

NATURE AND ORIGIN OF MINERAL COATINGS ON VOLCANIC  
ROCKS OF THE BLACK MOUNTAIN, STONEWALL MOUNTAIN,  
AND KANE SPRINGS WASH VOLCANIC CENTERS, SOUTHERN  
NEVADA

Dr. James V. Taranik, Principal Investigator  
Dr. Donald C. Noble, Co-Principal Investigator  
Dr. Liang C. Hsu, Co-Investigator  
Amy Hutsinpillar, Co-Investigator  
David Spatz, Co-Investigator

Mackay School of Mines  
Department of Geological Sciences  
University of Nevada, Reno  
Reno, Nevada 89557

July, 1986  
Semiannual Progress Report for Period January,  
1986 - July, 1986

Contract Number NAS5-28765

{NASA-CR-179738) NATURE AND ORIGIN OF N87-12067  
MINERAL COATINGS ON VOLCANIC ROCKS OF THE  
BLACK MOUNTAIN, STONEWALL MOUNTAIN AND KANE  
SPRINGS WASH VOLCANIC CENTERS, SOUTHERN  
NEVADA Semiannual Progress Report, Jan. - G3/46 Unclas  
44540

Prepared for  
The National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland 20771

TABLE OF CONTENTS

	Page
List Of Illustrations.....	i
Introduction.....	1
Work Accomplished.....	1
Coatings - General .....	11
Coatings, Imagery, Lithologies.....	19
Kane Springs Wash.....	19
Black Mountain.....	27
Stonewall Mountain.....	27
Schedule For Next Period.....	27

## LIST OF ILLUSTRATIONS

FIGURE	Page
1: General Location Map .....	2
2: Location Map, Kane Springs Wash.....	3
3: Location Map, Black Mountain and Stonewall Mountain Areas .....	4
4: Geologic Map, Stonewall Area.....	5
5: Geologic Map, Black Mountain .....	7
6: Geologic Map, Kane Springs Wash.....	9
7: Sample Location Map, Kane Springs Wash...	10
8: Scene, Photo, Kane Springs Wash .....	12
9: Scene, Photo, Kane Springs Wash .....	12
10: Photo of Trachyandesite, Kane Springs....	13
11: Photo of Hico Formation, Kane Springs....	13
12: Photo of Vapor Phase zone Kane Springs ..	14
13: Photo of Glassy Tuff, Kane Springs .....	14
14: Photo of Coatings on Dense Weld zone ...	16
15: Photo of Coatings on Vapor Phase zone ..	16
16: Photo of Coatings on Glassy Ash .....	17
17: Photo of Coatings on Rhyolite .....	17
18: Photo of Coatings on Basalt .....	18
19: Photo of Coatings on Gold Flat Fm .....	18
20: Band 5 Image, Kane Springs Wash .....	20
21: PC Image, Kane Springs Wash .....	22
22: ISH Image, Kane Springs Wash .....	25
23: PC Image, Black Mountain .....	28
24: Bands 3 5 7 Composite, Black Mtn .....	28
25: ISH Image, Stonewall Mountain .....	30
26: 3/1 5/7 4 Composite, Stonewall Mtn.....	30

INTRODUCTION

The Mackay School of Mines was awarded a 3-year contract in April, 1985 to investigate surface coatings on volcanic rock assemblages that occur at select Tertiary volcanic centers in southern Nevada using Landsat 5 TM imagery. This report describes and discusses progress and results of work accomplished during the 6 month period ending June 30, 1986.

Three project sites comprise the subject of this study: the Kane Springs Wash, Black Mountain, and Stonewall Mountain volcanic centers (Figure 1). Landsat 5 TM work scenes selected for each area are outlined on Figures 2 and 3. Local area geology is shown on Figures 4, 5, and 6. Descriptive geology and references presented in previous reports to NASA are not included with this report. An objective of this investigation is to determine the nature and composition of surface coatings on the rock types within the subproject areas, determine the origin of the coatings and their genetic link to host rocks, and relate geologic interpretations to remote sensing units discriminated on TM imagery. Establishment of this linkage is critical to evaluating the volcanogenic relationships in the three centers, between the centers, and the comparison of these centers with other volcanic regions in similar physiographic settings.

WORK ACCOMPLISHED DURING REPORTING PERIOD

Efforts during this reporting period included image processing using the Mackay School of Mines' ESL VAX/IDIMS image processing system and field sampling and observation. Aerial photographs were acquired, mostly black and white, to facilitate location on the ground and to aid stratigraphic differentiation.

IMAGE PROCESSING. Work scenes, 512x512 pixels in dimension were isolated within the 1024x1024 subscenes presented in the last 6-month report. One 512x512 work scene was selected at each of the three project sites. A fourth one was segregated at Black Mountain which borders the central scene on the south. This additional scene at Black

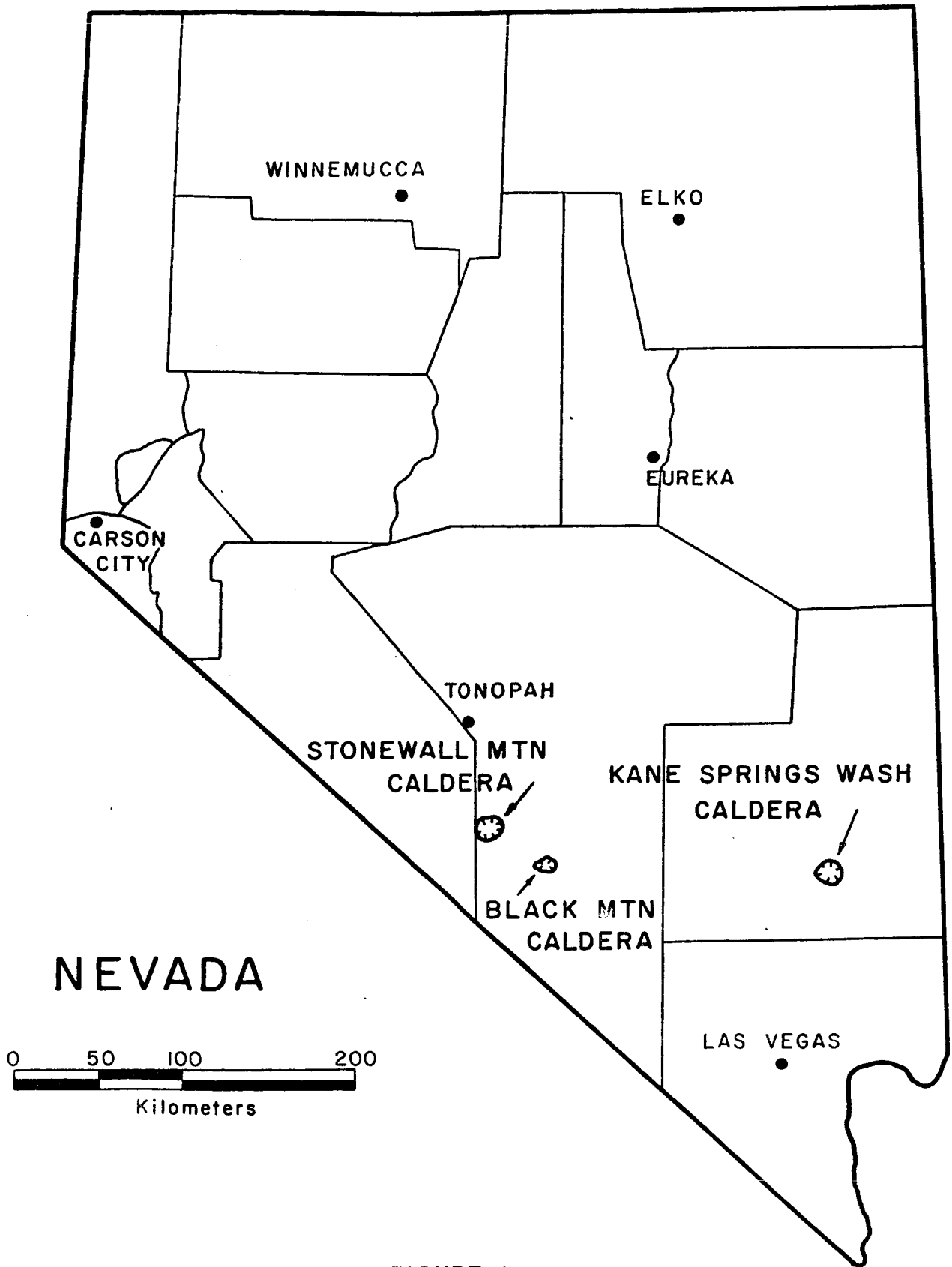
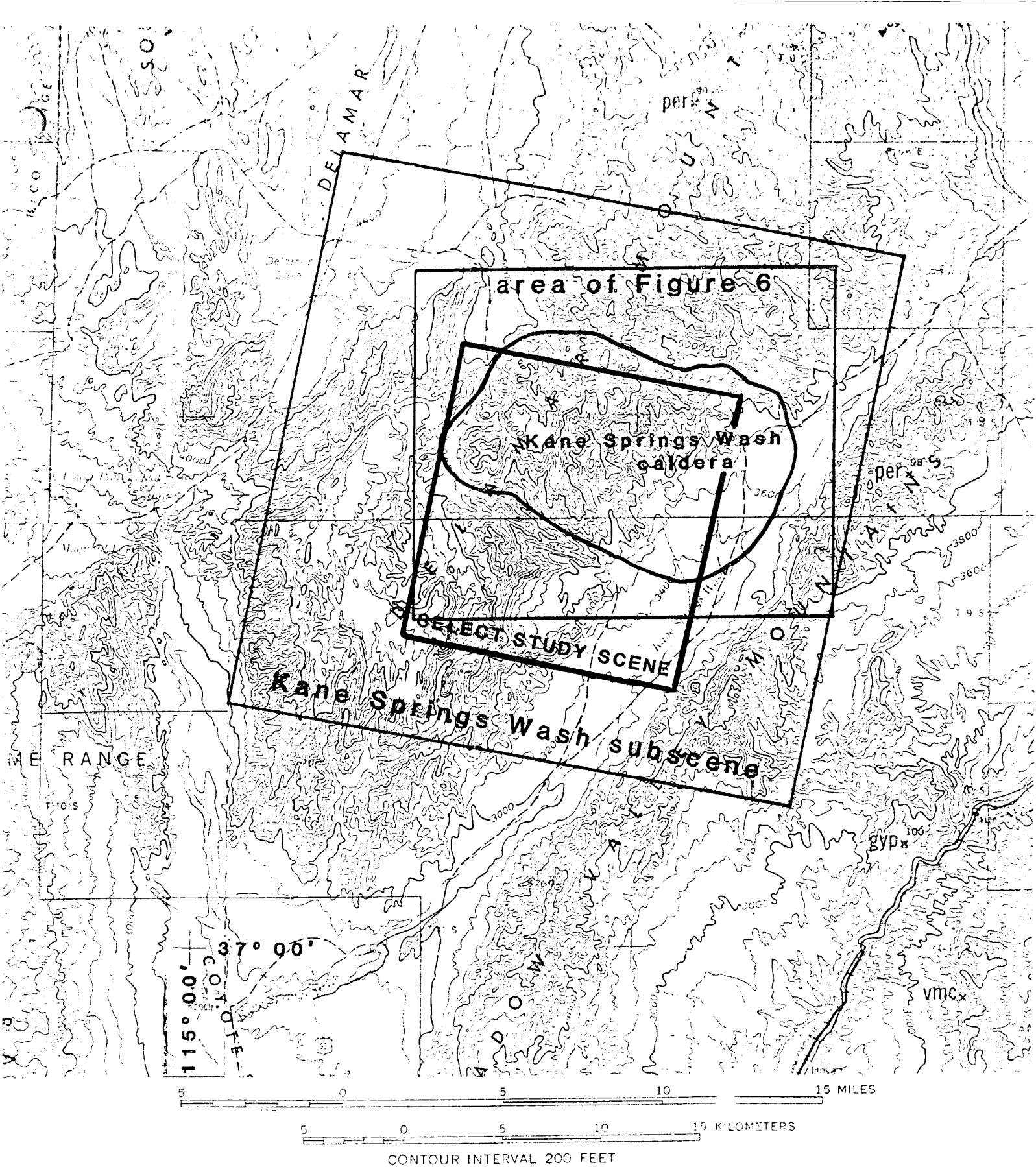


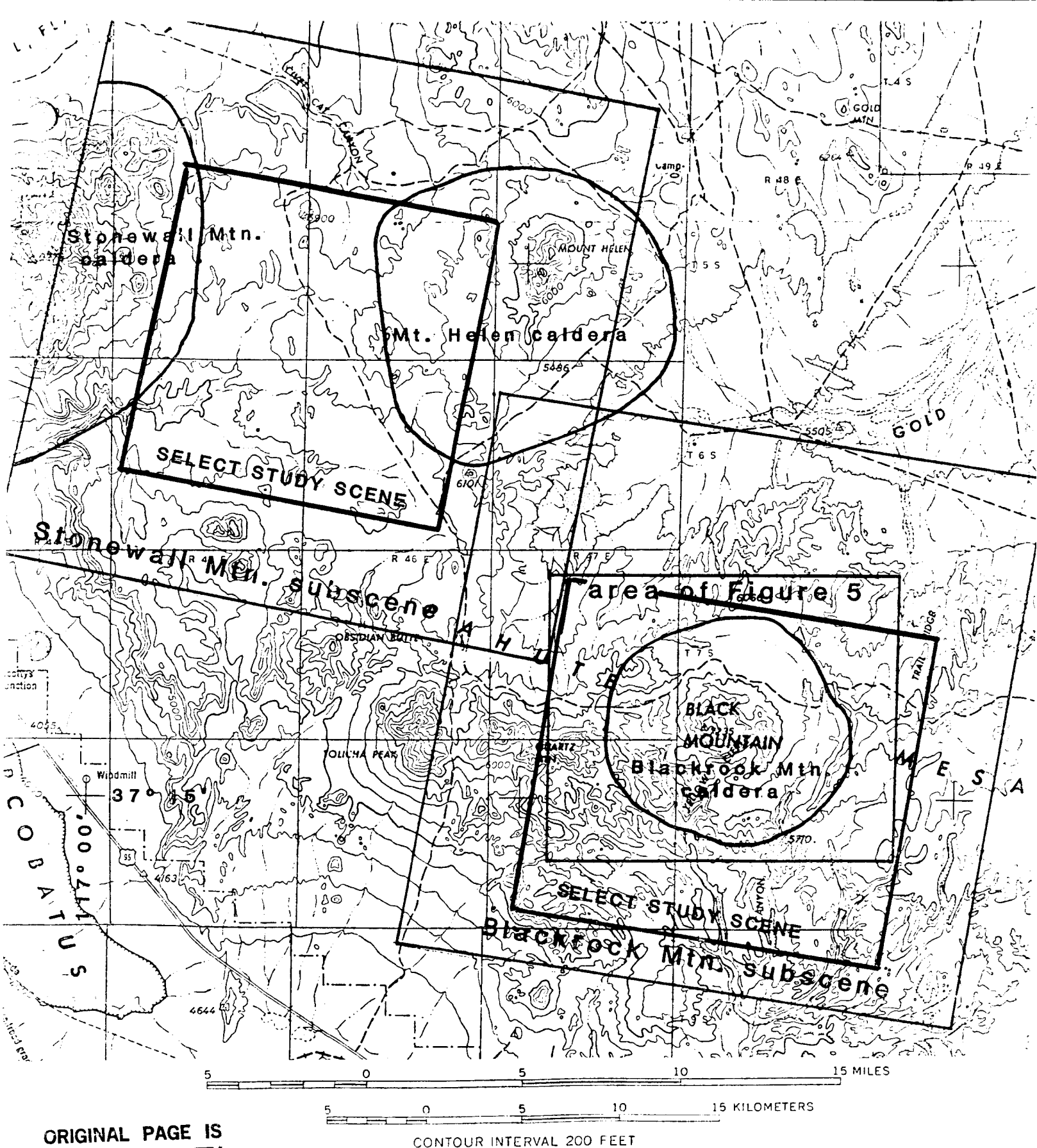
FIGURE 1

LOCATION OF LANDSAT TM TEST SITES



**FIGURE 2** Topographic map of part of Lincoln County, Nevada, showing locations of Kane Springs Wash subscene and figure 6 (from Tschanz and Pampeyan, 1972).

**ORIGINAL PAGE IS  
OF POOR QUALITY**



ORIGINAL PAGE IS  
OF POOR QUALITY

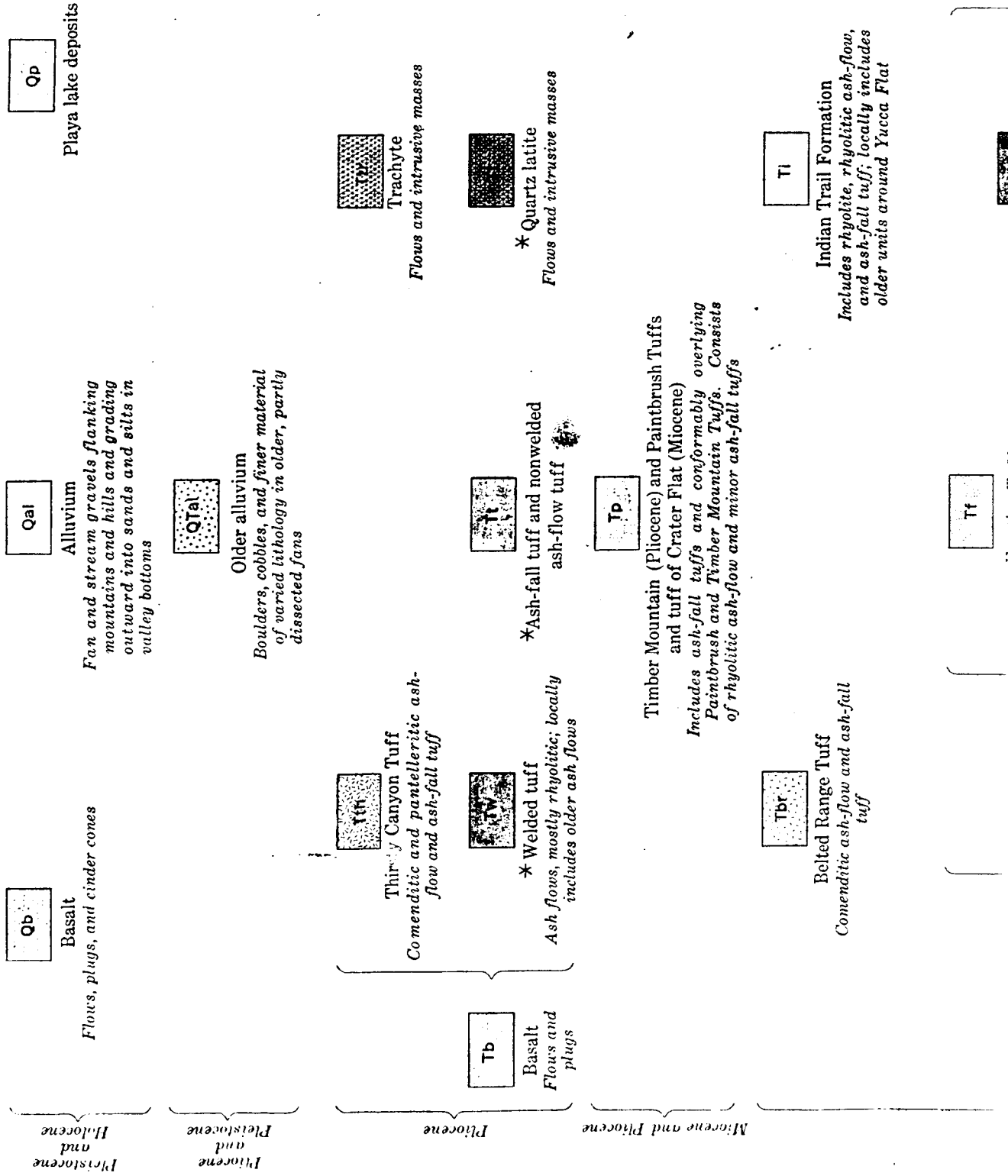
Figure 3. Topographic map of part of Nye County, Nevada, showing locations of Stonewall Mountain subscene, Blackrock Mountain subscene, and figure 5 (from Cornwall, 1972).





FIGURE 4 (continued). Explanation for geologic map of the Stonewall Mountain study area.

E X P L A N A T I O N





EXPLANATION

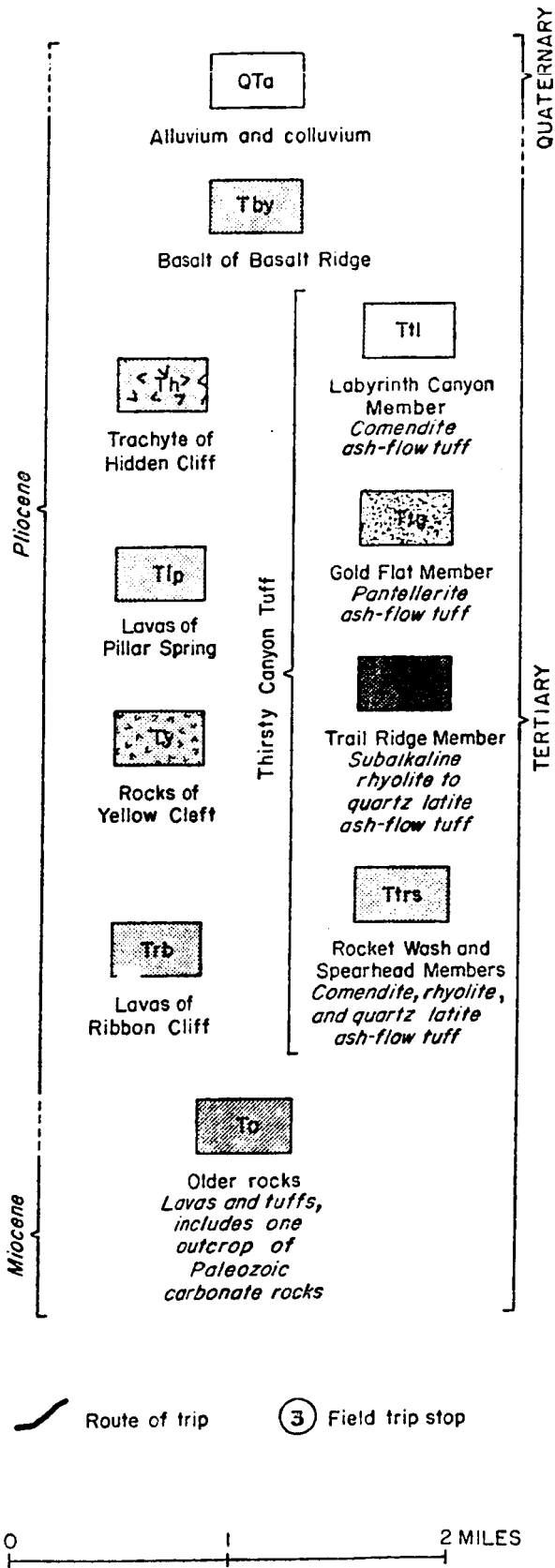


Figure 5. (continued) Geologic map of the Black Mountain volcanic center (after Noble and Christiansen, 1974), explanation.

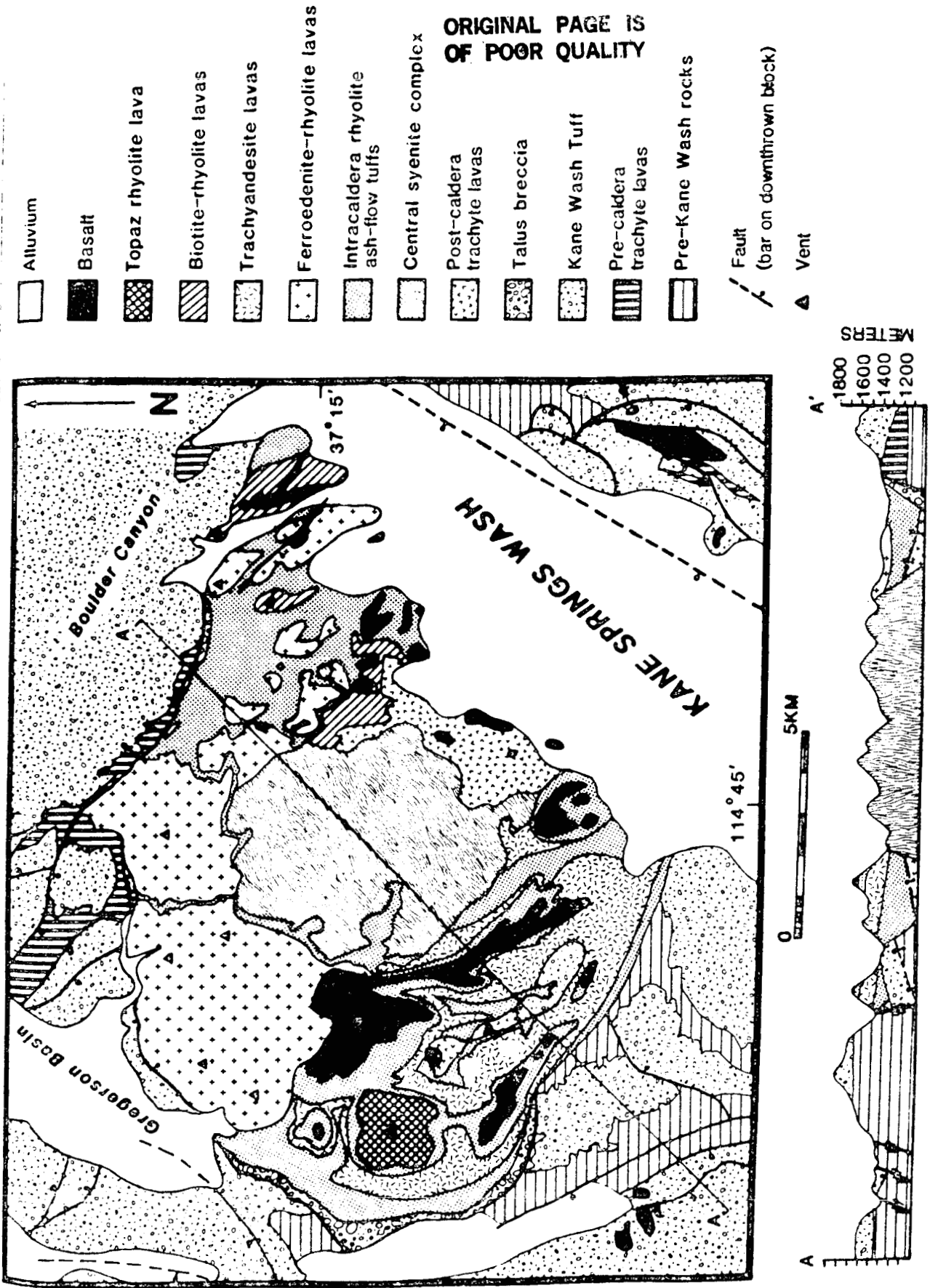
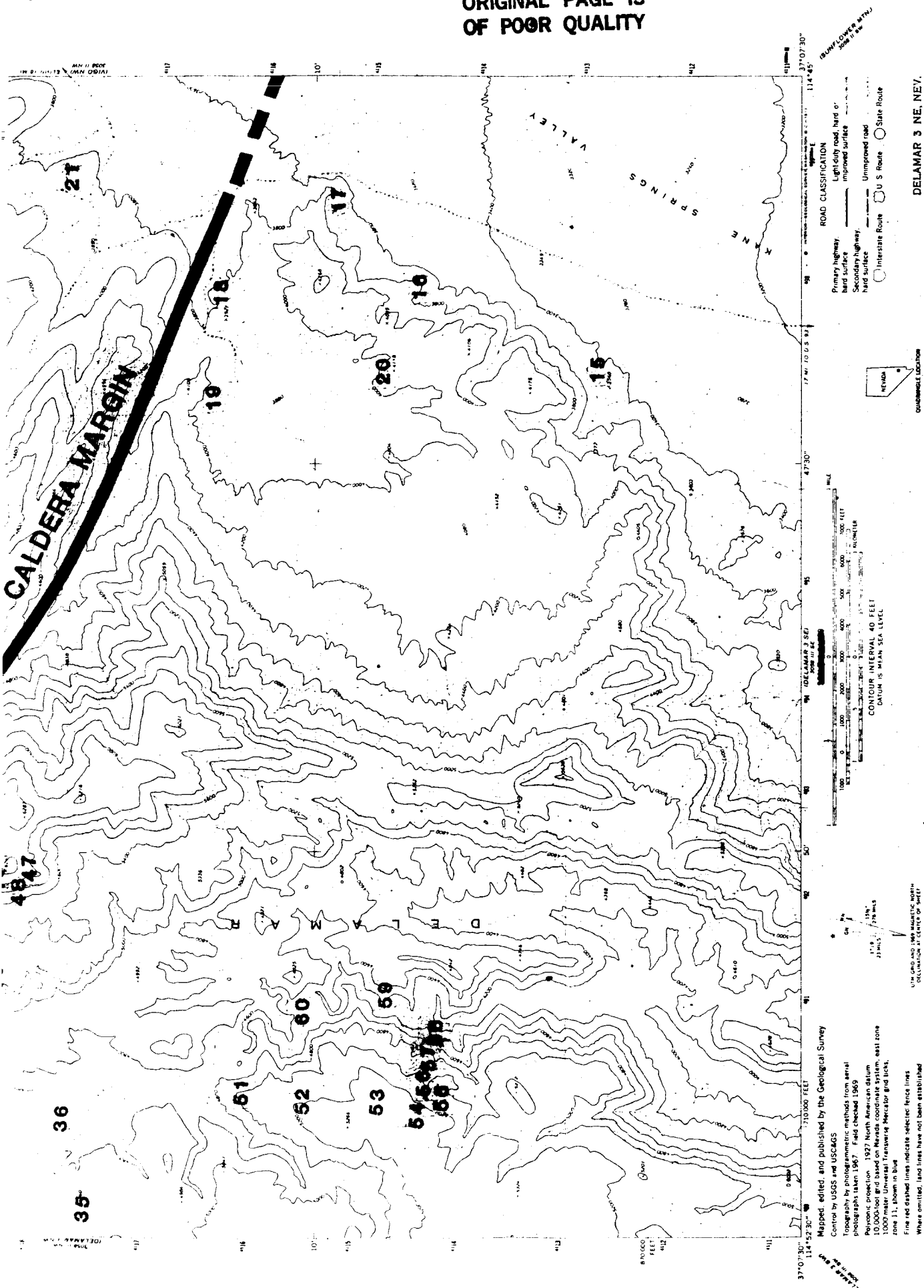


Figure 6. Geologic map and cross section of the Kane Springs Wash volcanic center (after Novak, 1984).



DELAMAR 3 NE, NEV.  
N 37° 07' 30" - 114° 45' 00" W

AMS 3008 III (NE-SERIES) 1989

ROAD CLASSIFICATION  
 Primary highway  
 Light-duty road, hard or improved surface  
 Secondary highway, hard surface  
 Unimproved road  
 Interstate Route  
 U.S. Route  
 State Route

CONTOUR INTERVAL 40 FEET  
 DATUM IS MEAN SEA LEVEL

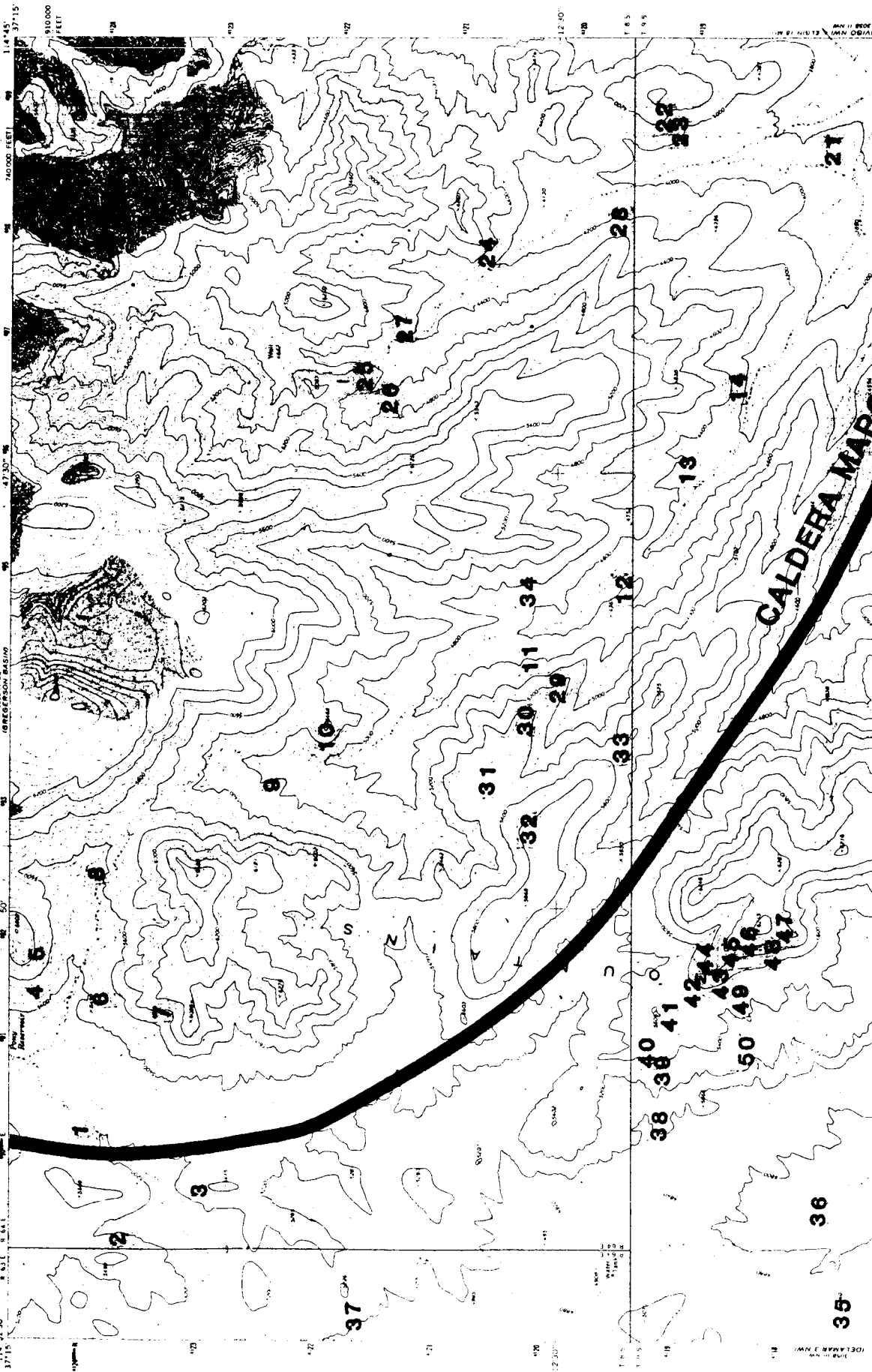
THIS MAP COMPLETES WITH NATIONAL MAP ACCURACY STANDARDS  
 FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242  
 A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

Mapped, edited, and published by the Geological Survey  
 Control by USGS and USCAGS  
 Topography by photogrammetric methods from aerial photographs taken 1967 Field checked 1969  
 Polyconic projection 1927 North American datum  
 10,000-foot grid based on Mercaator coordinate system, east zone  
 1000-meter Universal Transverse Mercator grid ticks, zone 11, shown in blue  
 Fine red dashed lines indicate selected fence lines  
 Where omitted, land lines have not been established

FIGURE 7: Kane Springs Wash study area, showing sample locations.

DELAMAR 3 NE QUADRANGLE  
NEVADA - LINCOLN CO.  
7.5 MINUTE SERIES (TOPOGRAPHIC)

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY



ORIGINAL PAGE IS  
OF POOR QUALITY

Mountain should provide advantages for studying ashflow sheet stratigraphy from the Black Mountain caldera.

As a matter of routine, the following images were produced for each of the 4 work scenes:

INDIVIDUAL BANDS: 1, 2, 3, 4, 5, 7  
 BAND RATIOS: 4/3, 5/1, 5/2, 5/7, 3/1, 3/2  
 COLOR COMPOSITES: 3 2 1, 3 5 7, 3/1 5/7 4,  
                                   3/1 5/2 5/7  
 ISH: 3 5 7, 3/1 5/7 4, 1 3 5  
 PRINCIPAL COMPONENTS: Individual PC's 1-6,  
                                   Color composites  
                                   1 2 3, 2 3 4, 3 4 5

All images were contrast enhanced, chiefly by scaling with a 0.5% truncation at both high and low ends of the brightness ranges. PC images were scaled at a 0.2% truncation. Other image renditions were computed, but those listed above were the ones routinely processed and photographed for comparison and field use. A few select prints from each area were enlarged to 8x10 inch to facilitate resolution, field location, and topographic registration.

**SAMPLING.** The bulk of field work was completed at the Kane Springs Wash center (Figure 7, 8, & 9) and a minor amount accomplished at Black Mountain. Both coating and petrographic samples were collected, and most sites photographed. Photographs were composed to frame representative surfaces including vegetation, soil, and regolith, as well as outcrop.

#### COATINGS - GENERAL

Igneous rock formations commonly exhibit secondary supergene mineral coatings that correlate with host lithologies. Field geologists have long utilized this relationship to aid geologic mapping. Coatings at Kane Springs Wash are fairly typical of weathered surfaces on volcanic rocks from siliceous centers throughout the semi-arid West and Southwest, U.S.

Coatings may vary with underlying formations partly as a function of petrochemistry, degree of welding, divitrification, hyalinity, porosity, and texture and other physiochemecal properties. These

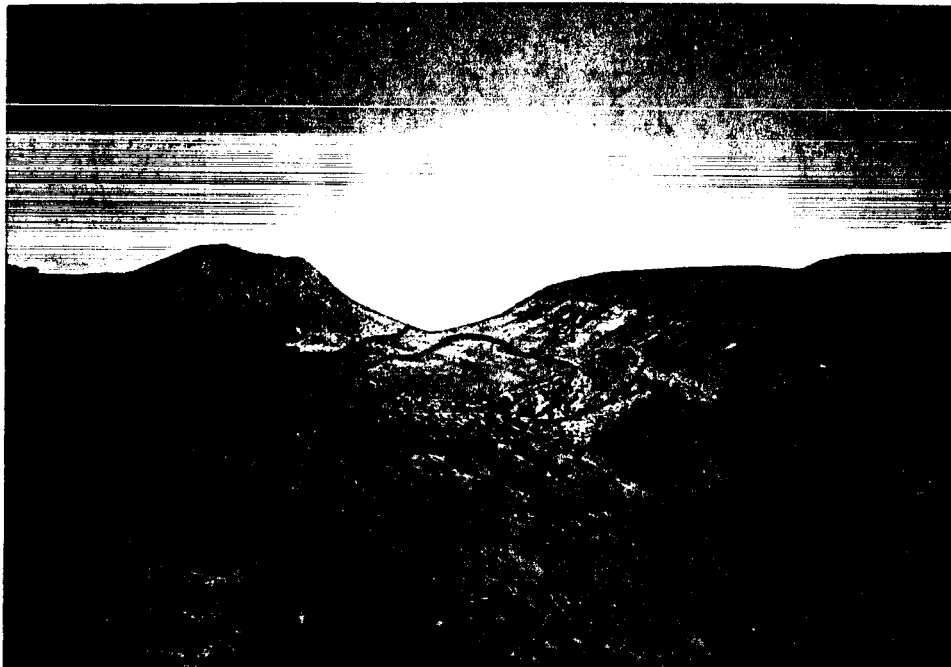


FIGURE 8. Kane Springs Wash volcanic center. Photo taken within caldera looking NW. Ta - trachyandesite. Tt - air and ash flow tuff. Tr - rhyolite flow dome complex. Tb - late basalt.



FIGURE 9. Kane Springs Wash volcanic center. Photo taken from west border of study area looking E. Th - Hico Formation (ash flow tuff). KWo - member o of the Kane Wash Formation (ash flow sheets of the Kane Wash caldera). KWw - member w of the Kane Wash Formation. KWv1 - member v1 of the Kane Wash Formation.

ORIGINAL PAGE IS  
OF POOR QUALITY



ORIGINAL PAGE IS  
OF POOR QUALITY

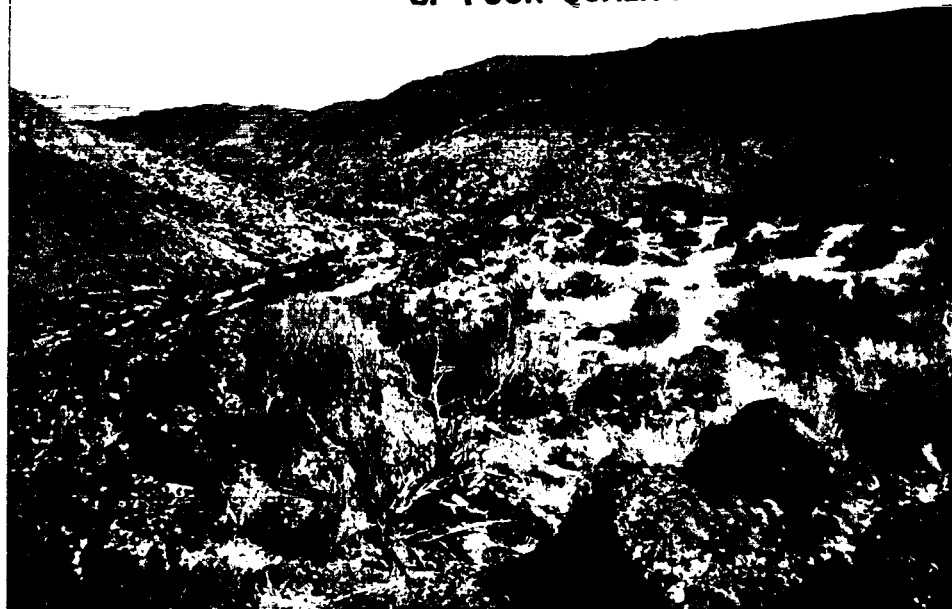


FIGURE 10. Kane Springs Wash volcanic center. Sample site 9 - Trachyandesite looking SSE



FIGURE 11. Kane Springs Wash volcanic center. Sample site 18 - dense weld zone of Hico Formation looking E.

ORIGINAL PAGE IS  
OF POOR QUALITY



FIGURE 12. Kane Springs Wash volcanic center. vapor phase altered zone of Kane Wash Formation. Sample site 20 looking SE.



FIGURE 13. Kane Springs Wash volcanic center. Sample site 42 - glassy air fall unit at base of Kane Wash Formation member w looking NE.

features may vary consistently enough from one formation to another that map units can be differentiated inferentially from their mineral coatings. One of the objectives of this investigation is to determine the mineral and chemical composition of the coatings, relate coatings to host rock lithologies, and discriminate units on the basis of imagery characteristics. Application of imagery results to other areas, particularly unmapped volcanic terrains is one of the ultimate aims of this study.

A general paragenetic relationship can be observed within the weathered surface zone on many of the units at the Kane Springs center. The outer surface rind on relatively resistant units such as dense basalt or densely welded tuff is typically dark and forms a thin hard mantle (Figures 14 & 18). Underlying this desert varnish or case hardened "tafoni" is commonly a lighter colored argillically altered zone, orangy buff in color. This intermediate zone grades into clay altered cream colored host rock in the case of felsic units, particularly ash flow tuffs, or in the case of mafic units - basalts and trachyandesites - more grayish clay altered products which border relatively fresh host rock. This entire 3-phase rind averages about 1-2 cm thick. Of course the entire zone with its most evolved desert varnish is never completely developed over any outcrop or regolith surface, thus the spectral response of the rock is a combination of all 3 zones.

Less resistant units such as vapor phase altered tuff (figure 15) and glassy air fall pumice tuff (Figure 16) or glassy basal zones do not exhibit as well developed surface varnish. They are lighter in color. A hard dense rind may develop, but susceptibility to mechanical weathering restricts longevity of the more mature weathering surface. The weathered zone is thicker on less resistant units with clay alteration propagation more advanced into the rock.

The desert varnish rind developed on resistant units is probably more exogenous than the other coating types. Surfaces are longer lived and the composition more magnesian rich, particularly over more mafic lithologies (Figures 10 & 18). The spectral character is more grayish throughout the coating zone. Densely welded ash flow tuff units are characterized by dark orangy brown or chocolate brown coatings probably enriched in goethite and other limonitic iron oxides (Figures 11 & 14). Densely welded tuff forms resistant



FIGURE 14. Surface coating on dense weld zone of Kane Wash Tuff.

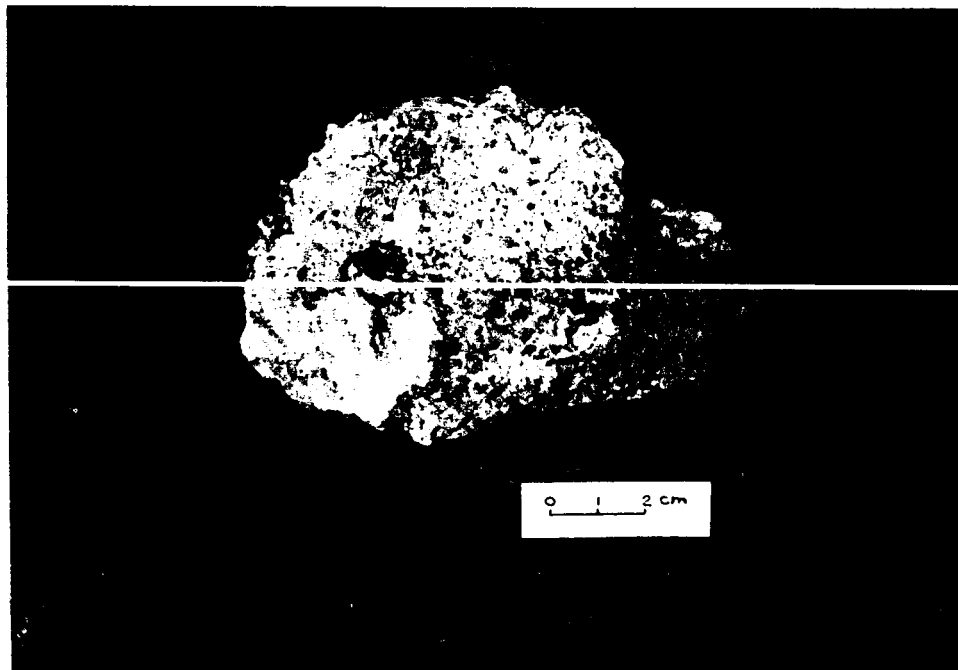


FIGURE 15. Surface coating on vapor phase altered zone of member w, Kane Wash Tuff.

ORIGINAL PAGE IS  
OF POOR QUALITY

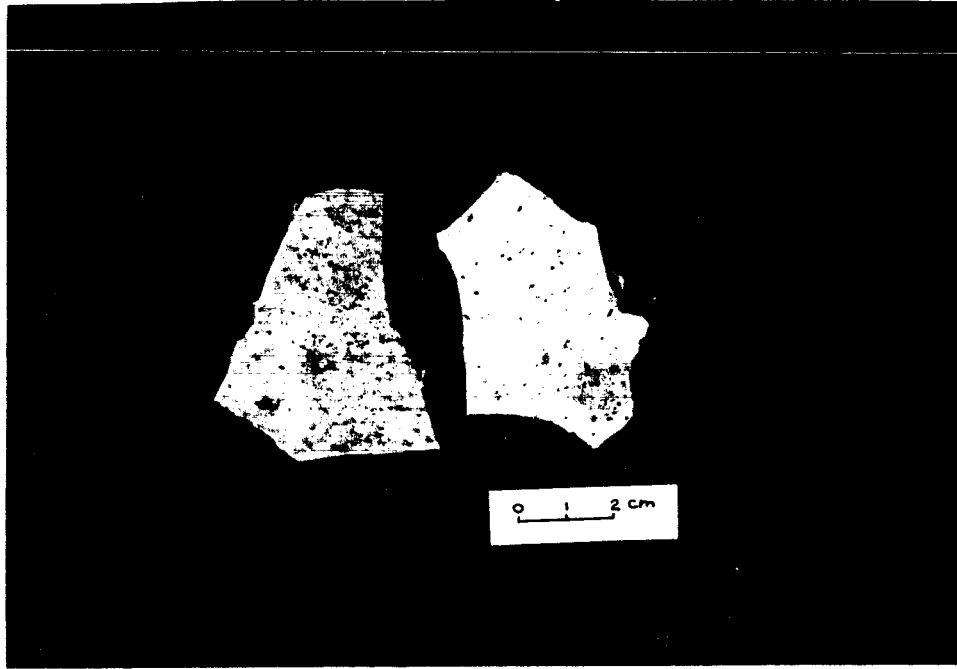


FIGURE 16. Surface coating on glassy ash at base of member v1, Kane Wash Formation

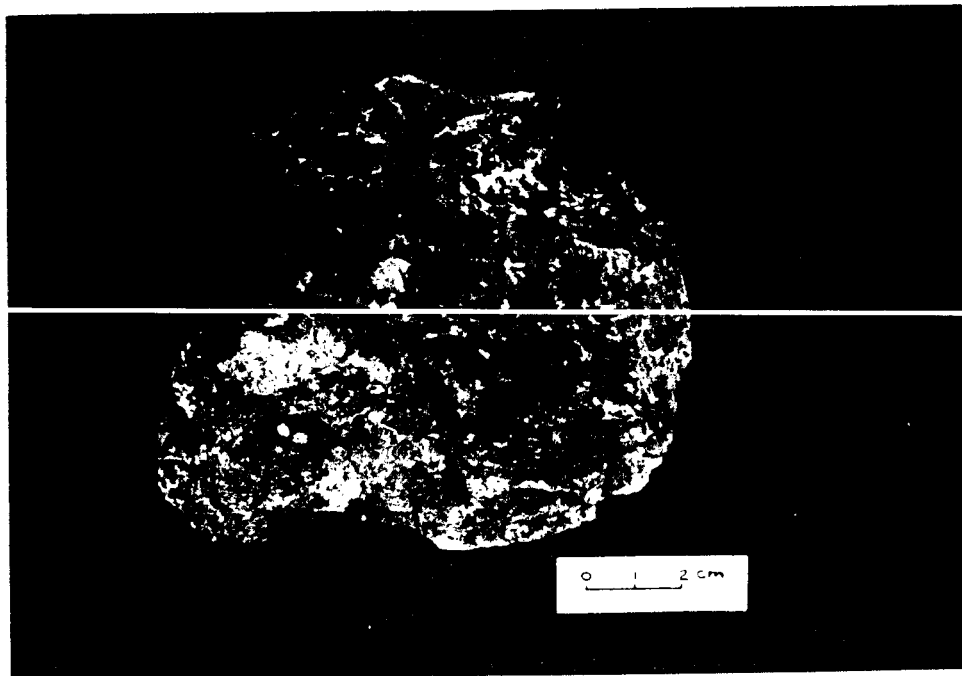


FIGURE 17. Surface coating on rhyolite flow unit, Kane Springs Wash volcanic center.

ORIGINAL PAGE IS  
OF POOR QUALITY



FIGURE 18. Surface coating on basalt, Kane Springs volcanic center.

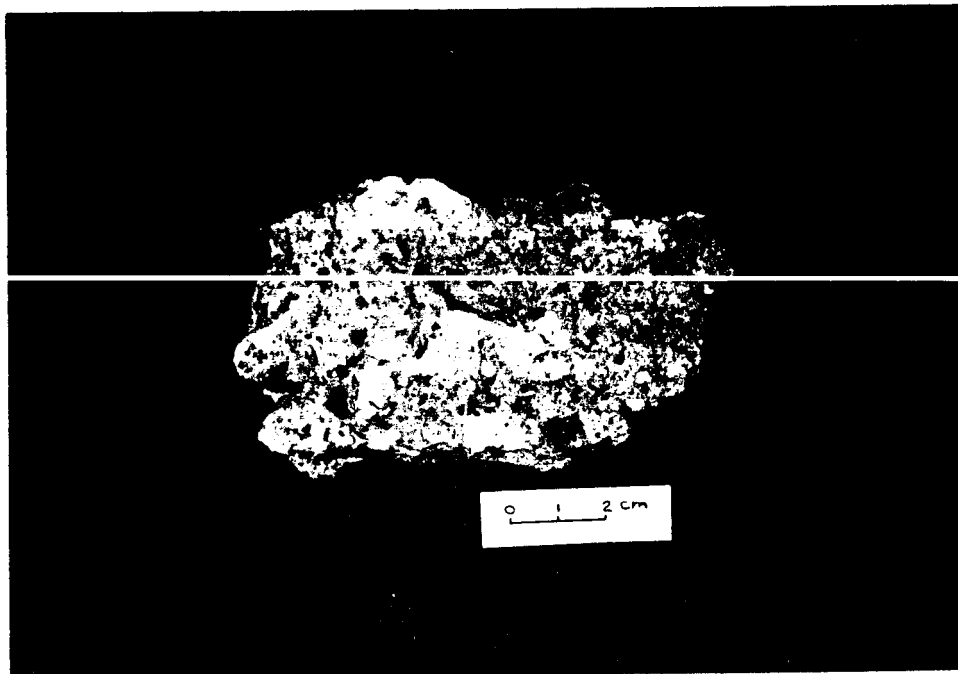


FIGURE 19. Surface coating on the Gold Flat Formaiton pantellerite, Black Mountain volcanic center.

ledges that may enhance gross intraunit patterns often characteristic of a particular formation. The result on aerial photos and Landsat imagery is textural patterns, which in addition to characteristic coating spectra, can aid formational discrimination. If a particular formation is composed of fairly consistent multiple dense weld zones, it might be possible to differentiate it on Landsat TM. The variably soft, friable, porous surfaces of vapor phase altered tuff (Figure 12), rather than supporting an evolved hard desert varnish rind, may instead yield a fairly healthy crop of lichen, particularly where topography favors moisture accumulation. The contribution of lichen must affect to some degree the spectral response of some vapor phase altered zones.

#### COATINGS, IMAGERY, AND VOLCANIC LITHOLOGIES

This section deals with results of imagery processing and field observations to date within the 512x512 project scenes selected for each of the three study areas. Important relationships are summarized for each area. Inasmuch as we have not yet produced analytical data, these observations are megascopic and conservative regarding compositional variation.

#### Kane Springs Wash

Individual band stretches on longer wavelength bands and stretched band ratios help discriminate melanocratic rocks (basalt and trachyandesite) from leucocratic rocks (tuffs, rhyolite flows, and syenite) at Kane Springs Wash (Figure 20). Pattern recognition enhances further discrimination on the basis of texture, tone and shade, and curvilinear patterns (outflow sheets and domal complexes for instance). The caldera margin is strikingly manifest, marking the boundary between subsided intracaldera flows and tuffs and extracaldera ash flow tuff sheets.

Forward transform principle components analysis produces more detailed contrast in the Kane Springs Wash volcanic pile. A false color composite of PC's 1, 2, and 3 (Figure 21) enhances outflow sheet stratigraphy. Narrow dark red bands interlaid with white bands are believed at this time to reflect densely welded zones at some localities. Some of the white or light cream colored bands betray glassy air fall or ash flow

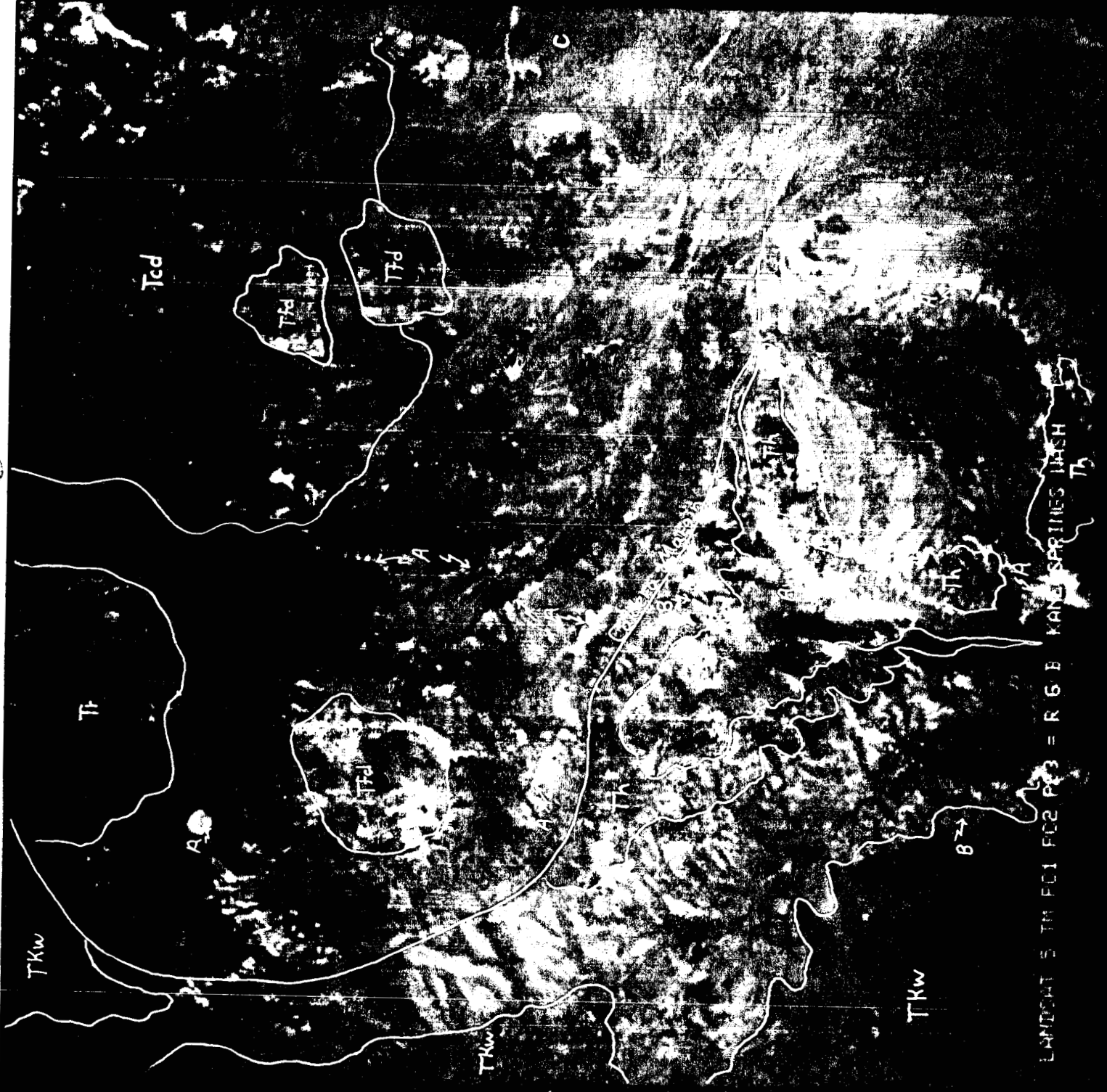
FIGURE 20. Landsat 5 TM band 5 image (scaled) of the Kane Springs Wash volcanic center. Scale: 1"= 6530', 1:78,360.

M - mesocratic color index (relative to rest of image). Corresponds largely to basalt and trachyandesite. L - leucocratic. Corresponds largely with ash flow tuffs, glassy air fall tuff, rhyolite and syenite flow dome complex. Undesignated areas are relatively melanocratic and correlate mostly with alluvium and ash flow tuffs. Many "mesocratic" areas are in shadow.





FIGURE 21: Landsat 5 TM principle components image (scaled) of the Kane Springs Wash volcanic center. PC's 1, 2, and 3 are represented RGB, respectively. Scale: 1" = 6530, 1:78,360. Remote sensing units are interpreted on the basis of color and textural pattern. Westerly shadows are green as well as mafic volcanic assemblages. Tfd - rhyolite and syenite flow dome complex. Tkw - Kane Wash Tuff. Th - Hico Formation. Tcd - syenite cumulodome complex. Tr - intracaldera rhyolite lavas. "A"'s - glassy air fall and ash flow deposits (white). "B"'s - densely welded ash flow tuff zones (red bands) interbedded with vapor phase altered and glassy air fall tuff. Note red dominated alluvial fan at "C" which represents the relatively reflectant detritus from the syenite complex.



LANDSAT 5 TM FC1 FC2 P3 = R 6 B KANE SPRINGS WASH

interformational deposits, a relationship important to formational differentiation in volcanic terrain. Some light cream colored bands on Figure 21 appear to correlate with glassy air fall units at the base of Kane Wash ash flow tuff members V2 and W respectively. The "busy" red stripped pattern is coincident with the Hico Formation. This signature, a result of alternating densely weld and vapor phase altered interbeds, could be applied at least at this locale to formation discrimination. A stretched PC3 image provided sharp contrast between some glassy pumiceous ash flows and their nonglassy neighbors. Variance (reflectance) is much more pronounced on eastern slopes than on western ones due to the morning illumination of Landsat 5 and resulting broader reflecting surfaces, the latter of which provides more favorable spectral response since distinctive units are commonly 10-30 feet thick, placing considerable strain on the discriminating ability of the 28.5m footprint of Landsat 5.

A stretched ISH image on bands 1, 3, and 5 is presented in Figure 22. White glassy deposits and relatively felsic units are red (intensity) grading to yellow. Again, as with PC's intensity and saturation are greater on eastern sunward slopes.

Stretched 5/7 and 3/1 images produce indistinct tonal contrast with diffuse boundaries, except over rhyolite flow dome deposits (Figure 17) which stand out in dark contrast to surrounding units on the 5/7 image, indicating less hydrous mineral components. On the 3/1 image the more mafic basalt and trachyandesite lava appear somewhat darker than the felsic deposits.

Influence of vegetation (from 4/3 ratio images) does not appear to be serious except for the northern part of the scene and two other irregular high altitude zones. Growth on subhorizontal and gentle slopes consists predominately of sagebrush, foxtails, and other grasses. High elevation growth, so conspicuous on the 4/3 image, is characterized by juniper trees and shrub plants. The greenish orange dedritic pattern in the SE portion of Figure 21 is vegetation produced (sage brush, yucca, cholla, broom grass, and other low growth). Some of the relatively light bands which coincide with glassy deposits and vapor phase altered tuff tend to be slope formers, flanked both below and above by dense weld ledge forming ash flow units. These more porous friable units often host distinctive floral populations,

FIGURE 22: Landsat 5 TM ISH false color composite (scaled) of the Kane Springs Wash volcanic center. ISH function performed on bands 1, 3, and 5. Scale: 1"= 6530', 1:78,360. Remote sensing units are consistent with those shown on Figure 21. Note that the white glassy ash and tuff deposits are red (intensity), and that dark basaltic assemblages and shadows are blue (hue).

ORIGINAL PAGE IS  
OF POOR QUALITY



LANDSAT 5 TM BANDS 1 3 5 - 10A - SCALED - 4-NE SPRING 1984

including greater density of scrub juniper, Joshua trees, foxtail grass, and lichen.

#### Black Mountain

Figure 19 shows coatings on the Gold Flat member of the Thirsty Canyon Tuff, an outflow deposit from the Black Mountain caldera. The Gold Flat member is a pantellerite (iron enriched peralkaline ash flow), and forms a thin cap over much of the mesa terrain south of Black Mountain summit. It exhibits in sharp contrast to surrounding units on ISH, PC (Figure 23), and false color composites such as a 3, 5, 7 stretch (Figure 24). Other units, including the Labyrinth Canyon tuff, the Trail Ridge Tuff, and the central caldera trachyte, also respond with characteristic imagery in TM band processing.

A second study scene (Figure 24) was selected at Black Mountain to provide an area more conducive to the study of stratigraphic relationships between multiple ash flow cooling units. Efforts will focus within the NE quadrant of this scene.

#### Stonewall Mountain

The 512x512 study scene selected for the Stonewall Mountain volcanic center (Figures 25 & 26) straddles the western margin of the Mount Helen caldera and the eastern paleorim of the Stonewall Mountain caldera. The scene encompasses diverse Pliocene volcanic rocks including the Stonewall Mountain Tuff (included with the Thirsty Canyon Tuff by original mappers, but redesignated in 1984.)

Image processing resulted in distinctive false color contrast correlating with lithologic properties. Scaled 3/1, 5/7, 4 and ISH images (Figures 25 & 26) highlight the Thirsty Canyon Tuff and other units as well. A major N-S normal fault, part of the Mt. Helen caldera margin, located east-central in the work scene, exhibits as a striking curvilinear in these enhancements. More subtle variations were displayed by a PC 1 2 3 false color composite.

#### SCHEDULE FOR NEXT REPORTING PERIOD

Sampling is continuing at this time at the

FIGURE 23. Explanation for remote sensing units shown on following figure.

- o - older rocks, mostly silicic volcanics
- t - Trail Ridge member of Thirsty Canyon Tuff
- g - Gold Flat member of Thirsty Canyon Tuff
- l - Labyrinth Canyon Tuff
- h - Trachyte of Hidden Cliff

FIGURE 24. Explanation for remote sensing units shown on following figure.

- tc - Thirsty Canyon Tuff outflow sheets of the Black Mountain caldera.  
Distinct blue image is Gold Flat Tuff
- b - late basalt



ORIGINAL PAGE IS  
OF POOR QUALITY



FIGURE 23. Landsat 5 TM scaled principle components false color composite of the Black Mountain volcanic center. PC's 1, 2, and 3 are RGB. Scale: 1"=14,330', 1:172,000.

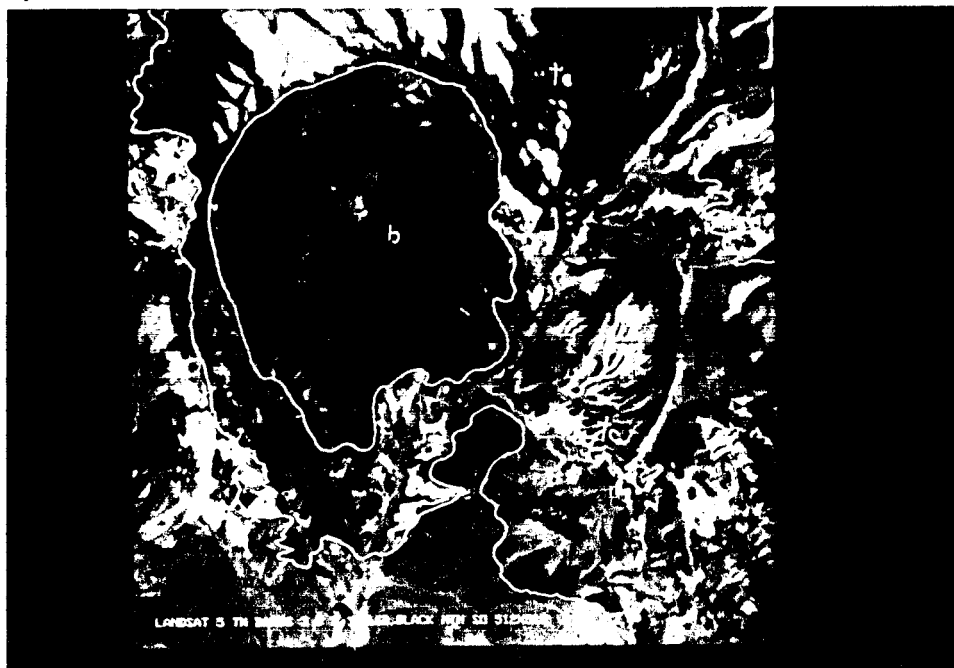


FIGURE 24. Landsat 5 TM scaled false color composite on bands 3, 5, and 7 over a southern portion of the Black Mountain volcanic center. Scale: 1"= 14,330', 1:172,000.

FIGURE 25. Explanation for remote sensing units shown on following figure.

- Q - Paleozoic quartzite
- S - Stonewall Mountain Tuff. Light moss green portions reflect Civet Cat Canyon member
- B - Basalt
- f - chiefly alluvial deposits (include some outcrop) derived from fine felsic quartz porphyry flows probably from the Mt. Helen caldera

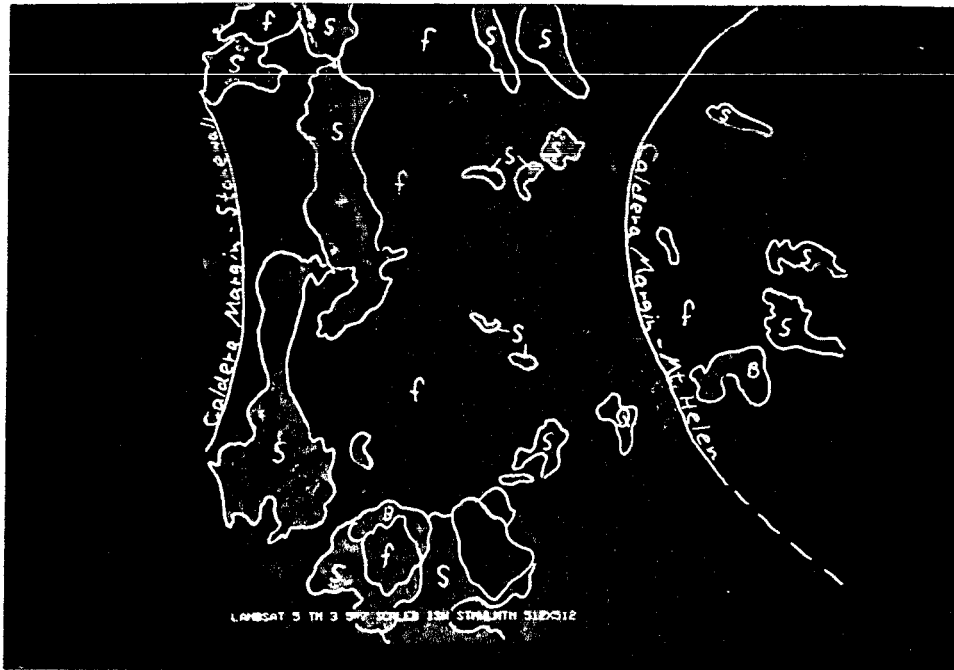


FIGURE 25. Landsat 5 TM scaled ISH false color composite of bands 3, 5, and 7 colored RGB, respectively, over the Stonewall Mountain study area. Scale: 1"= 14,330', 1:172,000.

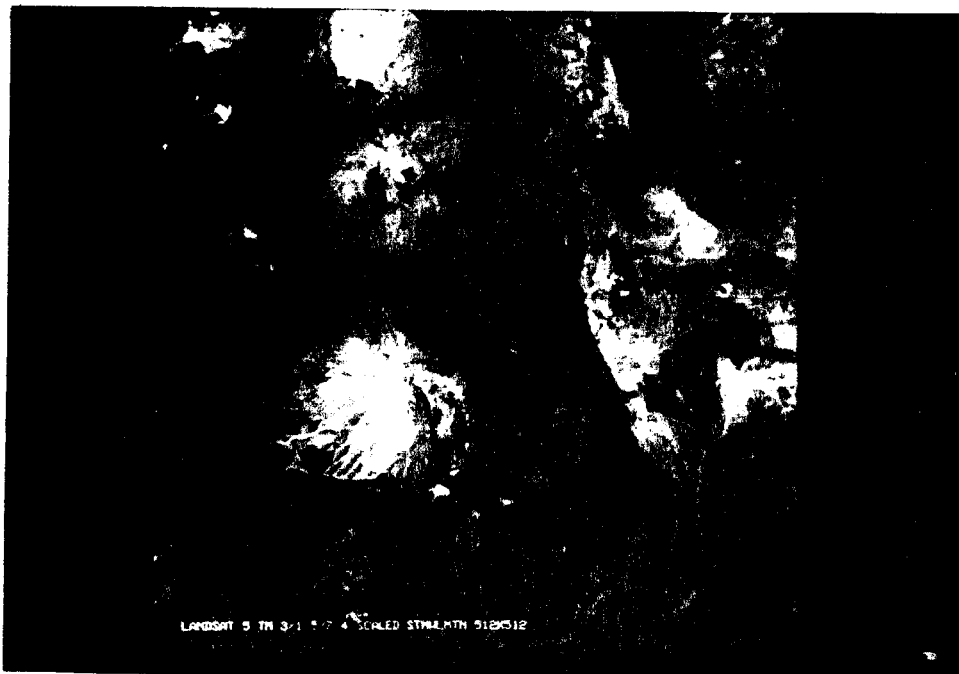


FIGURE 26. Landsat 5 TM scaled false color composite of bands 3/1, 5/7, and 4 colored RGB, respectively, over the Stonewall Mountain study area. Scale 1"= 14,330', 1:172,000.

Black Mountain and Stonewall Mountain project areas. Inasmuch as the Stonewall Mountain work scene is within the Air Force Gunnery Range, access is restricted to select weekends and subject to tight security and supervision by Nellis Air Force Base personnel. Petrographic thin section samples are being prepared to show relationship of coatings to host rock. Analytical techniques primarily involving XRD and XRF will be the thrust of our efforts during this coming Fall. Image enhancement and processing experiments will continue as well. A more detailed review and correlation of specific formations, coatings, vegetation, and other site complexities and imagery characteristics is also in progress.