

THE TRUSTEES OF THE
UNIVERSITY of PENNSYLVANIA
COMPTROLLER'S OFFICE, 3451 WALNUT STREET
Philadelphia, Pa. 19104

To: U. S. Department of Interior
National Park Service
Attn: Mr. Rex Wilson
Washington, D. C.

Date: October 12, 1972

Contract No. - 14-10-9-900-369

Contract To. Dr. F. Rainey

Account of 4-10100-3-5424

Contract Amount: \$6,000.00

TITLE: "Study of Aerial Photographic Systems"

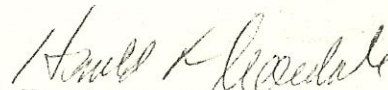
MAY 7, 1971 TO OCTOBER 15, 1971

Invoice per terms of agreement - - -

\$1,500.00

Contract	\$6,000.00
Receipts	<u>4,500.00</u>
PAYMENT DUE	<u>\$1,500.00</u>

Respectfully submitted,



Harold F. Coverdale
Manager - Contract Accounting

HFC/cs



United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:

H22-PHA

November 13, 1972

*John Coker
Julian*

*Beth Ralph
Bruce Bevan*

*Use bloody
copies?*

Jro

Dr. Harold F. Coverdale
Manager - Contract Accounting
University of Pennsylvania
Comptroller's Office
3451 Walnut Street
Philadelphia, Pennsylvania 19104

Dear Dr. Coverdale:

We have received an invoice for final payment of \$1,500.00 for contract 14-10-9-900-369, "Study of Aerial Photographic Systems."

We are unable to provide this payment because we have not received the required five (5) copies of the final report.

Sincerely yours,

Jack R Rudy
Jack R Rudy
Acting Chief Archeologist

cc:

Dr. F. Rainey, Univ. of Pa.

*John Hampton
Royal Comm. on Hist Monuments
Fortress House
Savile Row, London, W.1.*

*6.75
2.50
9.25*



November 29, 1972

Dr. Jack R. Rudy
Acting Chief Archaeologist
National Park Service
United States Department of the Interior
Washington, D. C. 20240

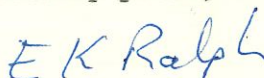
Ref. H22-PHA

Dear Dr. Rudy:

Dr. Rainey has asked me to reply to your letter of November 13 to Dr. Coverdale in regard to the final report for contract number 14-10-9-900-369, entitled "Study of Aerial Photographic Systems."

Unfortunately the report is not yet ready. Various aerial photographs are now being interpreted, and we hope to complete the report within a few months.

Sincerely yours,



Elizabeth K. Ralph

EKR/c
cc: Dr. H.F. Coverdale



United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:

H2219-PHA

August 31, 1973

Ms. Elizabeth K. Ralph, Associate Director
Museum Applied Science Center for Archaeology
University Museum
University of Pennsylvania
33rd & Spruce Streets
Philadelphia, Pennsylvania 19104

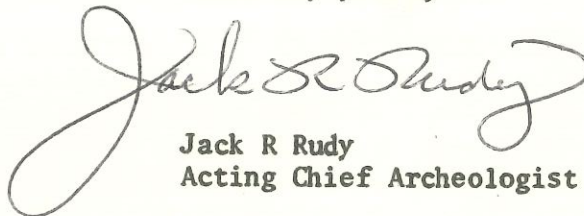
Dear Ms. Ralph:

Thank you for your letter of August 16 regarding Contract No.
14-10-9-900-369.

Your suggestion to provide additional detailed data on the experiments
conducted by Mr. Bevan in Great Britain will strengthen the report.
As I understand the situation, these experiments were actually part
of the project for the purpose of developing the type of information
specified in the contract.

Your assistance in this matter is appreciated.

Sincerely yours,



Jack R Rudy
Acting Chief Archeologist

September 27th, 1973

Dr. Jack R. Rudy
Acting Chief Archaeologist
U.S. Department of the Interior
National Park Service
Washington, D.C. 20240

Ref: H2219-PHA

Dear Dr. Rudy,

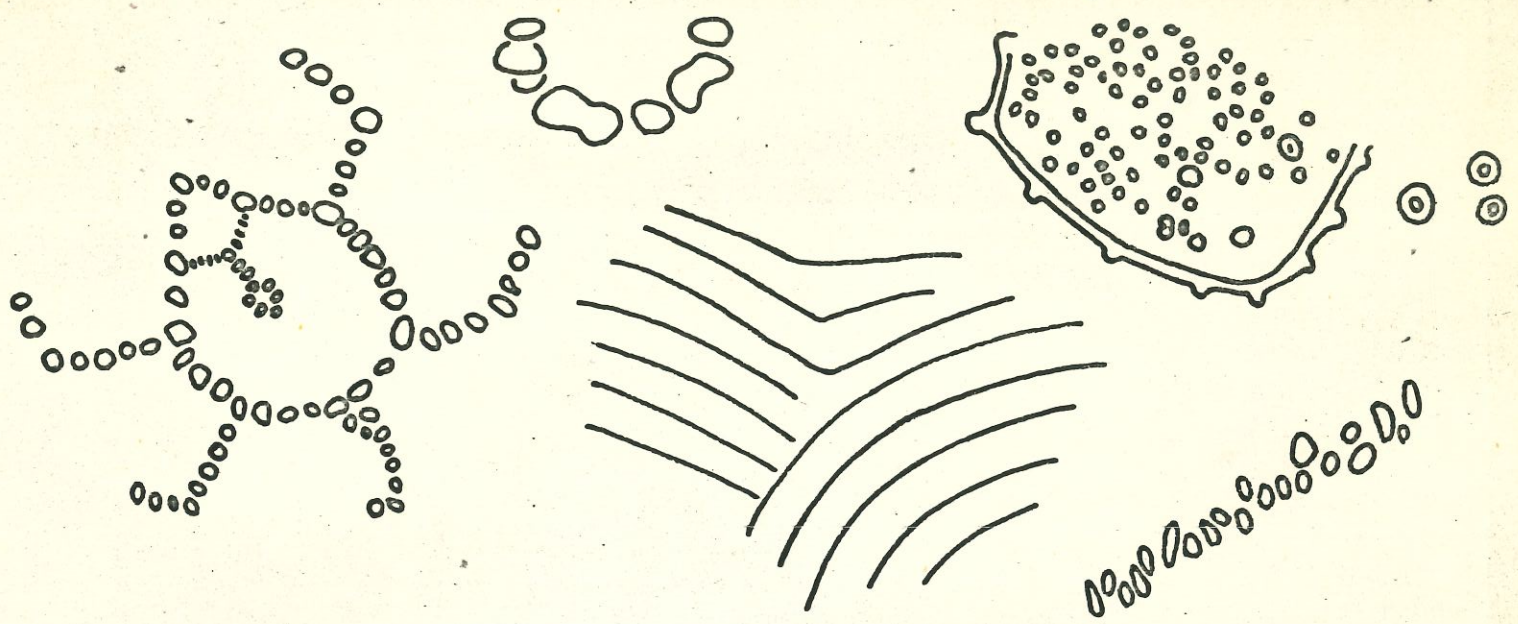
In regard to Contract No. 14-10-9-900-369 and your letter of August 31, 1973, we have prepared reports of the aerial photographic experiments in Great Britain (by John Hampden) and the subsequent magnetometer follow-up at Kingscote (by E. K. Ralph).

These experiments were actually part of the project although they took place before we received the written contract and its specifications.

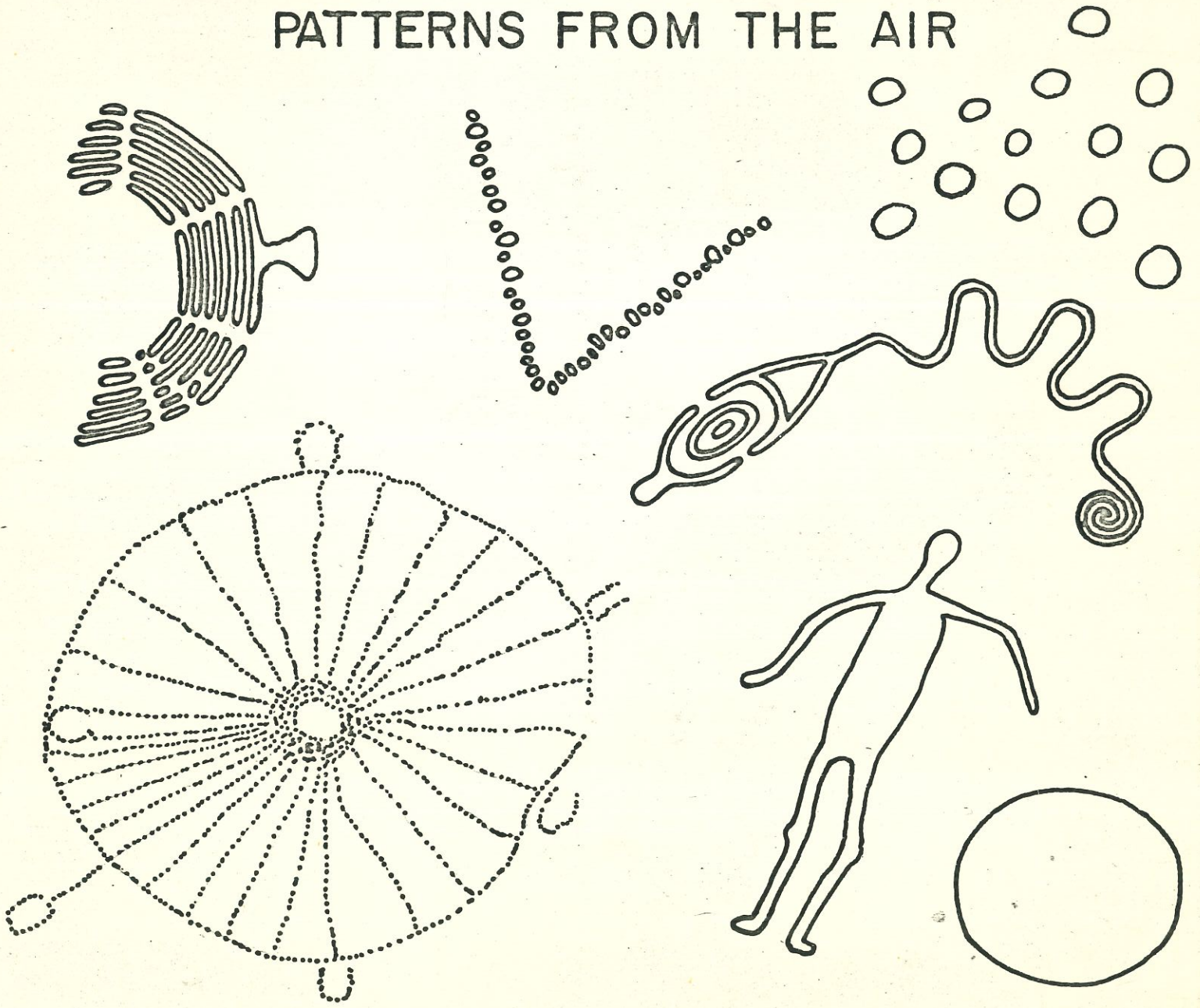
Sincerely yours,

Elizabeth K. Ralph

REPORT 1971



PATTERNS FROM THE AIR



AERIAL PHOTOGRAPHY AND ARCHAEOLOGY IN THE UNITED STATES

a report prepared for the
National Park Service

May 31, 1971

Museum Applied Science Center for Archaeology
The University Museum
University of Pennsylvania
Philadelphia, Pennsylvania

(This report marks the completion of the third quarter
of a contract with the National Park Service.)

AERIAL PHOTOGRAPHY AND ARCHEOLOGY IN THE UNITED STATES ----
PATTERNS FROM THE AIR

Before undertaking an analysis of the next applications of archeological aerial photography, a summary of prior work will indicate the past capabilities of photography and some of the surface features to be expected.

To do this, published examples of archeological objects which are or would be visible in aerial photographs are summarized below. One possible classification for these ground marks would be:

Topographic marks
Mounds
Depressions
Rock patterns
Field marks
Vegetation marks
Soil marks

Topographic marks are the result of man-made changes in ground elevation. Earth mounds and depressions can be very difficult to spot from the air unless a low sun angle shows their relief with shadows. Water or snow cover, by filling low points, can also enhance the visibility of these features. Also, they are often enhanced by soil and vegetation variations, so that a disjoint classification is not always possible. Rock patterns, like all archeological marks, are much more visible if they are obviously artificial patterns. While nature does create linear and circular shapes, more complex ones will be obviously man's, although modern man's will always be a confusing factor.

Mounds

Many circular mounds are found in the midwest. A noted example

is the Cahokia site along the Mississippi River near East St. Louis, Illinois. Aerial photography has been used at this site several times (1: p.13,14; 2: p.79). However, circular or conical mounds are often difficult to locate from the air because they are often in wooded areas or are covered with trees (3; 4: p.1-124).

One of the most famous effigy mounds is the great serpent ^{mound} in Adams County, Ohio (3: p.230,1). This 1300 ft long sinuous bank of soil is 2-3 ft high. A tremendous variety of animal effigy mounds are located in southern Wisconsin and the nearby states (3: p.295-301). The size of these averages about 100 ft, so they should be easily seen from the air.

An example of linear mounds is found at Oshkosh, Wisconsin (3: p.63). These curved parallel ridges are about 0.5 ft high and cover several acres; they are believed to have been indian garden beds. The ground photo with this reference shows the excellent contrast provided by snow fill in low areas and bare soil of the ridges.

A prehistoric cornfield in Waukesha, Wisconsin, could be call a mound array. The Huron tribes planted their corn on circular mounds spaced at about 2 ft intervals. At present the mounds are only several inches high, but once again snow filling makes the elevation difference very visible (3: p.62). Another mound array was discovered from the air because it was simply too big to be seen on the ground. This was the group of concentric mounds found at Poverty Point, Louisiana (5: p.18).

Depressions

Circular depressions are often house pits and are often quite shallow and difficult to see. As an example, one in Cass County, eastern Nebraska, is about 40 ft in diameter and 2 ft deep (6: p.331). A depression like this could form a field mark at some times of the year; otherwise it would probably be invisible from the air. Water fill in a circular moat in Franklin County, Ohio, makes it quite

visible even though it is only 1 ft deep (3: p.187). This 25 ft diameter moat is associated with the Hopewell culture.

Many trenches and pits are associated with fortifications. Many of these have been photographed along the Missouri River, usually as aid to salvage archeology. Near Mobridge, in north central South Dakota, a narrow circular 150 ft diameter ditch surrounds 6 circular depressions (7: p.963). This site was occupied about the mid 1500's, but since it has never been plowed, an aerial view easily shows the patterns. The Phillips Ranch site is similar. This 280 ft elliptical fortification ditch near Pierre, South Dakota, is 5-18 ft wide and 1-2 ft deep (8: plate 20a). There are over 20 circular pits inside. Another photo of this site was taken when the ground was probably drier (9: plate 15b), for the vegetation is now sparser and lighter, except that it is still dark in the trenches and pits. Additional photos are available of fortifications in the Dakotas (10: plates 9,10). An approximately 300 ft diameter 2 ft deep ditch in Stanley County, South Dakota, is the site of an 18th century Arikara village. A Huff village site in Morton County, North Dakota, of about 1500 A.D. has a bastioned fortification ditch. It is further unusual in that the included house sites are rectangular instead of circular. Many depressions are doubly visible from the air because their rims are often lighter in tone than their surrounding, while the depression itself is darker.

In Louisiana, abandoned and often forgotten roads are seen as linear depressions. These colonial roads are 15-30 ft wide and 1-15 ft deep; the erosion is due to a combination of traffic and gullying. While these roads are easily visible when they are water filled, more often they are noticed from the air because of the distinctive riverbank type of trees associated with them in regions otherwise occupied by pines (10).

Rock Patterns

In the northwest part of the plains (the Dakotas, Wyoming, and Montana), rock circles are the most common archeological feature.

These have been called tipi rings, in allusion to their possible use for holding down the edge of a tipi, but this is not proven. These^e boulder circles range in diameter from 5 to 40 ft (10: ~~p.228-33~~^{p.262-6}; 12: p.110).

Linear rock patterns can be difficult to tell from too modern stone fences. Some appear to be indian defensive works (12: p.115). Colonial and indian fish traps are found in many eastern rivers. These V-shaped rock patterns have their vertex downstream, forming an angle of around 55° between their arms which are 50-200 ft long (13).

Most interesting of all are the rock effigy patterns. Many are found in the Dakotas. These patterns depict men and animals and are about 10-20 ft in size, although one boulder snake is 360 ft long (10: p.228-33). Other, more geometric, patterns are the "medicine wheels". While they are few, they would be quite visible on an open plain, for these spoked wheels are several hundred feet in diameter (10: p.266-70).

Field marks are visible only because of their color or brightness contrast. While many mounds and rock patterns are marks made for their own sake by man, field marks are more unintentional. Many field marks are due to erosion of man-made topographic features, in particular, the filling of ditches. These marks are strongest in areas with thin or stratified top soil and markedly different subsoil. This insures that any of man's digging activities will drastically alter the soil structure and leave an enduring mark. These conditions seem to be much more common in England, with its many localities underlain by chalk and alluvial gravel. Vegetation or crop marks are more visible than soil marks, although it is primarily changes in soil and its moisture content which causes vegetation contrast. Contrast due to plant type occurs, but changes in plant growth are more common. The classic case of this is damp marks ((enhanced growth) over buried ditches and parch marks

(restricted growth) over buried walls. These vegetation marks are much more visible in an area of uniform, close-planted grass or grain crops; such a smooth background would be provided by a field of wheat.

Field Marks

One example of a bastioned village site no longer shows any appreciable ditches. They have probably long been filled in, but they are still visible from the air as crop marks. This Pre-Arikara village site along the Missouri River in South Dakota occupies a bench above the river's meander plain. The lodge circles are about 6 ft in diameter and show the typical dark center, light rim appearance (14; 15). A late Woodland site in Mineral County, West Virginia, appears as a semicircular cluster of smaller circles in an aerial photograph; the large semicircle has a diameter of about 250 ft (16). While it is sometimes difficult to tell from published photos and descriptions whether a field mark is caused by soil or crop differentiation, this site appears to be a crop mark. Another likely crop mark is associated with the Cahokia mounds in Illinois. While many markings^s at this site are likely meander patterns of the Mississippi River, one linear feature could indicate^e a buried prehistoric wall (1: p.13,90).

A definite soil mark located traces of a square at the Anderson mounds near Anderson, Indiana. An aerial photo taken just after a field had been plowed showed a dark square about 250 ft on a side outlined by lighter soil (¹⁷ p.39). The sand drawings above the Colorado River near Blythe, California, are quite different. These animal and man effigies and geometric patterns are several hundred feet in size (¹⁸ p.236,248-53). These patterns were also first located from the air.

In the southwest, some prehistoric garden plots which are visible in aerial photographs appear to owe their visibility to a combination of soil and vegetation contrast. Near the Little Colorado River in Arizona, agricultural plots in ash soil are 10 ft wide and 400 ft long lines with about a 20 ft spacing between them (¹⁹ p.18). The

relief of the lines, at about 0.5 ft could not be seen from the aerial photographs. At another site the rectangular borders of garden plots are visible as light marks (²⁰~~19~~: p.129).

The final report for this project will delve into the present and near future capabilities of technology to best sense and interpret archeological remains from the air. Below is a tentative outline for that report.

Photographic platforms

- balloon
- low and high plane
- satellite
- resolution capabilities

Photographic and nonphotographic sensors

- photo cameras
- multicameras
- available films
- narrow band filtering
- radar imagery
- IR scanners

Multispectral viewing

- additive projectors
- eye blink
- stereo color pair
- emulsion sandwich films

Human perception

- Mars illusion
- Mercury flights
- slant viewing
- line perception

Photographic enhancing

- film sandwiches
- edge detecting
- contrast improvement

Optical enhancing techniques

- cross correlation
- matched filtering
- Fourier filtering

Digital computer processing

- Mariner experience
- pattern recognition for shape and spectral response

Optimal spectral techniques

- filtering for grey and color contrast
- spectral variations and causes
- spectrophotometers

Vegetation effects

- root nutrient length
- foliage size
- plant distribution

Anomaly discernability

- growth and seasonal variations
- alignment with modern patterns
- field intersection
- confusion with modern manmade and natural patterns
- nonpatterns, without shape, size, or orientation
- soil moisture analysis and weather history

Paleo-ecology indicators

- ancient shorelines
- river channels

Time duration of topographic and field marks

Bruce W. Bevan

May 31, 1971

- 14) C. H. Strandberg, "Photoarchaeology", Photogrammetric Engineering, October 1967, pp. 1152-7.
- 15) "Archaeological Photointerpretation", Itek Corporation Technical Report 65-8458, August 25, 1965.
- 16) E. McM. Larrabee, "The Identification of a Village Site by Aerial Photography", West Virginia Archaeologist, #15, February 1963, pp. 7,8.
- 17) E. Lilly, Prehistoric Antiquities of Indiana, Lakeside Press, 1937.
- 18) L. Deuel, Flights into Yesterday, St. Martin's Press, 1969.
- 19) G. G. Schaber, G. J. Gumerman, "Infrared Scanning Images: an Archeological Application", Science, May 9, 1969, pp. 712,3.
- 20) G. J. Gumerman, T. R. Lyons, "Archeological Methodology and Remote Sensing", Science, April 9, 1971, pp. 126-31.

AERIAL PHOTOGRAPHY AT ARCHAEOLOGICAL SITES

A Final Report Prepared for the National Park Service

Contract Number 14-10-9-900-369

June 8, 1973

prepared by Bruce Bevan
Museum Applied Science Center for Archaeology
The University Museum
The University of Pennsylvania
Philadelphia, Pennsylvania

AERIAL PHOTOGRAPHY AT ARCHAEOLOGICAL SITES

Aerial photography is a technique for the reconnaissance of the archaeology of a region. Two recent photographic missions, which were initiated by the Museum Applied Science Center for Archaeology and supported by the National Park Service with Grant No. 14-10-9-900-369, are described in this report: one was in the vicinity of Chaco Canyon, New Mexico, and the other was in the vicinity of Glendive, Montana. Aerial photography was used at both sites to aid in the discovery of traces of Indian occupations.

At Chaco Canyon Dr. Thomas Lyons of the National Park Service and the University of New Mexico is applying aerial photography to the location and mapping of the prehistoric road system there. In collaboration with him, the University Museum took additional photographs of the Chaco Canyon area with a multi-spectral camera.

This photographic system has three electrically-driven Hasselblad cameras coupled together so that three simultaneous photographs can be taken of the same area. Different films were used in each camera as an aid in the detection of traces of the road system. Simultaneous photography allows the merits of different films to be compared easily; furthermore, the combination of evidence from different films increases the reliability and ease of interpreting them. This camera system was designed by Mr. Julian Whittlesey of New York City and loaned to the Museum for this experiment.

Three films were chosen to cover the photographic spectrum.

They are as follows: 1) A color reversal film recorded the entire visible spectrum; Kodak Ektachrome-X film was used with a Wratten 1A filter to absorb ultraviolet radiation. Because of the expense of this film, fewer than 75 photos were taken with it. 2) The visible spectrum was also photographed with a panchromatic black and white film; Kodak Plus-X film was the choice and a yellow Wratten 12 filter was employed for greater visibility through atmospheric haze. 3) Another film in the camera system was a black and white infrared film; Kodak Infrared Aerographic film #2424 was used with a Wratten 89B filter to remove all of the visible light. The black and white films used were 70 mm wide; this large-sized film enables small features on the photographs to be detected without excessive enlargement and subsequent loss of resolution.

On April 27, 1972, an airplane was rented for four hours to fly over Chaco Canyon. This plane had been modified for aerial photography, and a hole-in-the-floor enabled the operator of the multiband camera to take vertical photographs suitable for mapping. The flight elevation averaged about 2000 feet above the ground, and the ground speed when photographs were taken was approximately 90 miles per hour.

Many oblique photographs were taken also through the open side door of the aircraft. For this, the camera must be mounted slightly inside the airplane, away from the buffeting of the wind; this is illustrated in Figure 1. These oblique photographs included the horizon and some of the sky in the background; therefore, there is a wide

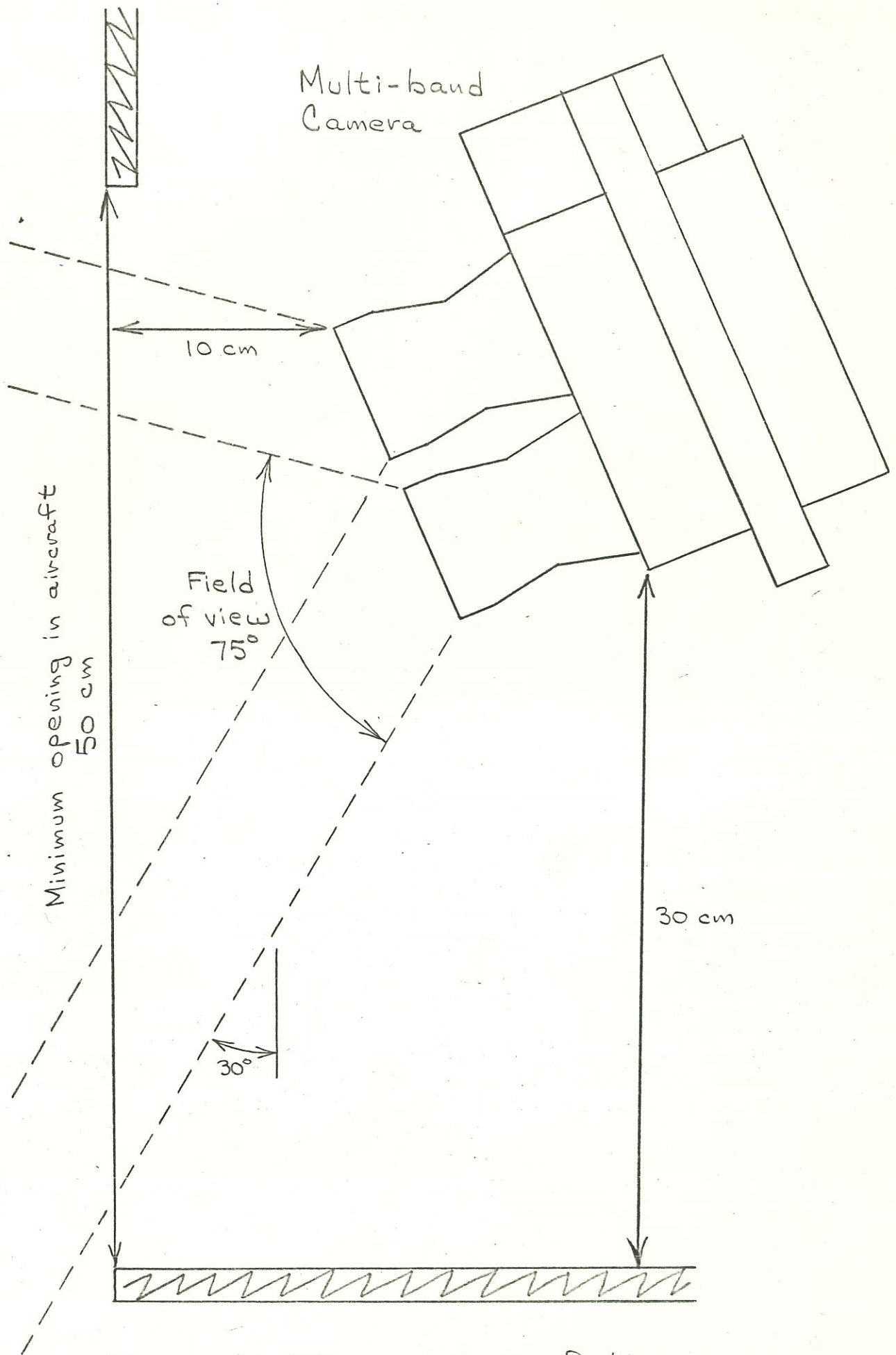


Figure 1: The position of the camera in the aircraft for oblique photography

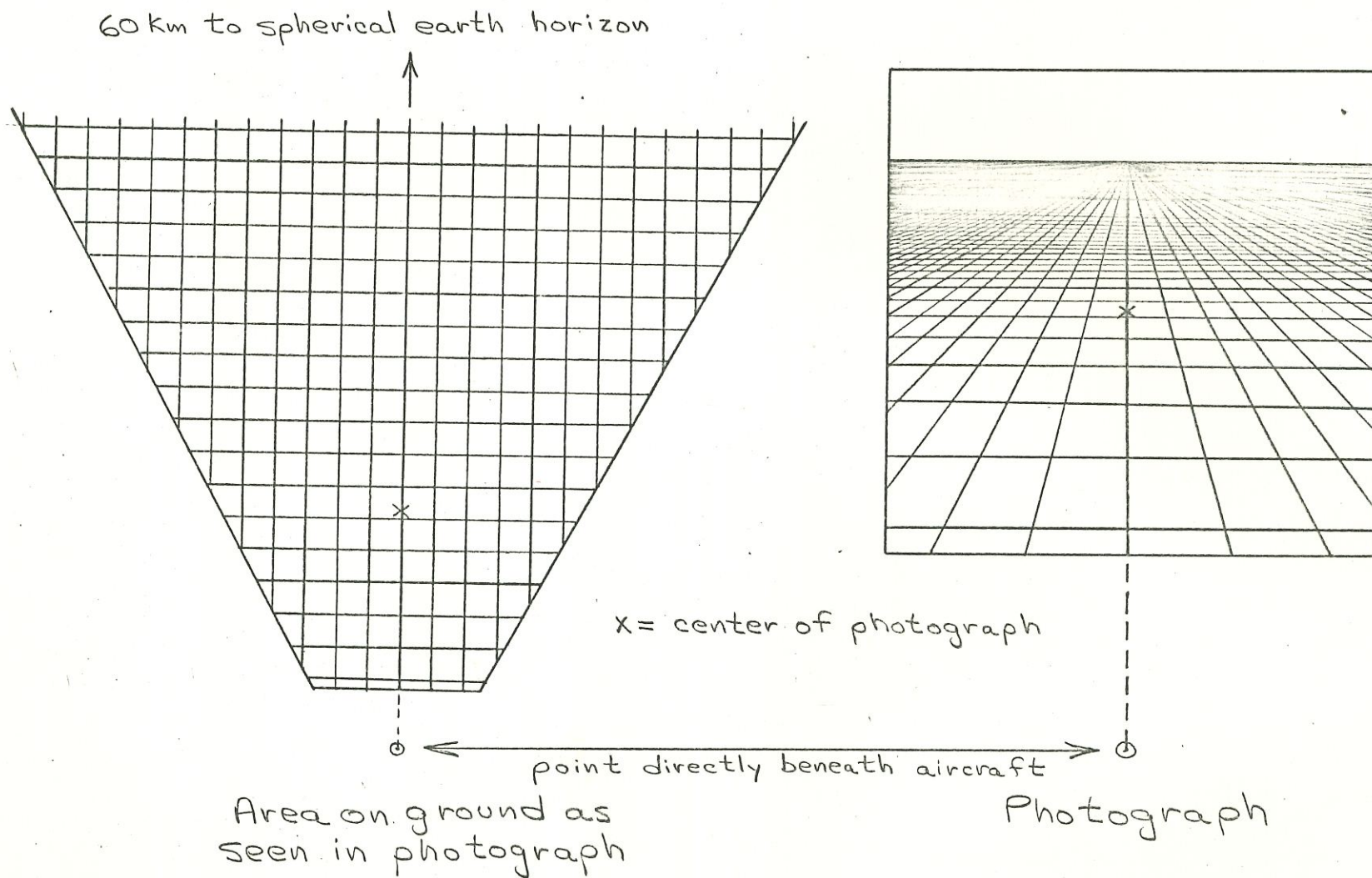
range in the scale of the photographs. This variation in scale is shown in Figure 2 for a flat landscape.

Approximately 450 photographs were taken in the Chaco Canyon region. Dr. Lyons is working on the archaeological interpretation of them. But two black and white copies of color slides are included with this report as Figures 3 and 4. While many of the linear features in these two photographs are traces of the prehistoric road system, definite answers require both careful interpretation of the photographs and detailed examination of these features on the ground.

In eastern Montana, Indian encampments and hunting grounds have been found in the vicinity of Yellowstone River. This area has few roads so that aerial photography is a valuable aid for the preliminary reconnaissance of this region.

On May 16 and 17, 1973, approximately 300 aerial photographs were taken in the area between Miles City and Glendive, Montana. An airplane was rented and the door on the copilot's side was removed so that oblique photographs could be taken with minimum obstruction. The multi-band camera was borrowed again from Mr. Whittlesey for this photographic mission. In order to insure a clear field of view between a wing strut and the airplane's landing gear, it was necessary to use only a single camera at one time for most of the photographs.

Once again, a variety of films was used, but sequential exposure was necessary instead of simultaneous exposure as used at Chaco Canyon. Kodak Plus-X and color transparency film enabled the recording of the entire visible spectrum. H and W Control VTE film allowed high resolution photography of small ground features.. Ground speeds as



camera angles are shown in Figure 1. Each square is 100 m on a side. Altitude above ground is 300 m (approx. 1000 feet)

Figure 2: The scale of an oblique photograph

Figure 3: The ruins of Pueblo Alto with traces of roads;
Chaco Canyon, New Mexico.



Figure 4: Traces of prehistoric roads; one kilometer northwest of Pueblo Alto; this photo covers an area on the ground of about 600 meters on a side.



low as 30 miles per hour were used during photography, and flying altitudes of about 1500 feet above the ground were chosen.

This region has somewhat more precipitation than Chaco Canyon, which is semi-arid, and wheat is a common crop in eastern Montana. Next to the Yellowstone River, irrigation is possible; farther away, dry land farming of wheat is practiced. It is this latter type of field which is susceptible to the formation of crop marks which can reveal archaeological structures buried at shallow depths in the soil.

Crop marks which indicate ancient occupation are particularly common in England and western Europe. The ditches and roads of prehistoric civilizations were buried or leveled-off by nature long ago, but pockets of disturbed soil still remain just below the depth of plowing. These soil anomalies typically retain a greater or lesser amount of moisture than the surrounding soil. If roots of plants reach this level, the growth of the plants will be affected. Therefore, one can detect buried foundations or refilled ditches or pits by the patterns of growth in the overlying vegetation.

Crop marks are visible primarily as changes in color, and the color shift can be very small. Fortunately, cameras can be made very color-sensitive with the proper choice of films and photographic filters. The National Aeronautics and Space Administration has obtained data on the differences in the color of wheat in both moist and dry soil, which is the difference that causes crop marks of archaeological origin. NASA's information indicates that the far red part of the visible

spectrum should provide the greatest visibility of crop marks, for the contrast in photographs of wheat growing in moist and dry soil should be maximum here. A technical description of this is given in Figure 5.

This experiment in the detection of crop marks was tried in eastern Montana by using a camera with a deep red, Wratten 92 filter and panchromatic black and white film. Because the deep red filter removes most of the light, the high sensitivity to light of Kodak Tri-X film was required.

Unlike Europe and some parts of the U.S.A., where crop marks in geometric patterns are common, none was seen while flying over the eastern Montana area. This aerial photography was done at the time during the growing season of the wheat crop in this area when crop marks should be highly visible; therefore, it must be suspected that the Indians did not create artificial earthworks or other structures in this area. Since all of the film from this expedition has not yet been developed nor interpreted, it is still possible that some difficult-to-see features such as traces of house pits will be found.

Standard panchromatic photography is also valuable for the reconnaissance of this region. This is all that is necessary for the detection of stone circles indicative of Tipi sites. This type of photography aids also in the evaluation of environmental factors, which might suggest the possible location of Indian sites. An excellent example of this was pointed out by Mr. William Woodcock of Miles City. About ten miles west of Miles City, a five-mile-square grassy plateau ends abruptly at a cliff which drops several hundred feet.

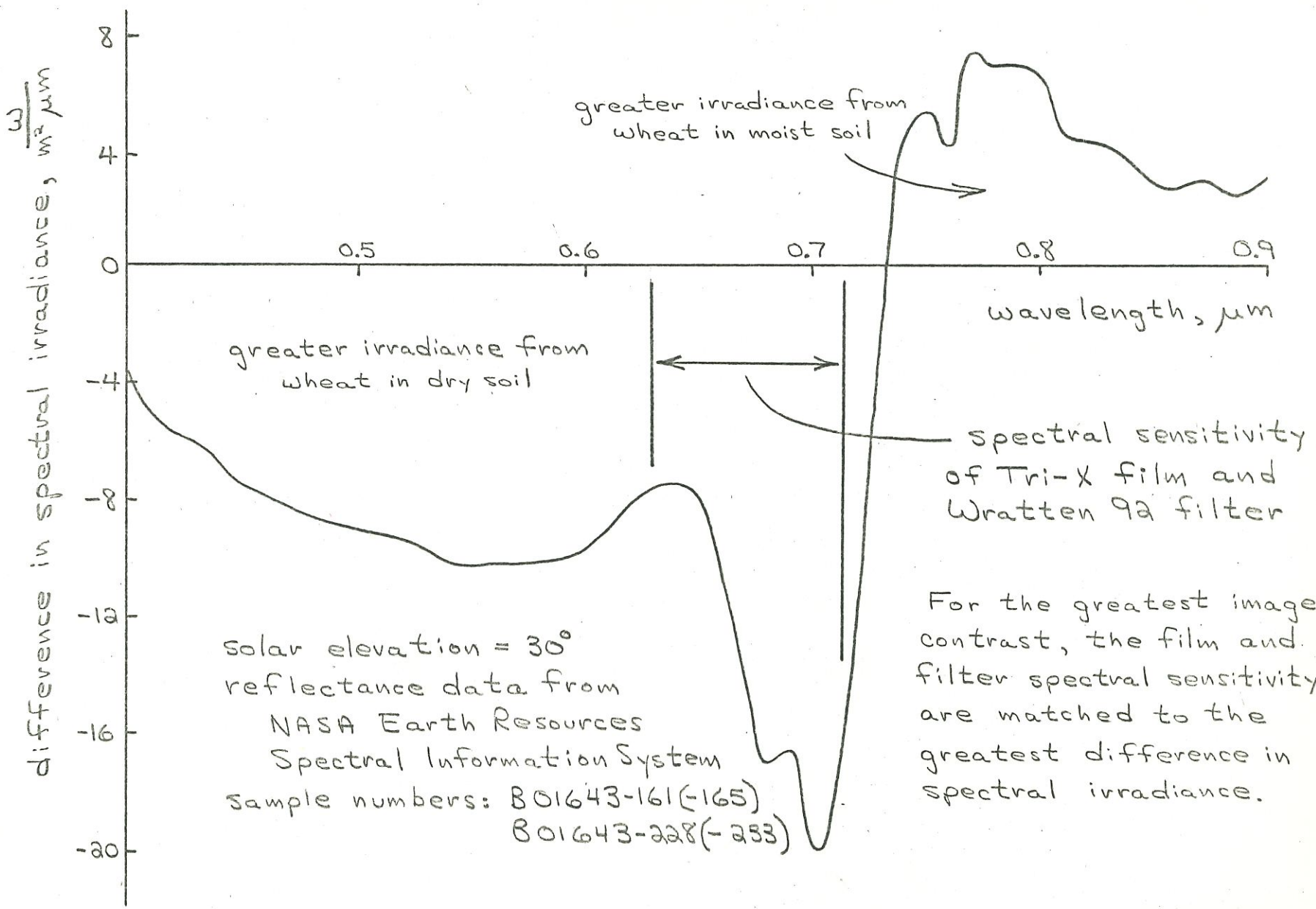


Figure 5: An optimum film/filter combination for detecting crop marks in wheat

A spring is less than three miles away. These factors indicate the possibility that this region would have been good grazing ground for bison and that Indians might have killed the bison by driving them over the cliff. Figures 6 and 7 are photographs of this plateau and cliff. While the spring is not shown in these pictures, the cliff and plateau are part of the evidence. Further evidence that this is a kill site is given by a ground examination; plentiful worked-stone tools were found at the top of the cliff. Some were made from local quartzite and agate cobbles and others from imported stone.

A wide search for possible sites as indicated by environmental clues would be the most valuable contribution aerial photography could make in this region. A considerable amount of terrestrial investigation will still be necessary. For example, about a dozen caves can be seen in the aerial photographs of the cliff discussed above. While these could have been Indian shelters, a ground check for artifacts of a study of the erosion rates of the cliff would be necessary for a definite answer.

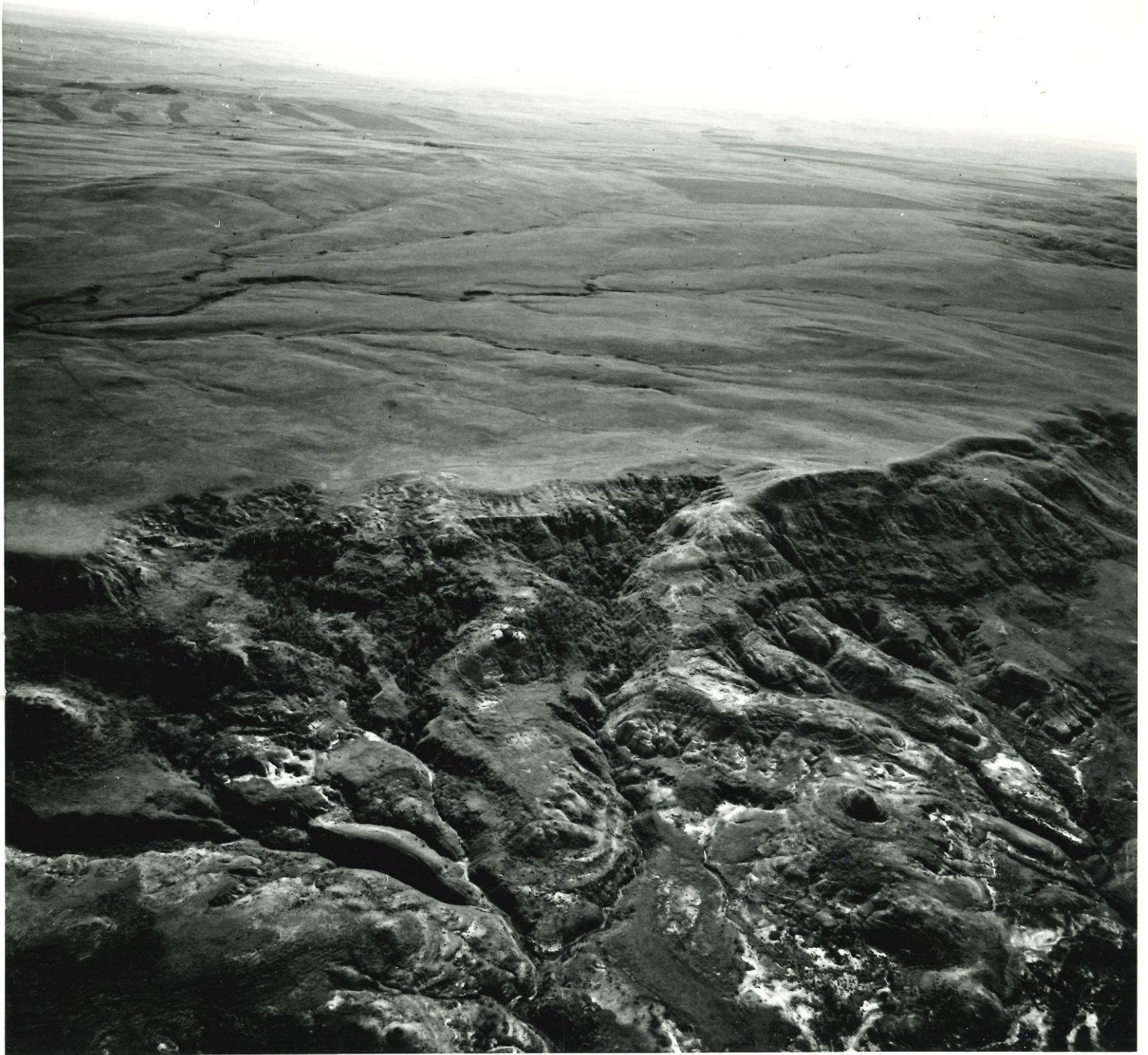


Figure 6: A plateau and cliff ten miles west of Miles City, Montana;
the caves are northwest of this area.

Figure 7: Near Figure 6; the arc-shaped growth patterns on the plateau are possibly caused by the propagation of a disease in the grass.





United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:

H2219-PI

November 6, 1973

Ms. Elizabeth K. Ralph
Associate Director
Museum Applied Science Center
for Archaeology
University Museum
University of Pennsylvania
Philadelphia, Pennsylvania 19104

Dear Ms. Ralph:

Please refer to Contract No. 14-10-9-900-369, dated May 7, 1971, between the National Park Service and the University Museum, University of Pennsylvania, for a study of aerial photographic systems.

We have reviewed and are accepting the two additional reports ("Multi-Spectral Photography," by John Hampton, and "Cesium Magnetometer Survey at Kingscote, Gloucestershire, England," by E. K. Ralph) submitted as supplemental data to the report "Aerial Photography at Archaeological Sites," by Bruce Beven, in fulfillment of the above contract. These three reports combined do satisfy the minimal contract requirements and understandings agreed to between the Museum and Dr. John M. Corbett, the Service's contracting officer's representative, who negotiated the contract on behalf of the National Park Service.

In order that we may initiate action for payment for these reports, please have your business office submit us a new invoice for the balance due the University on the contract.

Sincerely yours,

/s/ Jack R Rudy

Jack R Rudy
Acting Chief, Interagency
Services Division