

**REPORT ON
EXAMINATION
AND
PHOTOINTERPRETATION
OF
LAND USE EVIDENCE
FROM
HISTORIC AERIAL PHOTOGRAPHS**

James Ian Ebert, Ph. D.

April, 1986

**REPORT ON EXAMINATION AND PHOTOINTERPRETATION
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**James Ian Ebert, Ph.D.
Certified Photogrammetrist (ASPRS)
Ebert & Associates
3100 Ninth Street, N.W.
Albuquerque, New Mexico 87107
(505) 344-9676**

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In December, 1985 I was contacted by Mr. Terry Fenzl, who asked if I could undertake an inspection of photointerpretive work that had been done in conjunction with the 1934 Navajo-Hopi land claims case. In January 1986 I received a copy of a report by Mr. G. R. Wright, a Salt Lake City surveyor, entitled "1934 Reservation Litigation Aerial Photo Interpretation and Mapping Report" (not dated). This report describes the interpretation of Fairchild 4-lens composite aerial photographs believed to have been taken in March to July of 1934, at scales varying from 1:29,000 to 1:32,000.

Inspection of Annotated Aerial Photographs in Salt Lake City

On January 22, 1986 I traveled to Salt Lake City, where I met Mr. Stephen Maurer and Dr. William L. Graf, with whom I visited the offices of Kennedy & Pugsley. From a large number of aerial photographs -- we estimated the number to be more than 3,000 -- filed in a box, we selected those frames mentioned on the forms and maps in the abovementioned report. These consisted of frames 188, 192, 193, 196, 216, 217, 1-193, 1-194, 1-34, 1-38, 1-39, 1-40, 6223 through 6230, and 3-121.

These aerial photographs were inspected both monoscopically (with the "naked eye"), and stereoscopically using a Topcon mirror stereoscope equipped with a 3x binocular magnification attachment. While the illumination available at Kennedy & Pugsley's offices consisted of ceiling lights, and we were unable to obtain a desk lamp or other additional illumination, we were able to make a preliminary inspection of the areas referred to as "sites" in their report. The method used was to serially go through the forms and maps given in the report, to locate the corresponding areas annotated in red china-marking crayon on the aerial photographs, and to carefully examine these areas using the mirror stereoscope.

At the time of the preliminary inspection in Salt Lake City, my impressions were that the aerial photographs, while historic, were of relatively good quality. The 1:30,000 scale of the photographs, however, meant that small cultural features would be approaching the resolution limits of the prints. Three general classes of cultural features marked on the photographs were examined: (1) structures, including "dugouts," "buildings," and "corn ovens;" (2) "cultivated areas," and (3) "corrals."

The areas identified as corrals were of dark tone, and usually confined to areas along cliffs. In some cases what appear to be rock walls could be identified which would have closed the corral areas. The majority of the "corral" areas, however, did not offer sufficient detail or resolution to allow a determination to be made as to whether they were, in fact, corrals. Neither could it be determined that they were not

corrals.

The structures and "cultivated areas" were even more problematical. The annotated cultivated areas I inspected on the photographs in Salt Lake City are located in sandy playas (areas of internal or closed drainage), which would have been watered by small incoming drainages and may well have been suitable places to grow maize or other crops. I did not, however, see any traces of disturbed earth indicative of cultivation in these areas, nor were there any signs of growing plants, previous years' plant detritus, or water control modifications. I would expect to see one or more of these indicators in areas that were truly under cultivation at the time the aerial photographs were taken.

Areas which had been identified as containing structures had been marked on the aerial photographs with small, red circles made with a china-marking pen directly on the print's surface. (When I interpret aerial photographs, I prefer to mark my interpretations on clear mylar overlays, which can be removed to inspect detail surrounding a feature that is interpreted.) Within the crayon circles, small dots could be seen on the print in some cases, and in other instances there were no discernible markings within the circles. Given the lighting conditions at Kennedy & Pugsley's office, and the lack of time to carefully formulate interpretive keys, I was unable to make any decisions about whether or not any of the annotated "structures" were cultural features. It was determined that it would be advisable to re-interpret the annotated aerial photographs under better conditions at my Albuquerque laboratory, where in addition to stereoscopic interpretation, electronic image analysis could be applied to them and additional details perhaps brought out.

Inspection of the Annotated Aerial Photographs in the Albuquerque Laboratory

On February 28, 1986, I received eleven annotated 9" x 9" paper prints from Kennedy & Pugsley (frames 1-38, 1-39 [two copies], 1-40, 192, 193, 194, 6226, 6227 [2 copies], and 6228.

When interpreting photographs in an attempt to locate specific types of features, it is standard, accepted, scientific photointerpretive procedure to begin with some idea about the general characteristics of such features. Prior to looking at photographs, one compiles a photointerpretive key which outlines the photographic characteristics expected for each class of features to be inspected, and which serves to distinguish it from other features. In photointerpreting the annotated aerial photographs received from Kennedy & Pugsley, the following interpretive factors were compiled prior to interpretation.

INTERPRETIVE KEY

- CORRALS** Corrals should exhibit a dark photographic tone due to organic material deposited there, and its retention of water. Corrals should show evidence of rock walls or fences at their margins, and should be located on relatively level ground to which animals could have been herded.
- CULTIVATED AREAS** Cultivated areas should exhibit some sort of ground disturbance which would be revealed by variations in tone and photographic texture. They might also show evidence of either growing plants placed in regular or at least even patterns, or plant detritus from past years' harvests.
- STRUCTURES OR OTHER CULTURAL FEATURES** Structures and other cultural features are usually very conspicuous on aerial photographs due to their sharp, regular, linear outlines. Structures are expected to exhibit a regular, rectilinear or square shape revealed (1) by relief under the stereoscope, and (2) by highlighting of the structures' sunlit side and the outline of its shadow on the other side (see Photo 1). When structures or cultural features are used, they quickly develop a trampled, utilized area around them which appear light in tone in aerial photographs due to the disturbance of vegetation and the packing of earth. Finally, structures or cultural features are expected to be found in identifiable relationship with other cultural features; for instance, houses with water tanks, fields, corrals, outbuildings, or woodpiles.

Stereoscopic examination was undertaken with the Topcon mirror stereoscope used in Salt Lake City, with the addition of an x-y tracking mount which allows the image to be scanned without having to constantly readjust the relative position of the prints. This facilitates the comparison of different portions of the stereo image, particularly under magnification. The prints were illuminated by a fluorescent light suspended directly below the x-y scanning mount, giving "pinpoint" lighting at the ideal angle for viewing stereo photographs. Additional interpretive and measuring aids used at the Albuquerque laboratory were a Bausch & Lomb 7x reticle magnifier, a Peak 25x

stand microscope with reticle, and Max-Cal digital calipers.

Each of the "sites" noted and mapped in the Kennedy & Pugsley report which appeared on the photographs provided by Kennedy & Pugsley was inspected with the stereoscope at 1x and 3x magnification. This was done in order to compare the interpretations made in Salt Lake City from these prints with those made under more controlled conditions in the laboratory. The interpretive key listed above was used as a guide. Notes taken during the Albuquerque laboratory photointerretation of the prints received from Kennedy & Pugsley follow, divided by the stereo pair on which they are shown.

Pair: Frames 1-39, 1-40

Site 142: I cannot discern any cultural features in this area.

Site 146: Three small dots can be seen, all of which look similar; these may be shrubs or trees, since they are of consistent size. I cannot distinguish any as definitely cultural in nature. Trampling or ground disturbance may be visible in the form of a path in the immediate area of the dots.

Note: There are a number of structures outlined with small red squares on this stereo pair, but which are not listed in Kennedy & Pugsley's forms or maps. These structures provide good "comparison" data to compare with the other claimed structures. They exhibit rectilinear shapes and shadows, and there is evidence of light-toned, disturbed use patterns around them. Two of these structures appear magnified in Photo 1. Both the light-toned, sunlit side of the structures (A) and the dark-toned, shadows (B) are clearly rectangular in shape.

Pair: Frames 6227-6228

Site 90: This area is dark like other "corral" areas, with no other distinguishing features.

Site 89: Again, this area dark like other designated corral areas, although could just as well be dark vegetation at one of the many springs in the area. Springs or seeps along the bases of cliffs are quite common in Moenkopi and other nearby washes. Corrals are quite likely be located near springs, too, which could lead to confusion.

Site 112: While this area exhibits the dark tone expected of a corral, it can be seen under stereo to be located atop a pinnacle or erosional remnant, where sheep could not be herded. This is not a corral.

Site 82: This dark spot appears to be sharply sloped and located on loose talus. By virtue of these topographic cues I do not believe it is a corral.

- Site 81: A small dark dot immediately on the rim at the cliff top appears to be indicated as a "structure." No rectilinear pattern of either relief or shadow is apparent under the stereoscope, nor is any light-toned disturbed area. Both of these indicators would be expected to be present if this were a rectangular structure being used when the photographs were taken.
- Site 80: This site is also identified as a "structure." Under the stereoscope, I can see no distinguishing factors that would convince me that there is a rectilinear structure (or any other sort) here.
- Site 137: I can detect nothing indicating a cultural feature here.
- Site 111: Again, I cannot detect cultural features here.
- Site 110: This designated corral area is very small and darker than most of the other corrals, and appears to me to be heavy vegetation around a spring or seep at the cliff's base. Such springs, which issue from between resistant rock layers, are common in the Moenkopi area.
- Site 145: I cannot discern cultural features at this "site."
- Site 133: A number of shallow holes in surface sediments, within which bedrock is exposed, appear to be the result of quarrying here.
- Site 134: There appears to be a quarry here as well.
- Site 124: I do not discern any expected "corral" indicators at the area marked Site 124.
- Site 125: This site appears faint, and only slightly darker than the surrounding area. It does not convincingly exhibit the recognition factors which would identify it as a corral from the photographs.
- Sites 91, 138, 139: These darker areas may be corrals, but the lack of photo-identifiable walls make this interpretation inconclusive.
- Site 120: This is almost certainly a corral; the wall is plainly visible due to its dark tone and stereo relief.
- Site 119: I cannot see any cultural indications here.
- Site 114: This area fits all of the interpretive criteria for a corral.

- Site 127: There is nothing indicative of cultural features visible in the photographs at this point.
- Site 128: The "corn oven" is not visible at this point on the photograph.
- Site 126: I do not see a rectilinear structure using the stereoscope. There is no regular shadow indication, and while a small dot circled is visible, it appears round, has no component of relief when viewed with the stereoscope, and shows no lighter-tone trampling zone around the structure. There are no other indications which could be construed to be cultural features in the area, either.

Frame 192: Area with no stereo overlap:

- Site 92: I do not see any of the indicators of a cultural structure or of cultural use here on the photograph.
- Site 97: This site appears more like a shrub or tree than a structure, quite similar to many other dark points or dots in the same general area. No relief can be seen without stereo, of course.
- Site 130: There does not appear to be the same dark signature here as is found at some of the other areas designated as corrals; I would not distinguish this area, on the basis of photointerpretation, as a corral.

Pair: Frames 192-193

- Site 21: This appears to me to be a small internally-drained basin or playa. This interpretation is based on an extremely high reflectance, indicating fine, uniform, level sediments. No traces of cultivation, plant growth or detritus, or soil disturbance are discernible to me under the stereoscope.
- Site 93: There are possible rock walls across the arroyo here, and there are dark areas where shown in the Kennedy & Pugsley diagram. The shorter wall shown at the end of the rincon may extend completely across it, unlike on the map.
- Site 94: I cannot see anything indicative of cultural use or disturbance on the photo at this point.
- Site 136: This site, which is located in a closed basin or playa, has apparently been cleared of vegetation. I do not detect evidence of current cultivation or for that matter vegetative detritus from recent harvest. This area had not been used for growing crops for at least

several years before the photos were taken.

Site 135: This is a large, highly-reflective playa or blowout area which has been cleared, and also shows evidence of what may be two linear water-spreading dams along its axis. I do not, however, see any evidence of "cultivation" here indicated by either soil disturbances, planting, or crop detritus. If this was a field, it probably hadn't been used for a number of growing seasons.

Site 88: This "field area may have been cleared but it is unconvincing in that it is unlike the other more reflective areas identified as fields. The "stone structure" identified in the Kennedy & Pugsley map appears round under stereo photointerpretation, and it measures 0.52mm in diameter. At 1:30,000 scale, this would mean that the actual size of this "structure" is 16.5 meters in diameter. This is unreasonably large for either a field house or a living structure. I cannot detect pathways or activity-disturbed vegetation in area. In terms of the immediate drainage patterns, as well, this would be a very unwise place to put one's house. On the basis of stereo interpretation, this is probably a small erosional remnant or hill between the two small drainages rather than a cultural feature.

Site 21: The "structure" apparent from its shadow in this marked area appears to be identical to a number of other features which are all probably shrubs and not structures.

Summary of Laboratory Stereo Photointerpretation Results

Photointerpretation under controlled laboratory conditions allowed the careful interpretation of the "sites" noted on the eleven photographs sent by Kennedy & Pugsley. Following this more intensive photointerpretation, I doubt the validity of a number of the identification which I could not discount in Salt Lake City. Two of the indicated "corrals" are implausible due to their topographic placement and inaccessibility in one case, and because of a steeply sloping floor in another.

The "cultivated areas" are also difficult for me to agree with. The areas identified as cultivated could have been used for planting maize or other crops. In none of the cases however, is there evidence on the photographs of ground disturbance. The ground surfaces are, in fact, quite remarkably undisturbed. This indicates that these areas were not "under cultivation" when the 1934 aerial photographs were taken.

None of the "structures," nor the "corn ovens," show convincing evidence of actually being so. There are small, dot-like marks on the aerial photographs in some of the places circled and called structures, but no rectilinear relief, shadow marks, nearby trampling, or vegetative disturbance is visible at these "sites." Neither are there any associated cultural features. I would not expect structures to be located completely alone in places with no other cultural features or uses.

Electronic Image Enhancement

In order to further explore the identity of the "sites," electronic image analysis techniques were applied to four targets, specifically Sites 80, 81, 136, and 146. These are identified as two structures, a cultivated area, and a corn oven respectively. These sites were taken as examples of the identifications, which would be examined intensively using not only stereo photointerpretation, but also more sophisticated electronic techniques. If there were any valid indications of cultural features at these sites, they would be brought out by the combination of these two methods.

Image analysis was performed using a "Digicol" system, an analog video image processing system which I built using components manufactured by International Imaging Systems. The Digicol system performs analyses which are similar in methods and results to techniques used by the CIA and Defense Department to identify ships and structures from aerial photographs, or the analyses used by NASA to sharpen views of planets from satellites or more recently to inspect the Challenger shuttle photographs. The Digicol system focuses a video camera on a photograph (both prints and transparencies can be used) mounted on a light table. The camera records a matrix of electronic values representing the amount of light that passes through the photographic emulsion for a "blanket" of 512 x 512 points which comprise a video frame. The camera has a lens and bellows attachment, allowing a wide range of magnifications, up to about 100x, to be used. In this way, very small portions of an aerial or other photograph can be seen within the frame.

The Digicol system uses the data from the video camera to improve the quality and interpretability of such small portions of photographs through contrast enhancement and edge enhancement. Contrast enhancement "stretches" the range between the lightest and darkest parts of the scene viewed to show all parts of a scene more clearly. This is especially necessary when contrast is low, as it is in the photographs which were being examined. Many aerial photographs had low contrast, particularly multi-generational copies of aerial photographs as all those used in this case are. Essentially, contrast enhancement makes it easier for an analyst to see dark objects against a light background, or vice versa.

Edge enhancement displays the change in photographic density across the video scan lines, rather than its absolute values. It shows the edges of objects on the photograph, in effect making the focus of the photograph sharper. NASA employed edge-enhancement to show the puff of smoke on Challenger's booster rocket more clearly.

The appended photographs of the Digicol's black-and-white monitor screen show the results of the Digicol analysis.

Prior to looking at Sites 80, 81, 136 and 146 with the Digicol system, a number of "comparison" targets from the photographs supplied by Kennedy & Pugsley were inspected. These known fields, shrubs and rectangular structures were contrast and edge enhanced in order to make them optimally interpretable.

The first target inspected was two rectilinear structures outlined in red marker on the photographs, but not mentioned in the Kennedy & Pugsley report [Photo 1]. These illustrate what square or rectangular structures look like on aerial photographs. They exhibit a light side, illuminated by the sun (A), and a darker shadow (B). Both the illuminate side and the shadow have linear edges and are regular in shape. The rectangular shape of the structure can easily be seen regardless of the "fuzzy" edges of the image itself at high magnification.

The second "example" target examined was an area with a number of shrubs (probably greasewood) in Moenkopi Wash [Photo 2]. The shrubs appear circular, and do not exhibit rectilinear outlines or shadows. They uniformly measure approximately 0.1mm on the photograph, or 3 meters in diameter on the ground.

A third example area which was contrast and edge enhanced using the Digicol system [Photo 3] is from a cultivated field in Moenkopi Wash. Dark and light patterning representative of ground disturbance and/or growing crops can be seen clearly in this example.

Following the image analysis of the example sites, the four sites (80, 81, 136, and 146) taken to be exemplary of the Kennedy & Pugsley identifications were analyzed with the Digicol system.

Site 80

Within the circle marked "Site 80" [Photo 4], a number of dark spots can be seen in the image analysis, which is at the same magnification as that of the square structures in Photo 1. None of these spots show evidence of rectilinear outlines. The white marks on the enhanced photo are defects on the print. The dots within this area measure 0.1mm or less, indicating that their actual sizes are 3 meters or less. A rectangular structure being used when these photographs were taken should exhibit at least some of the recognition criteria listed for structures earlier in this report. This site does not.

Site 81

Site 81 is identified in the report as a rectilinear structure immediately on the rim above Moenkopi Wash. Within the circle marked as "Site 81," a relatively large dark dot appears. It does not exhibit rectangular shadow patterns characteristic of standing rectilinear-outlined structures; its size is about 0.17mm on the photographs, indicating that it is about 5.1 meters in diameter. I cannot accept this dot being the image of a rectangular structure currently in use.

Site 136

The portion of "Site 136" imaged using contrast and edge enhancement is in the center of the indicated "cultivated area." There are no traces of earth disturbance or crop patterning which would indicate cultivated areas as shown in the example area shown on Photo 2. On inspection, the area seems to be covered, in a "random" pattern, by shrubs measuring approximately 0.1mm or slightly larger on the photograph (3 meters or slightly larger in diameter on the ground). I would not expect to find such shrubs in any cultivated area, and hence I do not believe this area was being cultivated at the time the photographs were taken.

Site 146

Site 146 is identified as a "corn oven visible on aerial photo." Photo 7 is a picture of the Digicol monitor screen within the circle marked "Site 146." There are a number of indistinct spots visible in this photo. They consistently measure 0.1 to 0.15 mm in diameter, indicating their actual size on the ground to be between 3 and 4.5 meters in diameter. There are no distinguishing characteristics which would lead me to interpret any of these dots as being a corn oven.

In addition to examining examples of the Kennedy & Pugsley sites using Digicol analysis, also examined three Navajo use areas through identical analyses. These areas are View Point Well, Goldtooth Ranch, and a structure or group of structures located in Kerley Wash.

View Point Well

Conspicuous in this enhanced photograph is a large, square area which is undoubtedly a corral, in the lower center of Photo 8. A structure of some sort, perhaps a tank or shelter, appears at 45 degrees to the upper left of it. A small, dark spot on the cliff edge (arrow on Photograph 8) is a hogan.

Goldtooth Ranch

At Goldtooth Ranch (Photo 9), an ephemeral wash feeds into a cultivated field in a sandy blowout area. At the point the wash disappears into the sand there is a structure which appears clearly rectangular (at the arrow, Photo 9). The structure measures about 6 meters long, and about half that width (which is difficult to determine due to its orientation with the sun). The other marks on this photograph are not structures; they do not appear on both of the photographs in the stereo pair which indicates that they are blemishes on the print or the copy negative from which the print was made.

Kerley Wash Structures

The area in Kerley Wash shows a rectangular structure (at the arrow), above the scale directly above the "8" and "9", and topographically above a pond or eroded area, directly above Kerley Wash. There is another topographically distinguished high immediately to its right on the photo, which I interpret to be a tank or another structure. There is evidence of vegetative disturbance and trampling in the immediate area.

Field Check at Tuba City/Moenkopi

In mid-March, I conducted a brief field check of some of the interpretations I had made, by traveling to the Tuba City/Moenkopi area, visiting "Sites" 80, 81, and 146 as well as View Point Well.

Site 80

At site 80, I found the ruins of a square stone structure evidenced by two to four standing courses of flat stone, with a door oriented toward the Moenkopi Wash. This foundation measured 6 meters x 2.5 meters; the scatter of rocks which resulted from its fallen walls, however, is more nearly circular or oval, approximately 6.5 meters x 5 meters in size. It lies on a low terrace or erosional remnant about 8 meters above the present wash. It is shown in Photo 11. This structure lies at the approximate point identified as Site 80. Viewing this structure from the top of the nearby cliff, it was difficult to tell that it was rectangular due to the more circular or oval pattern of the fallen rocks.

One of the small, indistinct dots visible on the aerial photograph at this point may be the image of this structure, although I cannot determine which dot it is. There is, however, no indications on the aerial photograph of any rectilinear patterning. My conclusion is that if the structure I found on the ground at this site is responsible for the dot in the 1934

photograph, it was in approximately the same condition it is in today -- that is, it was a ruin then as well. The stones which had fallen from the walls "softened" the rectangular outline of the low foundation. This dot would exhibit neither rectilinear patterning nor topographic relief when viewed under the stereoscope.

Site 81

At the point identified "Site 81," the ruins of a stone structure were found immediately on the cliff rim. It was originally square, the doorway faces east, and there are many as 12-15 courses of masonry, standing some 1 meter high, on its north and west. Some mud chinking remains. The foundation of this structure measures some 3.5 meters west to east, and 7.5 meters north to south. It is filled with blown sand. The outline of this ruin, due to the fallen rocks from upper courses of the walls, is also roughly circular today.

My conclusion about Site 81 is the same as discussed above under Site 80. I feel that this structure, if it present and responsible for the dark dot in the 1934 photograph, was in ruins then as well and was not inhabited or used.

Site 146

This site, reported to be a "corn oven," consists of a scatter of rock measuring about 5 meters along the edge of the bank. It lies near a trail which extends from the top of that bank into the first terrace of the wash. There is a large and conspicuous wooden beam also partially imbedded in the ground at the foot of the bank. This site is either very eroded or covered by sediment derived from the leveling of a field directly above it. The surface of the terrace immediately above the bank in which the rocks are imbedded is slightly depressed. The rock is not visibly burned or discolored by heat.

On the basis of my experience, I would not expect a corn oven to leave such remains. Rock from a corn oven would be burned, reddened and cracked. It would not become incorporated into a bank in such a manner, either, but would remain near the surface. I do not believe this is a corn oven as it was marked on the photographs. The dark dots in the photo were probably shrubs.

View Point Well

In addition to checking Mr. Wright's Sites 80, 81, and 146, I visited View Point Well, a Navajo settlement area. At view point well, which is easy to locate due to the unique wind-carved rock formations, I could not locate the large, square corral or the tank or structure that appears next to it on the aerial

otos. There are, however, many flat stones in the area, which
uld have been parts of the corral walls or the tank or
ructure.

On the edge of the cliff, there is a round, stone hogan
oundation surrounded by rocks from the collapsed walls.

James Ian Ebert, Ph.D.