# The Western Papaguería from the Air:
# Digital Imagery Using Kite and Balloon Aerial Photography

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*Abstract*

Aerial photography has been a useful tool for archaeologists in identifying and recording sites since the early 1900s. More recently, kites and helium balloons have been used as a cheaper and more environmentally friendly alternative than airplanes. With the rapid development of compact, high-quality digital cameras, kite and balloon aerial photography has been pushing new boundaries, allowing photographs to be viewed immediately, and, more importantly, to be rectified using simple software packages. These techniques have been applied to recent surveys of the Papaguería in south-western Arizona, USA, where geoglyphs, farmsteads, and other prehistoric rock features have been recorded digitally from the air. The photographs were then rectified and digitised as line drawings for publication. This paper explains the equipment, field methods, and results from recent fieldwork by Statistical Research, Inc. Most importantly, it shows how spectacular results can be achieved with minimal costs by university departments and cultural resource centres alike.

## Introduction

Aerial photography has been a useful tool for archaeologists in identifying and recording sites since the early twentieth century. The main reason for this is that an overall view of a site, structure or feature can be gained from the air, and more importantly, can provide a more detailed view of the regional landscape. Much of this detail may not be appreciated or detected to an observer on the ground. This situation was best conveyed by Reeves, who wrote in 1936:

> On an air view the various markings combine to form a plan which identifies a site. A fly walking on a rug would have difficulty in recognizing the design, but upon flying above the rug, the pattern would become distinct. In areas known to contain antiquities, time would be saved and the accuracy in the field would be increased by making a preliminary air survey (Reeves 1936:105).

This paper gives a brief history of kite and balloon aerial photography and then describes the methods employed by Statistical Research, Inc. (SRI), in recent archaeological surveys in the

Papaguería in south-western Arizona, USA. Some results from that work are then presented, and, to conclude, the potential for aerial exploration in the future is discussed.

## Brief History

The potential of using aerial photographs for discovering or recording archaeological sites was first realized in World War I by pilots briefed to map enemy positions. This realization led to pioneering work in the 1920s by Dr O. G. S. Crawford in England and Pere A. Poidebard in Syria. Subsequent uses of the technique in the 1930s – including Major G. W. G. Allen's identification of sites in the Oxford region using crop marks and an important survey by the Shippee-Johnson Expedition in Peru (Johnson and Platt 1932) – led to wider recognition of the applicability of aerial photography to archaeology. A further increase in aerial activity took place during World War II, Bradford being most notable for his important discoveries in Italy and Yugoslavia (Bradford 1957). From the 1960s onwards, the growth of private and commercial flying made it possible for archaeologists to conduct aerial surveys of their regions and add further discoveries of new sites to an ever-growing record.

Aerial photography used in archaeology in North America can be traced back as far as 1921 to photos of the mounds at Cahokia, Illinois, taken by Lieutenants A. C. McKinley and H. R. Wells. In 1930, nearly 700 photographs were taken of the Gila River valley, in south-western Arizona, showing networks of a prehistoric canal system (Bobzien and Stockwell 1930). In the early 1930s, Reeves made discoveries based on the analysis of aerial photographs at Newark Works in Ohio and published photos of the Great Serpent Mound and Miamisburg Mound in an overlooked but important article on aerial photography (Reeves 1936). Although vertical photographs have shown early road systems in Chaco Canyon, New Mexico, and earthworks at Poverty Point, Louisiana (Deuel 1971), aerial exploration of archaeological sites has been of less utility in North America due to the prevalence of hunter-gatherer sites, which leave a subtle record almost impossible to see from an airplane.

The above provides a brief history of the development of aerial photography in archaeology and deals only with photos taken from airplanes. Other techniques have also been used since the last century. Reeves showed a photo of a balloon used for aerial photography in the 1930s by the Oriental Institute of the University of Chicago (Reeves 1936:Plate 4, Figure 2) and mentioned the first use of balloons to lift cameras by Major Elsdale of the British Army in 1880–1887. The first use of kite aerial photography (KAP) for an archaeological project is attributed to Henry S. Welcome, who used a kite system successfully on the Jebel Moya in the Sudan in 1911.

## Recent Developments

More recently, kite and balloon aerial photography have emerged as a cheaper and more environmentally friendly alternative. In the last 25 years, there has been resurgence in the use of KAP in archaeology. These techniques were used in the desert environment in Syria and Egypt (Anderson 1979) and during surveys of Libyan farms from the Roman period (Allen 1980). These early systems used an SLR camera rig that was attached to the kite line after the kite had already reached a stable height. As more line was let out, the camera would rise high above the feature or site. These early systems had to be fitted with a motor drive, which made them heavy and cumbersome to use in the field. The relative infancy of this technique was demonstrated in 1987, when Riley made only a passing reference to the use of kites and balloons in his methods section of *Air Photography and Archaeology* (Riley 1987), which is dominated by photographs taken from the airplanes.

With the rapid development of compact, high-quality digital cameras, KAP has been elevated to new heights, allowing lighter rigs to be built and producing photographs that can be viewed immediately and, more importantly, can be rectified using simple software packages. Kites and balloons have been used successfully on archaeological projects when conventional photos would be difficult, costly, or dangerous to obtain. These techniques have been successfully used by Drs. Marzolff and Ries at Johann Wolfgang Goethe University, Germany, to map and interpret erosional patterns that develop in semi-arid environments in western Africa. The team uses a kite for aerial photography when wind conditions are too strong for the hot-air balloon. KAP was used for environmental site assessment, in conjunction with geographic positioning system (GPS) equipment, to locate survey markers on the ground while mapping fluvial landforms south of the Ninnescah River in Kansas (Aber et al. 1999). Topographic maps based on photogrammetric principles have been created with KAP using stereoscopic pairs to create three-dimensional maps (Warner 1996). Kites have also been used for digital photography by Japanese research laboratories during archaeological surveys in the Philippines (Murooka 1998). A model for SRI’s work has been the recent work of Bernard-Noël Chagny in the Sudan, where photos of archaeological sites, taken by kite or tethered balloon, have been rectified and incorporated into a geographic information system (GIS) or converted into stereo pairs (Chagny 1994, 2001).

## Kite Versus Balloon

There are many practical problems with KAP, but the most prominent is the dependence on favourable wind conditions. The use of KAP in the field cannot be planned ahead of time because there might be light winds, which will not lift the kite, or strong and gusty winds, which make the kite impossible to control. For this reason, SRI uses a multiflare kite, which is

Figure 1- A multiflare kite being flown prior to the attachment of the camera cradle.

stable and has excellent lift (Figure 1), and has adapted a helium balloon to lift a camera cradle in windless or low-wind conditions (Figure 2). Experiments using both techniques have been very successful. Our design goals were to produce a cheap, high-resolution aerial photographic system based on a cradle that could be interchanged with a kite and balloon as weather conditions changed, and that could be set up easily and used swiftly in the field to document multiple sites or features within a day. We wanted to use a helium balloon with adequate lift but with a small enough diameter to be filled with a single 1.5-m (5-foot) helium tank for easy transportation. The system also had to be easily adaptable from the wide-open desert to sites in an urban setting. Finally, we hoped to use the system not only to document sites or features from the air, but also to produce rectified photographs that could be converted to line drawings for publication or included in reports as scaled photographs. More importantly, we hoped to integrate our aerial photographs into a geographic information system (GIS) so that future monitoring of site or feature conditions could be carried out more effectively. We now routinely use these techniques in our projects, some of which are described below.

Figure 2 - Helium-filled balloon flying with the camera cradle attached.

## Results

The deserts of the American Southwest provide an ideal setting for aerial photography. The use of low-level aerial photography in the desert environment, and more specifically, with regard to hunter-gatherer sites, had been proposed as early as 1958 by Meighan et al., who cited contemporary experimentation with KAP and its use in archaeology by Bascom (1941) and Roy (1954). Photographs from higher elevations have been used successfully to document prehistoric irrigation systems along the Gila River but fail to pick up smaller features in the landscape. SRI's system is geared more to documenting such low-relief sites and features as trails, rock rings, pit houses, geoglyphs, and intaglios. These features are ideal for low-elevation aerial photography because they rarely rise higher than 30 cm above ground level, causing less distortion when correcting aerial views, as opposed to walled structures like mesas.

With our two systems in place, SRI can now carry out aerial reconnaissance in most weather conditions. KAP can be effectively used in conditions where winds are greater than 16 kph (10 mph), whereas balloons are suited to calmer conditions. SRI's kite system was first tested at Mescal Wash, near Tucson, Arizona, during excavations of pit houses (Figures 3 and 4). Because weather conditions were unsuitable for kiting, however, the helium balloon was used for all other aerial photographs shown.

The photo below shows the set-up procedure for a 2.1-m- (7-foot-) diameter helium balloon. First, it is anchored and filled with helium (Figure 5). A simply constructed cradle that houses the digital camera is then attached to the bottom of the balloon. Using a remotely controlled trigger mechanism, the camera can be operated from the ground within line-of-site range. The

Figure 3 - Pit houses, showing four different occupation phases and construction types; Area D at Mescal Wash, Tucson, Arizona.

Figure 4 - Pit house in Area D at Mescal Wash, Tucson, Arizona.

balloon can remain inflated for long periods and can be transported to different sites on the back of a pickup truck. If wind speeds increase unfavourably, we simply switch the cradle to the kite. On the Kofa Range at the U.S. Army's Yuma Proving Ground (YPG), SRI used both systems successfully on the same day.

Figure 5 - Helium balloon being inflated.

One of the main advantages of aerial photography is the ability to take shots of the same object at different points in time, as a monitoring tool. This repeatability allows environmental agencies to monitor the condition of sites and to measure impacts over time and also allows them to prioritise which sites or larger areas need protection. The advantage of carrying out aerial surveys from the ground, as opposed to from a plane, is that the ground crew can record those site components not visible from the air. Artefact concentrations, site boundaries, and isolated artefacts can be recorded by ground crews in combination with the aerial photographic process, rather than after it is completed.

Figure 6 - Aerial photograph of geoglyphs, North Tactical Range, BMGR, Arizona.

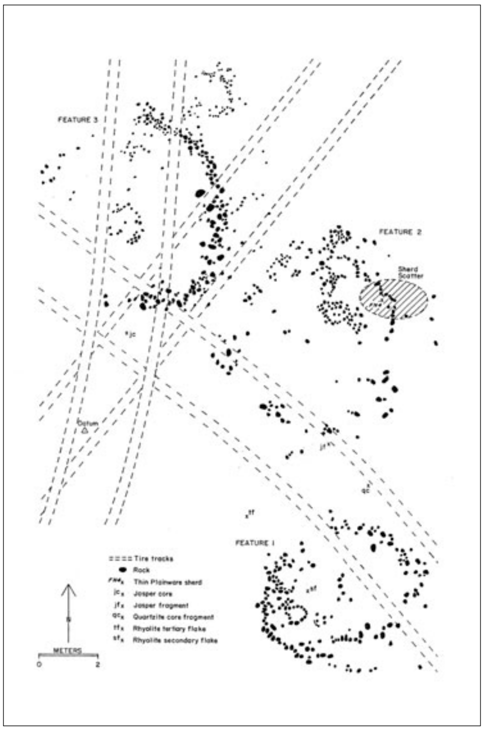


Figure 7 - Line drawing of geoglyphs by SWCA, Inc., North Tactical Range, BMGR, Arizona.

One of SRI's first experiments with the system involved a group of three geoglyphs originally recorded by SWCA, Inc., at site AZ:8:106 (ASM) on the North Tactical Range, Barry M. Goldwater Range, in southern Arizona. These features were chosen for aerial survey to see if any further impacts had occurred at the site since it was last recorded. First, a photo was taken to capture all the features. It was then rotated and cropped to match the line drawing done by SWCA to monitor the condition of the site (Figures 6 and 7). On the same day, SRI also documented two well-preserved geoglyphs just to the north of the Crater Range (Figures 8 and 9).

An obvious advantage in using our system is the ability to take photographs both at close range and at higher elevations. This flexibility is best demonstrated on a trail that runs east-west over Peanut Hill at Verbena Village on the South Tactical Range, BMGR. At ground level, the trail was barely noticeable except for a number of petroglyphs that lined the trail. Figures 10–12 show the relative positions of the petroglyph to the trail, using aerial photographs taken from three different elevations.

At Green Gate Well, a large historical-period ranching site was recorded using a helium-filled balloon and the resulting photographs pieced together to form a mosaic that shows the entire ranch perimeter (Figure 13). These photographs have recently been used to monitor recent damage to the site by multiple vehicle tracks.

Figure 8 - Large geoglyph, Crater Range, North Tactical Range, BMGR, Arizona.

Figure 9 - Concentric geoglyphs, Crater Range, North Tactical Range, BMGR, Arizona.

On-the-ground recording of rock features takes up valuable field time. A recent SRI project on the Kofa Range at YPG documented 49 rock features by aerial photography that would have been impossible to document stone by stone on the ground within the allocated survey time. The accurate recording in the field of features from the air is cost-effective, and as a result, is being used more routinely on projects as a recording tool.

On the Kofa Range at YPG, a total of 22 rock features, originally classified as rock rings, were recorded by kite and balloon over a two-day period. Paper-plate markers were spaced with a measuring tape at 5-, 10-, or 20-m intervals around the features, to indicate four corners of a square or rectangle around the feature. These corner markers were oriented to true north using a compass bearing and fixed in place using 15-cm (6-inch) nails prior to the aerial survey. The balloon or kite was then raised to an elevation sufficient to encompass all four paper plates in the picture frame. Determining the photo elevation was carried out by trial and error, and as many as 20 photos were taken at various elevations and then checked on the ground once the camera cradle was lowered. (Although a video transmitter is easy to attach to the camera so that video images from the camera can be transmitted to a handheld television, we have found our current techniques work very efficiently without adding another layer of gadgetry to the camera cradle). The images were then rectified using the paper plates as ground-reference points, and the images digitised to transform them into line drawings, which can be dropped into site maps or used as separate feature drawings. Sometimes the information provided by an aerial photograph can emphasize details difficult to

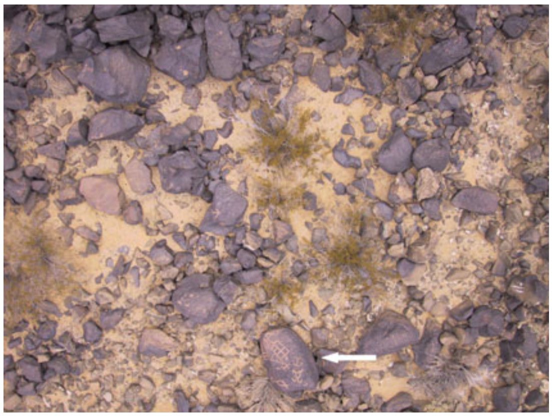

Figure 10 - Close-up of petroglyph (indicated by the arrow) on Peanut Hill, Verbena Village, South Tactical Range, BMGR.

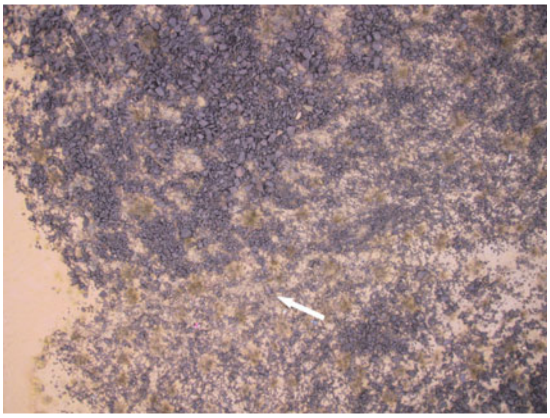

Figure 11 - The same petroglyph on Peanut Hill, from a higher elevation.

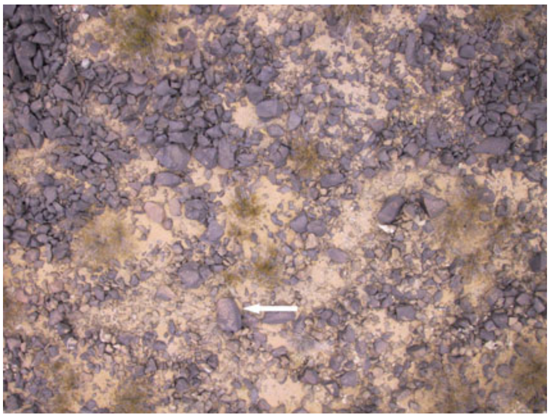

Figure 12 - Petroglyph on Peanut Hill, now seen as part of a trail running east-west, just above the petroglyph.

Figure 13 - Mosaic of aerial photographs showing the perimeter fence of a historical-period ranching site at Green Gate Well, Range 4, BMGR, Arizona.

Figure 14 - Recent vehicle tracks close to a rock ring site; Kofa Range, YPG, Arizona.

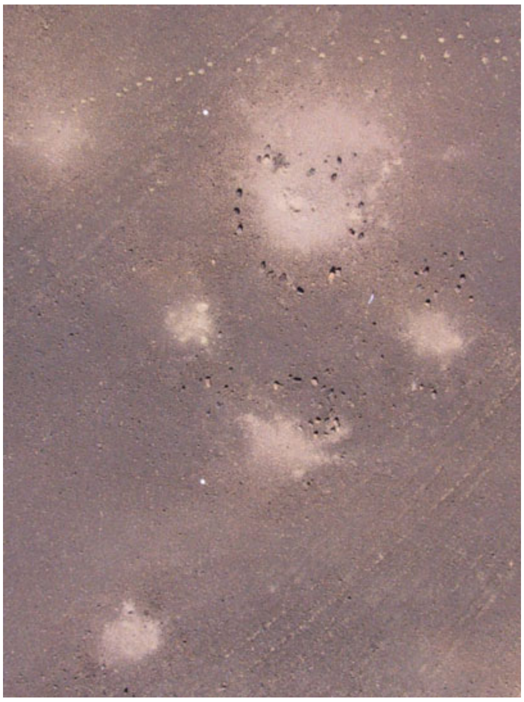

Figure 15 - Rock features, with newly forming animal trail running east-west at the top of the photo; Kofa Range, YPG, Arizona.

portray in line drawings, especially impacts to the feature or the area surrounding it (Figures 14 and 15).

## The Future

SRI hopes to continue to use low-level aerial photography to document sites in the Papaguería. We are experimenting with creating stereo-pairs to create three-dimensional topographical maps to measure quantitative changes in the landscape over time so that predictive modelling can help government agencies prioritise sites in need of protection. We also hope to adapt our camera cradle to house a multispectral scanner that can provide information about the types of materials found on landscapes and in archaeological features. The future of kite and balloon photography is assured until the resolution, cost, and accessibility of satellite imagery can match the resolution of a suspended digital camera.

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