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Multi-spectral Imaging of La Casa de las Golondrinas Rock Paintings

Research Year: 2000
Culture: Maya
Chronology: Pre-Classic, Proto Classic, and Early Classic
Location: Antigua Valley, Guatemala
Site: The House of the Swallows

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The Final Report

La Casa de las Golondrinas (The House of the Swallows), located in the Antigua Valley, Guatemala, is the largest rock art site in the Guatemalan Highlands. Like other painted rock art sites in the highlands, the site is at a sacred location near water. In Mesoamerican thought, caves, which often have streams within, are entrances to mountains and symbolically unite earth and water elements. Along with mountain peaks, they are the most important natural shrines in Mesoamerica. Places from which water emerges like caves also represent the female attributes of creation and fertility. Devotion to the deities, who monitored these aspects of life, could have taken place at Las Golondrinas.

Golondrinas may have been a religious and political landmark for thousands of years. Indeed, pottery that dates to the Preclassic (1000 B.C.-300 A.D.), Early Classic (300-600 A.D.), Protohistoric (1300-1500 A.D.) and Postconquest periods has been found at the site. Many of the 105 paintings recorded at the site so far, based on stylistic and thematic criteria, appear to pertain to late in the Postclassic period. Numerous abstract and fantastic motifs, however, have uncertain themes and styles admitting to the possibility that they date to earlier times.

Spreading over a 500-meter distance on a 30-meter tall tuff wall are areas with clusters of paintings. Delineated with red paint are Postclassic glyphs and shields, images of political domination from an external Mexican polity.

In an eastern section is a round 10-centimeter solar sight cut into a rock boulder about 2.4 meters above the ground surface (Figure 1, shown below). Sun images are lined up along a western wall perpendicular to the sight suggesting that these images match positions of the sun (or possibly other astronomical bodies) at different times of the year. An emphasis in solar imagery exists in this area of the site with human-like figures with rayed heads and murals including prominent suns.

Figure 1. Photograph of the sighting hole in Area C.

In another area a well-preserved painting is a group of animals appearing to cascade down the face of the rock (Figure 2, shown below). In this mélange are terrestrial and aquatic animals in frontal and profile poses. The complex composition of multiple animals fitted one into the other is unusual at Golondrinas. The painting expresses an animation unlike others at the site and suggests a theme concerning the fecundity of animal life if not creation itself.

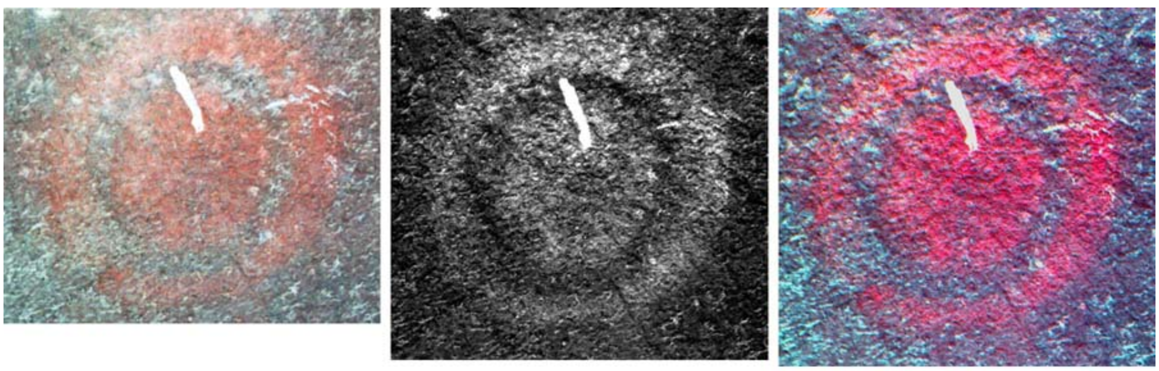
Figure 2. Photograph of painting 16 in Area A.

Multispectral imaging is a non-invasive preservation technique that can enhance faded details and differentiate between pigments used in paintings. The fundamental techniques of archaeological multispectral imaging come from the remote imaging of the Earth from space. For archaeological imaging, this distance is measured, at most, in a few meters rather than the hundreds of kilometers from a space-based sensor.

In order to form a multispectral image cube, images of the same scene, each at a different wavelength, are stacked on top of each other. This multispectral image cube may be processed to reveal image information associated with spectral differences between images, which may not be apparent in the individual images. In addition, individual images may show increased contrast due to a relatively narrow bandwidth around the image center wavelength.

For the Golondrinas data, each image cube contains ten wavelengths: 450, 500, 550, 600, 750, 800, 900, and 1000 nm each with a bandwidth of 40 nm. A Kodak Megaplus 4.2i/10 was used to produce the digital image files, which were recorded in the field on a computer hard disk and CD-ROM. There were 32 drawings imaged and some drawings were imaged in multiple parts leading to 57 image cubes containing 570 digital images.

In several cases, the multispectral images revealed details not easily seen by eye. For example, images in the infrared (Figure 3b) clearly showed a sun-like image with rays (Area B #8), especially in the upper-left quadrant. The color photograph (Figure 3a) also hints at these rays. The rays are not seen in images at 450 and 500 nm. A false color composite image (Figure 3c) was constructed from the 500, 900, and 1000 nm images in an effort to enhance the rays.



(a) (b) (c)

Figure 3. Images of drawing 8 in Area B: (a) color photograph, (b) digital image at 1000 nm, and (c) false color image comprised of digital images at 500, 900, and 1000 nm.

Surprisingly, the rays seem to fade and, if present, appear in a darker red color. The two different shades of red give rise to the possibility of different pigments. Spectral classification techniques likely will aid in the pigment identification and the possible existence of the rays.

Two digital images of a sun are shown in Figure 4, below. Note that the pigment has faded at 1000 nm (Figure 4a) but is clearly visible at 550 nm (Figure 4b). Most pigments, including those at Golondrinas, tend to become transparent in the infrared as illustrated by Figure 4. The pigment spectral characteristics of the pigments in Figure 3, however, are different in that they appear to become opaque in the infrared at 1000 nm. It is expected that further image processing and spectral classification will aid in the identification of the pigment detail and spectral characteristics of the Golondrinas drawings.

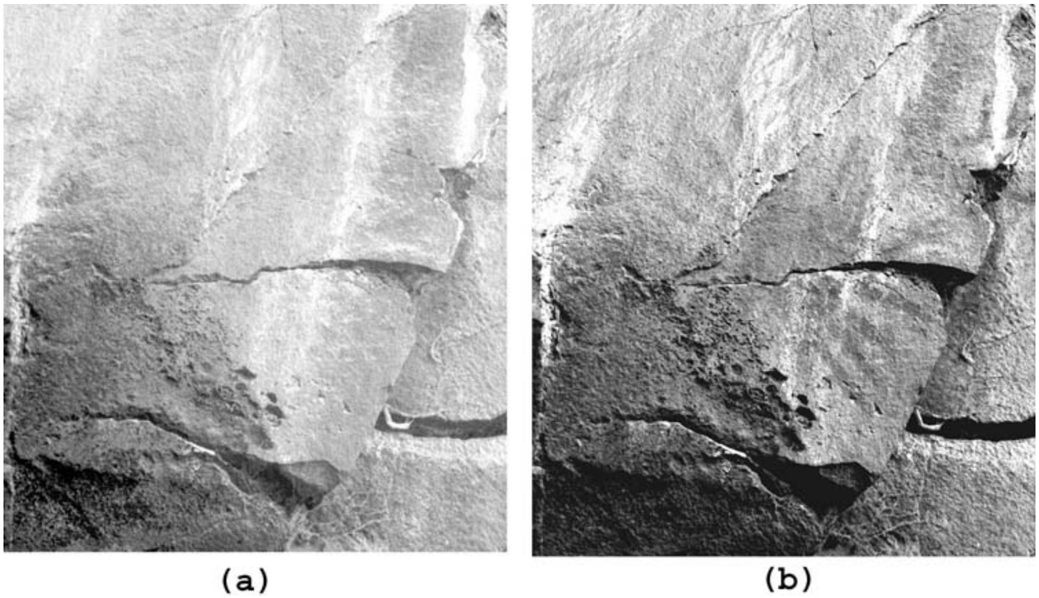


Figure 4. Painting 10 in Area C (a) at 1000 nm and (b) at 550 nm.

The multispectral imaging of the La Casa de las Golondrinas paintings posed several interesting challenges. Because the site is open to the environment, the images were obtained using natural light. This often made it difficult to track the variations in lighting caused by the sun's position and clouds. An attempt was made to select appropriate times during the day for each drawing. Also, drawings were located from ground level to over 6 meters above the ground. This often made head-on imaging difficult or impossible. In one case (Area B #1), a 6-meter scaffold was fabricated to allow detailed imaging (Figure 5, shown below).

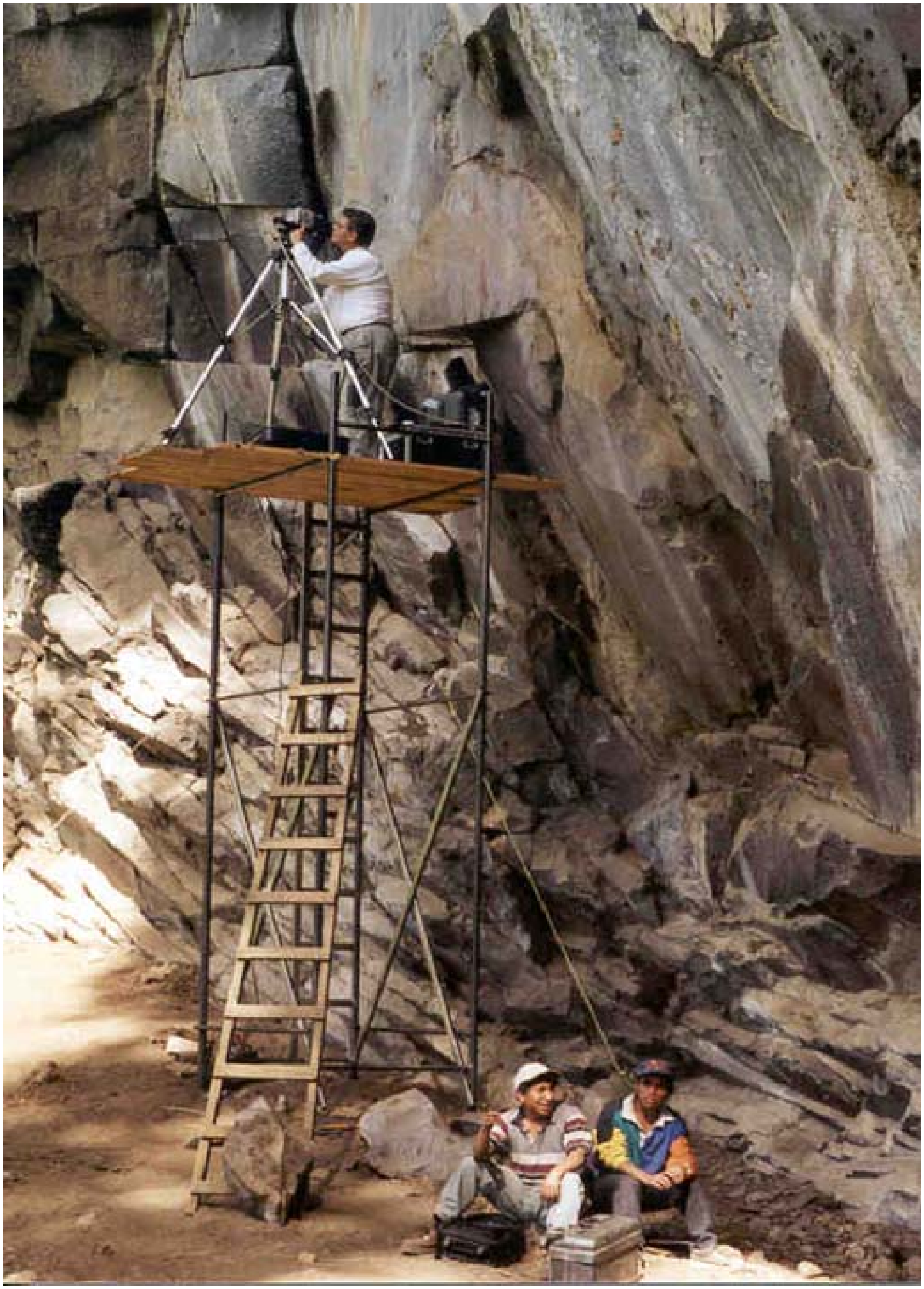


Figure 5. Gene Ware working on the 6-meter scaffolding at La Casa de las Golondrinas.

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The Technical Report

Multispectral Imaging

The application of multispectral imaging to archaeology is relatively new. An archaeological multispectral imaging system has been engineered and fabricated at Brigham Young University to meet the needs of this new area of research. This report describes the detail of this multispectral imaging system as used to image the rock paintings at Golondrinas in Guatemala.

Figure 1a. Typical setup of the multispectral imaging equipment at Golondrinas.

A typical multispectral imaging setup at Golondrinas is shown in Figure 1a. The camera, filter wheel, and lens are at the right while the camera control computer is at the left. Umbrellas are used to shield the equipment from direct sunlight. Direct sunlight on the camera increases the temperature of the internal imaging array which leads to an increased noise level in the image. Readability of the computer display is improved by the umbrella shade as well as reducing the temperature of the computer.

This system has been used effectively to obtain multi-spectral images of a wide range of archaeological artifacts including ancient documents, carbonized scrolls, murals, drawings, rock art, and ceramics. The imaging system has been reliably transported to and used in environments ranging from the laboratory to museums, the jungle, and caves.

Multispectral Equipment

The basic elements of this multispectral imaging system include a digital camera, a filter wheel, optical filters, a lens, and a camera control computer. These elements will be briefly discussed herein. A more complete discussion, presented by Ware, Chabries, and Baker (2001), is given in Appendix A.

Figure 2a. Closeup of the Kodak Megaplus 4.2i/10 camera and filter wheel used at Golondrinas.

The core element of the imaging system is the Kodak Megaplus 4.2i/10 digital camera shown in Figure 2a, above.[1] The 2029x2044 pixel imaging array of this camera is coated to provide response from 200 nm through 400 nm in the ultraviolet (UV) in addition to the normal response from 400 nm into the near infrared (NIR) at 1100 nm. This yields a 5-to-1 range in wavelength which is considerably greater than cameras used for normal color photography. The camera also has a 10-bit dynamic range which corresponds to a film density of greater than 3.

Optical interference (Schott) filters are used to restrict the spectral bandwidth of the camera to a desired wavelength range. A wide selection of these filters is available from the UV through the NIR. Filters for the Golondrinas project were selected from a set of seven visible filters and a set of six NIR filters, both of which were at a bandwidth of 40 nm. The filter transmission curves for these filters, manufactured by Thermo Corion Optical Filters, are given in Figure 3a, shown below. Notice that they cover the 400 through 1000-nm spectral region with small 10-nm interstitial gaps. A 62-filter set with a 10-nm bandwidth (manufactured by Andover Corporation) and a visible tuneable filter (manufactured by Cambridge Research Instrumentation, Inc.) are also available for detailed hyperspectral imaging.

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[1] The Kodak Motion Analysis Systems Division has been acquired by Roper Scientific MASD, Inc.

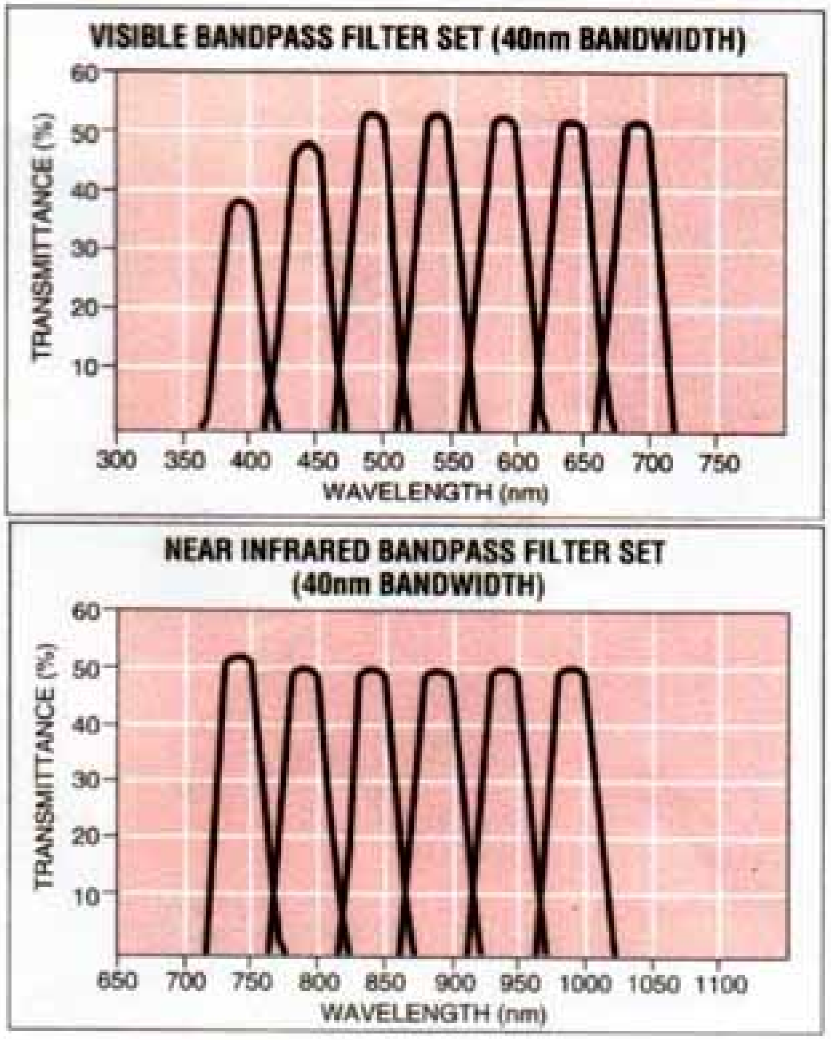

Figure 3a. Transmission curves for the Corion 40-nm visible bandpass filter set (top) and near infrared bandpass filter set (bottom) (Corion Optical Filters and Coatings, 1994 Catalog).

On-site tests were conducted at Golondrinas to determine the specific filters to be used. The testing involved determination of pigment spectral resonances and reflectance as well as a consideration of the wavelengths required for pigment spectral classification. No narrow-band pigment spectral resonances were observed with the test drawing allowing the use of filters with a 40-nm bandwidth. Ten wavelengths were selected: 450, 500, 550, 600, 650, 700, 750, 800, 900, and 1000 nm.

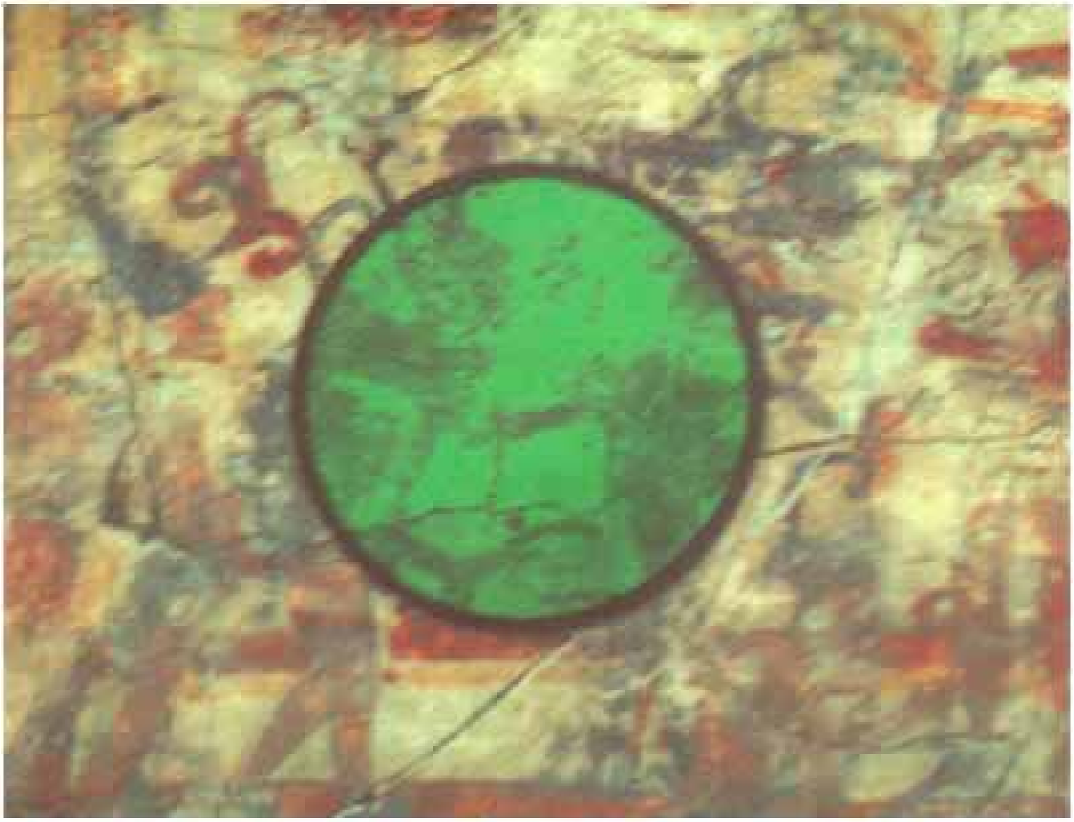

Figure 4a. An Andover 530 nm (green) filter.

A typical 2-inch filter is shown in Figure 4a. This particular filter is centered at 530 nm (green). Note that the image within the filter ranges from light green through dark green with all other colors filtered out. The camera converts this green light into a gray-scale image which records in intensity of the green filtered light. A similar process occurs for each filter used to produce the multi-spectral image set.

Rapid filter selection is provided by a filter wheel which can move the selected filter into position under remote control. The filter wheel in Figure 2a is the thin black disk located in front of the camera. The selected filters were mounted in a filter wheel similar to the one shown in top of Figure 5a, below. The front of the filter wheel provides a standard Nikon lens mount. The thickness of the filter wheel was designed to provide the proper focal length for the lens. Nikon 105 mm and 55 mm lenses were used as appropriate for the particular imaging requirements.

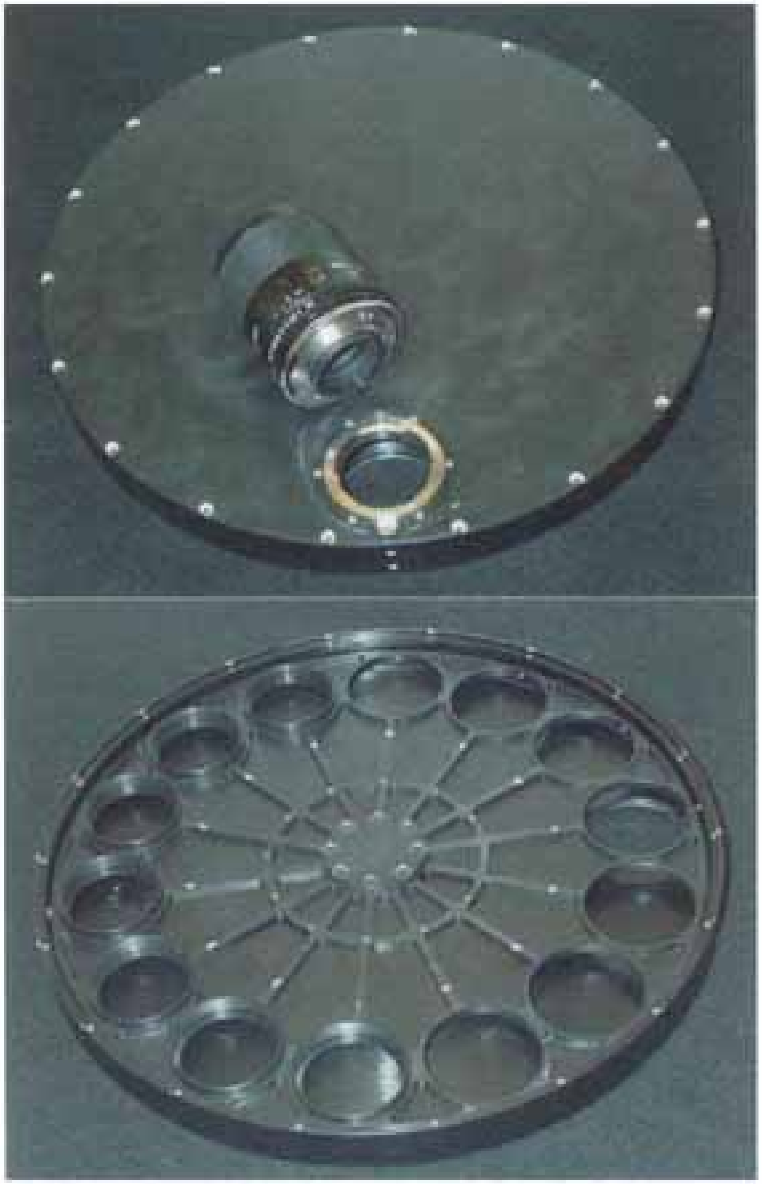

Figure 5a. Filter wheel and lens (top), and filter wheel interior (bottom).

The interior of the filter wheel showing the filter mounting positions is illustrated at the bottom of Figure 5a. The filter wheel used at Golondrinas contained 12 filter positions instead of the 14 positions shown in Figure 5a, but otherwise was identical. A belt (not visible) connects the wheel to a small external DC motor which is used to rotate the selected filter into place.

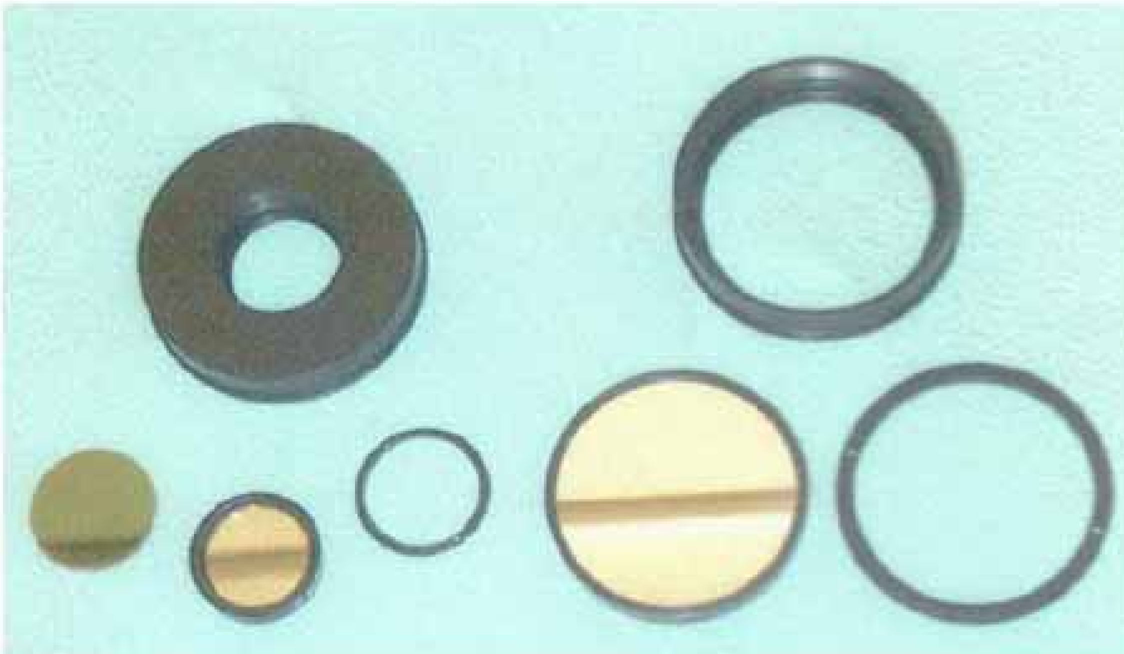

Figure 6a. Filter wheel mounting hardware.

The filters are mounted into the filter wheel using hardware adapters specific to the filter to be installed. Both 1-inch and 2-inch filters can be accommodated. This adapter hardware is illustrated in Figure 6a, above. Shown on the left is a 1-inch adapter with typical 1-inch filters. Shown on the right is a 2-inch adapter with a typical 2-inch filter.

Figure 7a. System control and data storage computer.

The camera is controlled by the computer shown in Figure 7a, above. A PCI-bus interface card is installed in the computer and connected to the camera with a SCSI-3 digital cable. The computer controls all functions of the camera through specialized software and transfers the digital image data to the computer hard disk for storage. The computer software also provides for automatic metadata storage which identifies the camera settings and filter in use. This computer also contains a removable hard-drive and a CD-writer (on the right side) for data storage and backup in the field.

The lunch-box configuration of the computer is necessary because computer-camera interfaces other than a PCI-bus interface have not been available. Laptop computers typically do not have a PCI slot (unless a docking station is used) and so cannot be used to operate the camera. A laptop-camera interface is currently under development and should allow laptops to be used in the future.

Image Processing

Image processing was not performed in the field at Golondrinas. The multispectral images were reviewed daily, checked for integrity, and backed up on CD. Techniques available with Adobe Photoshop were used to judge the quality of the images. It is expected that spectral classification techniques will be applied to the Golondrinas corpus to provide pigment differentiation and image enhancement. The theoretical foundation for this algorithm, presented by Martin and Ware (2001), is given as Appendix B.

Current image processing techniques which can be applied to the Golondrinas corpus include principle component analysis, transformations, image differencing, and spectral classification (Ware *et al*., 1999, 2000, 2001). Spectral classification has been effectively used with the Naj Tunich data set to separate pigments and is expected to provide significant results at Golondrinas.

As indicated above, (Multispectral Equipment) test images were obtained to determine the filter wavelengths to be used. This process is currently subjective, but special software, suitable for field operation, is being developed to quantify this decision. Also, the camera control software is being updated to allow more automatic operation and increased metadata capability.

Conclusions

The Brigham Young University multispectral imaging system effectively imaged the rock art drawings at Golondrinas. The project has provided significant insight into the techniques required to carryout rock art imaging under outdoor conditions including issues of access, calibration, and lighting (Robinson and Ware, 2001). Both equipment modifications to the system and software improvements have resulted. It is expected that laboratory analysis of the data will provide additional system improvements as well as significant understanding of the Golondrinas rock art.

Acknowledgments

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The mechanical design of the filter wheel was done by Dean Shaeffer of Space Dynamics Laboratory, Logan, Utah, and Robert Perry of the BYU Research Machine Shop. Robert also led in the filter wheel fabrication, and in the design and fabrication of associated system hardware. The custom camera control software was written by Craig Lindstrom of eSage, Pleasant Grove, Utah.

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List of Figures

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