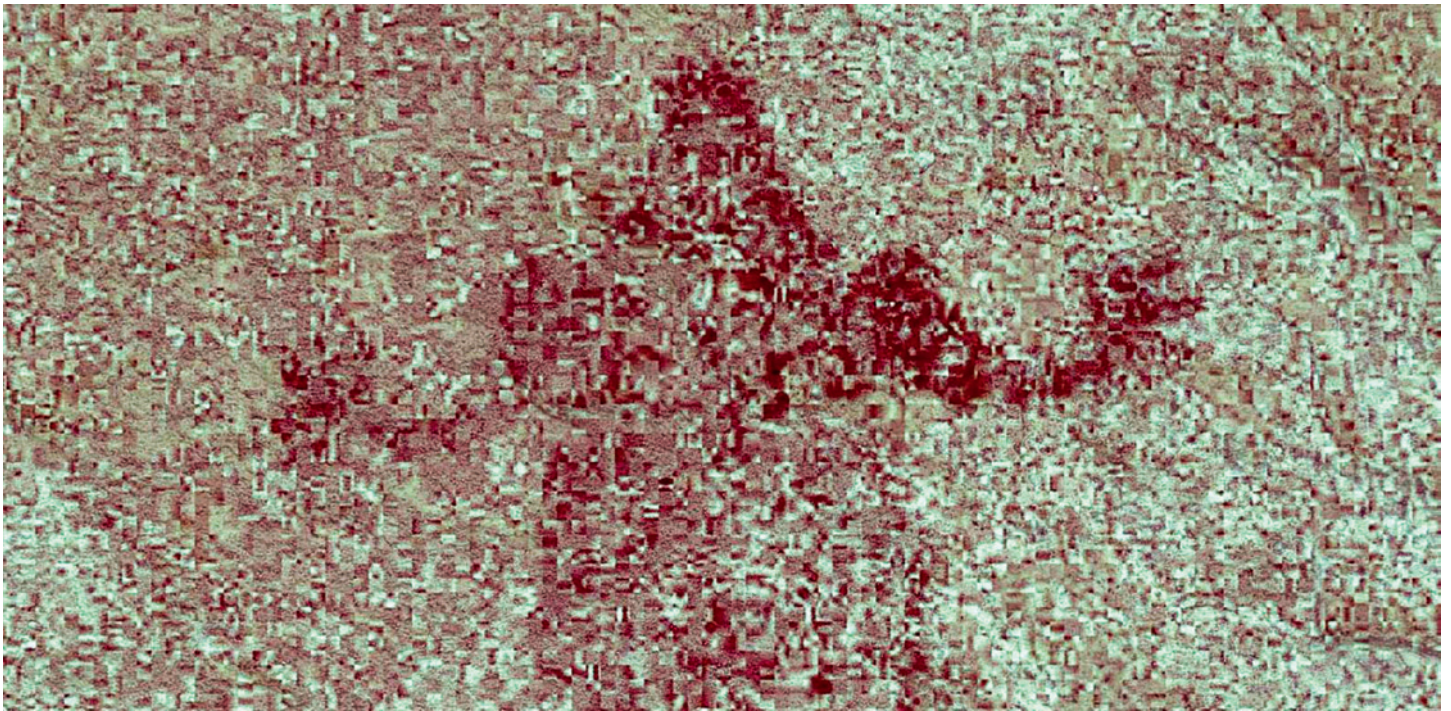
Fig. 2. YRE enhancement of low quality jpeg image.

image) produced by the camera. To reduce noise use a camera with a large sensor (i.e. digital SLR), use a lot of light (flash if necessary), use the lowest ISO possible, and use the highest quality jpeg setting. Best practice is to use a camera that can save the raw data or save uncompressed data (tiff). Many manufacturers "improve" image quality by smoothing the colors in noisy areas of the picture. This results in a blurry enhancement in DStretch. This can be avoided by saving as raw data and later producing a high quality jpeg or tiff with the noise suppression turned off. The jpeg setting can make a large difference for DStretch. Fig. 2 shows the result of low quality (small file size) jpeg compression applied to the image in Fig. 1 and then enhanced.

Repeatability of DStretch

Inherently the decorrelation stretch algorithm is not repeatable. It analyses the 3D histogram of an image and creates a transformation based on that unique histogram. In practice, judging from 10 years of experience, the DStretch enhancements are remarkably repeatable. Typical rock art sites consist of a background wall with a small amount (relative to the whole image) of paint. The painted area contributes little to the histogram and does not affect the enhancement. Repeatability is due to the overall similarity of background histograms. There is one caveat, however. Large areas of non-background (sky, foliage, dark areas) can affect the enhancement. This problem can be solved by using the ImageJ selection tool to create a selection that excludes

any large areas having colors different from the painting background. DStretch will use the colors in the selection to calculate the enhancement.

Using DStretch

Once ImageJ and the DStretch plugin have been installed, the DStretch commands appear in the Plugins Menu of ImageJ. See Figure 3. Both DStretch…Run and DStretch…One will add the DStretch user interface under an open image window or open a file chooser dialog to open an image if there is none open. The difference between the commands is that DStretch…Run makes a copy of the image and installs the user interface under the copy. DStretch…One does not create a copy and installs the interface under the image. These two commands can be used to create a side by side display of an image so that different DStretch enhancements can be easily compared. Use the DStretch… One command first then use the DStretch…Run command to open a copy.

ImageJ opens separate windows for images. Its main command interface is a relatively small window (Fig. 3) separate from open images. It can open a number of image formats including jpg, tiff, png, and bmp. It cannot open raw files.

Almost all DStretch commands are available without the interface by selecting other DStretch or DStretch Direct commands. The enhancements will apply to the image and are the same as if done in the interface. Reset is not available and the ImageJ undo command can only undo the last enhancement.
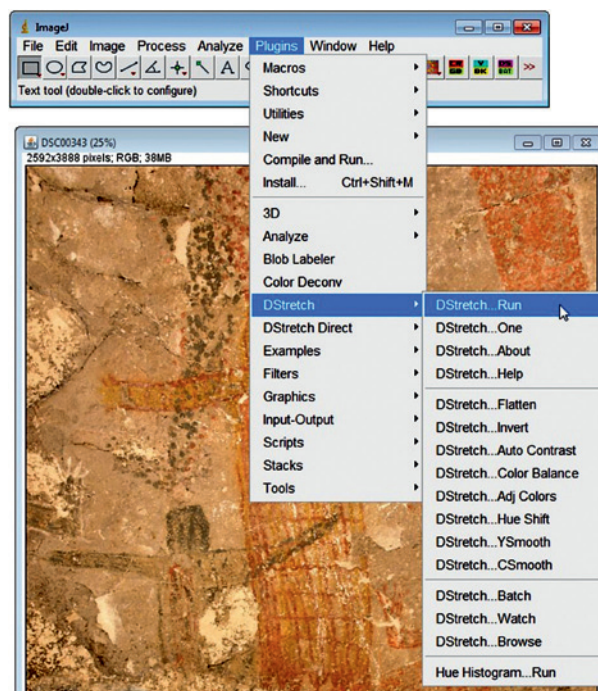

Fig. 3. ImageJ menu showing location of DStretch items.

Fig. 4. DStretch user interface and example enhancements. Image is from Cueva San Borjitas, Baja California Sur. Original image is on left, LDS (general purpose) enhancement on right.

Fig. 5. DStretch YRD (emphasizing reds) on left, YYE (emphasizing yellows) on right.

Fig. 6. DStretch YRE (emphasizing reds) on left, YBK (emphasizing blacks) on right.

Fig. 7. DStretch enhancements converted to grayscale – Left to right: original image, YRE (showing reds), YYE (showing yellows as dark), and YBK (showing blacks as dark.)

Fig. 8. Effect of the flatness enhancement. On the left is the flattened image with a flatness of 5; on the right is a LDS enhancement of the flattened image. The shading seen in figure 4 at bottom has been removed by the flatten routine.

Using DStretch Color Spaces

There are over 20 color spaces built into DStretch. Each has proven useful at some pictograph site. The number of them and their unfamiliar names can be confusing. As a practical matter testing only a few usually suffices. In this section some of the most useful color spaces are shown with comments on their applications.

In Fig. 4 on the left an image from Cueva San Borjitas in Baja California Sur has been opened in the DStretch user interface. Cueva San Borjitas contains sophisticated Great Mural imagery and DStretch enhancement reveals many fascinating details of the paintings. There are red, yellow and black pigments present in the image which makes it excellent for demonstrating DStretch color space properties. The orange buttons in the DStretch panel perform enhancements (the "More" button also in orange accesses a second panel of enhancements). One of the features of DStretch is that it is very easy to use. Press a button to see the effect of the enhancement. Various enhancements can easily be tried until the best is found for visualization needs.

LDS : This general purpose enhancement was originally developed to enhance yellows, something it does well, see Fig. 4, right. Other general purpose enhancements are LAB, YUV, YDS, RGB, YBR, and YDT. These enhancements can increase the color contrast and improve visualization, but they do not enhance only one color while suppressing others. Unlike enhancements intended for specific colors (see below), LDS can be useful in differentiating between different reddish hues.

YDT is another general purpose enhancement that can be useful in differentiating reds. Note the color difference between the dotted half of the anthropomorph at top and the one on the right.

YRD and YRE : Red pigments are found at the overwhelming majority of painted sites. From the first, DStretch has been developed with red pigments in mind. Two very useful enhancements for reds are YRD and YRE. YRD is in Fig. 5, left and YRE is in Fig. 6, left). Note the dotted outline of the left half of the top figure and the painting in the interior of the small black anthropomorph at center left. In the original image these are very hard to visualize. In the LDS enhancement faint red areas tend to get lost in the other colors. By emphasizing only reds (YRE is better than YRD in this respect) the parts of the paintings where red is used are easily identified. Other enhancements that do well on reds are LRE, CRGB, RGB0, and LRD. The strength of these enhancements on reds makes them unable to differentiate between slightly different shades. LDS can therefore be of use even if all pigments are red. YRD gives a more natural image, while YRE is more sensitive to faint reds.

YYE : This enhancement (Fig. 5, right) is extremely sensitive to faint yellows. Unlike LDS it maps yellows into a dark brown that is much easier to discern. It suppresses reds and blacks. It works well when desiring to show yellows in grayscale.

YBK : Although blacks and whites are difficult for DStretch to enhance because of a lack of color, many "black" pigments are not perfectly black, and suppress-

ing other colors can help show the blacks. YBK and LBK are examples of enhancements that can do well in some cases. As in the case of blacks there are some enhancements that can work for white pigments. LAB and (in the **More** panel) LWE and YWE should be tried.

Using Grayscale Mode

Grayscale mode is turned on (or off) by choosing "Grayscale" in the **AdjCol** choice menu. When in Grayscale mode enhancements are automatically converted to grayscale. This mode is intended to help authors whose enhancements will be printed in grayscale. Grayscale Mode makes it easy to judge which enhancement will work best in grayscale. Fig. 7 gives examples in grayscale of some of the enhancements used above. In an automated pigment separation routine this would be a first step in isolating areas of a particular color. For human eyes grayscale mode can help to judge the areas of different pigments without the distraction of color.

Using the Flat Button

Illumination can often be uneven in photos of rock art, especially when flash is used. The example of Fig. 4 is one such case where the illumination falls off towards the bottom. Using the **Flat** button can correct this. The flat algorithm affects only the brightness of the image, not the colors, but it can shift slightly the colors of enhancements. Fig. 8 shows the result of using Flat with a value of 5 to then applying LDS to the flattened image. As a general rule flattening is not needed for the red enhancement color spaces.

Other Elements of the Interface

The following is a very brief description of the buttons on the main DStretch panel. Button names will be shown in **bold**. More information is available in the DStretch **Help** screen.

Reset re-displays the original image. **Reset** is automatically performed if an enhancement is tried on an already enhanced image; i.e. you cannot perform an enhancement on top of an enhancement. The automatic reset does not occur after **Auto Contrast**, **Flat**, or **CB**.

Scale adjusts the strength of the enhancements. For most situations 10 or 15 are suitable values.

Auto Contrast maximizes the contrast in the image. It can be used either before or after enhancement. Usually it has no effect after enhancement, but if it does this is a clue to increase the scale to get a stronger enhancement.

Flat uses a band pass filter to even brightness across the image. Colors are not changed.

Save saves the current image as a jpeg. It assumes that further enhancement will not be done and uses a lower quality jpeg setting. This can be changed in ImageJ (Edit ->Options->Input/Output) or by using the **Save Jpg** button in **Expert** mode. DStretch gives the image a default name for saving based on its original name with short additions to indicate what was done to the image. For instance, if the original image is named "DSC00343.jpg" and **CB** then **LDS** were used for enhancement, then the resulting image will be named "DSC00343_cb_lds.jpg".

Help opens a help screen.

Expert changes the user interface to an older version that includes more image processing routines.

YXX and **LXX** allow enhancements to be done with color spaces intermediate to the existing ones by adjusting the parameters (with sliders) that modify the color space.

More opens a panel with more color space choices.

AdjCol accesses several different routines for adjusting the color of the enhancement. One of these is grayscale mode in which enhancements are automatically converted into grayscale. Others can modify the saturation or the color temperature of the image. There is also a routine to smooth only the colors in the image.

CB evens out the RGB color balance of the image. It can be useful if the image has an overall color cast.

Matrix saves or reads the 3x3 numerical matrix created by the decorrelation stretch algorithm.

Cycle sets up a routine which cycles through color spaces. Viewing the image change from one enhancement to the next helps attract the eye to subtle painted elements.

Xplor uses a different approach to calculating intermediate enhancements between color spaces. It calculates matrices for four color spaces on the current image then has sliders that calculate a new matrix by interpolations (and extrapolations) based on the calculated matrices.

Exit removes the user interface, but does not close the image window.

Using DStretch Enhancements in Papers

Writers should always indicate if an image has been enhanced. Enhancement alters the digital image and readers need to know that it has been used. If DStretch has been used then the color space used should be listed as well as the name "DStretch"; i.e. the caption should read something like "Image 5, DStretch LDS enhancement". The correct spelling is DStretch with the first two letters in caps.

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