AIR PHOTOGRAPHY and Satellite Image Interpretation
For Linears Mapping and Geologic Evaluation

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AIRPHOTOGRAPHY AND SATELLITE IMAGE INTERPRETATION
FOR LINEAR MAPPING AND GEOLOGIC EVALUATION
A PILOT STUDY IN
THE FLINT CREEK AND TRIANGLE QUADRANGLES,
OWYHEE COUNTY, IDAHO

by
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INTRODUCTION

HISTORY AND GENERAL STATEMENT

The Owyhee and South Mountain areas of southwestern Idaho (Figure 1) have long been recognized for their promising mineral potential. Interest dates back to the 1860's when the first gold claims were staked in the region. Asher (1968, p. 18) states that in the forty-nine years from 1865 to 1914 some $30 million worth of gold and silver was produced from the area. Activity in the South Mountain district was short lived, from 1868 to 1875, due to problems of transportation, lack of beneficiation technology, and management. About $150,000 in bullion was produced during one short season of smelting operations (Sorenson, 1927, p. 2-3). By the end of the 1920's most of the large scale activity had dwindled throughout the entire region, and presently only a few operations are active, although signs of pioneering effort can be found from Silver City (Sec. 6, T.5 S., R.3 W.) to South Mountain (T.8 S., R.5 W.).

Little geologic information on the area is available to the public. Most surface and subsurface mapping has been undertaken by private companies and consequently this information has not been released. However, with increasing prices and declining reserves for metals, renewed interest in the potential of the district has been demonstrated and expressed by several industrial groups. Recent work has been undertaken north of the study area by McIntyre (1972) and Asher (1968) for the Idaho Bureau of Mines and Geology. Kittleman and associates (1965, 1967, 1973) have worked extensively in the Oregon portion of the Owyhee region. Salman (1972) and Pansze (1971) have prepared theses on parts of the present study area as well. Continuing requests for geologic information on the Owyhee Mountains and
adjoining areas to the south indicate that study will prove beneficial to
the several agencies and groups seeking technical information.

Renewed interest also stems from the continued nation-wide concern
over the location and quantity of our national resources, the anticipated
state participation in land-use evaluation of all state and federal lands,
and the proposed consideration of Silver City mining district for a National
Historical Monument. Based upon these concerns and the results of a brief
examination in 1966, the Idaho Bureau of Mines and Geology has selected the
Owyhee Mountain district as the first pilot area for a photo interpretation
project. This program is designed to test the advantages of substitution
of photo interpretation of remote sensing imagery for some of the tradition-
ally slow field mapping methods employed in evaluation of areas for mineral
potential or other specific needs.

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ties and equipment of the Geophotography and Remote Sensing Center. The
cartographic division of the Boise office of the Bureau of Land Management
generously allowed us to use a strip of small scale vertical airphotos
covering a strip of Owyhee County very similar to the study area, but some-
what farther south.

The authors are grateful for the constructive criticism offered by
colleagues during the preparation of this report, but accept full responsi-
bility for the conclusions and opinions expressed herein.
Conventional vertical aerial photographs have for three decades been one of the major vehicles for efficient geologic, soils, and vegetative mapping. In the past few years the recognition of similar potentials available from special types of airphotography and satellite imagery has led to efforts or demands that such new products and technology be integrated into the whole procedure of land surface analysis. Such a broadened procedure would be beneficial not only for specific mapping but also for gathering a database of sufficient scope that meaningful land-use classification and evaluation will become feasible. The overall goal of this project is to determine how these remote sensing methods can be made particularly effective in areas of high relief, difficult access, and harsh climate such as typify many areas in Idaho.

BACKGROUND AND SPECIFIC GOALS

In 1966 a field test was carried out for the Idaho Bureau of Mines and Geology by W. B. Hall and F. S. Hensley, Jr. in and adjacent to the Silver City district of the Owyhee Mountains. In that project Hall and Hensley showed that color oblique stereo airphotography (COSA) could in a practical way be combined with conventional field mapping and airphoto interpretation to improve and accelerate reconnaissance geologic studies. They produced a reconnaissance geologic map of a 7-1/2 minute quadrangle area in three days, and estimated that about a week of work per 7-1/2 minute section would generate acceptable reconnaissance maps, provided a full complement of supporting conventional and COSA airphotos was available at the time of field work.
The 1966 study indicated that a large scale, perhaps regional fracture system was present to the south of the early COSA test area. It seemed reasonable that such a system might show prominently and be easily traced on satellite images, and if so, its extent and relation to the Silver City mining district might be discerned. Such information would seem particularly relevant because all previous geologic studies of the Silver City and South Mountain districts have emphasized that ore is found in vein fillings of fracture systems (Sorenson, 1927, p. 32-33; Asher, 1968, p. 68).

The present work is, in certain respects, a continuation and expansion of the 1966 study directed toward meeting current needs. This study emphasizes derivation of as much information as possible from airphotos or satellite images. In the nearly ubiquitous all-igneous terrane of this project these consist principally of structural trend and linears maps to be verified during anticipated followup field work.

The research project reported herein was initiated under the title "Correlation of ERTS-1 Satellite MSS* Imagery with Conventional Vertical Airphotos and Color Oblique Stereo Airphotos for Geologic Interpretation." It was a cooperative project between the University of Idaho and the Idaho Bureau of Mines and Geology and designed to determine the utility of satellite imagery as a source of geologic information in general, and specifically for mapping of fracture systems of other major linear structural trends. An important consideration was to discover to what degree satellite imagery might complement, replace, or duplicate high and low level

*Multi-Spectral Scanner
airphotography. Specific Goals of the original research included the following:

1. Determination of the types and scales of airphotography and remotely sensed imagery needed to produce acceptable geologic reconnaissance maps for mineral potential evaluation and land-use decision making.

2. Determination of the best type and scale of conventional stereo airphoto images to permit a speedy and effective interpretation transition from COSA to satellite images.

3. Determination of which MSS band is best suited for each type of geologic study and what the practical ground resolution cell dimensions (minimum size of detectable object) are for geologic features in ERTS images.

4. Compilation of linears maps of the Owyhee Mountain area using all the available airphotography and satellite imagery.

Most of the above objectives were realized. The order of discussion is as follows:

1. Geographic and Geologic setting.
2. Procedures for image analysis.
3. Information Generated.
4. Comparison of image types and scales.
5. Relative merits of aerial film types.
6. Conclusions.
GEOGRAPHIC AND GEOLOGIC SETTING

Flint Creek and Triangle 15-minute quadrangles lie in the west central portion of Owyhee County, southwestern Idaho. Combined, the quadrangles cover about six percent of Owyhee County's total 7662 square miles (Figure 1). Portions of the Owyhee Mountains, the South Mountain Range, and the low sediment-mantled lava plateau between the two highlands are included in the study area. These highlands and adjacent lava plateaus are considered to be the Owyhee Upland subprovince of the Columbia Intermontane Physiographic Province. Thornbury (1965, p. 463) believes that upwarping is the dominant structural control. Large scale northwest trending grabens and complex fracture patterns are superimposed on the basic structure.

Lavas in the Owyhee Upland subprovince are older and more silicic than the basalts of the Snake River Plain to the north. Rhyolites, latites, and welded tuffs compose the majority of the units. Interbedded with the lavas are clastic sediments of late Tertiary age.

Both the Owyhee and South Mountain blocks expose Cretaceous quartz monzonite and granodiorite plutons in their higher central parts. These plutons have been considered as equivalent in age to those of the Idaho batholith, whose nearest exposures are 50 miles to the northeast beyond the Snake River plain (Asher, 1968, p. 21). The South Mountain Range exposes pre-quartz monzonite metasedimentary rocks which follow the strike of the range core (Sorensen, 1927, p. 11). These metamorphic rocks are quartzite, calcareous quartzite, marble, and quartz-mica schists (Sorensen, 1927, p. 11).

Drainage in the area is to the Snake River, with lava plateau areas
dissected by structurally controlled steep-walled canyons and adjoining highlands characterized by high relief but streams that are not deeply incised. The North Fork of Castle Creek is the major southeasterly flowing stream. Most other trunk streams flow north or west. Of these, Boulder Creek, Flint Creek, Williams Creek, and Jordan Creek, are the most prominent.

Climate in the study area varies from arid (less than 10 inches of precipitation) in the north and east to sub-humid (greater than 20 inches of precipitation) in the highlands and near the west margin of the area. Most precipitation falls as snow; summer months are commonly hot and dry.

Vegetation communities in the study area reflect the climatic conditions and vary with precipitation. The relatively dry lava plateaus in the central portions of the Triangle and Flint Creek quadrangles are characterized by two communities - big sage (Artemisia tridentata) with blue bunch wheat grass (Agropyron spicatum) and alpine sage (Artemisia tridentata vasyana) with Idaho fescue (Festuca idahoensis) complexed with low sage (Artemisia arbuscula) with Idaho fescue. Rocky Mountain juniper (Juniperus scopulorum), alpine sage, mountain mahogany (Cercocarpus), and Idaho fescue occur in the highlands of the Owyhee and South Mountain ranges. Douglas fir (Pseudotsuga menziesii glauca) with alpine sage and Idaho fescue can be seen on the cold and humid west and north slopes in the high portions of the Owyhee Mountains, specifically in the area around Silver City.
PROCEDURES FOR IMAGE ANALYSIS

The raw materials for the bulk of the analysis consisted of four types of aerial imagery:

1. Multi-Spectral Scanner (MSS) imagery from bands 4, 5, 6, and 7 acquired by the ERTS-1 satellite for two dates in the fall of 1972.

2. Conventional 60% overlap, vertical black and white airphotos at a nominal scale of 1:27,000, dating from 1946. (Refer to Figure 2 for examples.)

3. Conventional 60% overlap, ultra-wide-angle black and white airphotos at a nominal scale of 1:72,000. (One strip was available for central Owyhee County; see Figures 3 and 4).

4. COSA slides in 35 mm transparency format, with 100% overlap, taken in 1966 and 1973. These stereo views were taken of selected portions of the Flint Creek and Triangle 15-minute quadrangles; complete and systematic coverage in COSA is impractical and unnecessary; they are best applied to specific features of concern. Approximately one-third to one-half of the map area was photographed in this manner (see Figures 5 and 6 for examples).

All linears maps included in this report were compiled from laboratory examination and interpretation of three of the four imagery types used, with no addition of trends previously mapped in the field. Procedurally, for the conventional airphoto analysis, all linears were plotted directly on the airphoto prints while being viewed in stereo. The annotations were then transferred by inspection and projection onto the topographic base. The COSA images were studied using stereo viewers. In the case of COSA and ERTS image analysis, all linears were plotted directly onto the
Triangle and Flint Creek 15-minute topographic sheets. Plates 1, 2, and 3
show linears plotted from ERTS-1, conventional black and white verticals,
and COSA images respectively.

Following the acquisition of all photos and the office plotting of
most of the linears, a team of five geologists spent two days in field
examination of selected linears and linear intersections. A more exten-
sive field check would have been desirable and is planned for the coming
season.
Figure 2

Conventional vertical airphoto stereo pair. This area is in T. & S., R. 4 W., in the southeast part of the Flint Creek Quadrangle, Owyhee County. The original contact print scale approximates 1:27,000, although here reduced to approximately 1:63,000 and spaced for optimum stereo viewing. The "east print" has been partially annotated with ink lines along plotted linears. The gray corners are from lack of full coverage by the lens used. Date and code numbers are along west edge.
Figure 3

Partially annotated vertical airphoto stereo pair. Original print scale 1:72,000, here reduced to about 1:150,000. The area is approximately 30 miles south of the part of the Owyhee region studied for this report. Photo courtesy of Bureau of Land Management.
Figure 4

Partially annotated vertical airphoto stereo pair. Original scale 1:72,000, here reduced to approximately 1:150,000. This is the Lost Valley area about 40 miles southeast of the present study area, and shows a region of nearly all volcanic rocks. Strong northwest trending graben-horst faulting is evident, and post-dates the Northeasterly fault trends. Photos courtesy of the Bureau of Land Management.
MAPS OF LINEARS

The major thrust of geologic interpretation for this project was the identification of major structural trends. These are normally detectable only as linear zones or actual photo image lines (created by such natural features as visible rock fractures, straight canyon segments, long rows of trees, or narrow bands of vegetation) and are all grouped and plotted together as "linears" (see Figures 3 and 4). Plates 1, 2, and 3 present the linear patterns mapped by remote sensing methods only for the two-quadrangle study area.

There are several reasons for making these linear maps rather than a complete geologic map:

1. ERTS images do not allow adequate geologic unit delineation on a scale that would be particularly useful, although some lithologic contacts are apparent.

2. ERTS images do show gross structure, especially major linear trends particularly well.

3. Linear maps from any source provide a useful product for preliminary study much sooner than is possible for a geologic map.

4. The linear maps may point out areas of structural discordance and disturbance and are useful guides for field study planning and priority determination.

5. Earlier studies of the mineralization of the old mining districts of the Silver City, De Lamar, and South Mountain areas (Piper and Laney, 1926; Sorenson, 1927; and Asher, 1968) show that the major ores occur as
vein fillings in fractures, not as irregular masses or disseminations. "The veins consist of gangue and ore minerals which were deposited by aqueous solutions rising in and along previously formed fractures, which in many instances are faults of different magnitudes." (Piper and Laney, 1926, p. 67) "...The relation of the several sets of earth fractures to the ore deposits has also been established..." (Piper and Laney, 1926, p. 38). Since the fractures acted as access paths and accumulation sites for the ore, it follows that comprehensive knowledge of the faults, joints, dikes, and veins is most pertinent.
Figure 5

A black and white print of one frame of an original color oblique stereo airphoto pair. The view is to the west in the southern portion of the Owyhee study area. This is an example of the expression of linear trends as expressed in sparsely vegetated areas of low relief. The linear trends form the only really distinctive feature in the topography.
Figure 6

A single frame in black and white made from a color oblique stereo airphoto slide pair. The view is to the west across the Seven Devils mountains; the Wallowa Mountains are visible in the left distance. This is an example of the type of viewpoint available for study when the COSA system is applied to mountainous topography.
GENERAL OBSERVATIONS FROM THE MAPS

(Refer to Plates 1, 2, 3)

1. There is little duplication or similarity between the linears maps made from the three imagery types, at least in detail. The writers were surprised at the differences between the maps, having expected to find a high degree of correspondence in overall patterns. This indicates that each format and scale of aerial imagery allows a certain resolution of geologic material or structure to be discerned which may not easily be interpreted from other formats.

2. There is a very prominent northwest trend displayed on all three plates.

3. It is unlikely that faults or fractures with dips less than 60 will be detected as linears on airphotos or satellite images, especially in regions of high relief. Therefore, the maps are partially biased in favor of steeply dipping features, despite the importance of some shallow faults (Asher, 1968, p. 66) in the overall geometry of a mineralized area.

4. All scales and types of imagery examined support the interpretation by Malde (1959, p. 272) and others that the northeastern margin of the Owyhee Range is essentially a northwest trending gravity fault system. This was disputed by Asher (1968, p. 70) who could find no evidence of down-faulting of the Snake River Plain area in the vicinity of War Eagle Mountain in the Silver City district. The main fault system is best expressed to the east of this project area, but the conclusions were reached using the images here discussed.

5. Very few linears were detected in plutonic rock on the ERTS image,
but the COSA and conventional airphotos showed a greater density of linears in such rock than average for the area as a whole. More work needs to be done on correlation of linears patterns with rock type.

6. The part of the Silver City mining district for which we had airphotos shows a linear pattern much greater in density than that of similar nonmineralized rocks in the surrounding areas.

7. Although most of the linears are demonstrably related to fractures, several may simply record geologic contacts or unintentionally recorded man-induced linear contrasts (ditched, fence lines, dozer paths, etc.).

8. Linears in coarsely crystalline rocks appear as a mosaic pattern, whereas those in lavas appear in long parallel bands.
OBSERVATIONS ON INDIVIDUAL IMAGERY TYPES

ERTS - MSS Imagery

1. Both the South Mountain and Silver City mining districts are approximately on the projected intersections of major linears detected from ERTS image analysis. The actual linears themselves could not be traced into either district.

2. Several major drainages of the area lie along linears mapped from ERTS - 1 imagery. (A list of these streams can be found in the Appendix).

3. Of those springs noted on the two quadrangle maps several occur along ERTS linears and linears intersections. These springs are listed by section, township, and range in the Appendix.

4. The prominent E-W linear set of the central sag area seen on conventional airphotos and COSA is not evident on ERTS imagery.

5. Areas affected by mining activity do not show at all on ERTS images unless the dumps are extremely large.

6. Mining activity has occurred along ERTS linears in sec. 8, T6S, R3W (Triangle Quadrangle) and along Williams Creek in the vicinity of South Mountain (sec. 4, T8S, R5W). The Flint Creek mining district occurs at intersection of ERTS linears (sec. 11, T6S, R4W).

Conventional Airphotos

1. A strong E-W trending set of linears is evident in the east central portion of Flint Creek Quadrangle and in the central portion of the Triangle Quadrangle. These linears appear to be generally confined to the
lava plateaus and the Succor Creek Formation of Kittleman (1973).

2. Triangle and Spencer reservoirs both occupy topographic basins in areas of linear intersections.

3. A great number of springs in both quadrangles are associated with linears mapped by this method. (A list of springs by section, township, and range are given in the Appendix).

4. North trending linears associated with mining districts are seen in sec. 8, 9, 16, 17, and 18, T5S, R3W, and on the boundary of sec. 3 and 4, T8S, R5W.

5. Few long linears (over 3 miles in length) were plotted using conventional vertical airphotography.

COSA

1. A strong E-W trending linear set is evident in the central portion of the Triangle Quadrangle and the east-central portion of the Flint Creek Quadrangle. This is the same set as noted from the conventional airphotos.

2. North trending linears are most evident in the South Mountain, Flint Creek, and De Lamar mining districts (adjacent to NE corner of Flint Creek Quadrangle).

3. In both the Flint Creek and De Lamar mining districts there is an array of short linears making a mosaic pattern.

4. A strong NE trending linear group is evident throughout the map area.

5. As in the map (Plate 2) from conventional airphotos, numerous springs lie along linears mapped from COSA. (Comparison of linear-spring association between conventional airphotos and COSA is not valid due to incompleteness of the COSA coverage.)
COMPARISON OF IMAGE TYPES AND SCALES

RELATIVE MERITS OF DIFFERING MSS BAND IMAGES

Through comparisons of different bands of MSS satellite imagery available for the Owyhee Mountain area, the following conclusions have been reached.

1. Band 5 by itself gives the most "normal" looking synoptic view of the landscape, perhaps because forested areas appear noticeably dark gray on this band, but are not easily delineated on other bands.

2. Band 4 by itself gives a low-contrast dull gray image with minimal overall potential for easy geologic interpretation unless used in combination with other bands.

3. Bands 6 and 7 are similar in appearance, and both offer generally good renditions of structural trends and open-water bodies.

4. Band 6 is tentatively selected as the best single band for general structural analysis, but it can be combined advantageously with either band 4 or band 5 for maximum utility and reliability of interpretation.

5. No single band is always superior for geologic interpretation. Some features almost always show up well on only one band, and only poorly on all others.

6. Further experimentation is warranted in a search for means of deriving the most information possible from all bands, either separately or in combination.

Practical Interpretation of Satellite Scanner-Images

The MSS images relayed from ERTS-1 are now widely available for many
regions and their characteristics of scale geometry, and spectral sensitivity have been assessed for the needs of this project with the following results.

1. The satellite images offer a very economical means for visualizing and grasping overall regional relationships of geography, geomorphology, vegetation patterns, drainage networks, and tectonic units. In a very short time one can better understand the general setting through satellite imagery than through any other single source.

2. Certain large scale geologic structures show on ERTS images which have not been noticed before on conventional airphotos because the latter cover too small an area for some features to be apparent as anomalies.

3. Very little real geologic mapping can be done from ERTS MSS imagery. The scale is so small that the diagnostic details of surface texture and tone, by which rock types can be differentiated on normal airphotos, are not resolved. Only a very few, very distinctive, gross lithotypes (e.g., recent basalt flows) can be identified with assurance on any band of ERTS imagery. It cannot yet be used for direct and reliable geologic mapping of most areas.

4. A map of major linears can be derived with relative ease from ERTS images (see Plate 1). However, many structural trends and known major faults do not show at all, and, therefore, the major linears map cannot be considered complete enough to stand alone as a basis for reliable tectonic analysis or mineral potential evaluation. Nevertheless, the information from ERTS images is far too valuable to be discarded or ignored.

5. A much truer picture of the overall linears pattern is possible
from careful interpretation of conventional vertical airphotos, but this is discouragingly slow and expensive when carried out on 1:30,000 scale photographs, as was necessary for the present study. A comparison of the ERTS linears (plate 1) with the conventional airphoto 1:30,000 scale linears (plate 2) indicates that few of the major or regional linear trends are detected on such airphotos. Once again, the indicated proper alternative would be regional linears mapping from 1:70,000 - 90,000 scale vertical airphotos.

SMALL SCALE CONVENTIONAL AIRPHOTOS AS PREFERRED FORMAT AND SCALE

A limited selection of types and scales of aerial imagery was available for comparative evaluation for this project. It had been hoped that during the initial stage much more variety in photographs might be available in terms of differing scales. Preliminary conclusions have been possible, however, and are believed worth noting here even if subsequent experience should lead to refinement or revision in future recommendations.

High quality small-scale conventional vertical stereo airphotos (sometimes referred to as "high altitude photos") seem clearly to be the one most valuable and economical remote-sensing product for rapid reconnaissance studies of the type envisioned as appropriate for regional preliminary assessment. We have not had available ultra-small scale vertical airphotos of the region (in the range of 1:100,000 or smaller) but these would probably prove extremely valuable as well as economical. However, as observed in the Introduction, we were permitted to examine one strip of Bureau of Land Management airphotos at a scale of 1:72,000, flown in 1964 with an RC-9 camera equipped with an ultra-wide-angle 3-1/2"
focal length lens. Examples from this are shown as Figures 3 and 4. The strip transects Owyhee County in the vicinity of 42° 20' N latitude. These stereo vertical, black and white airphotos, in our judgement, far surpass in general utility and economy the best of conventional older 1:34,000 and 1:20,000 scale photos for rapid regional study. Of the scales presently available to the average consumer, the 1:70,000 range is at least tentatively selected as the most useful so far for regional study based upon the following points.

1. They surpass satellite scanned images in general geologic interpretability because of superior clarity, stereo view overlap, and larger scale. Far more rock-type delineation can be achieved with these than so far has been demonstrable from ERTS images.

2. They cover an area of nearly 4 townships (10.8 x 10.8 miles) per frame, and are consequently far less expensive than larger scale airphotos for large study areas.

3. A larger region can be interpreted by the photogeologist per unit of time invested.

4. Regional, or large scale features, are more clearly and easily identified than on more detailed large scale photos. Major patterns are easier to recognize.

5. The scale is sufficiently small that direct identification of specific ERTS satellite image features is facilitated. This is important because satellite images are so very much smaller—and in many cases less distinct—than airphotos; and correct identification and location of particulars of interest on the airphotos can be very difficult, and subject to significant location error.
6. The scale is very close to optimum for locating views taken by any low-elevation large scale method, such as COSA.

7. The prints make a nearly ideal base upon which geologic interpretations derived from COSA analysis may be directly annotated. This is important because of the increased accuracy offered for transfer of such data over the direct observation-to-map transfer methods used in many studies.

8. Small-scale vertical airphotos, viewed in stereo, are superior to ERTS images or orthophotographic maps or larger scale vertical airphotos for planning future ground operations, for selecting areas for which larger-scale airphotos will be needed, and for selecting areas upon which to focus specific effort---as for COSA coverage or geochemical sampling.

9. The procedure of using 1:70,000 or smaller scale airphotographs for preliminary regional study will lead to better-conceived plans for future intensive studies in specific zones or localized problem areas.

COLOR OBLIQUE STEREO AIRPHOTOS (COSA)

Color oblique stereo airphotos formed an integral part of the present multiapproach evaluation project. The whole COSA system has been under development for the past 20 years, primarily by the writers. Consequently, from the outset many of the characteristics, capabilities, and limitations were known. The main concern thus revolved about the extent to which inexpensive COSA could substitute for the more customary conventional vertical airphoto coverage. A summation of COSA characteristics and capabilities follows.
Advantages

1. COSA pictures normally are custom-planned to show specific high interest or problem areas from an optimum distance and at the time of day or season desired. This sort of flexibility and capability for matching imagery to specific needs is almost unattainable when one depends entirely upon large-format conventional air cameras or when one must make use of existing imagery flown previously to some other project's specifications.

2. The equipment needed is relatively small, simple, and adapted to ordinary films. This means that small format aerial photography becomes practical for most research projects where it might be useful, and the costs will be very low because the equipment costs and expendables are comparatively inexpensive.

3. It is very rapid. Turnaround time from exposure to receipt of COSA is about a week if the exposed film is processed commercially. If faster turnaround is needed, a field processing darkroom could be established for an 8-hour cycle.

4. In spite of the low cost, it is a full-color product, and 100% overlap stereo. These characteristics are not met by any conventional imagery. Readily available small-format color products have tremendous advantages for the interpreter and have formed the basis for the massive attempts to develop operational high-quality color in large format aerial photography (Smith and Anson, 1968).

5. COSA, being in 35 mm slide pair format, is the only type of color airphoto available that is conveniently used in the field, as well as in office conditions. Rugged magnifying stereo viewers have been constructed
for field use by the Idaho Bureau of Mines and Geology personnel and fit into the small side packet of a day pack. The stereo pairs of COSA slides are taken to the field and protected from dust by ordinary plastic bags.

6. Annotation is not direct, but simple and accurate if features recognized in stereo view can be plotted onto sets of conventional black and white airphoto prints or large scale topographic maps.

7. Special-purpose emulsions, such as high contrast Photomicrography Color Film 2483 Ektachrome or Infrared Film is as easily used as regular color, and processes identically.

8. COSA by its oblique nature provides the only satisfactory means for obtaining meaningful airphotos of very steep slopes of cliffs; these show only as lines or very narrow bands on conventional airphotos.

9. Structural attitude (dip and strike of tabular units) is much easier to estimate on oblique views.

10. Assessment of short term events, such as flood inundation, landslide, shoreline storm erosion, or earthquake damage can be made at the time when information is critically needed because the equipment is very portable and charter flights in small planes can be easily arranged.

11. Periodic monitoring is practical in maintaining awareness of prospecting activity, revegetation, progressive land reclamation, dam construction, urban expansion, or sustained land surface creep.

12. Oblique air views are far easier for untrained viewers to relate to than are vertical air views. Either slide of a stereo pair may conveniently be selected to show to a group in any ordinary slide projector for purposes of planning, discussion, or instruction.

13. Ordinarily and ideally a geologist is the photographer for all
COSA pictures, and he selects views of things he sees as important from his point of view. He also selects the angle and distance he believes are most informative. This is a point of extreme importance.

14. The investigator-photographer sees the project area from an advantageous platform, and he is able to recognize field relationships for a relatively large area in a brief time while he is selecting targets and taking photographs. Frequently the photographer is able to add information to his map just from what he has synthesized during the flight. This is a very efficient procedure.

Disadvantages or Limitations

1. It is impractical to cover great areas systematically with COSA. That is better done with vertical photos.

2. Color desaturation and haze degradation are very noticeable at flying heights greater than three or four thousand feet above ground level. COSA pictures from great altitude, while technically easy to take, are almost always disappointing. This is the identical problem mentioned in regard to high altitude conventional vertical airphotos.

3. Air pollution and smog from industry and cities prevents one from obtaining optimum color pictures in certain areas downwind from the sources. In many parts of the country the problem has reached proportions which prevent successful color photography by any technique for many days at a time.

4. It is not a simple task to construct a photo-line index for COSA pictures on a complex flight. It takes a skilled person many hours to produce a flight-path index map showing views obtained.

5. Information cannot be marked directly on COSA images as it can
on regular airphoto prints.

6. The oblique images are not inherently map-like, as are the vertical airphotos.

7. COSA interpretation for geology is seriously reduced in areas of dense forest cover in the same manner as for conventional airphotos of wooded regions.

Project Related Specific COSA Observations

1. Two of the four photographic flight days available for this study had extreme smoke-haze conditions over the entire Owyhee Range. One flight was terminated because of seriously impaired visibility.

2. Seldom have enough COSA views been taken during the first flight over an area, and usually it is preferable to take several short photo flights instead of one long one.

3. The adoption of the COSA method as part of the standard operational procedure for most geologic reconnaissance studies would seem to be strongly indicated on the basis of the positive experience in its application to this study, as well as other concurrent studies.

4. It is estimated that actual field time for many projects can be reduced by at least 50% if both COSA and high quality vertical airphotos are available to the geologist throughout the project.
RELATIVE MERITS OF AERIAL FILM TYPES

In regard to film type and filtration we have had no selection available for comparison except for our own color film testing for the COSA portion of the project. At present conventional color is probably a poor choice for the high altitude vertical airphotos needed in this work. The reasons are many but include the following:

1. Color film exposure latitude is narrow; therefore, correct exposure is not as easily attained as for black and white materials.

2. Color film tends to lose color saturation and contrast when used at the high flight altitudes needed for small scale photography. Color film is particularly susceptible to overall degradation by haze, which can be controlled only partially by filters.

3. Color films are competitive in resolution with good black-and-white prints only as color transparencies, not as prints. Almost all production-line workprints of color airphotos are distressingly weak in color hue, spectral range, chroma, and resolution. Because the large transparencies are very inconvenient to use and to annotate, some users order prints, not aware that any advantages a color view might offer are normally far outweighed by the massive overall quality loss between color negatives and prints.

4. Color film is approximately four times as expensive to take or to print as black and white film.

For the reasons outlined above, it is recommended that high altitude photography be made on conventional panchromatic aerial film, with red (#25) filtration for general application. For special cases it may
be useful to use either black-and-white infrared aerial film, or color infrared film. These both offer a superior haze penetration, but re-
quire special filtration and are subject to exposure difficulties for a variety of reasons beyond the scope of this paper.

Although not recommended for high altitude work, "normal" color films do have a proper and useful place in aerial photography---specif-
ically in low elevation or large scale photography and in projects where film transparencies are practical as the work medium. These conditions are met in 35 mm format COSA views, and also in some low altitude ver-
tical photography for detailed analysis. For small format photography the study team has had superior results with Ektachrome-X film in both 35 mm and 120 roll sizes. Many other color films have been tested over the past 20 years, and several are useful in specific situations, but for one generally dependable film with a minimum of inconsistencies Ektachrome-X is recommended. In most cases it is necessary to increase the ASA film speed rating for aerial work. An increase of 75% over rated ASA is a useful value for first trials with a particular camera-
film combination. A skylight filter (1-A) is recommended for all nor-
mal-color aerial photography. At modest flying heights conventional color film will reproduce air views with sufficient color fidelity and detail to offer significant advantages to a geologist over regular black and white prints. Some of the advantages are:

1. Slight changes in soil or rock color can be apparent in color views but not in all black and white views.

2. Characteristic alteration halo colors can often be identified.

3. Many more color varieties and gradations are reproducible on
color film than can be distinguished from one another when shown in shades of gray (Anson, 1969; Fischer, 1958; and Grant, 1971).

4. Sediment load and water contaminants can often be shown better on color film.
CONCLUSIONS

1. Extension or projection of known linears may prove to be useful in analysis even though they may not be traceable on airphotos beyond where they are drawn. Linear projection introduces more intersections and areas of multiple intersections thus providing possible points for initial ground examination or geochemical exploration.

2. The optimum base scale for linear compilation is 1:125,000 unless detailed work is needed from low elevation imagery.

3. The most practical vertical view imagery scale for most reconnaissance geologic exploration and other land-use considerations is in the range of 1:120,000-1:70,000; such photography is taken from U-2 or ultra-high flying special aircraft and equipment, or with ultra-wide angle optics.

4. COSA system is impractical for systematic mapping of large areas and contributes most when applied to specific, important target areas. These may be pre-selected from ERTS and high altitude photography.

5. It is not possible from ERTS-1 imagery alone to map rock-type in adequate detail to be acceptable for standard reconnaissance mapping or geologic resource evaluation.

6. If it is necessary to use only a single band of ERTS imagery (although this is not recommended), band 6 appears to be the most suitable for structural analysis.

7. Thus far, the most useful ERTS product for geologic evaluation in southwestern Idaho is the color composite 1:250,000 scale enlargement
of three MSS bands---4, 5, and 7. Much more detail could be discerned from this composite than from any of the single-band, black and white images. (For future orders, we would recommend composite prints to be made from bands 4, 5, and 6.)

8. The most useful product for conventional black and white aerial photography is standard panchromatic film with a red filter. At higher flying altitudes a red filter will better minimize the image degradation from haze than will a "minus blue" filter (yellow). In general a more pleasing image quality will result.

9. If money is available for a moderate amount of photography and flying, more information can be obtained by selective COSA coverage than from any other remote sensing system which can easily be carried out by the scientific team members.

10. COSA is also the only system which offers time and scale flexibility at reasonable cost.

11. We recommend for geologic reconnaissance mapping, structural analysis, and land-use decision making, a combined approach using ERTS imagery, ultra-small scale vertical airphotos, and COSA—all coordinated to a selective field check.
REFERENCES


Kittleman, L. R., and others, 1967, Geologic map of the Owyhee region, Malheur County, Oregon: Bull. no. 8, Univ. of Oregon Mus. of Nat. History.


MAJOR DRAINAGES WHICH ARE IN PART COINCIDENT WITH LINEARS MAPPED FROM ERTS IMAGES

Flint Creek Quadrangle
  Indian Creek
  Bogus Creek
  Combination Creek
  Flint Creek
  East Creek
  Bridge Creek
  Stonehouse Creek
  Williams Creek
  Louse Creek

Triangle Quadrangle
  Boulder Creek
  Hart Creek
  Little Hart Creek
  Pickett Creek
  Jordan Creek (headwaters)
SPRINGS THAT OCCUR ALONG ERTS LINEARS AND LINEAR INTERSECTIONS

Triangle Quadrangle

Chimney Spring  Sec. 21, T 7 S, R 3 E
Lone Tree Spring  Sec. 36, T 7 S, R 3 W
Springs along Boulder Creek  Secs. 32 & 33, T 6 S, R 3 W
Springs in amphitheatre head of Jordan Creek  Secs. 18, 19, & 20, T 5 S, R 3 W
Spring (unspecified)  Sec. 4, T 8 S, R 3 W
Spring (unspecified)  Sec. 36, T 6 S, R 2 W
Spring (unspecified)  Sec. 26, T 6 S, R 2 W
Spring (unspecified)  Sec. 14, T 7 S, R 3 W

Flint Creek Quadrangle

Connors Spring  Sec. 7, T 6 S, R 5 W

If the linear that intersects Connors Spring were extended north it would also intersect the following:

Sheep Spring  Sec. 6, T 6 S, R 5 W
South Spring  Sec. 31, T 5 S, R 5 W
Springs near head of Split Rock Creek  Sec. 7, T 5 S, R 5 W

Other springs in the Flint Creek Quadrangle include:

Springs (unspecified)  Sec. 3, T 8 S, R 5 W
Spring (unspecified)  Sec. 7, T 7 S, R 5 W
SPRINGS THAT OCCUR ALONG LINEARS MAPPED FROM CONVENTIONAL VERTICAL AIRPHOTOS

Triangle Quadrangle

Buckaroo Spring  
Sec. 10, T 7 S, R 2 W

White Horse Reservoir (spring)  
Sec. 13, T 7 S, R 2 W

Charity Spring  
Sec. 14, T 6 S, R 2 W

Alibi Spring  
Sec. 1, T 6 S, R 2 W

Lone Tree Spring  
Sec. 35, T 7 S, R 3 W

Thomas Lakes  
Sec. 14, T 5 S, R 3 W

Spring (unspecified)  
Sec. 1, T 7 S, R 2 W

" "  
Sec. 35, T 6 S, R 2 W

" " linear ext.  
Sec. 26, T 6 S, R 2 W

" "  
Sec. 26, T 7 S, R 3 W

" "  
Sec. 23, T 7 S, R 3 W

" " linear ext.  
Sec. 4, T 8 S, R 3 W

" "  
Sec. 4, T 8 S, R 3 W

Springs (unspecified) along Boulder Creek  
Sec. 32, T 6 S, R 3 W

Springs (unspecified) along Mammoth Creek  
Sec. 32, T 6 S, R 3 W

Spring (unspecified)  
Sec. 23, T 6 S, R 3 W

" "  
Sec. 14, T 5 S, R 3 W

" "  
Sec. 9, T 5 S, R 3 W
Flint Creek Quadrangle

Dead Horse Spring  Sec. 20, T 6 S, R 5 W
Thorns Spring     Sec. 5, T 6 S, R 5 W
Sheep Spring      Sec. 6, T 6 S, R 5 W
Pack Hook Spring  Sec. 33, T 5 S, R 5 W
Mud Springs       Sec. 4, T 6 S, R 5 W
Goose Creek Spring Sec. 33, T 5 S, R 5 W
Barrel Spring     Sec. 9, T 7 S, R 5 W
Spring (unspecified)       Sec. 34, T 5 S, R 4 W
                       Sec. 1, T 7 S, R 4 W
                       Sec. 8, T 6 S, R 5 W
                       Sec. 24, T 5 S, R 6 W
                       Sec. 9, T 7 S, R 5 W
                       Sec. 35, T 7 S, R 5 W
                       Sec. 23, T 5 S, R 5 W
SPRINGS THAT OCCUR ALONG LINEARS MAPPED FROM COSA IMAGES

Flint Creek Quadrangle

Goose Creek Spring
Dead Horse Spring
Springs (unspecified)
  
Sec. 9, T 6 S, R 5 W
Sec. 20, T 6 S, R 5 W
Sec. 14, T 7 S, R 4 W
Sec. 3, T 8 S, R 4 W
Sec. 32, T 7 S, R 4 W

Triangle Quadrangle

White Horse Reservoir
Alibi Spring
Henderson Spring
Buckaroo Spring
Chimney Spring
Hardiman Spring
Springs (unspecified)
  "  "  linear ext.
  "  "
  "  "

Sec. 13, T 7 S, R 2 W
Sec. 1, T 6 S, R 2 W
Sec. 14, T 6 S, R 2 W
Sec. 10, T 7 S, R 2 W
Sec. 21, T 7 S, R 3 W
Sec. 10, T 7 S, R 3 W
Sec. 35, T 6 S, R 3 W
Sec. 22, T 7 S, R 2 W
Sec. 34, T 6 S, R 2 W
Sec. 9, T 6 S, R 2 W
Sec. 1, T 6 S, R 3 W
Sec. 27, T 7 S, R 3 W
Sec. 9, T 5 S, R 3 W
Sec. 33, T 6 S, R 3 W
Sec. 28, T 7 S, R 3 W
Sec. 30, T 7 S, R 3 W
Sec. 24, T 7 S, R 4 W
Springs (unspecified)  Sec. 32, T 6 S, R 3 W  
Sec. 29, T 5 S, R 3 W  
Sec. 18, T 5 S, R 3 W  
Sec. 19, T 5 S, R 3 W  
Sec. 21, T 5 S, R 3 W  

Springs along Boulder Creek  Secs. 22 & 27, T 5 S, R 3 W
PARTIAL LISTING OF REFERENCES ON LINEAR MAPPING AND ANALYSIS
PARTIAL LISTING OF REFERENCES ON LINEAR MAPPING AND ANALYSIS


PLATE 3. LINEARS FROM COLOR OBLIQUE STEREO AIRPHOTOS, FLINT CREEK & TRIANGLE QUADRANGLES OWYHEE COUNTY, IDAHO