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THE IDENTIFICATION OF ARCHAEOLOGICAL SITES

BY FALSE COLOR INFRARED AERIAL PHOTOGRAPHY

by

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## INTRODUCTION

For the last few years various remote sensing techniques, such as false-color infrared aerial photography and infrared scanner imagery, have been utilized as detection techniques with great success in such disciplines as geology, geography, and forestry. More recently these methods and devices have been applied to archaeological problems with varied degrees of success. Indications are that the greatest value remotely sensed data has to archaeology is in the detection of cultural features and in the delineation of environmental zones and microenvironments (Gumerman and Lyons, 1971). To date, however, no tests have been undertaken to obtain quantifiable data in an area characterized by differing microenvironments. Our tests indicated that the capabilities of false-color infrared film were potentially most sensitive and useful for such a project and it was selected as the medium for testing.

The Tehuacan Valley in the State of Puebla, Mexico, was chosen as the area of study for four main reasons. Primary among these was the extensive coverage with various aerial remote sensing devices that was available for the Tehuacan Valley because NASA had photographed the area at the request of the Mexican Comision de Espacio Exterior (Site 706 - Papaloapan Basin). This coverage was obtained to collect data on the hydrology, agriculture, and geology of the Valley. It is important to keep in mind that these data were collected for other than archaeological purposes. Since the cost of NASA missions are very high, and obviously beyond the reach of an archaeologist's budget, one facet of the test, and admittedly an uncontrolled variable, was the determination of the applicability of remotely sensed data to archaeology even though that information was collected for other purposes.

A second major reason for the selection of the Tehuacan Valley as the test area was the extensive work undertaken there in the early 1960's by Richard S. MacNeish and his associates of the Tehuacan Archaeological-Botanical Project. MacNeish (1964 and 1967) has demonstrated a long and continuous occupation of the Valley from at least 7000 B.C. to the present. In addition, there is a great variety of cultural features, such as platform mounds, ballcourts, terraces, canals, etc., within and associated with the sites of occupation. Consequently, the aerial photographs can be checked for the visibility of different types of sites and sites of different ages.

Thirdly, the Tehuacan Valley seemed a good choice to test the usefulness of false-color infrared photography in the construction of environmental maps for the archaeologists. This region was the location of some of the earliest and still ongoing studies emphasizing the necessity for the archaeologist to consider microenvironmental implications in the analysis for economic and socio-cultural systems and processes (Coe and Flannery 1964; Flannery 1967; Flannery and Coe 1968; and Flannery 1968). As a result, the microenvironments have been delineated in considerable detail and provide a good test situation.

Finally, the Tehuacan Valley was chosen because the region was known to the Principal Investigator, only through the publications of the Tehuacan Archaeological-Botanical Project. This insured a less biased, more valid testing for the identification of cultural and natural features using only the aerial photographs.

#### METHODOLOGY

Data was collected from the Tehuacan Valley by NASA in April of 1969,

using a camera cluster with multiband black and white photography, color photography, side-looking radar imagery (SLAR), infrared scanner imagery, and false-color infrared photography. Our test was restricted to the use of false-color infrared photography due to two reasons. First, experience in other regions, such as the Southwestern portion of the United States (Gumerman and Lyons 1971), has indicated the best results might be obtained from this type of film. Second, was the fact that time and money limitations made the examination of the other photographic and imagery materials impossible. Unfortunately, a direct comparison of panchromatic black and white film with the color infrared film could not be made as no standard panchromatic photographs without filters were taken of the Valley by the NASA team.

Infrared scanner imagery, which records infrared radiation further into the invisible part of the spectrum than regular infrared films, has previously been used successfully to locate sites, some of which are invisible upon surface inspection (Schaber and Gumerman 1969). However, the high altitude at which the infrared scanner imagery was taken in the Tehuacan Valley made it useless for archaeological reconnaissance.

Two hundred and fifty feet of color infrared photographs in a 9 inch by 9 inch format were taken at 5000 and 25,000 feet, providing our basic data. Since it is necessary to use the color infrared film as transparencies, unless extremely expensive color contact prints are made, we found it convenient to make two sets of black and white contact prints - one set for uncontrolled photo mosaics for field use, and the second set for use as stereoscopic pairs. Selected use of the stereo pairs was made at several sites, but no well controlled test of this technique

was undertaken during this program. Although the resolution is not as great on the black and white contact prints as it is on the color infrared film, most cultural features visible on the transparencies are visible on the contact prints. This is because cultural features usually do not show as different colors, but rather as different tones of the same color. Different natural features often do show as distinct colors and as a result the black and white contact prints could not be used for delineating natural zones.

Before going to the field a careful inspection of the low altitude color infrared film was made by archaeologists without field experience in Mesoamerica in an attempt to locate all presumed prehistoric cultural features. It was soon apparent that so many sites were visible that representative types of features such as platform mounds, canals, and terraced fields were selected for inspection on the ground. Furthermore, the area photographed was so large that only certain selected sections within the different microenvironments characterizing the entire valley were chosen for survey.

No attempt was made at delineating microenvironments until after a brief visual inspection was made of the valley. Coe and Flannery's 1964 Science article which briefly defines the microenvironments of the Tehuacan Valley was read, but Flannery's (1967) more detailed analysis in Volume I of The Prehistory of the Tehuacan Valley was purposely not consulted until after an attempt was made to determine ecological sub-areas from the color infrared photographs.

Finally, a month was spent checking the features observable on the infrared photographs with the ground truth in an attempt to determine

why different types of features were visible. After one week in the field, Dr. James A. Neely, who had been a member of the Tehuacan Archaeological-Botanical Project survey team, joined the project to point out sites in different microenvironments which were not visible on the color infrared photographs. At this point the process of explanation was reversed, that is, we had to determine why these sites were not visible on the photographs.

#### DATA AND RESULTS

It was soon observed that a major factor in determining the visibility or nonvisibility of a site on the color infrared photographs is the micro-environment in which the site is located. Therefore, before discussing the value of color infrared film in site determination we will discuss its use in constructing a detailed picture of the landscape or natural maps.

The detection and outlining of all of Flannery's ecological subareas and "specialized niches" from the color infrared photographs was done with virtually 100 percent accuracy before a study of Flannery's 1967 article. The ecological subareas and specialized niches were conspicuous because of color or tonal differences. This was true of all of the microenvironments with the exception of the specialized niche Flannery has named "The Short Grass Steppe West of Venta Salada." It was at first assumed that this area was photographically overexposed on the color infrared photographs because the transparencies are light and show relatively little color density and differentiation. The ground truth survey indicated that the reason for the lack of color on the film was not due to a photographic overexposure, but to an actual lack of vegetation. Flannery (1967:135)

describes the specialized niche as a barren plain, ". . . devoid of all but short-grass cover and an occasional tree legume." If we had had more familiarity with color infrared photography in widely differing environmental situations we would have realized that this apparent photographic "overexposure" indicated in reality a specialized ecological niche. With this single exception all subareas and specialized niches were clearly visible and their boundaries, where distinct, could be sharply defined.

More difficult to distinguish were the various cultural features. Even though all specialized niches were easily distinguishable, it is most convenient when discussing site visibility to use Flannery's four main ecological divisions or "subareas" - (1) Alluvial Valley Center and Broad Travertine Terraces on the West Side of the Valley; (2) The Limestone - Travertine Slopes and Steppes on the West Edge of the Valley; (3) The Broader Alluvial Slopes on the East Edge of the Valley; and (4) Narrow Canyons and Dissected Alluvial Slopes on the Southeast Edge of the Valley.

Table 1 summarizes the success of distinguishing sites in the different ecological subareas or microenvironments. Flannery's "Narrow Canyons and Dissected Alluvial Slopes" subarea was considered as part of the Alluvial Slopes subarea due to the identical problems in seeing sites in both of the subareas and the fact that Flannery (1967:139) himself observes that "Subarea 4 (Narrow Canyons and Dissected Alluvial Slopes...) might just as accurately have been considered a niche within Subarea 3 (The Broader Alluvial Slopes...), for it lies within and alternates with the latter."

	Alluvial Valley Center and Terraces	Travertine Slopes	Alluvial Slopes (Thorn Forest)
Total Items	20	11	11
Percent Visible	85%	100%	0
Percent Not Visible	15%	0	100%
Number Correct	17	10	0
Number Incorrect	0	1	0

**TABLE 1**

An index of the success of discerning archaeological sites and features located within three ecological subareas of the Tehuacan Valley through the study of false-color infrared photographs. Total Items: the number of sites inspected on foot in each of the ecological subareas. Percent Visible: the percentage of sites and features visible on the photographs within each individual ecological subarea. Percent Not Visible: the percentage of sites and features not visible on the photographs that were present within each of the ecological subareas. Number Correct: those sites or features which are visible on the photographs that were correctly identified as to their function. Number Incorrect: those sites or features which are visible on the photographs that were not correctly identified as to their function.

Site discrimination was quite successful for the Alluvial Valley Center and Terrace subarea. Of the 20 sites visited in this subarea, 17, or 85%, had previously been discovered on the color infrared photographs. Only three, or 15%, could not be seen. Furthermore, in all instances the types of features noted, platform mounds "fossil" canals, etc., were correctly identified.

Mounds were especially pronounced in this subarea because modern farmers avoid the larger, more difficult to plow and irrigate raised land forms. The distinction between plowed fields and associated cultivated plant forms and the natural vegetation on the valley floor is the recognition signal. It seems very likely that mounds surrounded by plowed fields would be almost as easily discernible on regular panchromatic film as on color infrared film, except that the vegetation differences are enhanced with the latter medium.

More difficult to distinguish are the smaller sites. In such cases the surface features have been almost completely destroyed by modern farming and all that remains are scattered sherd and cobble areas. The three sites within this subarea that are not observable on the film are sherd areas. However, under certain circumstances sherd areas may show clearly in plowed or harvested fields. This was evidenced by a site that is visible on the photographs as the outline of a rectangular structure. Surface inspection revealed only a sherd area and no rectangular pattern. The pattern is visible on the film because of an absence of color suggesting that where the structure stood, or the foundation presently exists below the surface, the corn did not grow as well, leaving the rectangular pattern not discernible on surface inspection.

Linear agricultural borders constructed of stone and brush are strikingly visible on the color infrared photographs of the broad alluvial slopes on the west edge of the valley. Hundreds of linear borders of two types are visible: those registering as dark lines and those visible as light lines. The dark lines are rock borders, most of which are only one course wide and one or two courses, about 10 to 25 centimeters in height. These features are visible as dark lines on color infrared film because the rock absorbs and reflects solar radiation to a greater extent than the surrounding soil and grass surfaces. The light lines represent long, narrow erosional surfaces characterized by almost a complete absence of vegetation. It is this lack of vegetation that causes the long, narrow strips to appear as light lines on the transparencies. There are several sources of evidence that indicate these erosional surfaces are the remnants of linear borders constructed of brush and other perishable materials. In fact, most of these narrow erosional surfaces appear to be parts of, or continuations of, the same water and soil control systems as the agricultural borders constructed of rock. The rock borders tend to characterize the upper slopes of the terrain while the erosional surfaces continue the evenly spaced pattern, closely following the contours of the lower, less steep portions of the slopes. The less steep portions of the slopes were apparently modified through the construction of very low terrace or linear border walls of brush and wood which have since disintegrated leaving the slight alluvial terraces with an erosion surface at the break in slope where the border once stood. Although the stone borders, and only the stone borders, were noted during the Tehuacan Archaeological-Botanical Project survey,

the extent and form of this particular water and soil control system was not, and could not be, discerned or mapped from the panchromatic black and white aerial photographs available to that project. The entire system could be mapped in several hours from the color infrared photographs.

Even better success was had at spotting sites from the color infrared photographs of the Travertine Slope microenvironment, although individual cultural features were not usually as clear as they were in the Alluvial Valley Center subarea.

Table 1 indicates that 11, or 100%, of the sites recorded on the travertine slopes within the study area are observable on our photographs. The individual features include "fossil" and modern canals, platform mounds, courtyards, etc. The reason for the prominence of cultural features on the photographs is that the ground surface is almost barren limestone or travertine with little or no soil cover. Consequently, the dominant vegetation is comprised of short grasses which do not grow well on the cultural features, resulting in their definition on the photographs. In some instances, such as the platform mounds at the large Post-Classic site of Venta Salada (designated as site TR-57 by the Tehuacan Archaeological-Botanical Project survey), grass covers the features, but not as densely as it does the surrounding lands, resulting in a poor but still recognizable definition of the features. Although this site and all associated features noted on the ground were visible on the photographs, one feature was misidentified. This was a partially filled in, grass-covered "fossil" canal that was at first identified as a wall partially surrounding the site. This misidentification was a result of the Principal

Investigator's unfamiliarity with the valley's archaeology.

One entire "site" was incorrectly identified from the photographs of the travertine slopes. The object on the photograph, approximately one kilometer northwest of the Venta Salada site and in the same ecological subarea, appeared similar to one of the Venta Salada platform mounds. After a considerable search for the site on foot it was discovered to be a recently abandoned field which had been cleared of vegetation. The lack of relief was not apparent on the photograph but after visiting the "site" and re-examining the transparencies with a hand-lens, furrows were discerned and should have been noted before the field check.

The Alluvial Slopes or "thorn forest" ecological subarea effectively concealed 100 percent of the sites. It is in this microenvironment that a number of important sites, ranging in date from the Santa Maria (Formative) Phase through the Venta Salada (Post-Classic) Phase, had been discovered by the Tehuacan Archaeological-Botanical Project survey team. Only after Neely pointed out some of the larger sites which he had visited previously did they become discernible on the transparencies. Recognition was with much difficulty and uncertain, and most of the individual cultural features within the sites could not be seen at all. For example, the Purrón Dam (TR-435), a structure some 400 meters in length, 125 meters wide, and 25 meters high, appears to be a natural topographic feature. It was discernible as a man-made structure only when, and if, it was considered in relation to the canyon bottom context across which it had been constructed. A nearby Palo Blanco (Classic) Phase hilltop site (TR-73) was extremely difficult to detect on the

transparencies even after visiting the site and having knowledge of its exact location. This site is approximately 1.0 by 1.5 kilometers in size, and is characterized by architectural terraces upon which were constructed large platform mounds flanking plaza areas, a ballcourt, and other architectural features.

The reason for the concealment of the sites within this ecological subarea is that although the climate is semi-arid, and the plant cover primarily consists of cactus and small leaf shrubs and trees, the vegetation is forest-like with a broad canopy closing from one to two meters above the surface (Smith 1965:117; Flannery 1967:138-139). The canopy is not generally or uniformly dense nor does it consistently obscure the surface of the ground. Nevertheless, it does effectively "blur" the cultural features so that they are indistinguishable from natural features.

#### CONCLUSION

The results of the Tehuacan Valley test of false-color infrared film for archaeological utilization indicate that the visibility of sites depends primarily on its environmental situation, and also that the delineation of environments and microenvironments is especially easy with this type of film. Furthermore, we can state that the age and size of the sites are not necessarily the deciding factors in their discernment. A special effort was made to study sites and features ranging widely in age and size within each of the ecological subareas represented. Unfortunately, one of the more important tests of this type was frustrated by the almost complete erosional destruction of the shallow Abejas Phase

(ca. 3500 to 2300 B.C.) pithouse hamlet discovered northwest of the modern village of San Gabriel Chilac in the early 1960's by R. S. MacNeish (1964:535-536). More important than age in site discrimination is the affect of the site on the vegetation and the resultant patterning in color and tonal variations on the film. For example, a single alignment of cobbles and small boulders one course in height or a small bare spot is conspicuous in an environment of grass cover because it interrupts the natural vegetative pattern.

Since the immediate environment is the most important factor in site discrimination the data obtained in the Tehuacan Valley can be transposed to similar environments and microenvironments on a world-wide basis. Table 2 lists the four critical factors, a combination of edaphic and vetative conditions, for site discrimination:

- 1) Agricultural land currently or recently under crop
- 2) Absence of vegetation
- 3) Locations where grassy vegetation is predominant
- 4) Locations having a forest or forest-like vegetation with a broad canopy cover

TABLE 2

Edaphic and vegetative conditions affecting archaeological site discrimination on false-color infrared aerial photographs

- 1) Agricultural land which is under crop or has recently been harvested reveals sites on color infrared film for several reasons. Color infrared film is especially adopted for determining plant speciation

and plant vigor (Colwell 1970). Habitation areas which are now used for agriculture affect plant vigor either by increasing or decreasing production. As noted previously, large cultural features may be partially or completely outlined by cultivation and the difference in vegetation is readily apparent on color infrared film, although regular panchromatic film may be almost as effective in this instance.

2) Sites are distinguishable in areas devoid of most vegetation in eroded, saline, or extremely arid zones if cultural features are constructed of materials different in consistency or type from the surrounding soil matrix because they absorb and reflect solar radiation differently.

3) Sites in a predominantly grassy environment are visible because in most cases either the grasses grow differently, that is with greater or lesser vigor, or different types of grasses grow on these features. As noted above, color infrared film is capable of reflecting differences in the presence of plant species and varying degrees of plant vigor.

4) Finally, it is apparent that for archaeological reconnaissance color infrared photography is unsuitable for use in a canopy forest environment because the canopy visible to the cameras usually does not reflect the disturbances caused by the past human habitations it covers.

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