GEOMORPHIC INTERPRETATION OF SKYLAB PHOTOGRAPHY COLLECTED OVER THE NEVADA PORTION OF THE GREAT BASIN[+]

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Abstract

SKYLAB S190B black and white photography has a useful reconnaissance capability in geomorphic mapping of landform features in the arid and semi-arid Great Basin. Enlargement of original photographic data products to a scale of 1:250,000 scale compatible with published topographic maps permits ready identification and classification of most landform elements. However, interpretation suffers through the lack of stereoscopic coverage and introduces problems relating to scale and loss of detail. When aircraft underflight photography for the same area is used as a data enhancement tool, problems of scale, detail, and interpretation are diminished. The combination of orbital and underflight photographic coverage provides a regional overview in which the interrelationships of both micro- and macro-scale landforms become apparent.

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INTRODUCTION

Location and Physical Description of Area

The study area in northwestern and central Nevada covers a part of the western sector of the Great Basin (Fig. 1). This semi-arid region is characterized by a series of north-south trending mountain ranges separated by long, smoothly sloping alluvial aprons, or bajadas, leading down to intermontane basins or playas occupying the lowest parts of these basins. The entire area is one of internal drainage without egress to the sea. Runoff, mostly snowmelt, collects in a few permanent saline or alkaline lakes or in dozens of ephemeral playas. Hydrographically the Great Basin is a complex of intermontane salinas, most of which are dry most of the year.[1] The only significant perennial stream in the area studied is Humboldt River, which flows westward and terminates in Humboldt Sink. Lesser streams are Quinn River and Reese River.

The average local relief is between 5,000 and 6,000 ft. The valleys are generally slightly more than 4,000 ft above sea level and the highest peaks approach 10,000 ft in altitude.

Geological Setting

The region is part of a dominantly volcanic province and there are widespread exposures of Tertiary flows, ashfall deposits, and volcanic lacustrine sediments. Locally, Paleozoic sandstones and carbonates are exposed because of pre-volcanic topography or post-volcanic erosion. There are also rather limited outcrops of Tertiary granitic intrusions. The basins are infilled mostly with Pleistocene and Holocene alluvial, colluvial, or lacustrine deposits of varying thicknesses. Small areas of glacial deposits may be present around a few high peaks, but these have never been mapped in detail and are not distinguishable on SKYLAB photography of the region. No glacial deposits are definitely identified in the study area covered by the underflight photography.

Vegetation, Climate, and Land Use

Climatic data are sparse but total precipitation ranges from about 4 in/yr in the basins to a maximum of about 16 to 20 in/yr on the high peaks, as estimated from known moisture requirements of various Western tree cover types.

SKYLAB GEOMORPHIC INTERPRETATION OF NEVADA

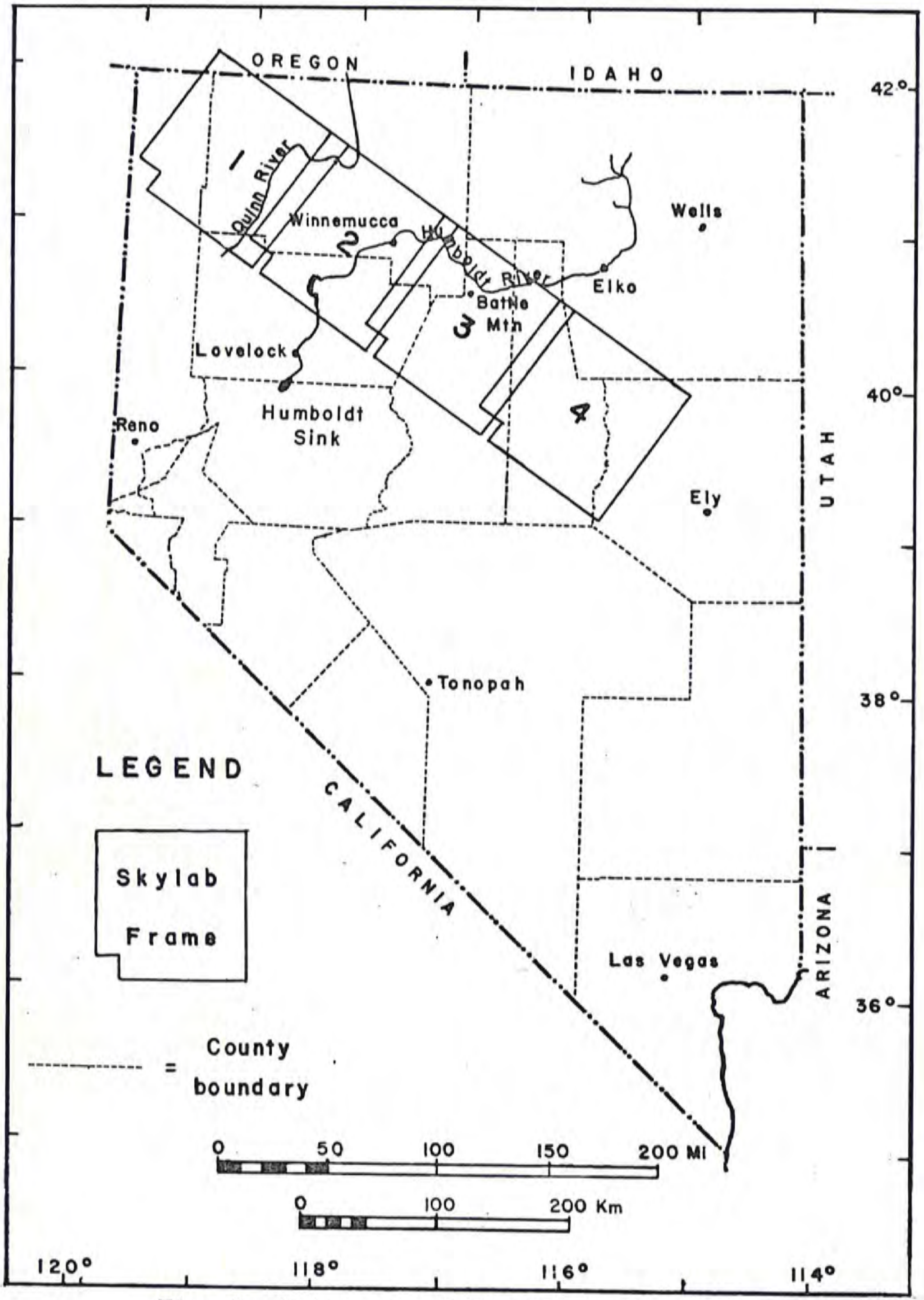

Fig. 1 Index map of Nevada showing location of SKYLAB frames.

Great Basin sagebrush (Artemisia) is ubiquitous, especially in the basins and on lower slopes of the ranges. Along Humboldt River, particularly downstream from Battle Mountain, there is some intermixture with saltbush (Atriplex), greasewood (Sarcobatus) and saltcedar, along with various low shrubs and grasses. Increasing altitude and moisture is marked by change to juniper-pinyon woodland (Juniperus and Pinus), but stands are generally thin and scattered. The volcanic plateaus of High Rock and Sheep Creek are sagebrush steppe of Artemisia and wheatgrass (Agropyron). Limited mahogany and oak scrub stands (Cercocarpus and Quercus) are scattered across the Shoshone and northern Toiyabe ranges. The highest peaks are above timber line and have a thin cover of grasses approximating a subalpine assemblage. Where water is perenially available in canyons, cottonwood, box elder, and multiflora rose are common. The dunes and playa area west of Winnemucca is bare desert.

Nowhere is vegetation thick enough to obscure geomorphic or geological details as seen on SKYLAB or underflight photography. Land use has been, is, and will continue to be dominated by mining, open-range grazing, and limited irrigation of potatoes, legumes, hay, and alfalfa.

BASIC DATA PRODUCTS

Basic data products consist of four cloud-free, black-and-white SKYLAB photographs numbered 85-001 to 85-004, and are hereafter referred to as frames 1 through 4. U-2 underflight (low sun angle) photography was obtained at a flight altitude of 65,000 ft MSL in October, 1974. The SKYLAB frames were obtained on August 11, 1973 by the 18 in. focal length S190B camera. Original data were second generation 4.5 in. x 4.5in. black-and-white diapositives on a scale of 1:936,000. The 17.5 in. x 17.5 in. black-and-white enlarged prints analyzed in this study were made from internegatives of the original data, and thus are fourth generation products on a scale of approximately 1:250,000.

Underflight data were available in two scales and formats, 1:120,000 (9 in. x 9 in.) and 1:30,000 (9 in. x 18 in.). The 9 in. x 9 in. photography was taken by a 6 in. focal length RC-10 camera and the 9 in. x 18 in. photography was taken with a 24 in. focal length HR-732R camera. The resultant 1:120,000 scale and 1:30,000 scale, respectively, assumes a mean terrain elevation of 5,000 ft. Both sets of underflight data were available for most of the area covered by the U.S. Geological Survey, Winnemucca 2° topographic map. Therefore the detailed analysis described in this paper was restricted to SKYLAB frame 3, most of which lies within the boundaries of the Winnemucca sheet (Fig. 2).

The enlarged scale of the SKYLAB frames used closely approximates the 1:250,000 scale of the 2° topographic maps. Use of three different photographic scales in conjunction with these topographic maps allowed detailed analysis in some key areas. Ground control consisted primarily of the topographic maps and published county geologic maps, although limited ground truth was available. Some larger scale topographic maps were available and were used where better detail was needed to delineate interesting geomorphic features.

It must be noted that the SKYLAB frames are perspective photographs and, because of the Earth's curvature, distortion increases outward from the center point of the frame. For the reconnaissance mapping undertaken, however, this problem is relatively unimportant. Scalar approximation between topographic maps and photographs is ample for the correlative work of topographic elevation and strandline occurrence described in a subsequent section.

ANALYTICAL PROCEDURE

Mylar overlays were fitted over each of the four SKYLAB frames, and letters were used to label mountain ranges and basins as identified from the topographic sheets. This was done for orientation and to facilitate written description of the area. Geomorphic analysis and interpretation of landforms was then completed. A number was assigned to each landform and written on the mylar overlay instead of the landform name in order to avoid cluttering. Landforms were numbered as identified, hence there is no specific ordering scheme. Continuity was established by labeling similar landforms with the same number on all four frames. For example, landslides were assigned "1" on frame 1, thus a "1" on any of the four frames indicates some type of landslide. The key for each frame includes all landforms identified and the number assigned to each, mountain ranges and valleys with their assigned letters, and also any supplemental notations made during the mapping (Tables 1 and 2).

Aerial photographic terrain analysis of each SKYLAB frame was initially accomplished by: 1) tonal variation indicating surface or near surface ground conditions,

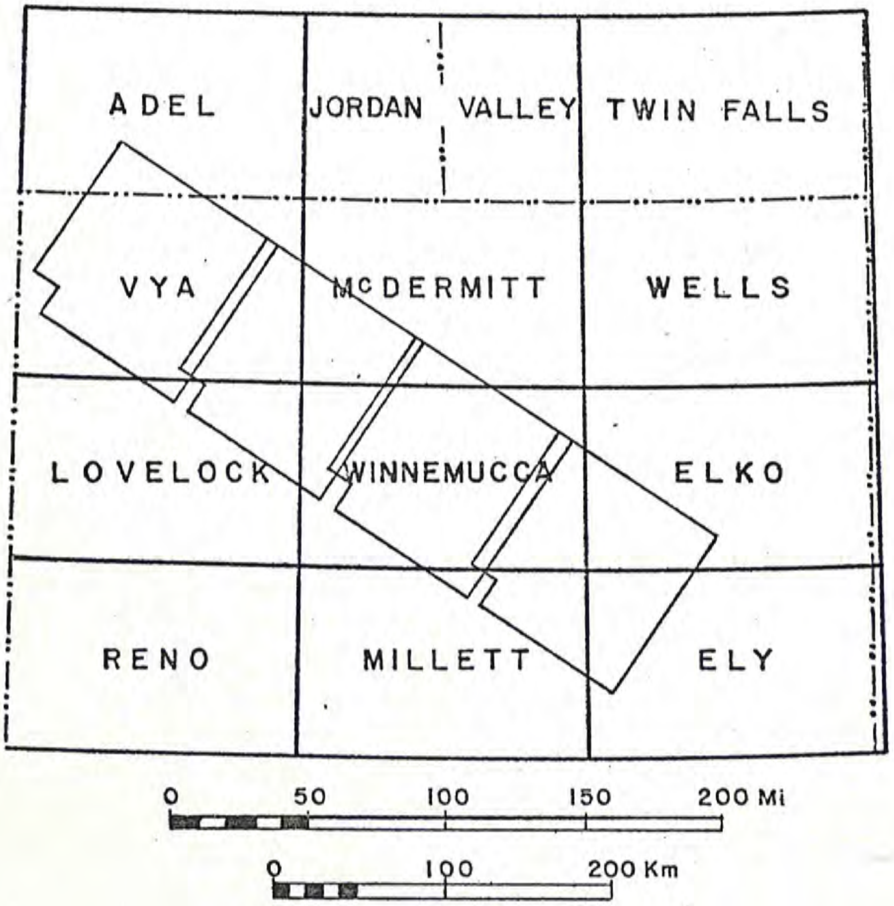

Fig. 2 Index map showing location of SKYLAB frames on 1:250,000 scale USGS topographic maps.

2) recognition of topography as deduced from shadow effects, drainage patterns, and topographic base maps, 3) drainage patterns indicating the type of parent rock and soil materials which in turn influences amount and type of runoff, 4) vegetation and land use, 5) landform association with surrounding features or, 6) any combination of these factors. An impression of stereopsis may be obtained if B & W diapositives at the original scale are viewed through a binocular microscope. However, these products were not in hand for use in this study, and because there is virtually no overlap, no stereoscopic analysis was possible on the SKYLAB products used. Therefore photographic interpretation was necessarily limited to simple pattern and textural recognition and the relationship of a given feature to its

Table 1. List of symbols for landforms.

Landform number	Name	Present on SKYLAB	
		frame 2	frame 3
1	landslide		x
2	louderback	x	x
3	wave cut bench	x	
4	strandlines	x	x
5	dunes	x	
6	playa	x	x
6a	playa lake		x
7	fault-line trace	x	x
7a	fault trace	x	x
8	bajada	x	x
8a	pediment	x	x
9	alluvial fan	x	x
9a	compound fan	x	x
10	spring/seepage area	x	
11	perennial lake	x	
11a	Rye Patch Reservoir	x	
12	intermittent lake	x	
12a	Pitt-Taylor Reservoir	x	
15	urban area	x	x
15a	Winnemucca	x	
15b	Battle Mountain		x
17	plateau		x
17a	mesa	x	
17b	butte	x	
18	inselberg	x	
19	volcanic cone		x
22	watergap		x
23	perennial river	x	x
23a	Humboldt River	x	x
23b	Quinn River	x	
50	fanhead trench	x	x

surroundings. After this initial analysis, the U-2 photography which covered parts of the Winnemucca topographic sheet was used for detailed analysis of parts of SKYLAB frame 3 (Fig. 2). Stereoscopic vision is possible with both scales of U-2 photography and thus added the valuable third dimension of the interpretation. Thus underflight data was used to enhance landforms already mapped and to locate landforms previously unrecognized.

Table 2. List of symbols for mountains and valleys.

SKYLAB FRAME 2

Symbol	Name	Symbol	Name
AA	Kamma Mountains	N	Winnemucca Mountain
A	Bilk Creek Mountains	O	Bloody Run Hills
B	Sonoma Range	P	Dry Hills
C	Humboldt Range	Q	Slumbering Hills
D	Jackson Mountains	R	Double Mountains
E	Majuba Mountain	S	Jungo Hills
F	Blue Mountain	T	Buena Vista Valley
G	Coyote Hills	U	Desert Valley
H	East Range	V	Grass Valley
I	Eugene Mountains	W	Paradise Valley
J	Hot Springs Range	X	Silver State Valley
K	Osgood Mountains	Y	Kings River Valley
L	Santa Rosa Range	Z	Lone Butte
M	Krum Hills		

SKYLAB FRAME 3

Symbol	Name	Symbol	Name
A	Shoshone Range	N	Reese River Valley
B	Battle Mountain	O	Cresent Valley
C	Fish Creek Mountains	R	Whirlwind Valley
D	Tobin Range	S	Boulder Valley
H	Sheep Creek Range	X	Buffalo Valley
M	Tuscarora Mountains	Z	Argenta Rim

RESULTS

General Statement

Geomorphic mapping was completed for all four SKYLAB frames, but owing to repetition of landform types or families, the need for brevity, and availability of underflight coverage for only one SKYLAB frame (frame 3), only SKYLAB frames 2 and 3 are discussed herein. Most landforms mapped in the study area are represented on these frames and a discussion of scalar problems in interpretation can be undertaken from the two frames selected.

Comparison of results for the three different scales used (1:250,000, 1:120,000, and 1:30,000) is interesting. The lack of stereoscopic capability from the enlarged SKYLAB photography is unfortunate, but this problem is remedied by resort to underflight data. SKYLAB's synoptic view of the Earth's surface provides an insight unique to this scale. In fact, large structural and geomorphic features never before seen on this scale stand out clearly, whereas only small, discrete parts of these features could be studied from previous photographs and thus the relationships and distribution of major features had not been recognized.

Conversely, owing to the small scale of the original SKYLAB photography, resolution elements are necessarily large. Because SKYLAB photography is of such high quality, however, enlargement up to 4 diameters is possible with excellent results if precision equipment is used. This enlargement capability restores much detail lost on the original small-scale photographs. However, with enlargement some interpretative insight still is lacking because of no stereoscopic coverage.

SKYLAB Frame 2

SKYLAB frame 2 (Fig. 3a and 3b) is an example of the 1:250,000 scale photography used. This frame is exemplified by typical Basin and Range topography. The only perennial rivers, the Quinn and the Humboldt, traverse this area. Except for these two rivers intermontane closed-basin drainage is typical. Many geomorphological and cultural features can be discerned. Agricultural areas, with conspicuous rectangular fields and center-stand irrigation systems are obvious in the valleys. Major roads are traced as they follow along valleys or cut across a mountain pass. Abandoned strandlines formed by Pleistocene lakes, a large band of playa-born sand dunes, compound fans, railroad tracks, urban areas, and springs or seeps, are visible.

The Great Basin presently is an arid region, but during the Quaternary the climate was probably colder and more humid, and at times the valleys were occupied by pluvial lakes. Some of these lakes had outlets to the sea (or into sister lakes) but the majority did not rise high enough to find such an outlet.[3] The history of the largest Quaternary lake, Lake Bonneville, has been described by Gilbert.[4] The second largest, Lake Lahontan[5], located in northwestern Nevada, occupied much of the area covered by SKYLAB frame 2. Russell recognized four "terrace" levels (hereafter called strandlines), at elevations of approximately 4,380, 4,350, 4,190, and 4,000 ft. Only small, laterally discontinuous portions of these strandlines still are evident around the periphery of many of the basins where preservation conditions

Fig. 3a Entire SKYLAB frame 2 (85-002). Original scale 1:250,000. For identification key refer to Tables 1 and 2.

were favorable. Conditions unfavorable for shoreline preservation include encroachment by alluvial fans, deflation, and complications from seasonal salina shoreline processes. All strandlines mapped on frame 2 can be correlated with the two highest elevations (4,380 and 4,350 ft) as noted by Russell[5] and Morrison[6]. Correlation is established by overlaying the proper 2° topographic map with the frame (Fig. 2). However, this correlation should be done with caution, because distinction between strandline, wave-cut benches, and curvilinear fault traces is locally difficult.

The most impressive landform shown on frame 2 is the band of sand dunes originating at the playa in Desert Valley and extending northeastward across two mountain ranges, the

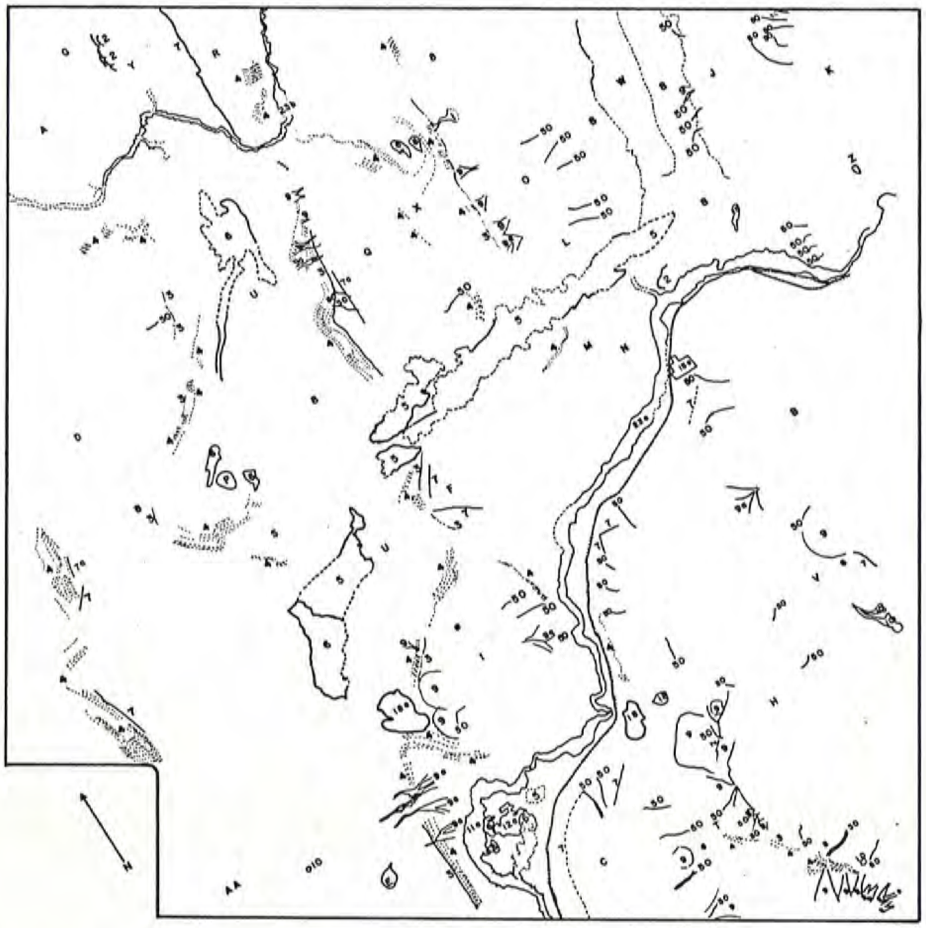

Fig. 3b Geomorphic sketch map of Fig. 3a. For identification key refer to Tables 1 & 2.

Slumbering Hills and the Santa Rosa Range, and into Paradise Valley. Resolution on the SKYLAB photography permits identification of these as crescent dunes, which can be traced for 30 miles from their source.

Compound fan development is distinguished by tonal variations of alluvial fan material. This variation probably results from differences in the amount of desert varnish accumulated on exposed surfaces of alluvial material of the fans. It is inferred, therefore, that the darker materials are older than, and underlie, the lighter materials. This is the same assumption that Hooke et.al.[7] tacitly made in their electron microprobe study of desert varnish on a California compound fan. At least two and possibly three stages of fan development can be ascertained by recognition of as many different photo tones. Caution should be exercised because tonal changes may also represent lithological differences of the fan material. Fanhead trenches, also present on frame 2, are discussed subsequently.

Numerous springs occur in the area of frame 2, and those discernible as such were mapped. A rather large area of hot spring activity (Leach Hot Springs), as indicated on the Winnemucca topographic map, is visible in southern Grass Valley ("V" on Figs. 3a and 3b) just south of Winnemucca.

SKYLAB Frame 3

Fig. 4 (a portion of SKYLAB frame 3) shows Battle Mountain and a prominent playa in Buffalo Valley. Note the short lineation ("7a" on Fig. 4) just to the west of Battle Mountain. This appeared to be a fault scarp, but its hummocky appearance and limited areal extent indicated the possibility that it was the toe of some type of mass movement, possibly an earthflow.[8] Stereoscopic inspection of the same area on the scale of 1:120,000 (Fig. 5) reinforced the fault interpretation. The hummocky texture perceived on the SKYLAB frame can instead be seen as a dissected area on the underflight photography. Four additional observations preclude the possibility that this is some type of flow. First, with stereoscopic inspection, another scarp is discerned (at the mountain front) that continues through the suggested "flow" area. If this area is flow material this scarp would have been obliterated, unless faulting occurred after flowage. Secondly, there are no scalloped indentations of the mountain front to indicate where the flow material originated. Furthermore, owing to the extreme vertical exaggeration of the short focal length camera that recorded the 1:120,000 scale photography (Fig. 5), it can be seen that this area is a topographic high. This can be inferred without use of stereoscopic equipment by observing the drainage pattern. The stream courses bend away from this topographic high on both the north and south sides. Finally, a slightly lower order of dissection can be discerned in the mountainous area adjacent to the area under consideration. A logical explanation is that this area is a bedrock high with alluvial fans covering it on both sides. This interpretation is supported by the presence of a similar structure ("8a" on Figs. 4 and 5) across Buffalo Valley on the east side of the Tobin Range (Fig. 5). If this is the case, the small linear escarpment on the west side of Battle Mountain is a fault, the area just to the east is a dissected pediment ("8a" on Figs. 4 and 5), and the straight mountain front is a fault-line scarp.

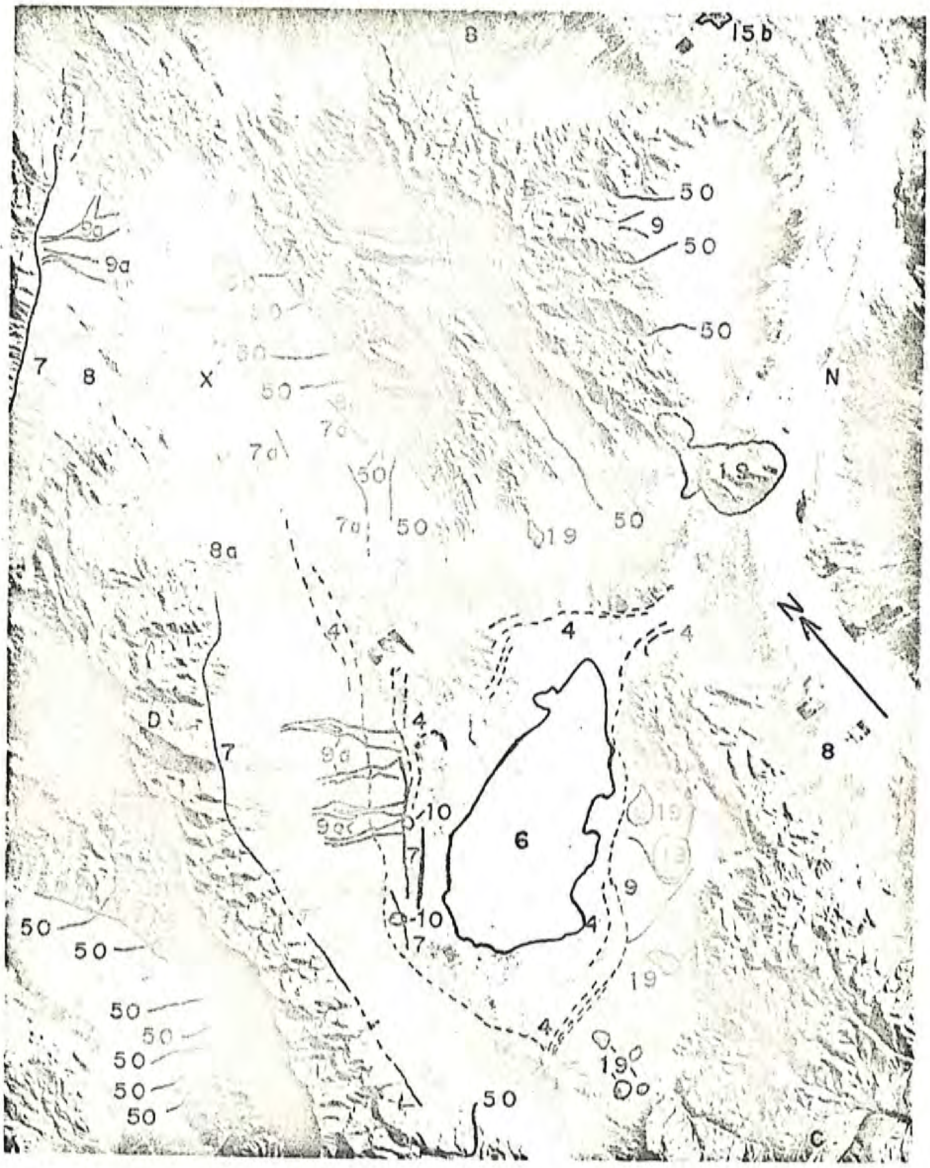

Fig. 4 Portion of SKYLAB frame 3 showing Battle Mountain (B) and Buffalo Valley (X). For identification key refer to Tables 1 and 2. Original scale 1:250,000.

Note the small alluvial fan developed over the pediment on the south side (Fig. 5).

Fig. 5 U-2 underflight photography showing west side of Battle Mountain (B) and adjacent Tobin Range (D). Notice small escarpment (7a) just west of Battle Mountain and similiar, more highly dissected area (8a) on the east side of the Tobin Range. Original scale 1:120,000.

Fanhead trenches, a common and obvious feature on frame 3 (Fig. 4), are channels which either 1) cut into an alluvial fan at its apex and subsequently grow downfan or 2) are initially cut into the toe of the fan and then migrate upfan. In case 1) they have been interpreted as a normal evolutionary stage of an alluvial fan as mountain streams continue downcutting.[9] They may also represent the lowering of base level of the streams or basins in the valleys to which they are tributary, as in case 2). More recently they have been interpreted as representing response to changes in rainfall intensity,[10] reestablishing a gradient in accord with existing discharge and load conditions.[11] Fan and fanhead trench development has also been described in connection with their relationship to mudflows.[12,13]

Strandlines marking former lake levels, such as those in the southern end of Buffalo Valley, are easily discernible on the SKYLAB photography (Fig. 4), except where masked by other aggradational forms. With the aid of a magnifying lens they can be mapped with less difficulty. Much more detail is recognized on the large-scale underflight photography (Fig. 6), including the complex relationships between strandlines and alluvial fans. In some places strandlines seem to truncate fans, whereas elsewhere a fan continues across the strandlines, indicating that fan development has occurred after the high stand of the lake. On the SKYLAB frame some strandlines tend to become lost in the tonal qualities of the fans. Even with magnification, delineation of strandlines through alluvial material is difficult.

A different scalar problem is exemplified by the Sheep Creek Range. Preliminary analysis of the SKYLAB frame revealed three distinct remnant volcanic cone forms (Fig. 7). Another roughly circular area of a photo tone similar to the obvious cones also appeared to be a remnant cone (dashed line on Fig. 7). When the underflight photography of this area was examined, there seemed to be no sign of this volcanic

Fig. 6 U-2 underflight photography showing well developed playa in Buffalo Valley (X). Note strandlines (4) possibly formed by glacial Lake Lahontan, volcanic cones (19) and compound alluvial fan formation (9a) as interpreted by three gray tones. Original scale 1:250,000.

cone (Fig. 8). However, to erase the landform identified on the SKYLAB frame overlay would be self-defeating. The underflight photography was intended as a data enhancement tool, not a primary reference. The fact that this form did not show clearly on large-scale photography is merely a scalar problem. Each integral element seen on the large-scale photography was not enough clue in itself to depict the entire landform. On the small-scale SKYLAB photography

Fig. 7 Portion of SKYLAB frame e showing Sheep Creek Range (H), Humboldt River (23a), and Argenta Rim (Z). For identification key refer to Tables 1 and 2. Original scale 1:250,000.

(Fig. 7) the combination of photo tone, geometrical pattern, and landform associations in the area led to the present conclusion.

The importance of stereoscopic vision cannot be overestimated. An excellent example occurs on the east side of the Sheep Creek Range (Fig. 7). This area was not

Fig. 8 U-2 underflight photography showing the Sheep Creek Range (H). Note volcanic cones (19), areas of differing dissection, and massive landslide forming entire east flank (1). On the western side resistant basaltic "caps" (c) remain on interstream divides. Original scale 1:120,000.

recognized as a series of large landslide blocks (analogous to those on pg. 170 of Way[2]) until examined stereoscopically on the underflight photography (Fig. 8). This landslide area is obvious on the SKYLAB frame if one realizes that the darker caprock areas occur at different elevations and that the intervening light areas are scarps along which movement has occurred. This area was therefore mapped on the SKYLAB frame as a landslide.

There are several different drainage patterns on the Sheep Creek Range (Fig. 7). Attempts to explain this apparent anomaly using only SKYLAB photography were speculative. Knowing that volcanics occur on the east side of the range, it was postulated that intense dissection of the western portion starts at the perimeter of the basalt that caps the range.[14] With larger-scale underflight photography it is noted that this caprock exists over the entire range (Fig. 8), but it has been dissected on the west side and only remnants remain on the tops of interstream divides ("C" on Fig. 8). It is reasonable to assume that this caprock is thinnest this far removed from the volcanic cones, explaining the apparent greater degree of dissection. The prominent straight gully may represent a fracture along which dissection has been maximized.

An antiformal flexure is indicated by the Sheep Creek Range, which dips almost north, and Argenta Rim, which dips south. The axis of this structure lies somewhere between the Sheep Creek Range and Argenta Rim and appears to parallel the Humboldt River valley. The Humboldt may have followed the path of least resistance by flowing along a fracture zone that developed along the crest of this antiform.

Argenta Rim appears to be capped by a large plate of basalt (Fig. 7), and was so mapped by Willden.[14] Although the whole area may be mostly basaltic, Argenta Rim is not completely covered by a resistant basalt layer. It appears on the underflight data to be capped by louderbacks or, more precisely, louderback lava flows (Fig. 9). A louderback is defined by the A.G.I. glossary as "a remnant of a lava flow appearing in a tilted fault block and bounded by a dip slope. It is named after George D. Louderback, a North American geologist, who used it as evidence of block faulting in basin and range topography." Fairbridge[15] states that "where base level has been lowered, the louderback stands out as a special type of lave capped mesa, coulee or abutment." This definition is applicable to Argenta Rim and the Sheep Creek Range.

CONCLUSION

SKYLAB's synoptic view of the Earth's surface provides insight into geomorphological interpretation never before available. This photography in its original scale of 1:936,000 and the enlarged scale of 1:250,000 is excellent for reconnaissance interpretation. However, with these scales and no stereoscopic coverage, there is a decrease in detail and interpretative capability.

Conversely, through observation, experience, and intuitive insight, large magnitude landforms can be perceived for

Fig. 9 U-2 underflight photography showing Argenta Rim (Z) and Whirlwind Valley (R). Louderbacks (2) form resistant "caps" of Argenta Rim and associated areas. Note landslide (1) in Whirlwind Valley. Original Scale 1:120,000.

the first time in their entirety. Previous missions involving low altitude large-scale photography allowed viewing only of a smaller components of these landforms. With SKYLAB's synoptic view these "macro landforms" become visible and can be related to other geomorphic elements.

Inferences regarding potential target areas in an exploration program for mineral resources can also be made on the basis of geomorphological analysis of enlarged SKYLAB photography.

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