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Low Sun-Angle Photography

Flight planning considerations and interpretive techniques for low sun-angle photography, as employed for the enhancement of topographic features, are discussed.

Introduction

During the past ten years many reports have been published expounding on the use of low sun-angle aerial photography as an aid to photointerpretation. As early as 1960 the *Manual of Photographic Interpretation* (American Society of Photogrammetry, 1960, p. 102-103) inferred that shadows may help the interpreter by providing a profile image of objects in the scene. Hackman (1967) and Wise (1968, 1969) showed that shadow enhancement using varying angles of illumination tends to increase the interpreter's ability to recognize low-relief features and features with parallel trends. Hackman further points out that the optimum sun elevation varies with the terrain characteristics. Wise's work provided a technique which defined structural trends which were aligned within 30 degrees of the illumination and were strikingly apparent across divergent tectonic styles. The use of low sun-angle photography for the mapping of fault scarps was employed by Slemmons (1969) in the Owens Valley area of California. He states that optimum delineation of scarps with varying trends can be optimized by selecting the time of day and time of year of photographic overflights.

More recent work (Clark, 1971a; and Lyon *et al.*, 1970) compared low sun-angle photography with side-looking airborne radar (SLAR) and showed that small-scale presentations (1:120,000) of low sun-angle photography provided as much if not more information than side-looking airborne radar.

A more recent study (Sawatzky and Lee, 1974) has extended the equation of Wise to include all conditions of shadow enhancement and has provided, with both relief maps and aerial photography, an example of the extended formula. Strict adherence to the extended equation need not be applied as shown by detection of very subtle topographic features.

Abstract: *The use of low sun-angle photography for the enhancement of topographic features has been known for many years. The analyses of low sun-angle photography in separate test sites in a mid-latitude region are used to describe interpretation techniques and to compare the effectiveness of different scales of low sun-angle photography. The critical question of when to fly a low sun-angle photographic mission based on the terrain, trends of topographic features, and the effects of sun azimuth and altitude (angle) are considered. It appears that strict adherence to the extended formula need not be applied as shown by enhancement of subtle topographic features.*

The purpose of this study is to show that theoretical considerations of the sun elevation and azimuth need not be applied in the strictest sense but can be applied more generally without degrading the interpreter's ability to identify low topographic features. It will also describe the techniques used and the sun elevation and azimuth which optimize various topographic features depending on height, slope, and trend.

Sun Angle, Azimuth, and Lineament Orientation

Low sun-angle photography for latitude 40 degrees north during the fall and spring provides optimum delineation for north-south trending lineaments. Limitations are encountered, however, due to the short time in which aerial photography may be acquired. As an example, on September 20th between 0630 and 0730 the sun-angle ranges from 08 degrees to 18 degrees (elevation) and solar azimuth ranges from 95 degrees to 105 degrees (direction of illumination). Comparable sun-angles are encountered during the period between 1630 and 1730. During this time the azimuth ranges from 257 degrees to 267 degrees. (Times are expressed here and throughout the paper in terms of "local solar time".)

During the winter months the sun is in such a position as to afford better delineation of trends parallel and subparallel to an east-west direction. During this time of the year there exist advantages in the length of time during which photography may be acquired with low sun-angle effects. As an example, on December 21st, between 0830 and 1000 hours, the sun-angle ranges from 10 to 21 degrees. This provides for 1.5 hours of good data taking with optimum sun-angles when analyzing areas of low to flat terrain where very subtle lineaments may be enhanced. Furthermore, the solar azimuth ranges from 140 to 160 degrees during this particular window. The maximum sun-angle is 27 degrees at solar noon for this latitude on December 21st (Figures 1 and 2).

Snow Produces High Uniform Reflectance

Linear trend identification by low sun-angle photography is a function of the orientation of the linear, angle of the slope, and relief. Steep-sloped topographic features commonly produce the straightest patterns (Sawatzky and Lee, 1974). Identification of lineaments in areas of high relief requires a higher sun elevation than areas of low relief. Low sun-angles such as 10 degrees in areas of high relief would produce a predominantly shaded photograph in which much of

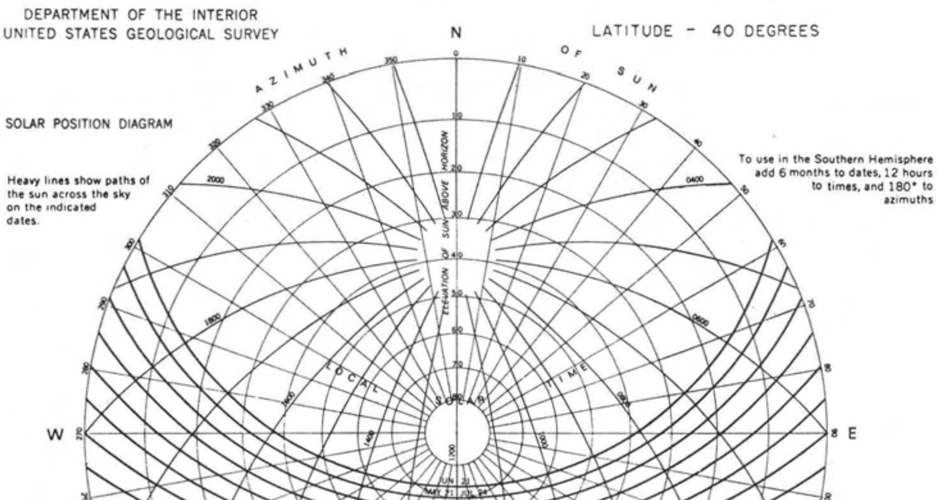


Fig. 1. Solar position diagram.

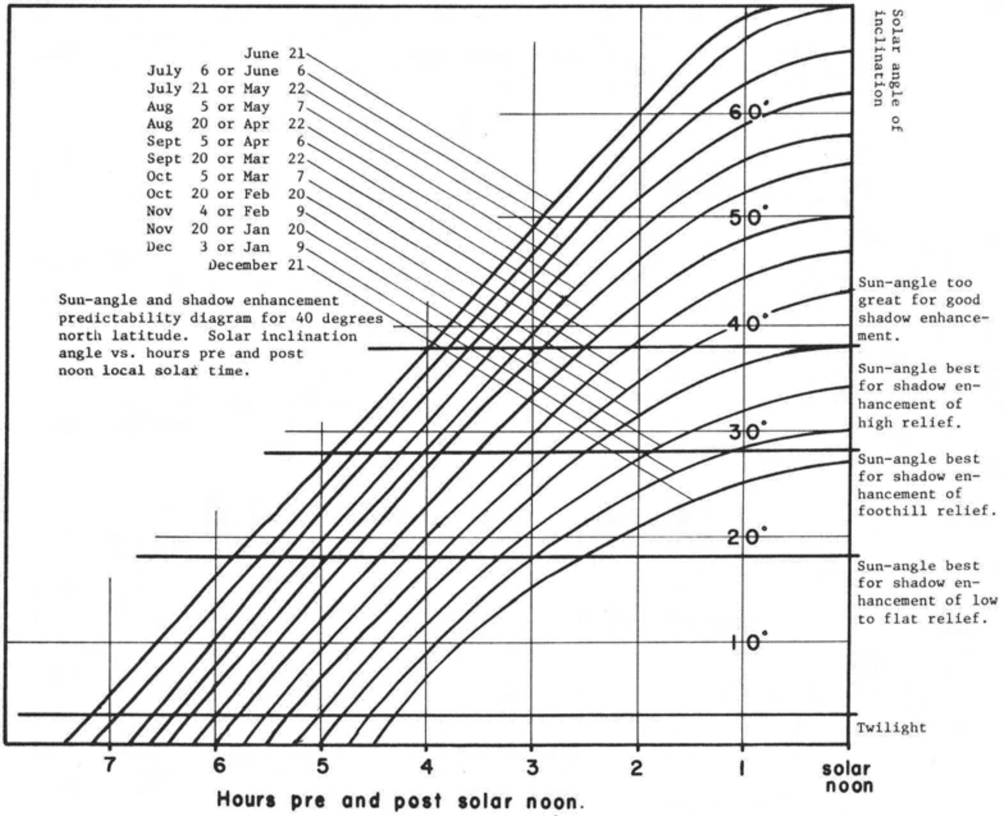


FIG. 2. Shadow enhancement predictability diagram for 40° north latitude.

the data would be hidden from view (in the shadows). This requires that areas of low relief be flown first during the morning and last during the afternoon. It follows that areas of high relief would be flown later in the morning and earlier in the afternoon when the sun-angle is greater.

Sawatzky and Lee (1974) describe three methods which can be employed to enhance contrast between shadows and illuminated slopes. Two of these methods are photographic and the third natural. Each method increases the contrast by increasing the reflectance. The first process is to increase the gamma of the film. This increases the contrast between shadowed and illuminated slopes. The second method is to increase contrast by making shadows darker with respect to illuminated areas at the time of exposure. This can be accomplished by using black-and-white infrared film with a Wratten 25 filter. The third method is to produce uniform high values of reflectance. This can be accomplished by photographing snow-covered scenes which produce high contrast between shadows and snow.

Data Collection and Analysis

The Test Sites

Test sites were selected for the purpose of taking repetitive low sun-angle aerial photography. The data were interpreted and compared to previously published reference data. In addition, flight planning data were compiled in order to extract useful "rules of thumb." These rules, then, would aid even the novice flight planner in determining just when a flight would yield the most useful geologic information employing low sun-angle aerial photographic techniques in the area of interest.

The first test site selected was a foothill alluvial fan complex on the east flank of the Carson Range just south of Reno, Nevada (Figure 3). The Carson Range forms the eastern boundary of Lake Tahoe and the extreme western boundary of the Basin and Range physiographic province. The fan complex (bajada) dips to the east at approximately 7 degrees, is about 250 feet thick, and overlies Tertiary volcanic bedrock. It can be seen in Figure 3 that the fan is highly faulted

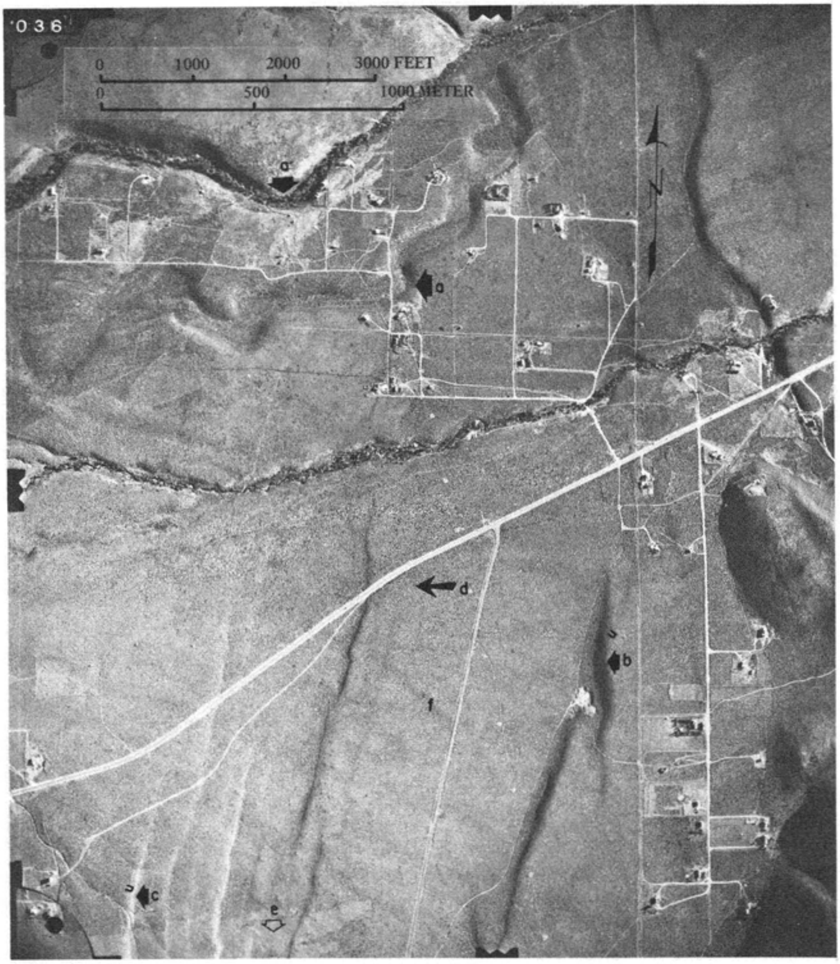


FIG. 3. The Reno test site.
Original scale 1:12,000 Longitude 119°48′45″W Latitude 39° 22′30″N (Southern edge of the Mt. Rose N.E.

Original scale 1:12,000
Longitude 119°48′45″W
Latitude 39°22′30″N
(Southern edge of the Mt. Rose N.E.
Nevada 7 1/2′ Quadrangle, 2062 IV NE)
23 June 1972 0550 Local solar time
Solar altitude 15°, solar azimuth 71°
Slope of fan is left to right
(a) Fault controlled stream beds
(b) Fan complex faulting with low sun-angle shadow enhancing, u = upthrown side.
(c) Fan complex faulting with low sun-angle sun slope enhancing, u = upthrown side.
(d) Direction of solar illumination (azimuth).
(e) Lowest point of the graben complex.
(f) Unique linear recognized initially only by shadow enhancement (see text).

with vertical displacements ranging from less than a meter to nearly 11 meters. The scarps are probably faultline scarps (Cordova, 1969), dip from 5 to 18 degrees, and form a terraced fault graben complex. This test site was selected not only for the orientation of the faults but also because it is an area of relatively large changes in relief over small distances. These criteria make the site, and the data collected therefrom, applicable to many areas of the world; that is, the area is not entirely flat nor is it entirely mountainous, but is in close proximity to both. This has allowed the study of the effects of enhancement by low sun-angle over a wide range of topographic relief within a confined area of relatively small dimensions. In certain respects, the test site is unique as compared to other areas. It is a semi-arid region and thus lacks significant vegetal coverage which in some cases can mask or alter the effects of low sun-angle enhancement. Finally, the site is located in the middle latitudes (39°N) where useful low sun-angles and sun azimuths occur throughout the year. The near equatorial latitudes are less desirable for application of low sun-angle photography in that the solar altitude changes so rapidly in these regions that the available flight-time windows are so short that they make meaningful low sun-angle imagery difficult to acquire. Additionally, far northern and southern latitudes may also be less desirable because of the rapidly changing solar azimuth (nearly 15° per hour). Solar altitude remains relatively constant throughout a given day in these latitudes, thus having little changing effect on low sun-angle data acquisition.

Figure 4, as a sequence of photos, shows the relative enhancement effects of changing sun-angle and azimuth at the Reno test site. The photos show the sun moving progressively north and more nearly illuminating the linear features perpendicularly. Photo 4D shows a lineament at "a" (as in (f) in Figure 3) which is not present in 4A, 4B, or 4C. This linear feature is nearly aligned with the solar azimuth in photo 4A and thus is now shadow enhanced. As the solar azimuth swings further north to its position in photo 4D (and even further north in Figure 3), the feature becomes shadow enhanced. A value then may be attached to repetitive aerial photography of the same area over a period of time to allow subtle features to be enhanced. In this case, this lineament was not known to exist until shadow enhancement exposed it. It will make an interesting feature to study in a future paper in that it appears to be unique in its trend with respect to the other fault scarps.

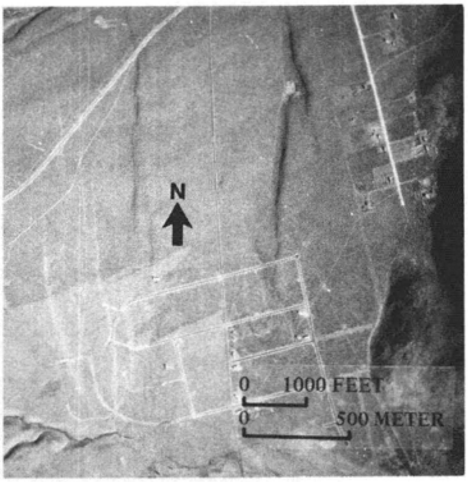
A second site was located in north-central Nevada several miles southeast of the town of Battle Mountain (Figure 5). It, too, is an alluvial fan complex (bajada) at the base of the Northern Shoshone Range which is a typical basin and range block faulted mountain structure. The fan extends out from the base of the Northern Shoshone Range nearly seven miles northwest to the present flood plain of the Humboldt River. The fan is extremely gentle with an average slope of less than one degree (by field measurement). The fan slope is broken by a series of linear and curvilinear features which, for the most part, are parallel or subparallel to the obvious basin and range frontal fault along the Northern Shoshone Range (Figure 5), all of which cut across older drainage patterns. Field investigations give good cause to believe that these breaks in slope are in fact faults in the alluvium. These fan slope breaks range in height, by field measurement, from 0.5 meter (18 in.) to as much as 3 meters (15 ft). This fan is similar to the fan complex at the Reno test site in that it is relatively uniform in slope, slope breaks appear to form a subtle graben complex (Figure 6), and the vegetal cover of this semi-arid region is also very sparse, lending to the ease of interpretation of the imagery. Exceptionally few of the lineaments at this test site are in any way enhanced by additional vegetal growth (which is typically caused by ground water seepage along the fault trace).

Figure 6 is a much smaller scale aerial photograph than Figure 5. The entire Battle Mountain test site is shown in Figures 6 and 7. In contrast to Figure 7, Figure 6 clearly shows the reasons for selecting the proper sun elevation for enhancement studies. The lineaments of the test site show up in Figure 6 markedly better than in Figure 7 even though some basin and range faults are shadow concealed. Figure 7 was taken one month earlier than Figure 6, but one hour later in the morning. The interpretive differences are obvious as are the effects of dodging during development of Figure 6, i.e., contrast has been achieved in the playa areas in Figure 6 thus allowing better tracing of the lineaments during interpretation*. Figure 7 is better suited for interpretation of the basin and range faulting than is Figure 6, but these faults were not the major objective of the test site.

THE DATA FLIGHTS

For the Reno test site, repetitive overflights of the area were flown from February through April of 1974. All flights were exactly one week apart, flown at the same time of the day and at the same altitude. The

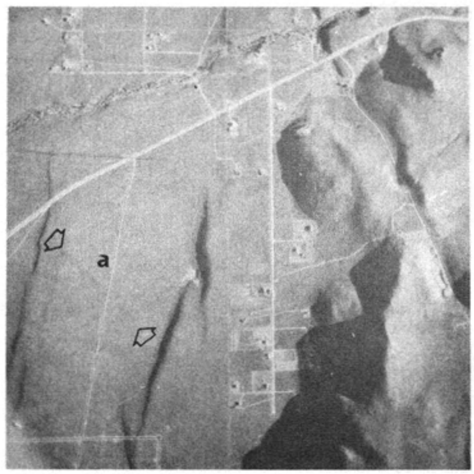
* Contrast and dodging with respect to low sun-angle interpretation are further explained under "Analyses Techniques."



(4a)
February 8, 1974
Solar altitude 20°
Solar azimuth 133°
Local solar time 0900

(4b)
February 15, 1974
Solar altitude 25°
Solar azimuth 134°
Local solar time 0913

(4c)
March 22, 1974
Solar altitude 33°
Solar azimuth 123°
Local solar time 0900



(4d)
April 12, 1974
Solar altitude 11°
Solar azimuth 88°
Local solar time 0630

FIG. 4. Reno test site sequential low sun-angle photography. Original scale 1:12,000.

data gathering technique was designed to reduce the effects of as many of the variables in aerial photography as was possible. In this investigation, then, the solar azimuth and sun-angle were the only significant variables, and the effects of these changes over a long period of time were observed. The photography at this test site (Figure 4) was flown at an altitude of 10,000 feet above ground level (17,500 feet above mean sea level). The final prints used in the interpretation were at a scale of 1:12,000 (1 inch equal to 1,000 feet). It was acquired with a Chicago Aerial KS-87 aerial camera with a 6-inch focal length lens. The imagery was taken with the camera operating in the automatic mode with radar altimeter and doppler radar ground speed computer inputs resulting in a product with 56 percent stereo forelap. Aerial film was GAF black-and-

FIG. 5. The Battle Mountain test site.
Original scale 1:30,000
Sun angle 25°, sun azimuth 127°
Longitude 116°57′ W
Latitude 40°33′ N
0845 Local solar time
(a) Battle Mountain airport
(b) Fan complex faulting, u = upthrown side
(c) Ranch
(d) Direction of solar illumination (azimuth).

white with a 4½ by 4½ in. format. Flights were as near to 0900 local solar time as possible each Friday for the three months noted previously. During the time of imaging at the Reno test site, latitude 39°22′18″N, the solar altitude ranged from 20 degrees on February 1st to 42 degrees on April 19th. During the same period, the solar azimuth ranged from 146 degrees to 124 degrees.

The two missions at the Battle Mountain site were flown one month apart. The first mission was flown on September 17, 1974 at 0945 hours local solar time (Figure 7). The second mission was flown on October 18, 1974 at 0845 hours local solar time (Figure 6). Two cameras were operated simultaneously onboard the NASA U-2 aircraft on each of the two missions. The HR-73R aerial camera provided black-and-white imagery at a scale of 1:30,000 (24 inch focal length lens at an altitude of 60,000 feet above mean sea level, Figure 5). The RC-10 aerial camera

FIG. 6. The Battle Mountain test site.
Original scale 1:120,000
Longitude 116°47′ W
Latitude 40°33′ N
Eastern 1/2 of Battle Mountain NV. 7 1/2′ quadrangle
October 18, 1974, 0845 Local solar time
Solar altitude 25°, solar azimuth 127°
(a) Battle Mountain, NV
(b) Basin and Range block faulting along the Northern Shoshone Range.
(c) Ranch (reference)
(d) Fan complex faulting, u = upthrown side.
(e) The Humboldt River
(f) The Reese River
(g) Battle Mountain Airport
(h) Sun-angle is too low for the topographic relief causing concealing shadows.
(i) Direction of solar illumination (azimuth).

provided black-and-white imagery at a scale of 1:120,000 (6 inch focal length lens at the same mean sea level altitude, Figures 6 and 7). During the time of imaging at the Battle Mountain test site, latitude 40°33′ north, the solar altitude ranged from 42 degrees (September 17) to 25 degrees (October 18), and the solar azimuth ranged from 132 degrees (September 17) to 127 degrees (October 18). Note that the October flight was earlier in

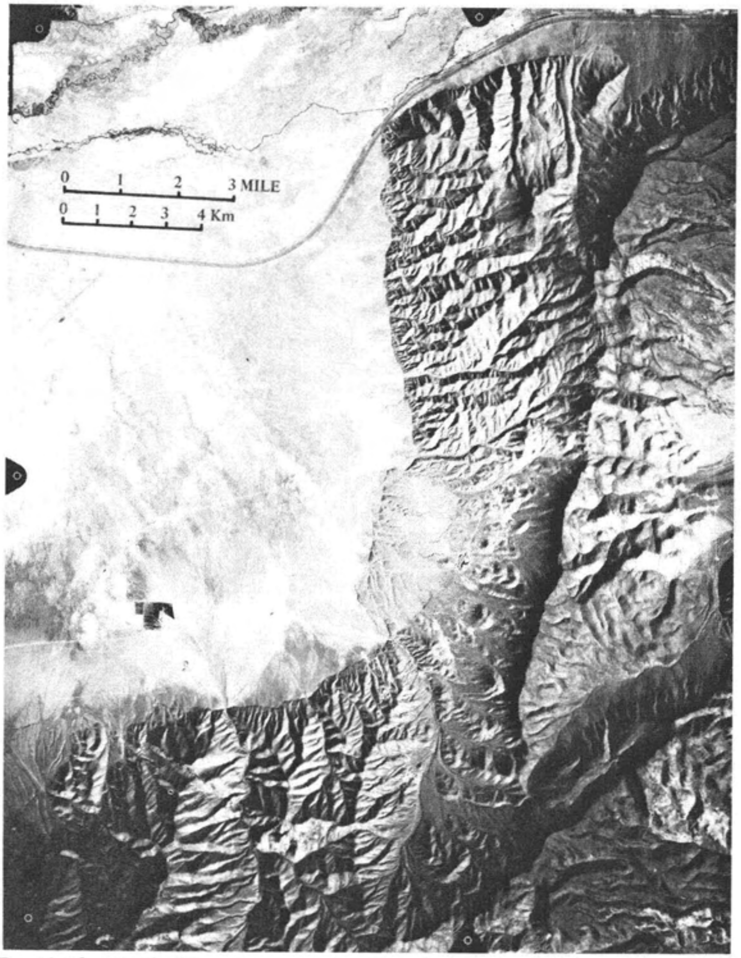


FIG. 7. The Battle Mountain test site. Details are exactly as in Figure 6 with the exception of:
Solar altitude 42°
Solar azimuth 132°
September 17, 1975
0945 local solar time

the day than was the overflight in September. The flight time was shifted to an earlier time in October in order to obtain a more radical enhancement of the fan and playa lineaments by a lower sun-angle, since repetitive photography was not available. The two U-2 flights were flown for the Lawrence Berkeley Laboratories (Harold Wollenberg, P.I.), and not specifically for this investigation.

THE ANALYSIS TECHNIQUES

Analysis of the data acquired at the Reno test site was accomplished using the 1:12,000 scale photography on 9 by 9 inch stereo pairs (black-and-white prints) (Figure 3). The only aid to interpretation was the Type 214GE, 2.5× pocket stereoscope and the Abrams CB-1 2×-4× desk stereoscope. Scarp heights, slopes, and other measurements were obtained by direct field measuring techniques (as ground truth) so that accuracy could be maintained in the interpretation process. Sun-slope and shadow enhanced scarps were mapped directly onto mylar overlays for comparison with previously mapped geology in the same area (White, Thompson, and Sandberg, 1964; and Cordova, 1969). Several interpreters mapped the photographed fault area independently, and more than 90 percent of all enhanced faults were recognized by each interpreter.

Battle Mountain test site Missions I and II

The solar altitude on Mission I was 17 degrees higher than on Mission II, and this produced noticeable differences in the degree of enhancement of the faults in the area. The change in solar azimuth was only 5 degrees and was not considered significant enough to warrant further investigation into its effects at this test site. The lack of significant effect of the azimuth change is for the most part due to the fact that the breaks in the alluvial slope parallel the range-front in an arcuate manner rather than in a straight line manner, thereby making any significant changes harder to detect. Interpretation of the 1:30,000 scale photography was accomplished on 9 by 18 inch black-and-white prints using mylar overlay and the unaided eye. It was determined that 10 to 20 percent more lineament detection could be seen and readily mapped on the Mission II (25 degree sun-angle) photography than on the Mission I (42 degree sun-angle) photography, and that each interpreter was mapping at least 95 percent of the linears that were independently mapped by the other interpreters. It should be noted that these variations in the ability to clearly distinguish individual linears are attributed to the following reasons:

(1) Photos taken within the Great Basin most generally cover, within an individual frame, steep, dark-toned mountain ranges, lighter toned gently sloping fans, and very light toned to nearly white flood plains, dry lake beds, playas, or salinas (Figures 6 and 7). An obvious problem in printing black-and-white photographs must be dealt with using dodging techniques in order to preserve important detail in the interface areas as mentioned above. Lack of regard for this problem during printing will result in specific areas being extremely subdued or totally washed out and interpretation will be significantly degraded if not impossible. Single frames with some or all of these gross terrain differences generally occur in high altitude, small scale photography encompassing large areas. In the Basin and Range province these gross terrain change problems are compounded by gross tonal changes; high, dark shadowed mountains are adjacent to flat very white evaporite covered intermontane basins and separated by intermediate toned alluvial fans. Figures 6 and 7 exemplify these problems vividly. Processing these photos required several attempts using various contrast-sensitive papers and dodging variations. These techniques are not limited to high-altitude, small-scale photos, but may be very useful to individual interpreters who wish to examine more closely low altitude or large scale photographs.

(2) In addition to using dodging techniques in the printing process, it is quite important to use a high-contrast film and high-contrast film processing. The object of low sun-angle photography is to obtain as much contrast as possible, and to lose the contrast in processing would defeat the purpose. The film processing is more important when the interpretation is going to be accomplished using positive transparencies on a light table. The authors feel that the best positive print results are obtained using high-contrast photographic paper and dodging techniques.

(3) It is not always the case that these extremes in relief and ground reflectance will occur within an individual frame (Figure 5 versus 6 or 7). However, it is much easier to dodge out too much contrast than to try to force contrast into prints from a negative that has little original contrast.

(4) Prints were also made professionally using a Log E printer (Figure 4 sequence). Detail was certainly acceptable; however, this process incorporates automatic dodging. The net effect is that the lightest and darkest portions of the photographs are transformed into varying shades of gray, and the desired high contrast is lost. If good shadow enhancement is present on the negatives, it will be present on prints produced by a Log E printer but with a lesser degree of surrounding contrast. Marginal shadow contrast or sun-slope enhancement on the negative will produce poor results in Log E printing, and the ability to trace lineaments to their otherwise detectable limits will be lost.

Battle Mountain test site interpretation.

By far the best technique in mapping low sun-angle enhanced lineaments from aerial photography was found to be working with positive transparencies. Black-and-white positive transparencies placed on a well-illuminated light table produce very good formats from which to plot sun or shadow enhanced structural features. In addition to this technique (with mylar overlays), a binocular microscope was used for magnification of detail on the small scale photography. Two degrees of magnification were employed; 10.5× (0.7×15) and 22.5× (1.5×15). It was determined that the degree of magnification should vary inversely with the scale of the imagery so as not to get "too close"; that is, the smaller the scale, the greater the magnification that can be used for successful interpretation results, 1:120,000 scale photography will allow greater magnification than will the 1:30,000 scale imagery. The important point is, however, that this technique does work very effectively, and additional data can be detected and mapped beyond other conventional interpretive techniques. Another plus for the positive transparency and magnification technique is that a pseudo-stereo effect is produced. Use of a single positive transparency frame on a light table produced the following observations:

(1) By far the best interpretation was accomplished by using positive transparencies mounted on a light table. A print frame will only show so much detail regardless of the amount of surrounding illumination, but the intensity of light on a light table may be infinitely varied through a positive transparency and the resulting observations in interpretable data were significant and noticeable using magnification.
(2) A pseudo-stereo effect is produced when magnification is used over the positive transparency on the light table. This is probably best observed using small-scale and high-contrast transparencies. This observation may well be limited to interpreters who have had experience in stereoscopic effects. Both monocular and binocular microscopes were used. The stereo effect and the interpretability between the two devices did not seem to vary, but the use of these devices increased the interpretability significantly over the unaided eye.

FLIGHT PLANNING AND COST ESTIMATION

A timely, complete, and well written paper by J. J. Ulliman (1975) must be used as a primary reference for all flight planning and preliminary cost analysis where aerial photography is the objective.

Flight planning for a low sun-angle mission requries some modification and some additional attention given to some factors which might be taken for granted on a normal aerial photographic mission. These factors are—

(1) Orientation (azimuth) of terrain and structural trends: these data may be obtained through preliminary field reconnaissance, normal aerial photography (preferably stereo pairs), and topographic maps of several scales.
(2) Location of structural trends: whether they are located in flat valleys, low foothills, or mountainous terrain will determine in part at what time flights should be made.
(3) Azimuth of the sun: together with the location of structural trends, this factor will determine whether it is the right time of the year to attempt low sun-angle imagery. Primarily, a sun azimuth which is parallel or subparallel to the trends of the structures to be imaged will produce poor results, as recognized by Sawatzky and Lee (1974)
(4) Sun-angle/time of day relationships: use of the solar position diagrams presented for a selected northern latitude (Figure 1) originally presented by M. M. Clark (1971b) (and Figure 2) will help the flight planner to determine the time frames for any specific day in which low sun-angle illumination will most effectively enhance the structures in the study area.

Summarizing, sun elevation has a major effect on photographing terrain, whereas sun azimuth has a major effect in identifying the structural trends. Figure 8 will help the flight planner to understand the relationships between flight altitude, lens focal length, and the scale of photography they will produce. Further, Table 1 will help both the flight planner and the potential interpreter to understand, after they have chosen a particular scale, approximately how much photography the mission will produce. This table is a product of the relationships of photographic altitudes, aircraft airspeed and lens focal length.

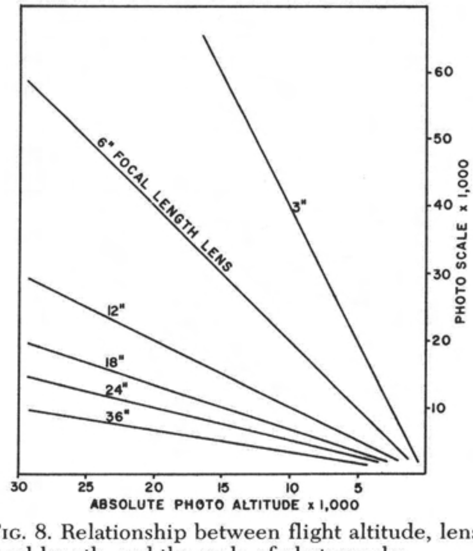


FIG. 8. Relationship between flight altitude, lens focal length, and the scale of photography.

TABLE 1. (a) SQUARE MILES OF COVERAGE PER HOUR IN STEREO WITH 60% FORELAP AND 30% SIDELAP AT THE DESIRED AIRSPEED. (b) TOTAL FRAMES (9″ × 9″) GENERATED PER HOUR.

	Elevation Above Mean Terrain (Feet × 10^3)	Airspeed (MPH) 100		200		300		400	
		a	b	a	b	a	b	a	b
6 in. Focal length	5	710	88	1,420	176	2,130	264	2,841	352
	10	1,420	44	2,841	88	4,261	132	5,682	176
	15	2,179	30	4,213	58	6,392	88	8,500	117
	20	2,840	22	5,681	44	8,521	66	11,362	88
	25	3,430	17	7,063	35	10,696	53	14,382	71
	30	4,068	14	8,426	29	12,785	44	16,852	58
3 in. Focal length	5	355	176	710	352	1,066	528	1,421	792
	10	710	88	1,420	176	2,130	264	2,841	352
	15	1,071	59	2,124	117	3,195	176	4,248	234
	20	1,420	44	2,841	88	4,261	132	5,682	176
	25	1,765	35	3,531	70	5,296	105	7,112	141
	30	2,179	30	4,213	58	6,392	88	8,500	117
12 in. Focal length	5	177	352	355	704	532	1,056	710	1,408
	10	355	176	710	352	1,066	528	1,421	792
	15	531	117	1,062	234	1,598	352	2,130	469
	20	710	88	1,420	176	2,130	264	2,841	352
	25	882	70	1,778	141	2,660	211	3,543	281
	30	1,075	59	2,124	117	3,195	176	4,248	234
24 in. Focal length	5	39	704	79	1,408	118	2,112	158	2,817
	10	177	352	355	704	532	1,056	710	1,408
	15	265	234	532	469	798	704	1,065	939
	20	355	176	710	352	1,066	528	1,421	704
	25	445	141	886	281	1,331	422	1,776	563
	30	531	117	1,062	234	1,598	352	2,130	469

CONCLUSIONS

Low sun-angle illumination enhancement in aerial photography has proven itself a very valuable tool to the photointerpreter in a wide variety of professions and applications; geologists, engineers, land planners, and geographers, to list but a few. Both shadow enhancement and sun-slope enhancement are very useful indicators of topographic anomalies. The photographs draw the attention of those who must investigate these anomalies for their particular specialty application. A striking example of the usefulness of this type of photography to the geologist is the photograph in Figure 3. There is no question concerning what the photograph shows. Site development studies and land-planning recommendations for this potential rural development area near Reno may be made with a much better understanding of the area within the photo and of the surrounding area.

Orientation of topography and/or structural trends is an important factor to consider in low sun-angle photography, but it is not critical unless the sun azimuth very nearly parallels the structures. The solar altitude/topographic relief relationship is probably one of the most important considerations to be dealt with after it has been determined that low sun-angle enhancement of aerial photography can be successfully acquired. If the topographic relief is steep, very low sun-angle illumination will cast concealing shadows rather than revealing the sought after, and often subtle, features of surface faulting in the adjacent foothills or valleys. If the area of interest is flat, all subtle features will be totally washed out by the sun before the sun-angle is at any significant elevation. This will require a very early flight so as to acquire the data at a sun-angle when the sun just breaks the horizon. The photography of such a flight can be extremely revealing. Complete washout or abundant concealing shadows could have easily occurred in Figure 3 had the solar altitude been somewhat higher or lower, respectively.

Interpretive techniques heretofore undescribed in literature were found to be very effective. Use of binocular magnification of small-scale positive transparencies on a light table proved very effective in mapping, in detail, the faint, low-relief pinchout ends of fault scarps beyond what the unaided eye could detect. Further, when available, the comparison of several scales of aerial photography will greatly enhance the interpreter's ability to detect nearly all anomalies. Further, it was found that large-scale photography was more easily interpreted on black-and-white prints without magnification greater than that provided by desk model stereoscopes.

Finally, good flight planning using all available information and aids will give the best results the first time. The cost analysis paper by J. Ulliman will provide a very good basis for considerations of hardware and aircraft required for the project and an approximate cost projection.

Aknowledgments

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Frederick J. Doyle, Photogrammetry: The Next Two Hundred Years

Heinz Gruner, Photogrammetry: 1776-1976.

V. Klemas and *D. F. Polis,* Remote Sensing of Estuarine Fronts and Their Effects on Pollutants.

Clarice L. Norton, Gerald C. Brock, and *Dr. Roy Welch,* Optical and Modulation Transfer Functions.

W. D. Renner, M.S., A Photogrammetric Technique for Use in Radiation Therapy.

Charles J. Robinove, A Radiometric Interpretive Legend for Landsat Digital Thematic Maps.

R. Welch, Progress in the Specification and Analysis of Image Quality.