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CENTER FOR REMOTE SENSING AND CARTOGRAPHY

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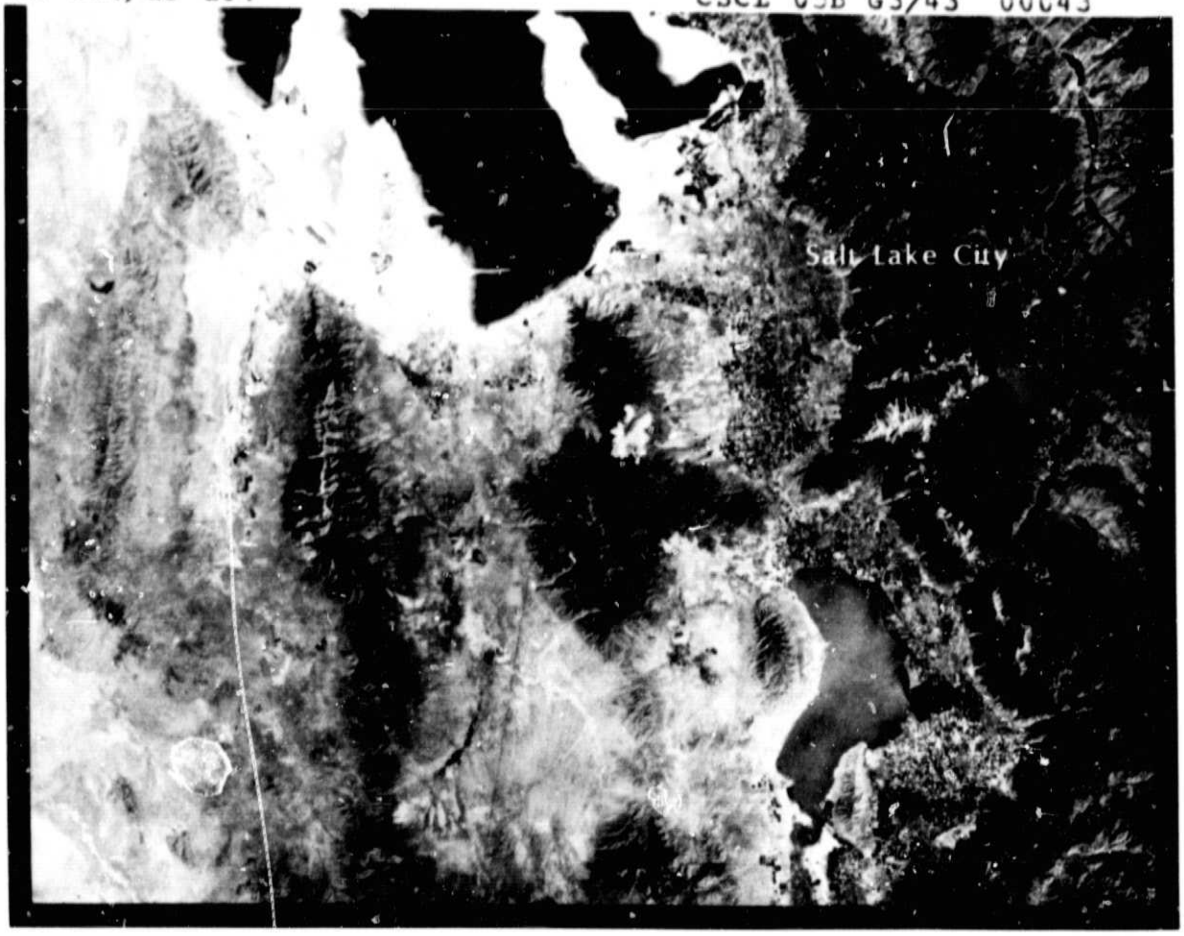

UNIVERSITY OF UTAH RESEARCH INSTITUTE

Salt Lake City

CLASSIFICATION OF VEGETATION COMMUNITIES
in the
BATTLE MOUNTAIN SE QUADRANGLE, NEVADA
with
MSS DIGITAL DATA
CRSC Report 84-7

by

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OBJECTIVE

The objective of this investigation is to identify vegetation types with Landsat MSS digital data, and to determine ways in which terrain data may improve spectral classification. Ultimately, an effort will be made to correlate the classification to ground level radiometry of specific plant species and soil characteristics.

STUDY AREA

The study area is the 7.5 minute USGS quadrangle of Battle Mountain SE in northern Nevada. It lies at the eastern flank of Reese River Valley against the toe of the Shoshone Range, Figure 1. Topographically, the area is bounded by foothills of the Shoshone Range on the east, and extends across an alluvial fan complex westward toward the Reese River; it extends from the Humboldt River floodplain on the north to near the mouth of Crum Canyon in the Shoshone Range on the south. Except for the foothills along the east, the whole quadrangle consists of basin alluvium, gently sloping toward the northwest.

The area lies in the northern Great Basin of the Basin and Range Physiographic Province. Elevations in the vicinity range from just over 4,000 feet to above 9,000 feet. Within the quadrangle, the elevation is about 4,517 at the northwest corner, and about 5,800 feet at the highest point on the foothills at the east edge of the quadrangle.

Geomorphically, the area consists of five general units: bedrock controlled foothill slopes on the east, an old alluvial apron at the foot of the eastern mountains, a coarse alluvial apron along the east and

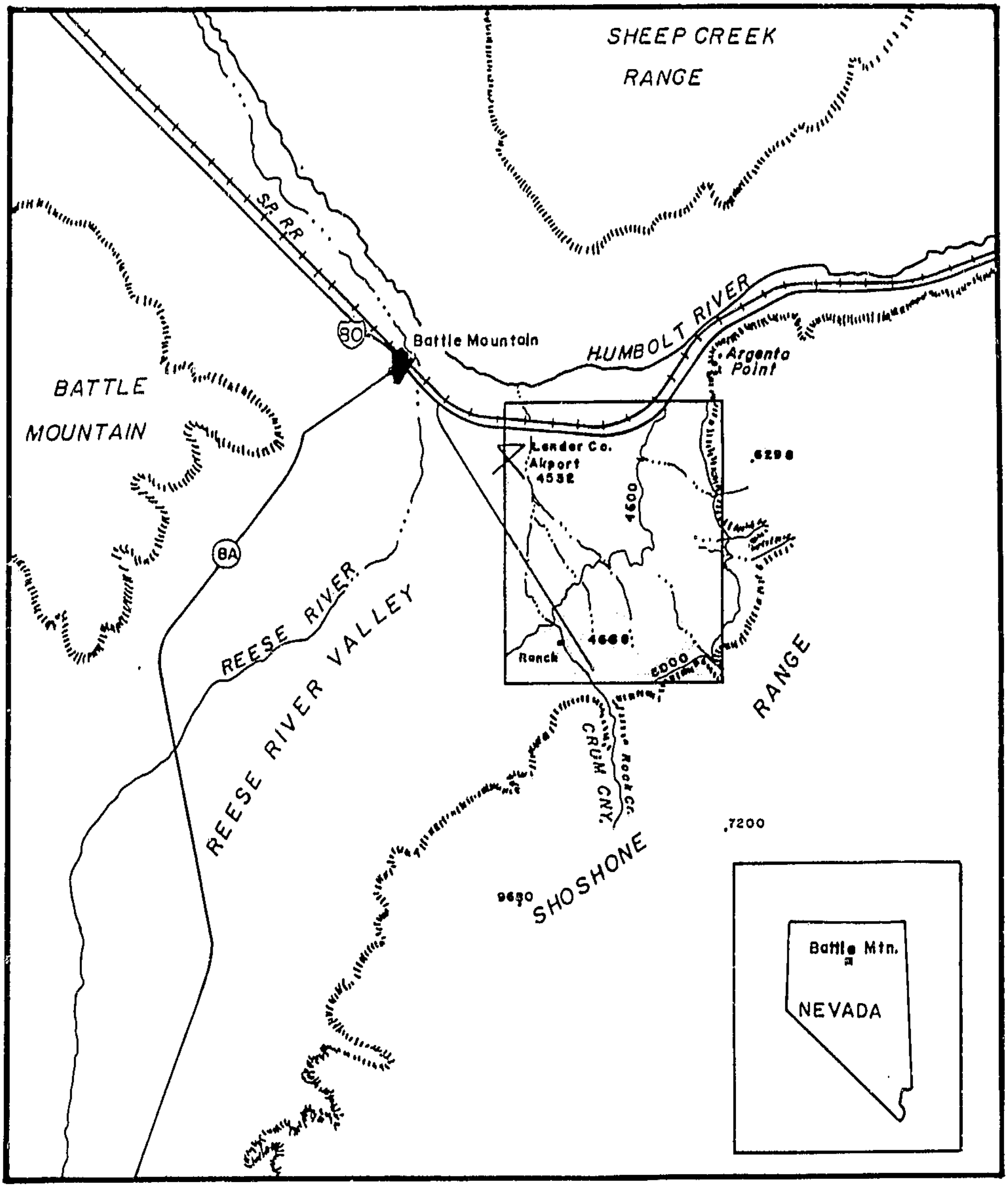

Figure 1. The Battle Mountain study area (shaded).

south, a fine alluvial basin in the central to western and northwestern portion, and an occasional swale associated with a northwest trending washes. A series of northeast-southwest trending fault scarps traverse the area creating a set of low bluffs facing outward from the mountains.

The area is part of the cold desert region lying in the rain shadow of the Sierra Nevada. Annual precipitation at the Lander County Airport on the edge of the quadrangle is a scanty 7.5 inches, with a winter maximum derived from snowpack, and a decided summer drought. Nearby mountains provide the only runoff of note, and then only at peak snowmelt and following occasional summer thundershowers. No permanent streams traverse the area. However, there are a few springs and seeps that appear to be associated with the faultlines. In some places, it appears that ground water is redirected along fractures to emerge here and there, or to rise near enough to the surface to create a vegetation anomale in the otherwise desert shrub and annual grass-forb dominated region.

MATERIALS

The basic data set is a computer compatible tape (CCT) of Landsat scene 82233617450, dated 15 June 1981, provided by the U.S. Army Engineer Topographic Laboratories. This was augmented with a USGS 15-minute Battle Mountain conventional quadrangle at 1:62,500 scale, an orthophotoquad of the 7.5 minute Battle Mountain, SE quadrangle at 1:24,000 scale, aerial oblique 35mm color slides made on 17 September 1984, and ground level 35mm colored slides made on 16 and 17 July, and 18 and 19 September, and 16 and 17 November 1984.

PROCEDURE

The analytical methodology followed seven steps, alternating between laboratory and field procedures, as described below. All laboratory work was done at the Center for Remote Sensing and Cartography (CRSC), University of Utah Research Institute (UURI). All digital MSS processing was done using NASA's ELAS software on UURI's PRIME 400 computer. Figure 2 shows the basic sequence of digital analysis.

Preliminary Classification

Prior to initial field investigation an unsupervised classification map was prepared for the study area using the reformatted raw Landsat data (Figure 2). The classes for the map were derived using a program from the ELAS program package called SRCH (abbreviated from Search). SRCH derives classes by passing a 3x3 window through a selected area, or areas, of the image according to parameters set by the operator: standard deviation lower bound (SDLB), standard deviation upper bound (SDUB), and the coefficient of variation (COV), applied to all channels. These parameters were set at 0.05, 5.0, and 1.0, respectively, in this study. These parameters, along with the average and the variance for each channel for the 3x3 window, are used in a "test for homogeneity."

The test of homogeneity is used to assess the variance for a given channel. As the test is passed, that is, the variance is within the prescribed bounds, an HTFS (homogeneous training field statistic) is saved in one of the BINS, or storage locations. Appendix A explains the procedure beyond this point.

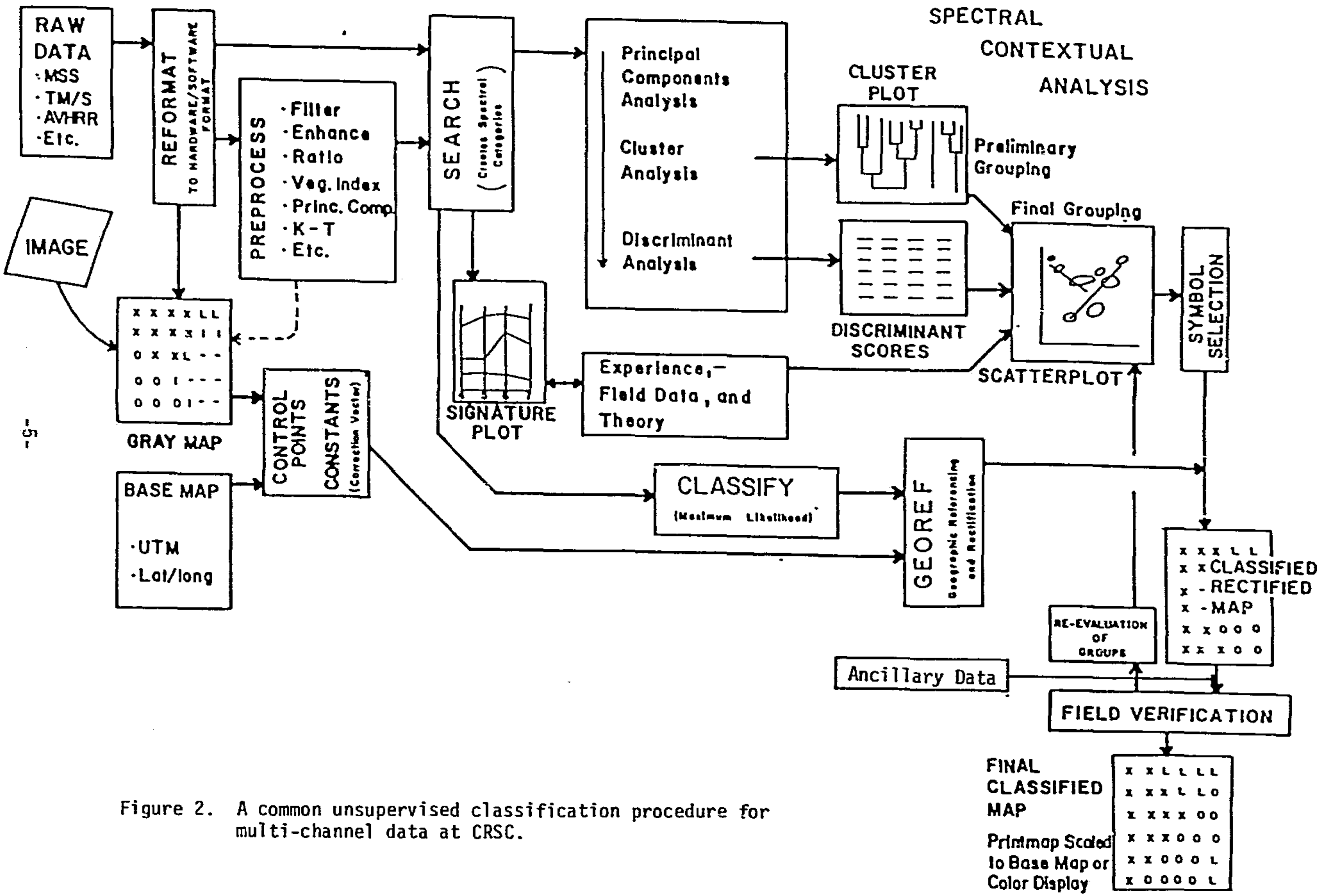

Figure 2. A common unsupervised classification procedure for multi-channel data at CRSC.

All the statistics are saved and made available to the operator. In addition to the statistics, the final product of SRCH is a set of signatures. A signature is the mean digital number (DN), or reflectance value, for each channel for each class finally identified by SRCH. In the preliminary classification for the study area, 46 signatures (spectral classes) were identified. These were derived from a SRCH area slightly larger than the quadrangle.

Using the mean DN values for the 46 spectral classes, a series of routines involving principle components, clustering, and discriminant analysis (Figure 2) generated a set of statistics and a scatter plot of the 46 classes. Figure 3 shows the scatter plot. Function 1 depicts the visible light component, increasing to the right. Function 2 depicts the infrared component increasing upward.

The so-called "soil line" would extend from the darkest signature (class 25) at the lower left, to the brightest signature (class 45) off the diagram to the right. The figure has actually been enlarged to better separate graphically the swarm of points in the central area. Consequently, classes 45, 46, and 40 are displayed off the plot. The "green point," classes 36, 38, and 41, are also off the plot to the upper left, where infrared is maximum and visible light reflectance is low. It is clear that the latter classes represent anomalously green biomass from the otherwise desert vegetation in the swarm of classes.

Print symbols arbitrarily assigned to each class are written beside the class number. For convenience of reading the printmap, related symbols are designated for visually and statistically related clusters of signatures. From the green point, alphabet characters are assigned from

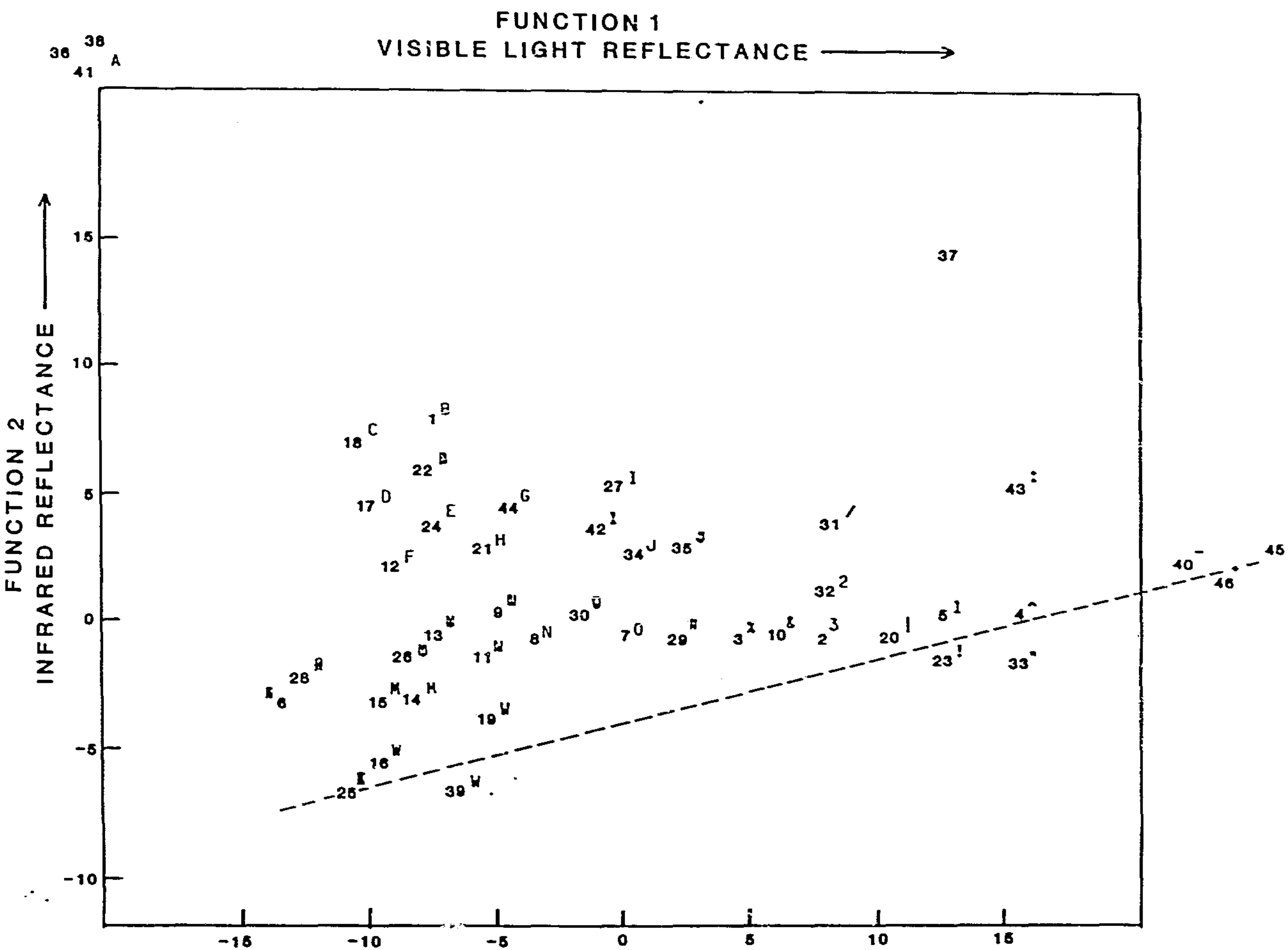

Figure 3. Scatter plot of the 46 spectral classes derived from SRCH.

"A" downward, depicting decreasingly green vegetation to the center of the swarm. Where two classes are closely spaced, a single letter, such as "B", may be assigned, as in the case of classes 1 and 22. To distinguish the two, an overstrike is used, such as B:.

Heavy overstrike symbols are used for the darkest signatures. Thus, class 25 is symbolized as WXI in a triple overstrike. On the printmap, such pixels fall on the darkest (least reflective) positions of the study area. With increasing brightness toward the right, lighter symbols are used, culminating in a period (.) for class 45. In this way, the printmap, when produced at quadrangle scale, is easily interpreted and related to field characteristics of shades of gray.

To produce the printmap to scale, two steps must be taken: control point selection for geographic referencing and resampling. See Figure 2. Control points are selected by first producing a gray map from the raw data (of a region much larger than the study area). Key landmark features visible in the gray map and on a base map quadrangle are identified. Scan line and element "addresses" from the gray map are matched to UTM (Universal Transverse Mercator) easting and northing "addresses" from the quadrangle. The Landsat data set is then geographically referenced to fit the UTM grid.

Resampling occurs as the chosen print symbols are scaled to the quadrangle to produce a printmap. In this case (at the latitude of Battle Mountain) each print character is 61.2 meters in the east-west dimension, and 76.0 meters north-south. Thus, each print character on the printmap may represent parts of several original Landsat pixels. This process is accomplished through a set of routines identified as GEOREF in Figure 2.

From the above procedure, a printmmap of the preliminary classification is created, and scaled to the quadrangle. In this case, as no USGS quadrangle yet exists at 1:24,000 for the study area, the 1:62,500 Battle Mountain quadrangle, dated 1957, (Figure 4) was enlarged to a photographic print at 1:24,000 scale. This obviously provided less than ideal field reference, but was all that could be done at the time. (An orthophotoquad at 1:24,000 had been ordered but not yet received.) Target field sites were selected by identifying polygons of like symbols on accessible and locatable points. Figure 5 represents a part of the preliminary printmap with a few field site polygons shown. The print symbols represent the classes shown in Figure 3.

With the printmap scaled to fit the enlarged quadrangle at 1:24,000, a clear acetate overlay was prepared of the printmap. The overlay was registered to the enlarged quadrangle and taped in place, ready for the field. The registered printmap and the scatter plot were the principle materials for the field, together with a camera and data sheets.

Field Reconnaissance

On 16 and 17 July, Merrill Ridd and Gordon Douglass joined ETL scientists Melvin Satterwhite and Ponder Hendley in the field. Because the enlarged quadrangle was less than ideal for determining field position, this became a reconnaissance mission. The purpose was to familiarize ourselves with the ecotypes and terrain, and to coordinate efforts with the ETL scientists.

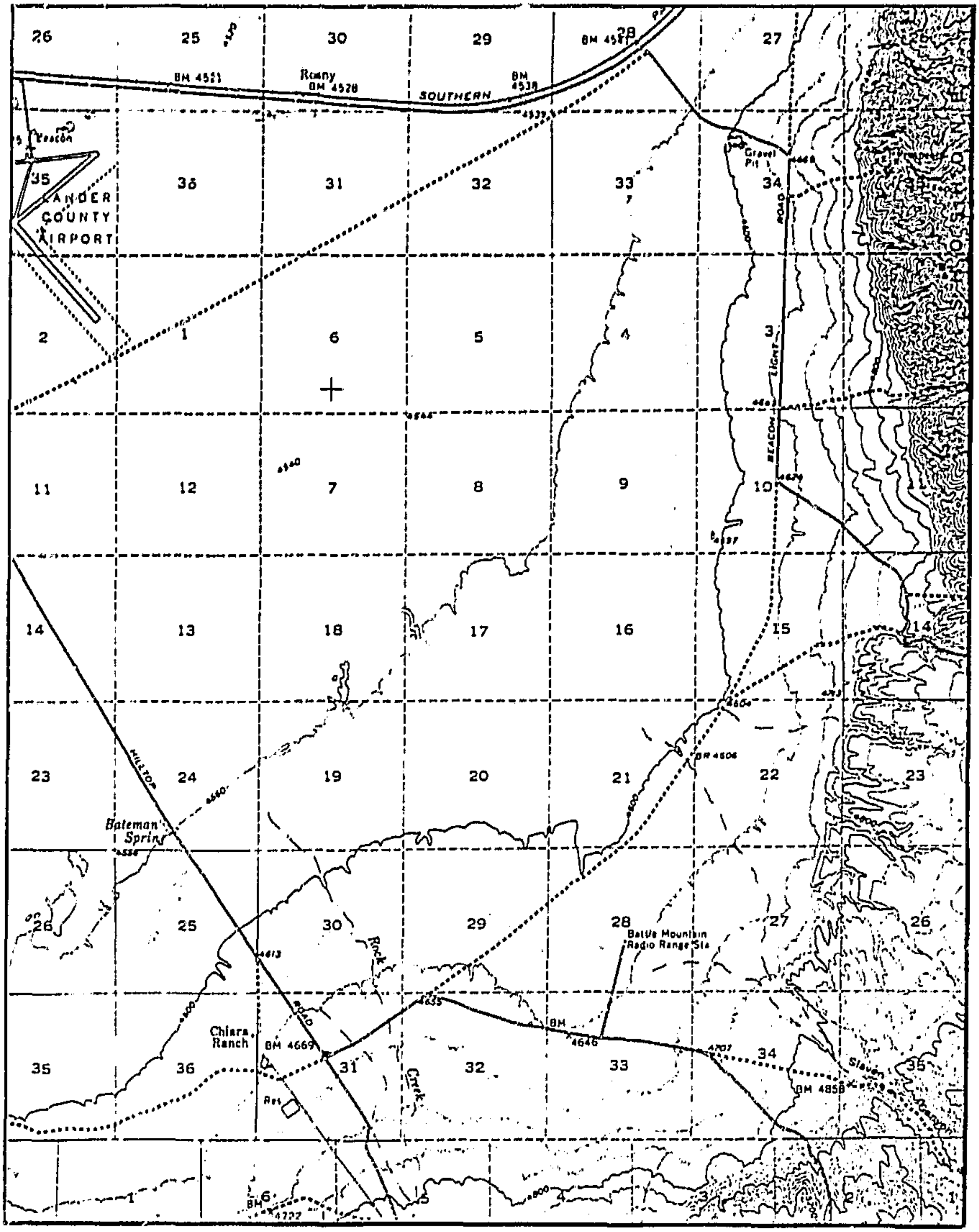

Figure 4. Southeast Quadrant of the 1957 Battle Mountain quadrangle at 1:62,500 scale.

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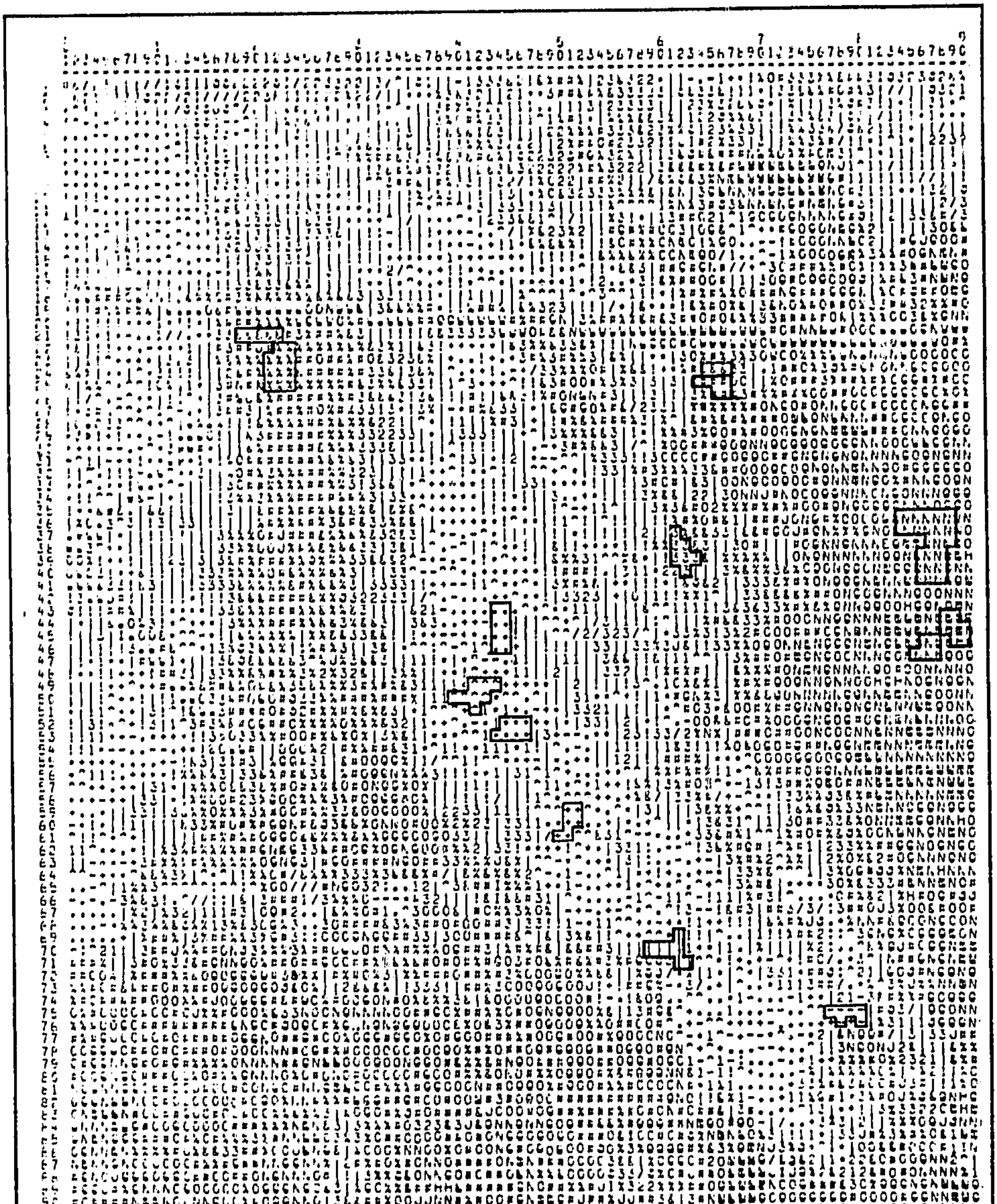

Figure 5. Northwest corner of the printmap of the preliminary classification. Relate symbols to Figure 3.

In addition to a general reconnaissance, field data were recorded and photographed for a limited number of field sites. The field data form is shown in Figure 6. For each site, the class symbol and other pertinent data were recorded at the top. Ocular estimates were made of the cover by life form, and then broken down by species. Two 35mm color slide photographs were typically taken per site, one depicting setting or location, the other showing a close-up of representative plant species and arrangement. The site number and photos were keyed to the printmap for future reference in the laboratory.

Laboratory Evaluation

On the basis of the early field data, associations were made with the scatter plot and preliminary groupings ascertained, according to plant species associations. However, only limited work could be accomplished until the orthophotoquad arrived to enable more precise field location assurance.

Field Data Collection

When the orthophotoquad finally arrived, the printmap overlay was registered and taped to the 1:24,000 orthophotoquad, dated 1975. A field excursion was scheduled immediately. Kevin P. Price and R. Douglas Ramsey, two Ph.D. candidates with master's degrees in range science and experience with the Bureau of Land Management (BLM), went to the study area on 17, 18, and 19 September 1984. They obtained field data for 31 sites.

To qualify as a field site, two criteria had to be met. First, the site had to be homogeneous (a single printmap class symbol) within at least a 2x2 pixel cell, preferably 3x3 or more. reason for this is

SITE CHARACTERISTICS/ LOCATION FORM

PROJECT: BM REGION: ______ (State or area)
QUADRANGLE: ______ GENERAL LOCATION: ______ DATE: 9/18/84

GENERAL SITE INFORMATION • • • • • • • FIELD SITE # 1, 12, 14

TOPOGRAPHY		PRINT MAP INFORMATION	
ELEVATION (m):		GENERAL COVER TYPE:	Annual/grass
SLOPE (%):	5%, 2%, 1	CLASS SYMBOL:	F
ASPECT (deg.):	W, NW, E	CLASS NUMBER:	14

COVER COMPONENTS	A (1)	B (12)	C (14)	D	E	GENERAL
LIFE FORM: SHRUB COVER (%)	1	20	35			
LIFE FORM: ~~PERENNIAL~~ Annual FORB COVER (%)	7	20	1			
LIFE FORM: PERENNIAL GRASS COVER (%)	0	0	0			
LIFE FORM: ANNUAL ~~COVER~~ Grass (%)	65	30	20			
TOTAL LIVING COVER-	73	70	55			
CRYPTOGAM COVER (%)	1	0	0			
Total Living Cover	74	70	55			
LITTER COVER (%)	17	20	35			
SURFACE ROCK COVER (%)	5	0	5			
BARE SOIL (less than 1 cm diam.)	4%	10	5			
Total to 100%	100	100				
PREV. SPP. 1. DOMINANT (code/%)	BRTE/65	BRTE/30	ATCO/30	/	/	/
PREV. SPP. 2. SUBDOMINANT (code/%)	SVAV/4	ATCO/20	BRTE/20	/	/	/
PREV. SPP. 3. SUBDOMINANT (code/%)	LUFE/3	LUFE/20	ARSP/5	/	/	/
PREV. SPP. 4. SUBDOMINANT (code/%)	ARSP/1	/	ARTR/T	/	/	/

PHOTOGRAPH LOG	A	B	C	D	E	GENERAL
PHOTO #1 (roll/#, direction)	1-3(W)	1-28 SE	1-32 NW			
PHOTO #2 (roll/#, direction)	1-4(W)	1-29	1-33			
PHOTO #3 (roll/#, direction)	1-5(SE)					

COMMENTS: SOIL/EROSION (1) Silty Loam (12) Silty loam

LAND FORM--

OTHER--

Figure 6. Field data form used in the study.

to avoid boundary pixels and misregistration. The second criterion was access: field sites would be within 0.2 miles from a well-identified road. This would assure sufficient pacing accuracy to the site. From numerous indications, we are confident of our field locations to within a pixel. The orthophotoquad was invaluable in assuring both exact field position and registration of the overlay establishing the correct printmap class symbol.

Second Laboratory Evaluation

With substantial field data, accurately locatable, it was possible to create tentative groupings of the 46 spectral classes on the scatter plot. While many associations were readily identified on the plot, confusion appeared in some key areas. Some spectral clusters appeared to have split personalities, with the same symbol sometimes representing two quite different ecotypes as observed in the field. The I's and J's, for example, in Figure 3 seemed quite mixed. Also, the M's seemed to represent differing heavy shrub types in different topographic and soil settings.

More field data were needed to enlarge the sampling base, with careful observation of topographic/soil conditions.

Final Field Data Collection

On 16 and 17 November, R. Douglas Ramsey and Merrill Ridd returned to the field. An additional 30 field sites were analyzed, bringing the total to 64 in all. It was particularly important to enlarge the sample size of J's, M's, N's, and O's. These represent the bulk of the shrub types across the alluvial terrain units. Particular attention was paid to the fault scarps and the swales, and their influence on moisture and vegetation.

Final Laboratory Analysis and Mapping

The final step involved three interrelated activities: (1) statistical analysis of the field data, (2) examination of field photography (35mm slides), and (3) examination of the scatter plot.

A master table of field data was compiled showing breakdown by spectral class (printmap symbol), with each field site as a row in the table. The columns were percent cover by life form (shrub, annual forb, annual grass, perennial grass/forb, and cryptograms); percent non-living (litter, bare soil, and rock fragments over one centimeter); and percent breakdown by species.

The scatter plot was scrutinized to compare the actual field data and photos with spectral space theory, e.g. greenness, brightness, shadowing, etc. Tentative groupings were defined and redefined through successive cycles. Where confusion could not be eliminated by logical spectral groupings on the scatter plot, geomorphic/soil conditions were employed as ancillary data. The previously mentioned geomorphic/soil types were digitized for purposes of stratification of spectral data. (See Figure 7.) A special algorithm was prepared for the stratification process.

Statistics for each group were compiled and recorded. Means and ranges per ecotype class were analyzed. All field sites were assigned to a group, based on field statistics, and each final group was given an ecotype name according to plant composition.

RESULTS

A total of 17 groups were finally created. The group names are shown in Table 1. Figure 8 shows a generalized pattern of the ecotypes, extend-

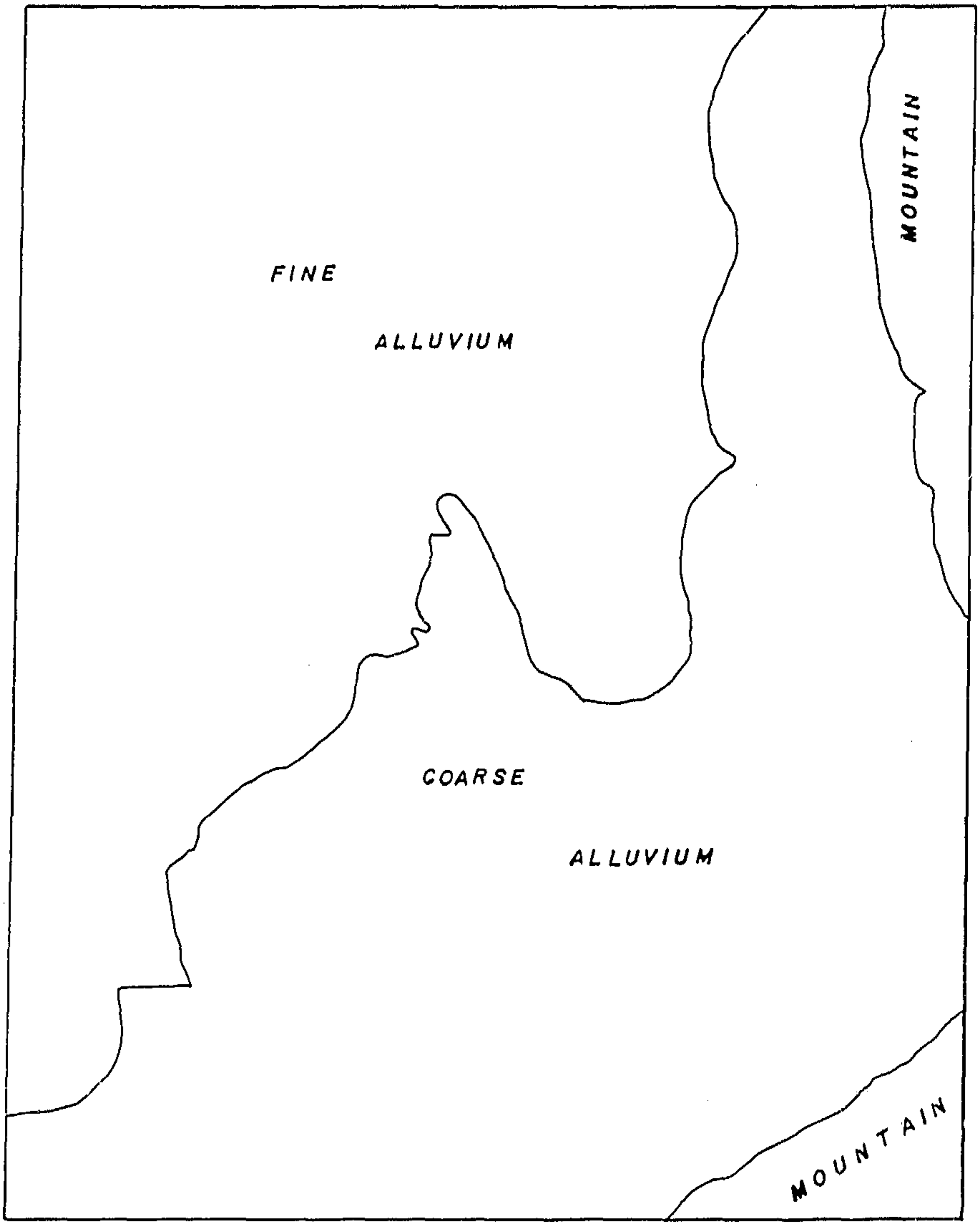

Figure 7. Geomorphic/soil units to stratify the spectral data.

Table 1. Final Classification of 17 Ecotypes in the Study Area.

Print Symbol	Ecotype	General Topographic Setting
Blank	Atriplex falcata	Saline communities of bottomlands
-	Salt desert mixed shrub	
*	Greasewood	
L*	Greasewood/Big saltbush	
=-	Salt desert mixed shrub/annuals	
S	Shadscale/Annuals	Alluvial apron communities
C.	Annuals/Mixed shrub	
C	Annuals	
H	Spiny Hopsage	
A+	Sagebrush	
M	Mixed shrub, sparse (south slope)	Mountain communities
MIX	Mixed shrub, dense (north slope)	
R	Riparian	
W.	Grass, moist site	Moist sites near ground water
D	Saltgrass	
A	Agriculture, irrigated	
/	Disturbed land or sand dune	

ing from the salt tolerant communities of the northwest lowland, through the shadscale, annuals, sagebrush/hopsage, to the mountain slopes. The vegetational transition is consistent with the geomorphology/soil units and hence, the hydrologic regime. Table 1 is arranged to demonstrate this transition.

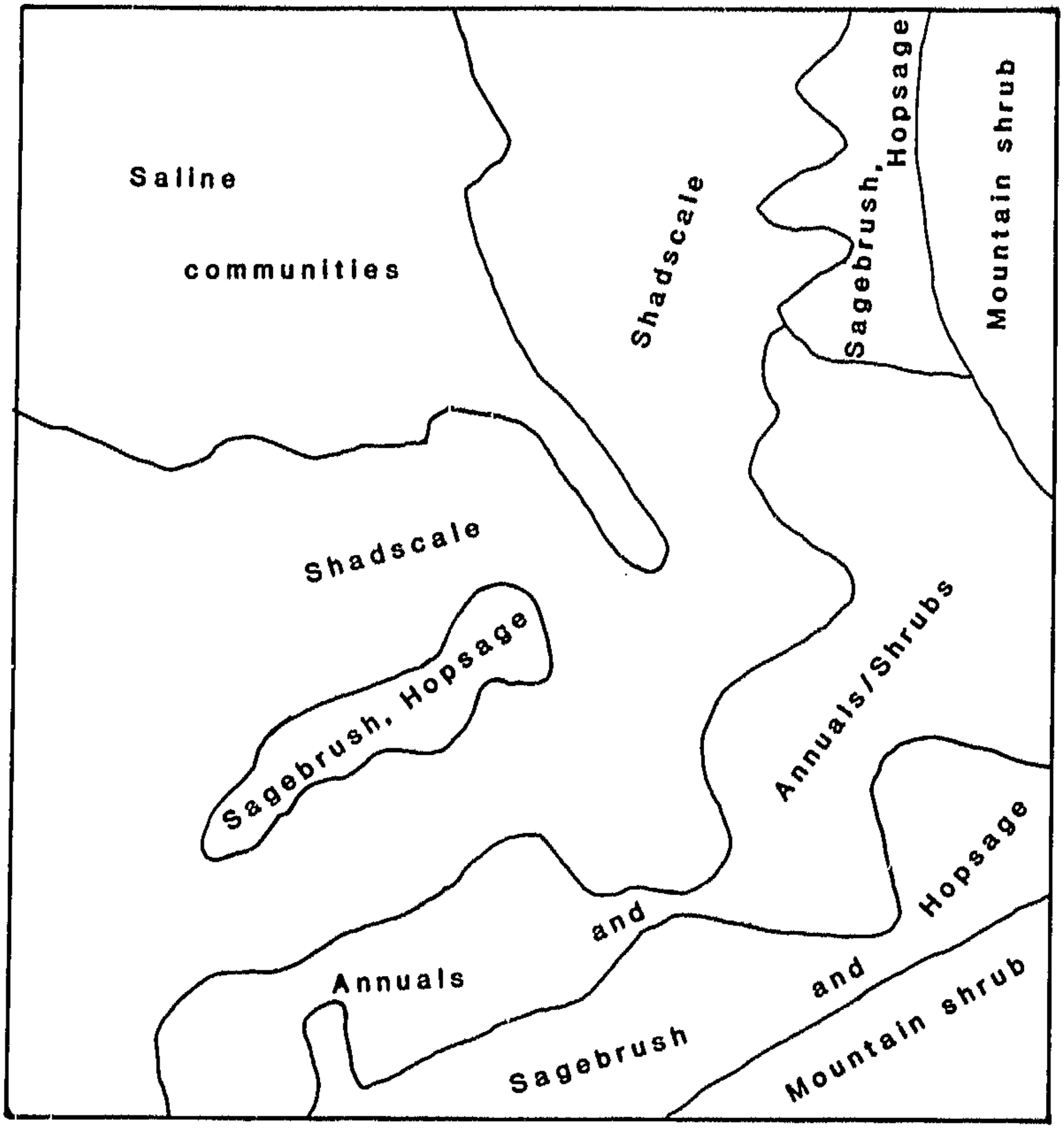

Figure 8. Generalized pattern of ecotypes as mapped in the study.

Map Display and Scatter Plot

Table 1 also shows the print symbols used on the final classification map. The NW quadrant of the map is shown as Figure 9a. Note the comparison with Figure 5, the preliminary classification. Figures 9b, 9c, and 9d complete the study area quadrangle. A full scale (1:24,000) version of Figure 9 is folded in as an endpiece. (An unfolded copy of the printmap, a transparent version of the printmap, and a half-tone of the orthophotoquad are submitted with the report, all at 1:24,000 scale.)

Figure 10 is a color image of the 17 classes taken from the color monitor with professional Ektachrome film. The color legend shown at right is in the same order as Table 1, as follows:

White	Atriplex falcata
Lime green	Salt desert mixed shrub
Bright green	Greasewood
Brown	Greasewood/Big saltbush
Olive green	Salt desert mixed shrub/Annuals
Light brown	Shadscale/Annuals
Orange	Annuals/Mixed shrub
Yellow	Annuals
Med. purple	Spiny hopsage
Dark purple	Sagebrush
Turquoise	Mixed shrub, sparse (south slope)
Indigo	Mixed shrub, dense (north slope)
Bright blue	Riparian (mountains only)
Maroon	Grass, moist site
Dark green	Saltgrass
Red	Agriculture, irrigated
Pale blue	Disturbed land or sand dunes

Figure 11 shows portions of the final classification in color at larger scale. Figure 12 shows the final groupings (map classes) on the scatter plot. Final classification printmap symbols, shown in "boxes," are consistent with Table 1 and Figure 9.

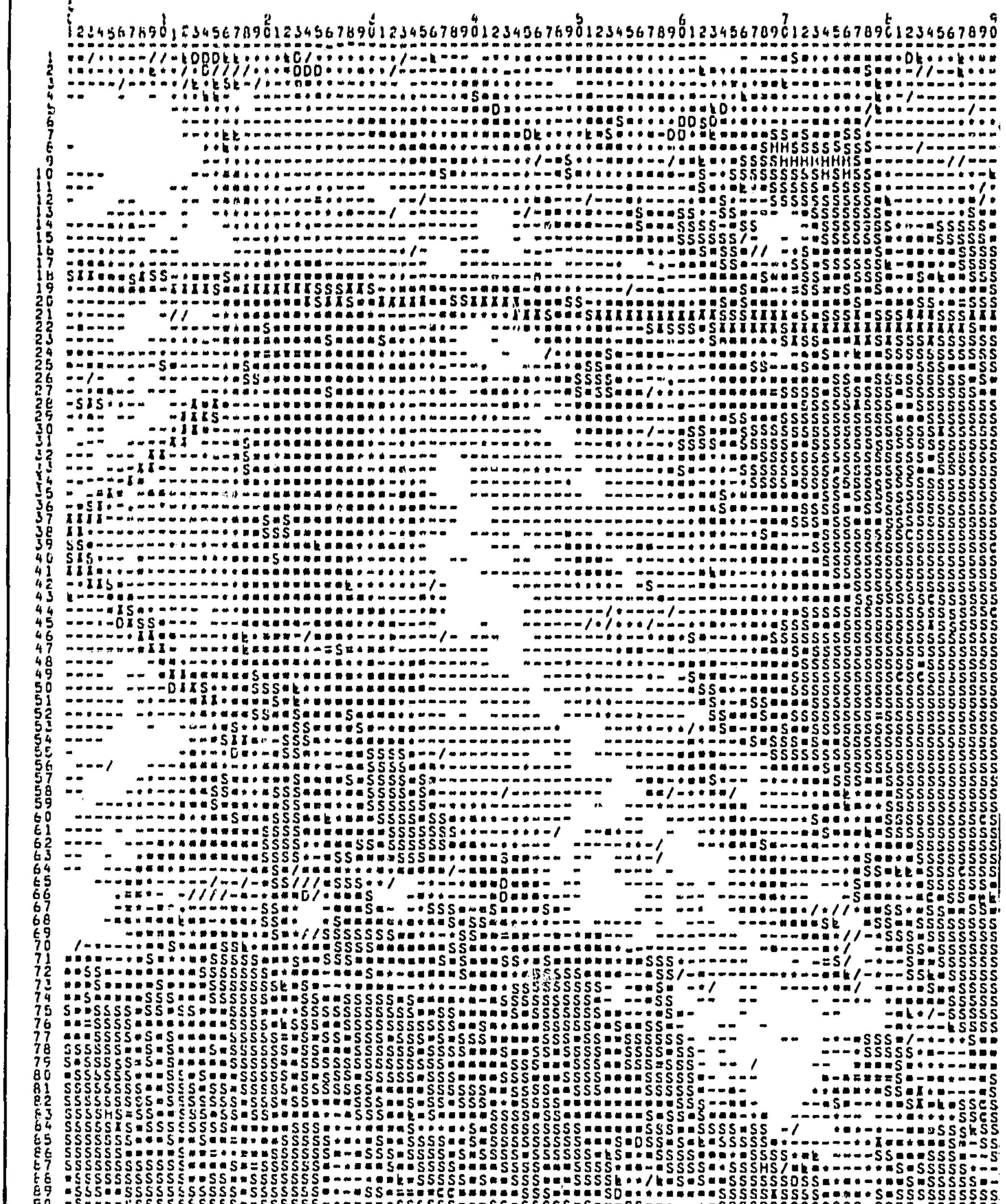

Figure 9a. Northwest quadrant of the final printmap.

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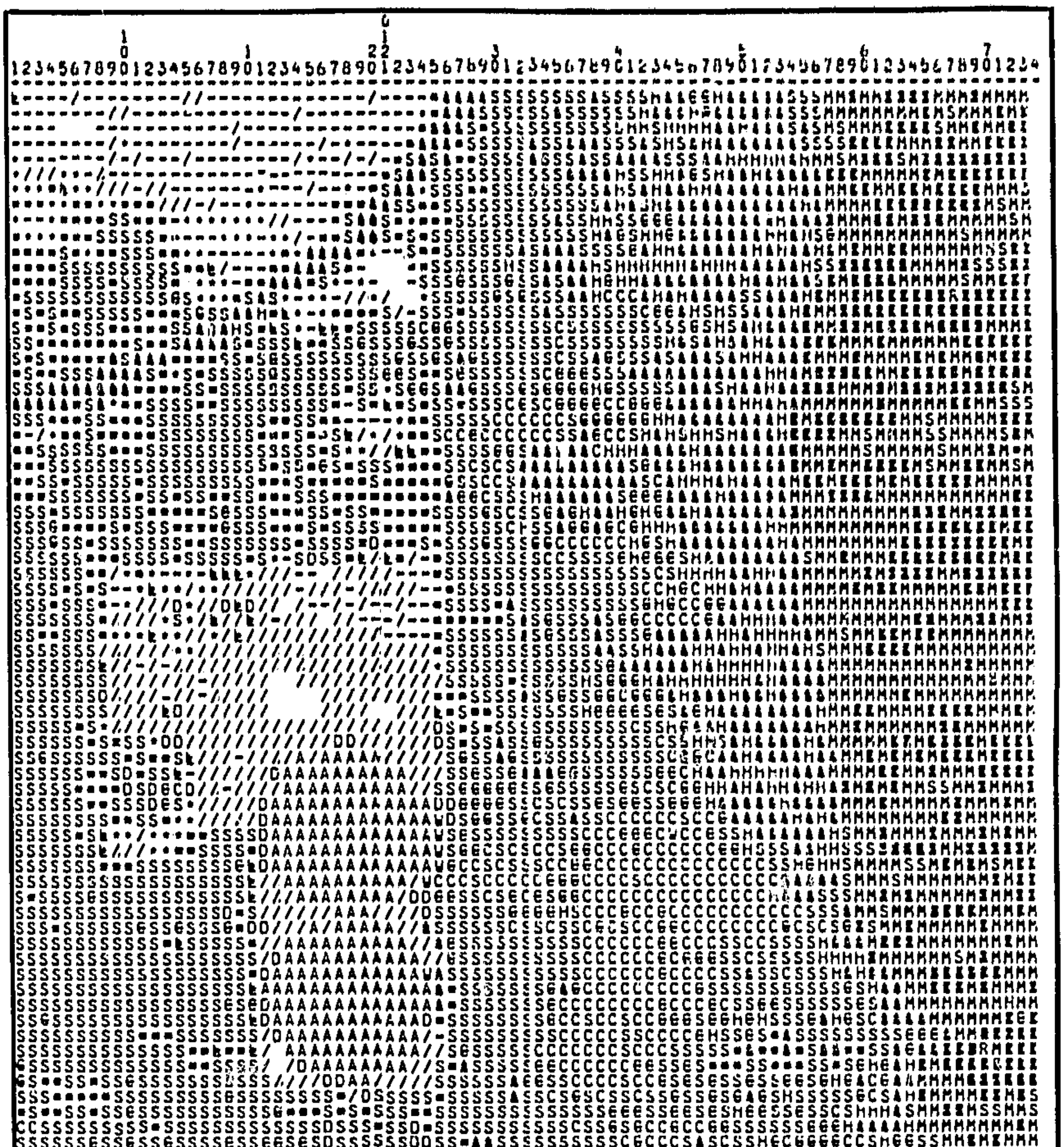

Figure 9b. Northeast quadrant of the final printmap.

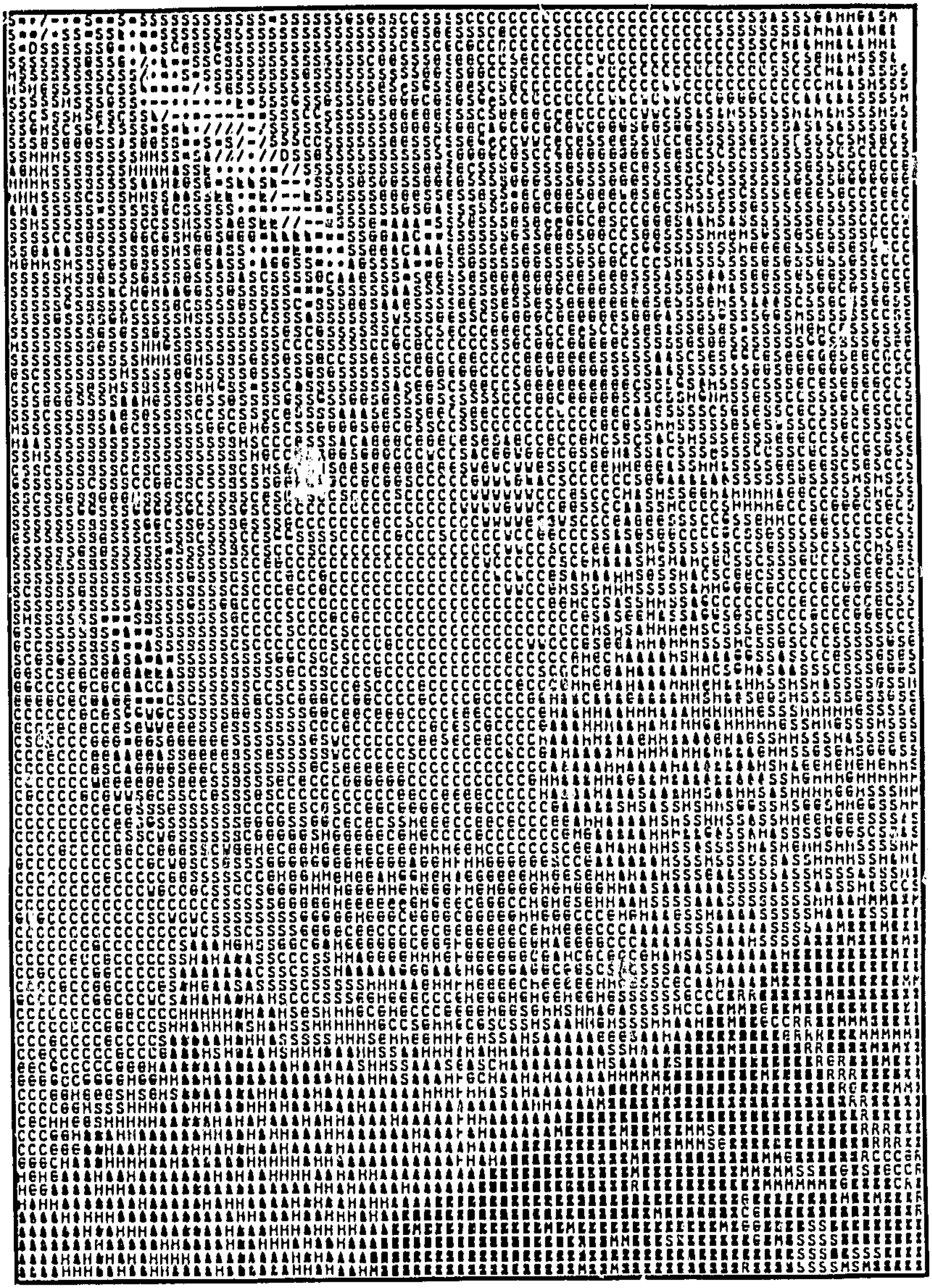

Figure 9c. Southeast quadrant of the final printmap.

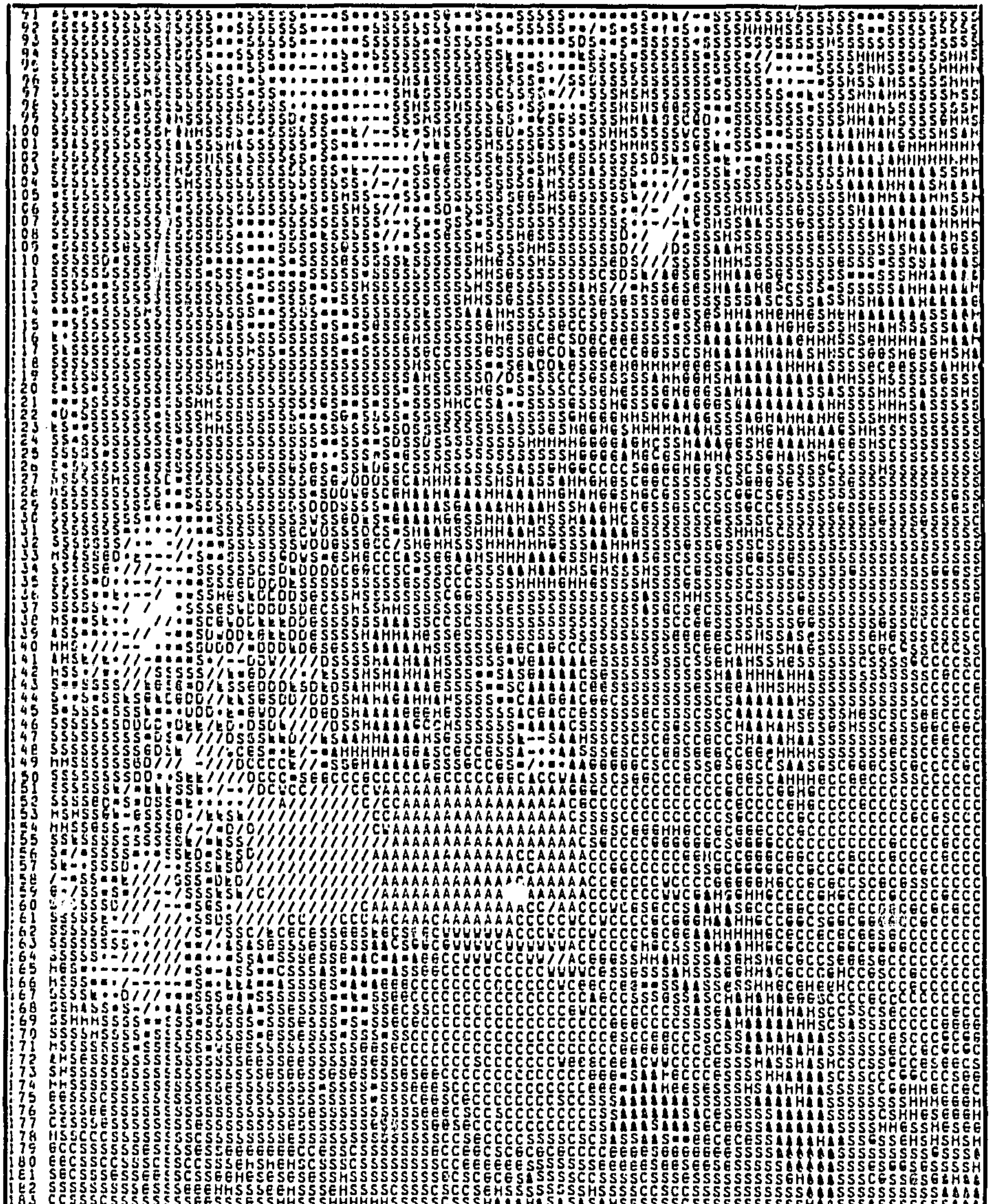

Figure 9d. Southwest quadrant of the final printmap.

Figure 10. Color image of the final classification map.


Atriplex falcata
Salt desert shru
Greasewood
Greasewood/
Big saltbush
SD shrub/Annuals
Shadscale/Annual
Annuals/Shrub
Annuals
Hopsage
Sagebrush
M shrub (south)
M shrub (north)
Ripirian
Grass, moist
Saltgrass
Agriculture
Disturbed

Figure 11. Portions of the final classification map at enlarged scale.

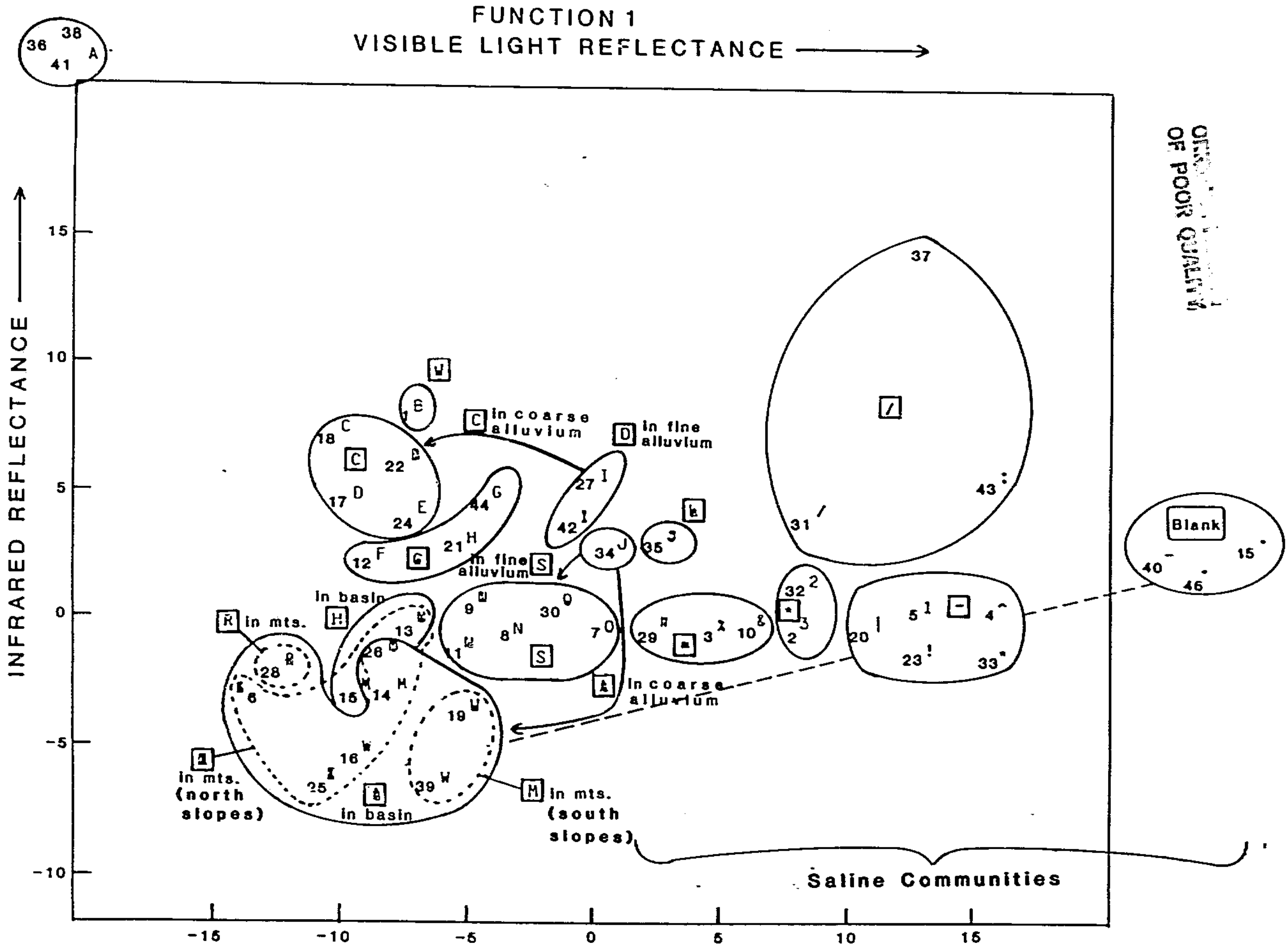

Figure 12. Final groupings of the map classes on the scatter plot, based on field data.

Of the 46 original signatures, 33 remain unchanged by geomorphic/soil stratification. The 13 that were changed are:

I I:	Saltgrass (Distichlis) on fine alluvium Annuals on coarse alluvium
J	Shadscale/Annuals on fine alluvium Sagebrush on coarse alluvium
M+ M.	Spiny hopsage in basin Mixed shrub, dense (north slope) in mountains
W. W-	Sagebrush in basin Mixed shrub, sparse (south slope) in mountains
OX-	Sagebrush in basin Riparian environment in mountains

Figure 12 also shows the changes. All but the I's and J are dark signatures. In the basin areas, the darkness is created by the heavy shrub content -- generally big sagebrush (<u>Artemesia tridentata</u>) shown as an "At" overstrike on the printmap and purple on the colored map, but in some places a dominant spiny hopsage (<u>Graya spinosa</u>) shown as an "H" and a light purple. In the mountains (dashed lines in Figure 12), the original "W." and "W-" are south-facing slopes of sparse mixed shrub, designated "M" on the final map. The north-facing slopes and darkest signatures are somewhat denser mixed shrub, designated with a "MIX" overstrike and indigo. A third mountain category is the original "OX-" symbol, designated as "R" for riparian on Figures 9 and 12, and bright blue on the colored map. The three mountain classes were derived largely from aerial photography and the scatter plot, with limited field observation, as the major emphasis in the study was placed in the basin.

"I" and "J" sites were limited in their distribution on the preliminary printmap. Three "J" sites were recorded in the field. They were very similar in growth form percentages, with 40-50% shrub and 30% annuals. However, in one site, the shrub composition was entirely sagebrush, while the other two were entirely shadscale (Atriplex confertifolia) and greasewood (Sarcobatus vermiculatus). The first site was on coarse alluvium near the mountains, and the other two on fine alluvium further from the mountains. The first site was assigned to the sagebrush class "At" (purple) and the other two to shadscale/annuals, or "S" (light brown).

Two "I" sites were recorded during the field work, but they represented very different environments. One was 90% annuals, consisting of 50% pepperweed (Lepidium perforatum) and 40% cheatgrass (Bromus tectorum). The other site was 20% shrubs, mostly rubber rabbitbrush (Chrysothamnus nauseous) and sagebrush; 45% saltgrass (Distichlis spicata); and no annuals. It was found that the first site was on coarse alluvium and the other on fine alluvium, presumably better able to hold soil moisture. Spectrally, they were inseparable but were separated by ancillary data input. The first site was assigned to the "C" category of cheatgrass and other annuals (yellow on the colored map), and the second was assigned to a class of its own, "D" for Distichlis (dark green) on the colored map. No 2x2 cells of "I:" pixels could be found, and they were categorized with the "I" sites.

An interesting ecological association occurs with the Distichlis sites and the moist grass sites. Along the fault scarp (near Bateman Spring, for example) the moist sites of perennial grasses (Poa, Sporobolus, etc.) occur at the foot of the scarp near seeps and springs. They appeared as "B" in the preliminary printmap and "W." (maroon) on the final map. On the edge of the upthrown block are clusters of saltgrass. The supply of fresh water supports non-salt tolerant grasses at the foot, while capillary rise to the upthrown ledge supports a salt tolerant community of perennial grasses. Spectrally, the two are shown on Figure 12. The "B" is assigned "W." in the final printmap. It is both darker (visible axis) and greener (infrared axis) than the "I". The "I" in fine alluvium, where it can carry capillary water, is assigned "D" in the final map. The "I" in coarse alluvium is heavily populated with annuals, and is assigned to join the annuals category "C" in the final printmap.

Away from the moist sites at the foot of the scarp, "B" sites were found to appear near the mouths of major canyons where moisture is abundant although the alluvium is coarse and recent. In such sites, the grasses are typically annuals, however. Two such sites were recorded in the field, one of which had a fair amount of sagebrush (15%).

In cases where field data is limited, class assignments must be regarded as tentative. However, where integrated logic of spectral data and ecological setting converge with field statistics, confidence is increased.

No field data were obtained for either the irrigated agriculture category nor the disturbed land. They stand apart spectrally ("A" and "/" respectively on Figure 12) from all other classes, and are not of direct concern in this study. The irrigated farmland is designated red on the colored map, while the disturbed land is light blue. Disturbed areas are of two types, those that were man-induced such as fallow fields, farmyards, other fields surrounding farms, and naturally disturbed sites such as aeloian deposits making up sand dunes. Man-induced disturbance was easily recognizable by their large square or rectangular spacial distribution and the internal homogeneity of spectral classes. Natural disturbance was more difficult to identify due to the irregular shape and internal heterogeneity in spectral classes. These areas were identified by using field observations and aerial photography.

Pictorial Summary

The major ecotypes represented by the final classes are illustrated in colored slides as Appendix B. The mountain classes, agriculture class, and disturbed land class are not depicted.

Figure 13 is an unrectified false color composite (FCC) of raw MSS data of the study area. Figure 14 is a rectified FCC of the same. A comparison with Figure 8 reveals the general pattern of ecotypes in the study area.

Statistical Summary

Table 2 shows the frequency distribution and coverage of the original 46 class symbols derived from SRCH. The table also shows the number of field sites per SRCH class. On the right side, the table shows the groupings into 17 final classes, the frequency, coverage, percent each class is of the total study area, and number of field sites per final class.

The "shadscale/annuals" class makes up 33.5% of the total quadrangle (10,719 of 32,016 pixels). In descending order, "annuals," "salt desert mixed shrub/annuals," "annuals/mixed shrub," "salt desert mixed shrub," and "sagebrush" make up 10.2%, 9.9%, 8.2%, 7.9%, and 7.1%, respectively.

Table 3 summarizes the percent cover by life form and non-living material for the 17 final classes. Table 4 summarizes the percent cover by species for the 17 final classes.

Figure 13. Unrectified false color composite (FCC) of raw MSS data of the study area.

Figure 14. Rectified FCC of the raw MSS data of the study area.

Table 2. Preliminary SRCH Classes and Final Classes, with Frequency, Hectares, and Field Sampling Base.

PRELIMINARY CLASSIFICATION					FINAL CLASSIFICATION					
SRCH Class	Prelim. Symbol	Pixel Count	Hectares	Field Sites	Final Symbol	Class Name	Pixel Count	Hectares	Percent of Total	Field Sites
45	.	279	130	1	Blank	Atr falc	699	325	2.2	3
46	+	258	120	1						
40	-	162	75	1						
4	^	450	209	1	-	Salt Des Sh	2,518	1,171	7.9	5
33	•	409	190	2						
5	1	365	170	0						
23	|	447	208	0						
20		847	394	2						
32	2	323	150	0	*	Greasewood	1,164	541	3.6	1
2	3	841	391	1						
35	J:	241	112	1	L*	Gr - Atr lent	241	112	0.8	1
10	&	523	243	1	*-	Salt DS/Ann	3,179	1,478	9.9	6
3	%	1,116	519	2						
29	#	1,540	716	3						
7	O	2,045	951	4	S	Shadscale/Ann	10,7[illegible]	4,985	33.5	20
30	O.	2,259	1,051	4						
8	N	2,440	1,135	6						
9	N:	1,831	852	2						
11	N.	1,813	843	2						
34	J	389	181	2						
44	G	291	135	1	C-	Ann/Shrub	2,625	1,220	8.2	9
21	H	1,017	473	3						
12	F	1,328	618	5						
24	E	1,426	663	1	C	Annuals	3,268	1,520	10.2	5
17	D	904	420	1						
18	C	595	277	1						
22	B:	249	11[illegible]	1						
27	I	49	23	1						
42	I:	50	23	0						
13	M·	1,239	576	1	H	Hopsage	1,549	720	4.8	3
15	M+	310	144	2						
26	M:	1,079	503	4	At	Sagebrush	2,294	1,069	7.1	8
14	M-	365	170	0						
19	W.	389	181	2						
39	W-	109	51	0						
16	W+	139	65	1						
25	WXI	20	9	0						
6	OX+	12	6	0						
28	OX-	34	16	0						
34	J	147	68	1						
19	W.	321	149	0	M	Mix Shrub Sparse	781	393	2.6	0
39	W-	460	244	0						
13	M·	54	25	0	MXI	Mix Shrub Dense	1,335	620	4.2	0
26	M:	208	96	0						
14	M-	200	93	0						
15	M+	202	94	0						
16	W+	381	177	0						
25	WXI	238	111	0						
6	OX+	13	6	0						
28	OX-	39	18	0	R	Riparian	34	16	0.1	0
1	B	183	85	2	W·	Grass, moist	183	85	0.6	2
27	I	127	59	1	D	Saltgrass	224	104	0.7	1
42	I:	97	45	0						
36,38,41	A	419	195	0	A	Agr. irrigated	419	195	1.3	0
31,37,43	1,Blank,:	766	357	0	/	Disturbed	766	356	2.4	0
TOTALS		32,015	14,891	64			32,016	14,891	100	64

Table 3. Percent total cover by life form and non-living material for the 17 final classes.

Preliminary Map Symbol	Final symbol	Description		Shrub	Annual forb	Annual grass	Perennial grass	Total	Cryptogams	Total	Litter	Rock	Bare
. + -	(blank)	Atriplex falcata	Mean	35	1			36	38	74	4		22
			Range	10-45	0-1			30-46	25-45	71-75	3-5		20-26
• !	-	Salt desert mix shrub	Mean	44	1	1		45	35	79	1		19
			Range	40-50	0-2	0-3		40-50	30-40	70-90	0-5		10-25
2 3	•	Greasewood	Mean	35		10		45	25	70			30
			Range										
J	E	Greasewood/ Big saltbush	Mean	50	5	5		60	10	70			30
			Range										
& % #.	=-	Salt desert mix shrub/Ann.	Mean	33	7	10		48	22	70	5		23
			Range	25-35	0-30	0-20		38-60	15-40	60-92	2-10		13-30
J O O N N N	S	Shadscale/ Annuals	Mean	35	7	23		65	11	76	9		14
			Range	15-50	0-30	2-50		55-80	0-30	55-90	9-25		5-50
F G H	C	Annuals/ Mix shrub	Mean	17	18	32	1	67	2	69	17	1	10
			Range	T-35	0-70	10-70	0-5	19-85	0-15	30-95	10-35	0-5	4-24
I I B C D E	C	Annuals	Mean	T	21	32		63		63	19	1	19
			Range	0-T	5-50	10-60		50-90		50-90	2-39	0-2	9-30
M M	H	Spiny hopsage	Mean	30		38		68	13	80	9	8	5
			Range	25-35		25-50		60-75	0-25	55-85	5-10	0-15	5-5
M W V W ? # # J	A	Sagebrush	Mean	40	3	24	3	70	9	78	5	2	15
			Range	30-50	0-15	3-40	0-20	46-90	0-25	70-85	5-5	0-15	5-25
W W	M	Mix shrub, sparse (south slope)	Mean										
			Range										
W # # M M M M	M	Mix shrub, dense (north slope)	Mean										
			Range										
#	R	Riparian	Mean										
			Range										
B	W	Grass, moist site	Mean	8	30	36		74		74	12		15
			Range	0-15	15-45	2-70		62-85		62-95	10-13		2-28
I I	D	Saltgrass	Mean	20			45	65		65	10		25
			Range										
A	A	Agriculture	Mean										
			Range										
(blank) : /	/	Disturbed	Mean										
			Range										

Table 4. Percent total cover by species for the 17 final classes.

Preliminary Map Symbol	Final symbol	Description		Bromus tectorum	Lepidium perforiatum	Descurania pinnata	Sisymbrium altissimum	Artemisia tridentata	Atriplex confertifolia	Artemisia spinosa	Sarcobatus vermiculatus	Tetradymia spinosa	Grayia spinosa	Chrysothamnus viscidiflorus	Atriplex falcata	Suaeda fruticosa	Atriplex lentiformis	Gutierrezia sarothrae	Chrysothamnus nauseosus	Distichlis spicata	Bouteloua spp.	Poa spp.
. + -	(blank)	Atriplex falcata	Mean			33			1		6				25	1						
			Range			0-1			0-4		5-7				20-30	1-4						
+ !	-	Salt desert mix shrub	Mean	1					14		6				13	11						
			Range	0-3					0-10		5-7				3-25	7-25						
2 3	•	Greasewood	Mean	10					5		25											
			Range																			
. J	t	Greasewood/ Big saltbush	Mean	5	5						30						20					-
			Range																			
& X #	=-	Salt desert mix shrub/Ann.	Mean	11	5	1	1		11		12				4	6						
			Range	0-25	0-30	0-3	1-8		0-25		0-20	0-4			5-20	0-12						
J O O N U N	S	Shadscale/ Annuals	Mean	23	6	1	1	3	23	1	6	1	1			2		1				
			Range	2-50	0-30	0-2	0-4	0-30	8-45	0-15	0-25	0-5	0-5			0-10		0-10				
F G H	C	Annuals/ Mix shrub	Mean	29	20		1	1	12	2	2											1
			Range	10-85	0-70		0-4	0-5	0-30	0-5	0-20											0-5
1 I B C D E	C	Annuals	Mean	30	20	6																
			Range	10-60	5-40	0-25																
M K	H	Spiny hopsage	Mean	35				1	6		4		19	1								
			Range	20-50				0-2	3-8		0-7		18-20	0-2								
M W U W # # # J	A	Sagebrush	Mean	24	1	3		28	1		1	1	6	1				2			1	
			Range	3-30	0-5	0-15		0-49	0-5		0-3	0-2	0-39	0-5				0-8			0-10	
H W	M	Mix shrub, sparse (south slope)	Mean																			
			Range																			
W Z # N H M H	M	Mix shrub, dense (north slope)	Mean																			
			Range																			
8	R	Riparian	Mean																			
			Range																			
B	V	Grass, moist site	Mean	35	28		3	8														
			Range	2-70	10-45		0-5	0-15														
I I	D	Saltgrass	Mean					5											15	45		
			Range																			
A	A	Agriculture	Mean																			
			Range																			
(blank) : /	/	Disturbed	Mean																			
			Range																			

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Some general observations may be in order. It can be seen that in the first five classes, the saline communities of bottomlands, shrub cover is uniformly high, with means from 33 to 50% (Table 3). In addition, the range is fairly close, from 25 to 50% for all 16 field sites. Further, the shrub species are dominantly *Atriplex* spp. (*confertifolia*, *falcata*, and *lentiformis*) and greasewood (*Sarcobatus vermiculatus*), with some alkali seepweed (*Sueda fruticosa*). Annuals in these communities are limited, with none of the means above 10%, and no field site above 20%. Cryptogams, on the other hand, are at a maximum in these communities with means from 10 to 38% and a range from 10 to 45%. Litter is minimal, but bare soil is substantial, with means from 18 to 30% and a range of 10 to 30%. The abundance of bare soil, consistently higher than the alluvial apron communities, where means run from 5 to 18%, is consistent with the spectral location in Figure 12, at the right side of the brightness axis.

However, there is a paradox. Within the saline communities, the two groups with highest brightness ("*Atriplex falcata*" and "salt desert mixed shrub") also have the highest cover of cryptogams among all classes. The two greasewood classes, consisting of *Sarcobatus vermiculatus* and *Atriplex lentiformis*, have the highest percent bare soil, but lie inward from the bright end on Figure 12. Presumably shadowing from the shrubs overrides the bare soil influence, even in mid-summer, with a satellite overpass prior to 10 a.m.

Within the five classes of saline bottomland, there is a recurrent pattern where in the "*Atriplex falcata*" environment lies at the core ("blank" symbol on the printmap and white on the colored map). Around the perimeter of this saline core lies the "salt desert mixed shrub" ("-" and lime green on the maps), "greasewood" (* and bright green), "greasewood/ big saltbush" (L* and brown), and finally "salt desert mixed shrub/annuals" (=- and olive green). This pattern is repeated from place to place and is closely tied to microrelief.

Within the five classes dominating the alluvial apron communities is considerable variation. The "annuals" class is most unique, with no shrubs, and 63% annual grasses and forbs (dominantly two species, Bromus tectorum or cheatgrass, and Lepidium perforatum or pepperweed). The range of cover is wide for both species, 5 to 40% for pepperweed and 10 to 60% for cheatgrass. The two seem to be very interchangeable, usually totaling about 60%, with one or the other dominant. The "annuals" class occurs at a mid-level on the alluvial fans stretching outward from the mountains. The "annuals" group occupies the "greenest" space on the scatter plot. Later in the season, this would not be so, and the class would be much more difficult to detect spectrally.

The "annuals/mixed shrub" class consists of a slightly lower cover of annuals (50%), with a scattering of shrubs (17%), dominantly shadscale (Atriplex confertifolia). This group is quite varied in shrub-annuals proportions, and in total vegetation. The "G" sites (Figure 12) are lower in total vegetation, hence brighter than the "H" and "F" sites. The latter is often more shrubby, but not always. This group needs further study.

The "shadscale/annuals" class somewhat reverses the order of shrubs and annuals from the previous group, with 35% shrubs and 30% annuals. The shrubs are dominantly shadscale (23%) with some greasewood, sagebush, and others. The annuals are dominantly cheatgrass (23%) with 6% pepperweed. This group is in the heart of the swarm in Figure 12, lifting slightly above the "soil line" toward the green point due to the influence of cheatgrass.

The "sagebrush" (Artemisia tridentata) and "spiny hopsage" classes are quite intermingled spectrally and geographically. There is some risk in separating the two. Percent shrub cover is a little greater and percent annuals is a little less in the sagebrush sites, with total living cover about the same (78 vs. 80%). The apparently significant difference is the species composition, wherein Graya spinosa rises to 19% in the "H" sites. In the field, the distinction of the two classes seems quite consistent with subtle spectral changes from pixel to pixel. On the scatter plot, however, the two are quite intermingled. This division calls for further field and spectral study.

The mountain communities were not studied with actual field data. It could be that, upon field examination, the same species composition and cover characteristics that were observed in the basin would be obtained in the mountains. To be safe, the investigators delineated the mountain mass and digitally separated the area, so as to make no inferrence about its composition. It was observed on the printmaps that the original "W-" and "W." classes were consistently on south-facing slopes, while most of the remainder of the "sagebrush" and "hopsage" signatures (M: M- W+ WXI OX+ and M. M+, respectively) were consistently on north-facing slopes. Without attempting to search out the actual species composition in the field, we simply refer to them as mixed shrub, sparse, and mixed shrub, dense, in relative terms. The OX- "sagebrush" signature of the basin, when appearing in the mountain mass, was consistently in the bottom of major drainages where water appeared to be abundant, and where examination of the orthophotoquad seemed to justify the term "riparian."

The "moist grass site" seems to be justified from limited field data and orthophotoquad examination. As expressed earlier, wherever the "B" symbol occurred on the original printmap, a moist site was evident. This is definitely the case along the scarp at Bateman Spring, where perennial grasses are abundant. We obtained no field data there because no 2x2 pixel units were available. The two sites where "B" data was gathered were low places in alluvial fans adjacent to canyons, where annuals were more dense than for any other class (66%), and some shrubs were present, to bring the total living cover to 74%, the greatest of all classes.

The "saltgrass" class is limited in distribution (0.7% of the quad area as seen in Table 2). It is particularly noticeable near the fault scarps in the basin, on the upthrown block, where it apparently receives moisture upward from below, sufficient to support an abundant stand of grass (45%) but only salt tolerant grass (*Distichlis spicata*).

CLOSING COMMENT

The field data and statistical foundation of this pilot study are limited. The conclusions are only tentative. The landscape is varied. However, the 17 classes, as observed in the mean cover percentages seem to be fairly distinct and justifiable. In most cases the breakdown is supported by field observation, ecological relationships, spectral analysis, and theory.

If one looks below the surface, to the ranges of data, both by life form and species composition, considerable overlapping is evident. Thus, while the logic seems clear, there is sufficient noise in the system (e.g. overlapping ranges) to require (a) field verification and accuracy statements, and probably (b) further field data and analysis.

The spatial variability of field ecosystem patterns is nicely scaled to Landsat geometry. Although the field pattern is varied, there are generally large enough ecotype units to be approachable with MSS data. The general patterns across the quadrangle are orderly (as seen in Figure 8), and the subunits within are generally large enough and homogeneous enough to yield to MSS pixel geometry, and apparently to MSS spectral and radiometric fidelity as well. Yet there are both linear and areal patterns of small enough dimensions, and distinct enough ecological character, to provide a substantial challenge.

It appears there is a sound opportunity to correlate MSS data with field radiometric data. Because of the combination of field patterns of ecotypes, it would seem an ideal test case to explore statistical correlations between ground level data and satellite data.

This preliminary investigation should form a good foundation for several avenues of research. A few such avenues are:

1. Correlation of ground radiometry with MSS data to better understand atmospheric influences, ecotype, radiometric, and statistical associations.
2. Further analysis by MSS to determine its range of capabilities in determining ecotypes in this part of the Great Basin.
3. Comparative study by TM as related to MSS for <u>accuracy</u> and <u>efficiency</u> assessment.
4. Comparative study of the above with other sensors, including radar (for topographic and soil moisture determination), TIMS

(for vegetation and moisture assessment), AIS (for detailed determination of vegetation as well as soil moisture and chemistry), and other sensors.

5. A comprehensive modeling of the various integrated natural systems in the northern Great Basin, in terms of geology (structure and lithology), physiography (terrain and geomorphic process and material), soil (texture, structure, chemistry, and dynamics of movement), hydrology (surface and subsurface regimens in contrasting seasons), and vegetation response to the above.
6. The implications of the above to military, agricultural, or other specified uses.

These may be lofty objectives, but they do seem to have a rational potential for remote sensing investigations.

APPENDIX A. A SUMMARY OF SRCH

Prior to initial field investigation, an unsupervised classification map was prepared for the study area using the reformatted raw Landsat data (Figure 2). The classes for the map were derived using a program from the ELAS program package called SRCH (abbreviated from Search). SRCH derives classes by passing a 3x3 window through a selected area, or areas, of the image according to parameters set by the operator based on several sets of statistics: standard deviation lower bound (SDLB), standard deviation upper bound (SDUB), and the coefficient of variation (COV), applied to all channels. These parameters were set at 0.05, 5.0, and 1.0 respectively in this study. These parameters, along with the average and the variance for each channel for the 3x3 window, are used in a test for homogeneity. The test is used to assess the variance for a given channel. If the variance is within the prescribed bounds, the test is passed, and an HTFS (homogeneous training field statistic) is saved in one of the "BINS," or storage locations.

The maximum number of BINS is determined by the parameter NBIN, or number of BINS. In this analysis, NBIN was set to 100. SRCH continues to collect HTFS until all BINS have been filled. Typically, NBIN is filled before the specified area has been fully searched. When all BINS are filled, another set of statistics is generated. This set is called "merged statistics."

The merging process is used to make room for more HTFS, as SRCH continues. The HTFS are merged based on the parameter called SDIS, scaled distance between statistics. The scaled distance is computed for each pair of HTFS. For NBIN set at 100, (100x99)/2, or 4,950, scaled distances are computed. The scaled distance is a measure, over all channels, of the difference between the mean value of the pixels used to derive each HTFS.

The process of merging statistics begins by determining the lowest scaled distance for all pairs of HTFS. If this value is lower than threshold value set by the operator (3.0 in this study), the two HTFS are averaged together, to accomplish the merger process. If the lowest scaled distance is higher than SDIS, then the discard logic is invoked. The discard logic is given in the ELAS manual (Vol. II, pp. 7-1 and 7-2). If a reasonable SDIS is chosen, the discarding of HTFS would not occur. An SDIS of 3.0 is the default value and most likely with this threshold no statistics have been discarded.

After merging two HTFS, one BIN is opened and is available for another HTFS. Another HTFS is collected and the merging process is initiated again until the entire area or areas are processed. At this point, the final set of statistics are derived in the process called "final preparation" (FP). The final statistics are based on two parameters. The first parameter is SDIS, and the second parameter is MAXC, maximum number of classes to be used in classifying the image (60 in this study). The HTFS and merged statistics are iteratively merged until all scaled distances between pairs are greater than SDIS; if the number of remaining sets of statistics is greater than MAXC,their discard logic is invoked (op cit).

All sets of statistics including HTFS, merged statistics, and final statistics consist of the following:

1. Mean value for all channels.
2. Standard deviation and coefficient of variation for cell channels.
3. Upper triangle of the covariance matrix for cell channels.
4. Chi-square value, a priori value, and number of points (pixels).

All equations used for computing statistics in SRCH are given in the ELAS manual (Vol. II, Appendix A, pp. A-11 to A-13).

APPENDIX B.

SLIDES OF MAJOR CLASSES