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THE COMPARATIVE EVALUATION OF ERTS - I

IMAGERY FOR RESOURCE INVENTORY IN LAND USE PLANNING

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Preface

This is a progress report for a multidiscipline study of ERTS applications in resource monitoring inventory and land use planning in Oregon. The overall objectives of the investigation are:

1. Use a multidisciplinary team approach to determine features that can be successfully monitored by ERTS-1 imagery for resource inventory, land-use planning, zoning and resource development.

2. Using carefully selected sample areas, develop a comprehensive resource inventory mapping system for use in resource planning and development.

The work is state-wide in scope, but a major in-depth study is being conducted only on Crook County, in Central Oregon. Resource maps of geology, soils, vegetation-land use, land forms and timber volume have been prepared on ERTS and highflight support imagery. These are being consolidated into Land Resource Units to present coordinated interpretations for making land use decisions. Local evaluation of applications of the imagery and resource data is to be done with the aid of an extension specialist working in the county.

The final design for the multistage Timber Volume inventory is described, applications for inventorying clearcutting practices and monitoring forest disease and insect damage are reported. Stereo-Viewing of ERTS imagery for lineament mapping in forested terrain of Western Oregon is shown to be very useful. Programs for automatic classification of digital data are operational, and several areas have been classified to demonstrate computer implemented mapping of geologic features and classes of natural vegetation.

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16. Abstract

Multidiscipline Team interpretation and mapping of resources for Crook County is nearly complete on 1:250,000 scale enlargements of ERTS imagery. Maps of geology, landforms, soils and vegetation-land use are being interpreted to show limitations, suitabilities and geologic hazards for land use planning. Mapping of lineaments and structures from ERTS imagery has shown a number of features not previously mapped in Oregon. A multistage timber inventory of Ochoco National Forest has been made, using ERTS images as the first stage. Inventory of forest clear-cutting practices has been successfully demonstrated with ERTS color composites. Soil tonal differences in fallow fields shown on ERTS correspond with major soil boundaries in loes-mantled terrain. A digital classification system used for discriminating natural vegetation and geologic material classes has been successful in separation of most major classes around Newberry Cauldera, Mt. Washington and Big Summit Prairie. Computer routines are available for correction of scanner data variations; and for matching scales and coordinates between digital and photographic imagery. Methods of Diazo film color printing of computer classifications and elevation-slope perspective plots with computer are being developed.

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INTRODUCTION AND SUMMARY

During this reporting period, substantial progress has been made in compiling a multidiscipline resource and land use inventory for the pilot study area of Crook County. Maps of geology, landforms, soils, vegetation-land use are nearly complete on enlarged ERTS imagery with a scale of 1:250,000. More detailed mapping and ground truth checking of these resources has been made with NASA U-2 support highflight photography and is being compiled on a photo-mosaic constructed for the county at a scale of 1:125,000. Descriptive legends have been prepared for use with these maps, as well as digital legends to facilitate computer storage and retrieval of resource information. Geologic interpretations for land use have been made and soil interpretations of land use suitability and limitations have been compiled for most of the recognized soil taxonomic units.

A photo-lineament map of Crook County at 1:125,000 scale is partially completed. Comparative mapping techniques using ERTS 1:1000,000 scale imagery have been analyzed in heavily forested areas and a preliminary lineament map of Western Oregon has been made. Stereo viewing was found to be essential for reproducible results. Lineaments and structures have also been delineated on several ERTS frames in Eastern Oregon. Much of the multistage timber inventory experiment on the Ochoco National Forest is completed. Analyses of the results from initial sample plots indicate some limitations of both ERTS and the U-2 highflight photography for stratifying stands using the initial sampling design. Accordingly, the sampling design was modified to include two, rather than five stocking classes on ERTS; a second stage of sampling plots on 1:30,000 scale air photos; and two stages of field measurements on subplots. Statistical analysis of the data and comparison of results with the 1972 conventional inventory, with a cost-benefit analysis will complete this experiment.

ERTS color composite imagery at 1:250,000 and 1:1,000,000 scales has been used successfully for analysis of forest clear cutting practices by ownership on two sampling blocks in N. W. Oregon. This testing will be expanded to include sample areas in S. W. Oregon and the use of sequential imagery for identification of new clearcuts. Preliminary investigations with ERTS imagery have shown limited success in identifying areas of lodgepole pine mortality from Mountain Pine Beetle infestation, but the investigators were unable to discern Poria weirii damage in Douglas fir.

Areas of periodotite bedrock in S. W. Oregon, as distinguished on ERTS color composite imagery, were found to correspond with previously identified serpentinitic soil areas occupied by open stands of Jeffrey pine and brush. Dry soil tonal reflectence patterns on ERTS imagery of fallow fields in loess-mantled terrain were shown to correlate with soil associations mapped along a climatic transect in N. E. Oregon.

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A computer classification system for ERTS digital data is operational and has been used to classify several test areas in Oregon. A vegetation classification using the 4 bands of digital data was developed and tested for 10 natural vegetation cover classes in the Big Summit Prairie area of Crook County. A close correlation was found with photo interpretive mapping. However, training sets from one date resulted in greater misclassification when used with data for a subsequent date, or when used in a different ecological zone. Training sets for the additional classes of vegetation corrected some initial errors but did not eliminate confusion between low sagebrush scabland and juniper/sagebrush classes.

Terrain features of the Mt. Washington region in the Central Oregon Cascades were automatically classified into 4 classes of geologic material, two vegetation cover classes and water. Separation of Recent Lava Flows into two classes was successful. Salishan Spit on the Oregon coast was classified automatically into wet sand, dry sand, and mud flat areas to establish base information for subsequent monitoring of erosion and sediment transport. A digital classification of the Newberry Cauldera area in Central Oregon successfully separates rock materials, vegetative cover and water into 7 classes by composition and texture.

The Diazo process is now being used to produce false color infrared and other color reconstitutions. These have been used to date in the forestry clear-cutting analysis. This method will give our investigation the advantages of greater availability and flexibility in use of color products and will be used in comparative evaluations by several co-investigators.

Computer routines have been developed to detect and summarize variations within scanner sweeps. These routines provide a guide for applying corrections to digital scanner data. Programs have been implemented that allow transfer of digital data and map coordinates to different scales. This will permit computer-derived overlays of digital data classifications to match photographs or maps and derivation of resolution element coordinates for areas located on photos or maps - an aid in locating training sets on gray scale printouts.

Methods of digital information display under development include colored classification maps produced by stacking Diazo color films representing each class, and perspective plots visually portraying elevations and slope of an area with a three dimensional effect.

With the multidiscipline resource inventory now nearing completion we will be initiating an intensive evaluation of the data and forms of presentation within the pilot study area. We will be combining the information into coordinated descriptions and land use interpretations for Land Resource Units derived from the separate soil, vegetation, geology, land forms and land use inventorys. The Land Resource Units will be delineated on ERTS Imagery at appropriate scales. An extension specialist will be located full time in Crook County to facilitate the evaluation and to aid local users in applying the information and using the imagery.

FORESTRY APPLICATIONS

Multistage Timber Inventory in Central Oregon

In the initial phases of this research, it was believed that strati-
fication of timber density classes from ERTS-1 imagery was both feasible
and beneficial. The results of this stratification has been previously
reported and summarized in the first six-month report. For any stratifi-
cation to be beneficial to the resource there must be a reduction in the
sampling error (standard error of the mean expressed as a percent of the
mean) among stratified as compared to non-stratified plots. The separation
of forested versus non-forested lands, which is easily accomplished with
ERTS-1 imagery, was not considered to be of much value on the Ochoco Nat-
ional Forest because this separation within the forest boundary is already
known. To determine the statistical gain in efficiency resulting from
crown density stratification the following analysis was conducted using
the interpretation results of three experienced interpreters.

Twenty plots were randomly selected in each of the five strata de-
lineated on ERTS imagery and previously reported. These 100 plots were
then located on the NASA-Ames 1/120,000 highflight color IR positive
transparencies. Interpretation of the percent crown closure for each plot
was then completed by all three interpreters, (Table 1).

To test the efficiency of density class delineation, the same 100
plots were then considered to be one non-stratified sample and used as the
basis for comparison of gains in sampling efficiency. The results of this
comparison (Table 2) showed only a slight (average 5.20%) gain in sampling
efficiency when using all five forest density classes delineated on ERTS-1
imagery.

Based on a statistical analysis of the initial stratification, it ap-
peared that we attempted stratification into too many classes and that com-
bining certain strata would prove to be more efficient. Table 2, shows
the results of several groupings of strata and their resultant gains in
efficiency.

These results clearly demonstrate that the use of two strata provides
the largest gain in efficiency (19.54) over the non-stratified population.
The question arises then: "What was wrong in the original five strata de-
termined from ERTS-1 imagery?" Preliminary analysis and review indicate
that three major factors influenced this problem of stratification. The
first factor is that of shadow. With a 10 o'clock sun angle, north-facing
slopes are in shadow and therefore appear anomalously dark on the color-
enhanced imagery. The more dense forests of the region coupled with shadow
on the north and west slopes caused the interpreter to overinterpret the
dark tones on the color-enhanced imagery. This error was even greater when
only the black and white MSS-5 band was used.

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Table 1. Photo Interpretation Results of Percent Crown Closure from 1:120,000 NASA-Ames High-flight Photogrammetry

Density Class (Strata)	Percent Crown Closure Statistics		Interpreters A	B	C	Average A+B+C
I	$\bar{x}$	(mean)	13.0500	10.2500	7.7000	10.3333
	s	(standard deviation)	14.9225	11.7063	10.5536	12.3941
	$s_{\bar{x}}$	(standard error)	3.3367	2.6176	2.3598	2.7714
II	$\bar{x}$		36.0000	27.0000	23.7500	28.9167
	s		15.1830	11.4017	14.1305	13.5717
	$s_{\bar{x}}$		3.3950	2.5494	3.1596	3.0347
III	$\bar{x}$		49.7500	42.7500	39.7500	44.0833
	s		19.8994	16.7390	21.7325	19.4570
	$s_{\bar{x}}$		4.4496	3.7429	4.8595	4.3507
IV	$\bar{x}$		60.5000	55.2500	59.0000	58.2500
	s		20.7681	18.3155	18.8204	19.3013
	$s_{\bar{x}}$		4.6438	4.0954	4.2083	4.3158
V	$\bar{x}$		52.7500	53.0000	50.4000	52.0500
	s		19.2268	25.2044	28.6822	24.3711
	$s_{\bar{x}}$		4.2992	5.6358	6.4135	5.4495

Table 2. Sampling Errors and Gains in Efficiency for Non-Stratified and Various Groupings of Strata

Strata Grouping	Interpreter A $S_{\bar{y}st}$	Gain	B $S_{\bar{y}st}$	Gain	C $S_{\bar{y}st}$	Gain	Average $S_{\bar{y}st}$	Gain
Non stratified	6.36%		6.27%		6.97%		6.53%	
Five strata	6.42%	- 0.94%	5.35%	14.67%	6.81%	2.30%	6.19%	5.20%
3 Combined strata (1,2), (3,4), 5	5.94%	6.60%	5.10%	18.66%	6.04%	13.34%	5.69%	12.68%
3 Combined strata (1,2), 3, (4.5)	7.94%	-24.83%	6.94%	-10.69%	8.35%	-19.8%	7.74%	-18.47%
2 Combined strata (1,2), (3,4,5)	5.15%	19.03%	4.94%	21.21%	5.68%	18.51%	5.16%	19.54%

The second factor contributing to error is the lack of tonal signature distinction between forest species and brush species in this region. Because of the lack of height definition on ERTS-1 imagery, tonal signature becomes the critical defining characteristic of vegetation. Although little difficulty has been found in separating grasslands from forest lands, separation within the forest lands of trees and brush presents some difficulty.

The third factor contributing to error is the lack of proper processing of ERTS-1 imagery to produce a balanced grey scale within the image frame. It appears that the imagery received is processed for maximum total delineation of the range and agricultural lands which are primarily in the lighter shades of grey. The forested lands, imaged in darker tones are reproduced with a resulting lack of tonal separation sufficient for fully utilizing the information content of the image. (Examples: ERTS-1 Frame E-1076-18211-5 and E-1040-18210-5.)

Interpretation of Forest Lands from NASA-Ames Highflight Imagery

The second and third stages of the multistage sampling design consisted of photo interpretation of selected plots on NASA-Ames highflight imagery at 1/120,000 and 1/30,000 photo scales. Interpretation of 100 random plots allocated at 50 plots per strata, was completed by three interpreters. On each of these 20.25 acre plots, three interpreters estimated percent crown closure - separately for both the upper and lower tree canopies for two-storied stands. From these data the next PPS subsample was selected and located on the 1/30,000 color IR positive transparencies.

Before subdividing the 1/30,000 plots into nine subplots, each interpreter interpreted the entire plot to estimate percent crown closure again. These measurements were then used to create ratios between the percent crown closure measured on 1/120,000 imagery and the 1/30,000 imagery. Statistically, these ratios should be about one, however, more important is consistency between the ratios among the plots. This consistency was not found in this case; for nonstocked stands, the ratios ranged from 1.111 to 15.789, while for the stocked stands, the ratios were from 0.802 to 7.857.

Review of each interpreter's results at this point showed that the ratio ranges were about the same in every case and therefore, it could be concluded that these ratios did not result from one interpreter's errors. Critical review of the imagery showed that the error arose from the quality of imagery contained in the NASA-Ames Highflight Mission No. 72-134 at 1/120,000 photoscale. The problem is shown in the loss of detail within the shadowed areas and is probably caused by underexposure or underdevelopment of the film. The latter cause is most probably due to the lack of vignetting in each frame. While the lack of quality does not seriously detract from the imagery use for range and agricultural land analysis, which are primarily restricted to fairly level topography, it basically defeats any use of forest land analysis in the Pacific Northwest where forest land is primarily mountainous topography. The result of this lack of quality resulted in the removal of the 1/120,000 imagery from the multistage sampling design.

Interpretation of Forest Lands from Contractual Imagery

To form the third stage of the multistage sampling design, contractual imagery was obtained of selected plots within the test area. The imagery format was 9 x 9 inch images at a photo scale of 1/4,800 taken with a new Zeiss 12 inch camera using Kodax Aeronegative film. Both color positive transparencies and panchromatic prints were obtained. Initial interpretation was completed on the transparencies and the black and white prints were used for locating plots in the field.

Each subplot was delineated on these images and interpreted for percent crown (%CC) closure, average visible crown diameter (VCD) and average total stand height class (HTC) for the upper and lower stories, if both were present.

Final Multistage Sampling Design for Forest Inventory of the Ochoco National Forest

The final multistage sampling design for this experiment consisted of three levels of imagery and two levels of field measurements. The first stage consisted of stratifying the Ochoco National Forest into two strata, poorly stocked and well stocked, from a color enhanced image of ERTS-1 frames E-1076-18211, 5, 6 and 7. The strata boundries were then plotted and 25 randomly located 20.25 acre plots are located in each strata. Ten plots per strata were then selected by probability proportional to size (PPS) for further sampling. These plots were located on the 1/300,000 NASA-Ames high flight No. 72-134 imagery and each plot was subdivided into 9 subplots of 2.25 acres size. Each of the 90 subplots was interpreted and measurements of percent crown closure (%CC) and average stand height class (HTC) were taken. Tweny subplots in each strata are then selected by Hartley's PPS rule for further measurement.

The second stage consisted of locating the twenty subplots of each strata on the contractual 1/30,000 imagery and measuring the %CC and HTC for each plot to establish ratios with the measurements from the previous stage. Each subplot was then further subdivided into 9 subplots of .25 acre in size. Each of these 360 plots was then interpreted for %CC, HTC and average visible crown diameter (VCD). Forty of these subplots were then PPS selected to be field measured as the final two stage of the design.

Field Measurement of Selected Subplots for Forest Inventory

Field measurements of the 40, .25-acre subplots, 20 from each strata, were completed as follows:

After each corner of the subplot had been located on the ground from the aerial photos, every tree over 5 inches diameter at breast height (dbh) was measured or estimated to the nearest two inch diameter class and total

tree height was estimated to the nearest ten foot height class. This information was used to calculate the volume of each tree using the Comprehensive Tree-Volume Tarif Tables (Turnbull, Little and Hoyer, 1972). Since this is primarily a ponderosa pine forest, ponderosa pine tarif access tables were used for all species at this stage. The use of tarif table instead of standard volume tables is justified by the findings of Hazard (4) who found that many of the standard pine volume tables for eastern Oregon contain a bias of 10 percent or more. The use of tarif tables is more fully explained in Appendix F.

These individual tree volumes were then listed to allow a selection of two trees per plot by PPS for more precise measurement, i.e., dbh was measured to the nearest 0.1 inch and the height to the nearest foot. At this stage, the tarif access tables used were correct for each species involved. The final results and statistical analysis of the inventory system will be included in our final report.

Analysis of Clearcutting Practices in Western Oregon from ERTS-1 Imagery

As an aid to the administration and enforcement of the Oregon Forest Practices Act of 1972, the Oregon State Department of Forestry is interested in monitoring the acreage of clearcuts made each year within the northwest and southwest regions of the state - especially the private industrial land holdings. Sequential ERTS imagery offers an excellent opportunity to collect this type of information. Potential success is particularly high in the Douglas-fir forested regions of western Oregon where clearcutting blocks of 20 or more acres is the common practice.

For a preliminary analysis, two areas have been sampled. The Cascade sample area consisted of 743,000 acres in the west central Cascade mountain range, east of Sweet Home, Oregon (see areas D in Figure 1). A 256 dot per square inch grid was used to sample the acreage of land classes by major ownerships on a slight enlargement (1:750,000 scale) of a color composite transparency - ERTS-1 Frame E-1041-18265. The Northwest sample area consisted of ten randomly selected townships on ERTS-1 Frame E-1006-18315 (Figure 2). A 400 dot per square inch grid was used directly on the ERTS composite without enlargement.

Acreage estimates for both test areas were made separately for private (Pvt.), Forest Service (U.S.F.S.), State (Oreg.) and Bureau of Land Management (B.L.M.) ownerships as to: clearcut, forest, non-forest and water surface areas. Clearcuts are those areas judged by the interpreter to have supported commercial timber, were cut and will be used for another timber crop. That is, areas judged to have been cleared for permanent agricultural use (valley bottoms etc.) were not counted as clearcuts in this study. Clearcuts were separated from other forest land based on the skill and judgement of the interpreter to distinguish clearcuts from the surrounding timber. That is, the new crop of vegetation within the clearcut is still distinguishable from the surrounding timber. Based on a previous study, this includes clearcuts, cut up to 20 years ago. Burned areas were classified as forest land and not included in the clearcut acreage. In general, clearcuts are relatively easy to distinguish because of their great contrast with surrounding timber, their geometric shapes, and frequent straight sides (see Figure 1).

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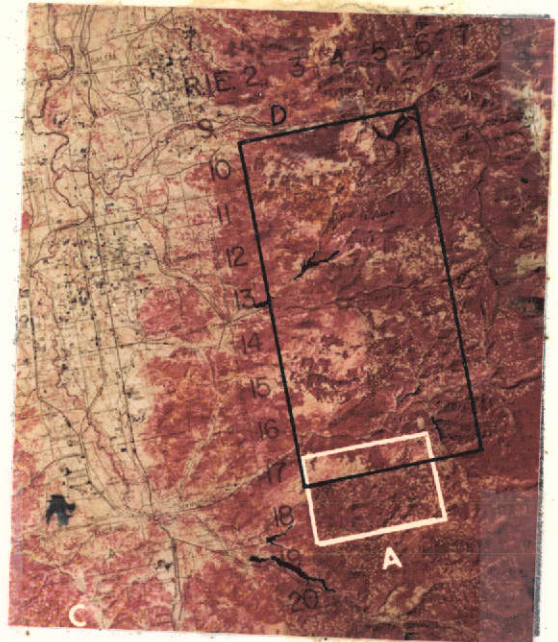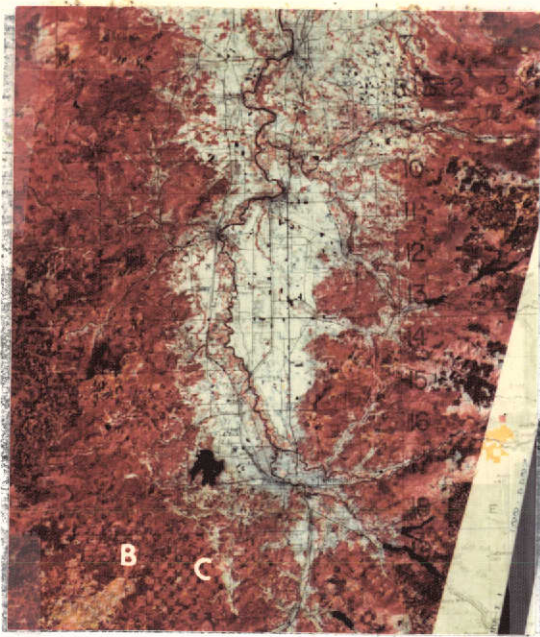
Figure 1. Comparison of diazo (upper left) and General Electric (upper right) color composites. The lower photograph is a high-flight reproduction of area A showing patterns and condition of clearcut units.

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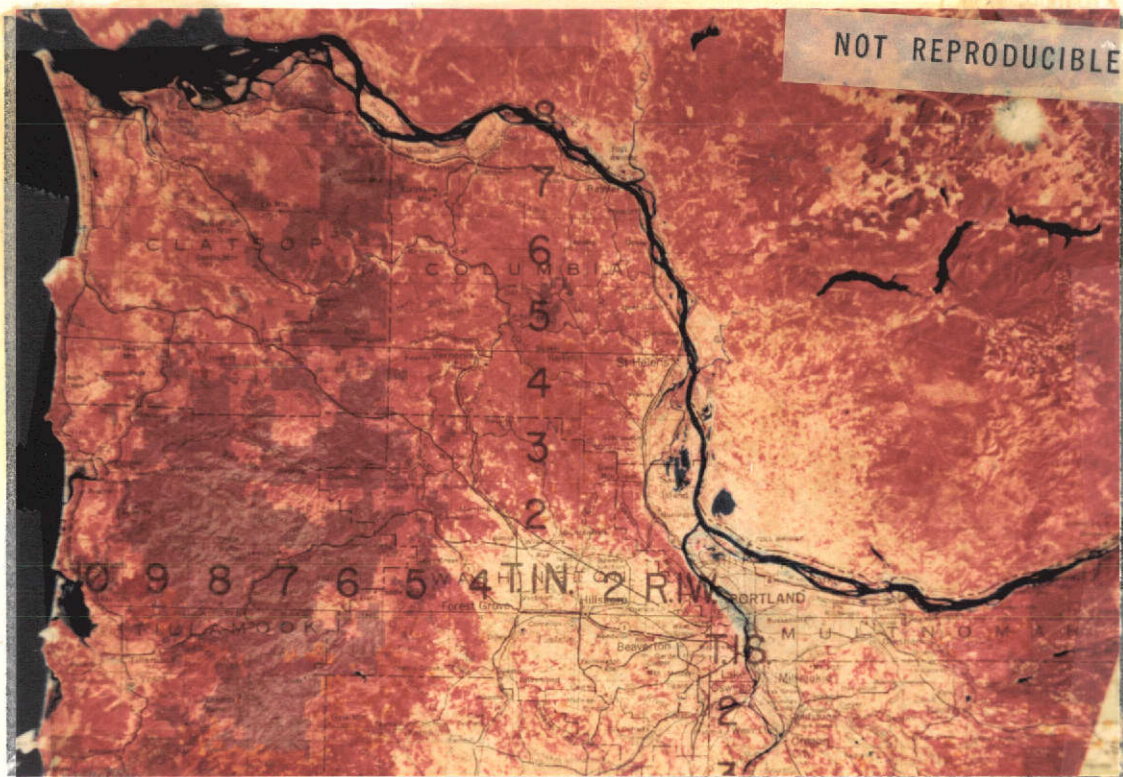
Figure 2. Location of Northwest test area, bounded by the Pacific Ocean and the Columbia and Willamette Rivers. Notice the Blue State Ownership showing through the transparency as a purple color.

In any further study we would recommend a multi-stage sampling approach using ERTS imagery (100% sample), one high flight sub-sample (1:120,000 scale) and a small field sample. This would not only increase the precision and accuracy of the results but would also allow the classification of clearcuts as to size and condition of returning vegetation. Notice the high flight coverage (lower photo) of area A on the ERTS Frame (upper right) of Figure 1. Notice the shades and colors of the clearcuts indicating their age and condition of returning vegetation.

The results of this study are summarized in Table 3 (Cascade sample area) and Table 4 (Northwest study area). These figures verify that private ownerships are short of timber as evidenced by the high percent of clearcut area as compared to other ownerships. A larger sample would be necessary to get adequate regional or statewide results. For example, the Northwest sample has no U.S.F.S. land and the B.L.M. shows 100% clearcut for the Northwest area, but this amounts to only 165 acres. The state land is blue on the original map and is clearly visible in Figure 1. The B.L.M. ownership is yellow (visible in Figures 1 and 2) and the U.S.F.S. ownership was light green in Figure 1.

TABLE 3 -- LAND USE CLASSES BY OWNERSHIP - CASCADE SAMPLE

LAND USE CLASS	PRIVATE ACRES	%	USFS ACRES	%	STATE ACRES	%	BLM ACRES	%
Clearcut	38,880	44	20,453	31	1,215	8	14,175	37
Forested	50,220	56	45,765	69	12,555	79	22,073	58
Non-forested					810	5		
Water					1,215	8	2,025	5
TOTAL	89,100	100	66,218	100	15,795	100	38,273	100

TABLE 4 - LAND USE CLASSES BY OWNERSHIP - NORTHWEST SAMPLE

LAND USE CLASS	PRIVATE ACRES	%	STATE ACRES	%	BLM ACRES	%
Clearcut	6,377	36	288	8	165	100
Forested	7,815	43	2,880	81		
Non-forested	3,786	21				
Water			411	11		
TOTAL	17,978	100	3,579	100	165	100

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We hope to pick out the new clearcuts made during the past year by sandwiching different combinations of diazo bands, using different colors, of ERTS frames taken one year apart. So far we have not received suitable imagery for this purpose. In Figure 1 we have included a comparison of the General Electric (G.E.) composite print ($65.00 ea.) (ERTS Frame E-1041-18265) with our relatively inexpensive diazo composit of roughly the same area (ERTS Frame #-1006-18322). The diazo technique yields superior detail of the forested areas, for example, compare the separation of conifers (dark red to black) from the hardwood and brush species (light red) in the vicinity of C in Figure 1. The contrast is much less on the G.E. print and much of this contrast is due to the checkerboard B.L.M. ownership patterns showing through from the map. The particular bands used and their respective colors are shown below:

	Bands	Colors for each Band
Diazo	4 – 5 – 6 – 7	Yellow – magenta – black – cyan
G.E.	4 – 5 – 6	yellow – magenta – cyan

Evidently the improved contrast in forest land detail is due to reproducing band 6 in black and to a lesser extent, the addition of band 7. The area just below B on the diazo reproduction is a 3 to 4 year old burn. Again the yellow checkerboard pattern is BLM land. More research with various bands and color combinations is clearly warranted.

Forest Disease and Insect Damage Detection

Two other areas of application of ERTS-1 imagery to forest management have been investigated during this reporting period. These investigations have been only preliminary in nature, but show potential for the solutions of some important problems.

One area of investigation has been the identification and location of a known infestation of Mountain Pine Beetle (Dendroctonus monticole) in lodgepole pine (Pinus contorta) in the Ochoco National Forest (Figure 3).

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Figure 3. Lodgepole pine mortality caused by Mountain Pine Beetle,
           Ochoco National Forest, Oregon.

This area can be located on both ERTS-1 multiband imagery and digital tape
output, but only for already known infestations. At present, a definite
tonal signature has not been developed for locating unknown infestations
because the preliminary signatures do not allow separation of this mortality
from very thick stands of true fir (Abies sp.) reproduction. Further in-
vestigation of the area on NASA high flight imagery at 1/120,000 scale and
field examination, confirmed correct identification, but distinct differenta-
tion from the true fir reproduction areas is still not possible on ERTS.

The second area of investigation has been the identification and location
of tree mortality caused by Poria weirii. This root disease affects Douglas-
fir (Pseudotsuga menziesii) causing mortality. The disease spreads from one
tree root to the next and produces characteristic circular to semi-circular
patterns which are easily seen on NASA-Ames high flight imagery of 1/120,000
scale. These areas have not yet been successfully delineated on ERTS-1
imagery, in part due to the quality of the imagery discussed earlier.

Both these investigations have been preliminary in nature, but the results
seem to demonstrate a potential use for ERTS-type imagery which could be
beneficial to forest management.

The following steps will be taken to complete the forest inventory of the Oregon test site.

Statistical analysis of the Ochoco National Forest data will be completed including sampling errors for all three interpreters will be completed. Comparison with the 1972 U.S. Forest Service inventory will be made when this data becomes available. Cost-benefit analysis will also be computed at this time.

Based on the above findings, a more efficient sampling plan will be designed. This will be possible since we will soon have precise estimates of the sample variation at each stage of the multi-stage sample - information which was lacking for our first design. This new design will be applied to the forested lands of Crook County, Oregon which includes a large proportion of the Ochoco National Forest, as well as other forest lands. We will utilize the same field data as on the Ochoco National Forest inventory. This inventory should reflect both the increase in efficiency of the new sampling design and increased precision due to interpreter familiarity with the local forest lands gained while gathering field data for the Ochoco inventory.

Program for Completion of the Clearcutting Practices in Western Oregon from ERTS Imagery

We will sample approximately 30 townships in the S.W. Oregon administrative unit for clearcuts. We will use our improved diazo technique, possibly experimenting with still different color combinations, and then enlarge the ERTS imagery to 1:500,000. When and if suitable late 1973 ERTS imagery becomes available for our clearcut test sites we will attempt to inventory only the new clearcuts which have occurred over the previous year - or shorter time period if necessary. We will attempt to do this by sandwiching several diazo bands of ERTS frames from different dates.

Preliminary Conclusions on the Use of ERTS-1 Imagery for Forest Management Applications

The preliminary conclusion based on the research presently completed is that the use of ERTS-1 imagery for forest management applications has been severely limited by the quality of imagery being furnished by NASA. The G.E. color composites are better but too expensive for general use. Our diazo process shows promise, but it too has a shadow problem and this process has been available to us for only a short time. We will make maximum use of it during the time remaining. Review of a majority of the ERTS-1 imagery of Oregon, especially those from MSS band 5, show that the attached grey scale has excellent tonal difference in the mid-range scale, but little to no difference in the upper and lower ranges. In the Pacific Northwest, the majority of the forested lands occur on rugged, mountainous topography. In these areas, shadow is a serious problem in any form of remote sensing

imagery and special care must be taken to produce imagery which does not
cause shadowed detail to be lost. A sun angle closer to noon might be
better for forestry interpretation. Every effort should be taken to pro-
duce a complete range of grey scale tones on any form of panchromatic
imagery. Until this is done, ERTS-1 imagery cannot be fairly evaluated
in regards to its use for forest management applications. In the non-
shadowed areas, ERTS-1 imagery does have excellent potential in forest ap-
plications, but since a considerable proportion of the steep mountainous
areas are shadowed, the potential is lessened.

Preliminary Conclusions on the Use of NASA-Ames Highflight Imagery for
Forest Management Applications

Review of two NASA highflights of the Oregon area, Mission No. 72-134
flown for Oregon State University and No. 73-110 flown for the USGS, both
at 1/120,000 photo scale, show that serious quality control problems exist
in the production of this scale imagery. The imagery from Mission No. 72-134
shows severe lack of detail in shadowed areas of each frame. Although lack
of shadow detail is a common problem in the use of color IR imagery, the
severity of this problem in the two missions listed above has resulted from
two sources which can be corrected in future missions. The imagery from
Mission No. 72-134 has been underdeveloped resulting in darkness throughout
the frame and lack of color balance. The imagery from Mission No. 73-110
shows severe vignetting of each frame which results from either using a
panchromatic camera with color film or underexposure of the film in a
proper camera. In both missions described above, proper quality control can
correct the problem sources and provide imagery which can be used to its ful-
lest potential.

The 1/30,000 scale, 9 x 18 inch format color IR imagery taken during
Mission No. 72-134 is an excellent example of color IR imagery which can be
fully utilized. This imagery has been successfully used for species identi-
fication insect damage location, and accurage measurement of photo inven-
tory characteristics of the forest lands in the test area. Imagery of this
quality even at the 1:120,000 scale can provide a successful intermediate
step between ERTS-1 imagery and actual on-the-ground measurements, essential
to the success of the ERTS program for forestry purposes.

Recommendations

As discussed in the previous sections, the major recommendation that
can be made at this time is to increase the quality control used in the pro-
duction of both ERTS-1 and supporting NASA-highflight imagery to allow
investigation of the full potential of both forms of imagery in the field
of forest management applications. For forestry purposes we believe and
11:00 o'clock or even a noon sun angle would be better than the present
10:00 o'clock angle. There would still be some shadow, except at the
equator, which we are sure is desirable for some disciplines - including
forestry.

GEOLOGY APPLICATIONS

Crook County Multidisciplinary Study

During this period most of the effort of the geology group on the
Crook County Resource Inventory has gone into compilation of groung truth
data on stereo models of highflight infrared imagery from flight 72-114.
The results have been collated on the black and white mosaic of the county.
These maps will be used to evaluate the 1:1,000,000 and 1:250,000 scale
mapping done on ERTS-1 imagery. Preliminary versions of these maps are
completed and have been previously reported. Final versions will be rea-
died as the ground truth compilation is finished.

At this time the geologic map of the county on the high flight mosaic
is complete using both the multidisciplinary digital legend and a tradi-
tional letter legend such as is normal in geology. A photo-lineament map,
basically representing faults and joints is over half complete. Both maps
are at 1:125,000, which is twice as detailed as existing maps of the entire
county area. The principal improvements over existing maps are as follows:

(1) Greater detail in the mapping of some units.
(2) More differentiation and detail in the mapping of uncon-
solidated materials than previously available.
(3) Much more detail in the mapping of faults and fractures.
(4) Chronological differentiation between faults and fractures.
(5) More uniform interpretation of critical units such as
landslides.

Table G-1, on the following pages, shows the geologic units of the county
area that appear on this map as interpreted according to land use cate-
gories. The units are interpreted according to their susceptibility to
mass movement processes, their erodibility, their susceptibility to wind
erosion, and the ease of excavation of the unit. Appendix G shows a
sample frame of this highflight interpretation (frame 3200, flight 72-114).
Maps of geology, landforms, structure, and preliminary interpretive maps
are included. The interpretive maps will be further developed by including
vegetation and soils primary maps in their development.

With the completion of the highflight ground truth base, mapping on
the ERTS-1 frames covering Crook County can be resumed and carried to
final versions of the 1:250,000 scale maps.

Table G-1
PROPERTIES OF GEOLOGIC UNITS OF CROOK COUNTY, OREGON

Digital Symbol	Letter Symbol	Unit	Mass Movement	Erodibility	Deflation	Ease of Excavation	Other Comments
100 000 400 009 409	Qa	Recent valley bottom, materials, mostly alluvium	Very low	Moderate	HIGH	Easy - minimal power equipment	
001	Qt	Valley terrace material	Very low	Moderate	HIGH, except Prineville Basin	Easy - minimal power equipment	Prineville Basin gravel terraces major resources both for gravel and for agriculture
002 402	Qf	Alluvial fans	Low	HIGH		Easy - minimal power equipment	High flash flood, debris flow, and mudflow potential
105	Qg	Pediment gravels	These gravels are so thin that their properties are largely determined by the underlying materials				
012 412	Ql	Landslides	EXTREME. No separation has been made between active and inactive slides	HIGH		Variable - generally easy but may contain very large resistant blocks	
113 013 413	Qs	Talus and scree	Moderate, but these are areas that receive major rock fall debris	Low		Moderate - major power equipment	
020	Qla	Lake beds	Low	HIGH	Locally HIGH	Easy - minimal power equipment	
121 021 420	Qp	Playas	Very low	Low	HIGH	Easy - minimal power equipment	

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130 030	Qw	Air-fall ash accumulations	Very low	Moderate	EXTREME	Easy – minimal power equipment	
602 702	QTts Tts	Poorly consolidated relatively fresh tuffaceous sediments	HIGH	HIGH		Easy – minimal power equipment	
620 720	Tct	Andesitic tuffs and tuffaceous sediments	VERY HIGH serious soil creep, potential on thicker regolith	VERY HIGH – regions of thin regolith record recent cycle of badland erosion	Locally HIGH	Easy – minimal power equipment	Expansive clays common – major contributor to reservoir turbidity
621	Tjmv	Andesitic and basaltic vent material	Very low	Very low		Moderate – major power equipment	
622 922	Tcf Tjf Ta	Andesite flows	Very low	Low		DIFFICULT – major power equipment and local blasting	
624	Tc	Mixed andesitic flows and fragmental rocks	HIGH. Serious soil creeps potential	Variable – low on flows, moderate on rest		Variable – flows difficult with local blasting, rest moderate	Expansive clays common principal source rock hound material, especially near intrusive rocks
630 730	Tjt Tt	Silicic tuffs and tuffaceous sediments	VERY HIGH, especially where overlain by basalt. Serious soil creep potential on thicker regolith	VERY HIGH – regions of thin regolith record recent cycle of badland erosion	Locally HIGH	Easy – minimal power equipment	Expansive clays common locally has ceramic material sources. Major contributor to reservoir turbidity
631	QTsv	Silicic vent rocks	Very low	Very low		VERY DIFFICULT much blasting needed	

632 732	Tjr Tr	Rhyolite flows and domes	Low, except where underlain by soft materials on steep slopes	Very low		VERY DIFFICULT much blasting needed	
633 733 933	Twt Tjw Ttw	Silicic welded tuffs	Low, except where underlain by soft materials on steep slopes. Rockfall potential from cliffs	Low		DIFFICULT - major power equipment and local blasting	
639	Tj	Undifferentiated silicic rocks	Probably HIGH	Probably HIGH		Probably variable	
640 740	QTbv Tbvt Tbv Tcmv	Basaltic vent materials	Low	Low		Variable - cinders may be easy, but other portions may require blasting	Cinders are valuable quarry material
642 742	QTb Tbt Tb Tcr	Basalt flows	Very low, except where underlain by soft materials on steep slopes. Severe rock fall from cliffs	Very low		VERY DIFFICULT much blasting required	Good gravel resource if crushing is employed. Fair building stone
763 963	Tmi Tcmi	Andesitic intrusive rocks	Low	Low		DIFFICULT - major power equipment and local blasting	Good building stone, good gravel re-sources if crushing is employed
664 964	Tsi	Silicic intru-sive rocks	Very low	Very low		VERY DIFFICULT much blasting required	Good building stone
690	pT	Old (pre-Tertiary) sedimentary and volcanic rocks undifferentiated	HIGH. Serious soil creep potential	Moderate		Variable - easy to local blasting	

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During this reporting period considerable effort has gone into mapping lineaments in areas of heavy forest cover in Western Oregon. A preliminary compilation has been prepared on our 1:1,000,000 ERTS-1 mosaic of the State. This kind of study is of particular interest because little is known about the deformation behavior of the rocks under this heavy forest cover. Even where faults and joints can be identified in road cuts and other openings to bare rock, they cannot be traced into the forest. At this time no satisfactory understanding of the internal structure of these areas exists. Thus the ability to see regional lineament on the ERTS-1 imagery offers an important contribution to the geology of the area. The map compilation is in the jacket at the back of this report.

Questions that arose during the course of these studies have made it clear that some careful statistical evaluation of the results obtained using different combinations of imagery is essential to understanding the data produced. Preliminary results of such a study that is now underway are reported here. Of specific concern to us is the possibility that the constant sun angle of the imagery results in the preferred observation of northeasterly trending features, especially during non-stereo viewing. Stereo viewing suggests that the southeasterly azmuth of the sun sharply illuminates northeasterly trending ridges and valleys while those which are northwesterly trending have a more rounded appearance. Only the former are readily identified as photolineaments. Thus a serious discrepency between the statistical orientation of lineaments measured and their actual orientation is probable. Such a discrepancy casts doubt on any regional tectonic interpretation that might be based on such measurements.

With the questions raised above in mind, we have initiated a study of the results of different approaches to the use of ERTS-1 data. The sample areas selected are shown on the compilation map enclosed in the back pocket. Areas A and C have stereo overlap while areas B and D do not. Areas A and B are in similar geologic environments, as are areas C and D. Figure G-9 shows rose diagrams of the lineaments maped in each area. The dominance of northeasterly trends in the non-stereo areas is clear. In the stereo areas northeasterly trends are still abundant but several other sets are also present. Further studies are being conducted on area A for which the data are not yet available to report. Subjective impressions of the results are reported below.

Our detailed experiments on area A have used the following frames: 1006-18322, 1041-18265, and 1294-18333. We have used color composites, band 5 and band 7. We have done interpretations on each frame without stereo viewing and have used stereoscopic observation on various combinations. Our data will allow
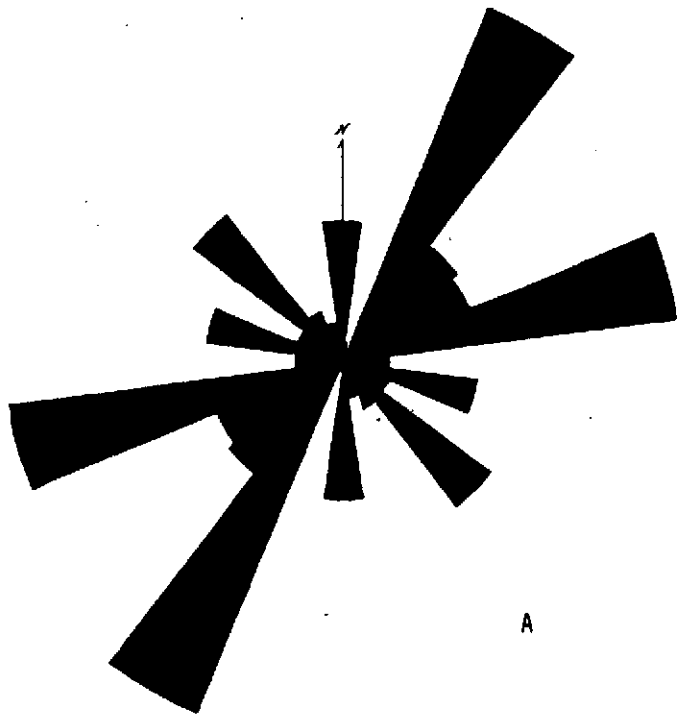
A
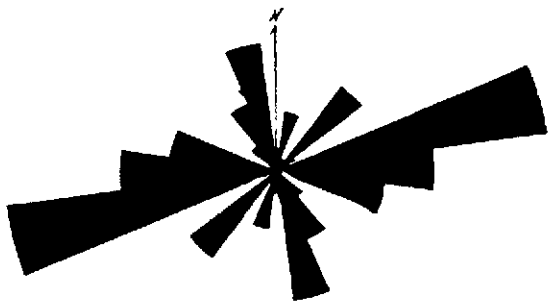
B
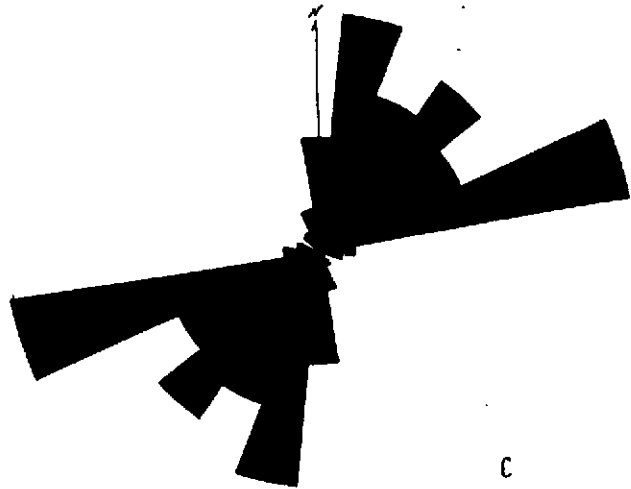
C
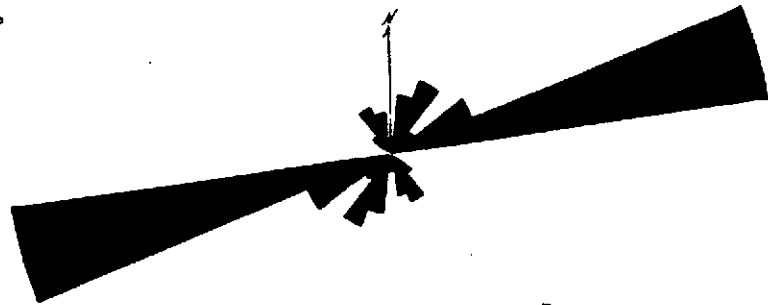
D

APPROXIMATE
SOLAR ASIMUTH
135°

Rose diagrams of lineament trends in areas A, B, C, D,
Western Oregon   (15° segments)

Figure G-9

evaluation of the reproducibility of results by the same observer using the same band, by the same observer using different bands, by different observers using the same band, and by different observers using different bands. The above combinations will be available both with and without stereo viewing. Visual comparison of the results, which will be replaced by measurements shortly, suggest the following observations:

(a) Lineament mapping on band 5 without stereo is basically not reproducible. Patterns on band 5 imagery without stereo do not match those mapped on band 7 imagery without stereo.

(b) Lineament mapping on band 7 without stereo shows poor to fair reproducibility.

(c) Lineament mapping on color composites of bands 4, 5 , and 7 without stereo shows moderate reproducibility.

(d) Lineament mapping on band 7 and on color composites of bands 4, 5 and 7 with stereo shows fair to moderate reproducibility.

(e) Lineament mapping on band 5 with stereo shows the best reproducibility, but even that is only moderate to good.

The poor reproducibility of individual line segments in non-stereo viewing may be less serious than it at first appears, but this will require the completion of our statistical evaluation. Some of it results from the peculiar strengths and weaknesses of the indiviual imagery bands. For example, without stereo band 5 is extremely dark in the forested areas and in addition has a pattern broken by the very light clearcut spots. Band 7, in contrast, shows great detail in forested areas within a very narrow gray scale range that highlights topographic effects. Thus band 7 shows more lineaments than band 5. However, different observers will mark a particular lineament either on a ridge crest or a valley bottom adjacent which helps to reduce the reproducibility of the results.

In areas without stereo overlap a useful technique to produce a partial stereo effect is to use two very different dates of imagery in a stereoscope. The difference in sun angle produces an observable binocular enhancement of the topography that does much to clarify the interpretation of lineaments.

Individual features of importance which are visible on the lineament map of Western Oregon (pocket) include the northwesterly trending features of the Clackamas River drainage, the similar northwesterly trending features of the southern Willamette River drainage, three long northeasterly trending lineaments that cross the Columbia River near the Trojan nuclear power plant, the prominent northwest trending fractures of the Deschutes Basin, the northwest trending set just south of Walker Rim, and northwest and northeast sets in the Coast Ranges. Throughout the area most features seem to trend northwest or northeast to the virtual exclusion of north-south or east-west lineaments. If this pattern can be confirmed, it offers an important contribution to the interpretation of the tectonic development of the state.

Continuing studies will involve completion of the statistical record of the Western Oregon test area and selection of similar

Test area in Eastern Oregon where comparative data can be obtained. Such an additional test will be significant for several reasons First, considerable ground truth is available in order to evaluate the accuracy of the mapping results. Second, the east to northeastern ridge pattern of the Cascade and Coast Ranges is not a factor in much of the eastern portion of the state and more meaningful results may be possible for this reason.

The interpretation difficulties observed in the area reported on here underline very strongly the need to employ traditional photointerpretation techniques in interpreting lineaments as faults and fractures on ERTS-1 imagery. The northeast bias suggested here will cause major problems if it is not taken into account. Some success can surely be achieved if criteria such as the following are employed: (1) linear topographic features must cross stream divides to be considered significant. (2) Tonal variations should relate to some known ground condition, such as soil moisture controlled by ground water, before they will be considered significant. Many linear elements are visible on ERTS-1 imagery, however, that do not meet these cautious criteria. Interpretations based on such insubstantial evidence must be considered quite tentative until some relations to other ground-based information is available.

Digital Classification of the Newberry Cauldera Area

A digital classification of the ERTS-1 data of the Newberry Cauldera area was performed using the computer programs developed by members of the miltidisciplinary team. The perspective of the classification was primarily geological with a major emphasis being placed on the ability to differentiate rock types. The resulting classification is shown in figure G-10. The area covers about 7 miles by 10 miles centered on the area around Paulina Lake and East Lake which occupy the collapsed basin of the cauldera. We were able to classify 95% of the data points into 7 classes. Some errors of classification are present, but on the whole a remarkably successful job was done. The categories used on the figure (G-10) and comments follow:

Color code	Significance
Red	Barren basalt flows. Generally an excellent class.
Black	Barren rhyolitic obsidian flows. A fairly successful class. All units identified that are present in the area. Where trees have begun to appear on the obsidian the signature becomes confused with the basalt flows.
Orange	Pumice flats that are free of forest. Very successful.
Pink	Newberry pumice, other pumice, mostly with forest cover. This class also picks up most south slopes in the area which have very similar signatures.
Yellow	Forest with relatively high density. Mostly lodgepole Pine forest.
Green	Forest with relatively low density. On the flanks of the volcano this is largely Ponderosa Pine forest. In the cauldera it is various areas of low density forest.
Blue	Water.
Blank	Unclassified.
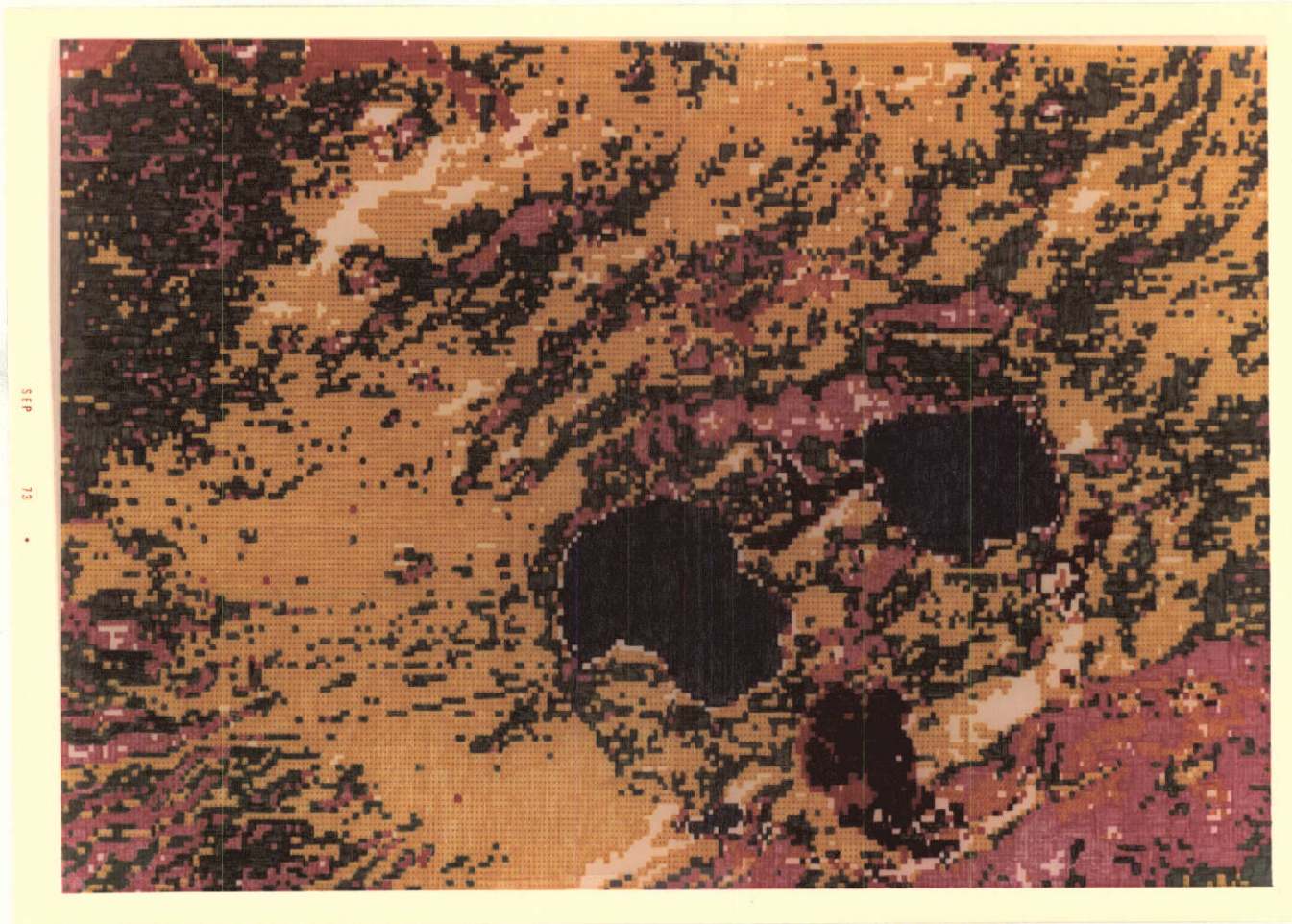
Figure G-10. Digital Classification of Newberry Crater area, Deschutes Co., Oregon, using frame number 1076-18213.

The ability to differentiate units of different rock types is fairly good where the rocks are barren of vegetation. The signatures used for each of the main geologic materials, plus water for comparison, follows:

	Band 4	Band 5	Band 6	Band 7
Basalt	8.14	5.66	4.99	3.98
Obsidian	10.94	9.01	7.43	5.71
Pumice Flats	14.54	14.50	14.89	13.31
Newberry Pum.	9.29	7.50	11.41	12.65
Water	6.93	2.13	1.11	1.00

Typical errors that result from the use of these signatures in this error include single points along the edge of water bodies identified as basalt, probably where the data includes part water and part land; single points along the edge of obsidian flows identified as basalt, probably due to the same kind of mixed date; and older portions of the obsidian flow identified as basalt, due to the presence of some forest cover which alters the signature. The area includes 4 major fresh obsidian flow, all of which are correctly designated by the digital classification. All of the basalt flows are correctly shown, but considerable errors in classification occur as discussed above. This ability to differentiate basalt and rhyolite obsidian is probably based on the iron content of the two rock types. All of the pumice flats were identified, and almost no other areas were so classified. The Newberry Pumice is correctly identified, but the class includes several other materials. Other pumice areas are identified as the same unit. South slopes are also frequently included. Thus this class is somewhat mixed.

In addition to this ability to differentiate different rock types, our classification shows several important geologic features. Most important is the strong indication that the Newberry Pumice was erupted from the same vent as the largest obsidian flow. This interpretation is in direct conflict with existing interpretation which suggests that the Newberry Pumice came from the central cone between the two lakes. (The Newberry Pumice is the large pink area in the southeastern corner of Figure G-10.) Other significant features include the visibility of the arcuate pattern related to the fractures that formed the cauldera, and the ability to see the drainage pattern down the flanks of the volcano in the changes in forest type. The greatest disappointment in the classification is its failure to clearly show cinder cones. No distinctive signature is present, although some of the cones can be seen as combinations of other signatures.

VEGETATION AND LAND USE MAPPING

Objective 9, Pattern Recognition in ERTS Digital Data

Classification of the same area (Big Summit Prairie) on ERTS frame 1040-18210 was not as accurate as that of 1021-18151 using training sets from the latter. Errors may be attributed to phenological changes in vegetation, changes in sun angle, and errors in locating the training sites in the digital imagery between dates.

Gross misclassification resulted when the training sets from 1021-18151 were transferred to a different area (between Ochoco and Prineville Reservoirs) on frame 1040-18210. Some of the vegetation types did not occur in both places (Table 1). However, an accurate classification did not result from the use of the training sets for vegetation types in Big Summit Prairie which do occur near Prineville Reservoir. The juniper-sagebrush lands *(Juniperus occidentalis/Artemisia* spp.) were classified as pine types *(Pine ponderosa)*. Also pine types were classified as mixed conifer (apparently due to shadow on north slopes "looking" like dense forest). Change in scene date and the transfer of training sets from one ecological zone to another (pine zone to juniper sagebrush zone) seem to account for the errors. Changes in soil color (dark to light) and degree of vegetative cover (to more sparse) seem particularly relevant.

Current Progress

Ground Truth Mapping on Highflight, Objective 1

During this report period, the vegetation land-use mapping for Crook County was completed on highflight 72-114 CIR at a scale of ~1:120,000. All mapping (delineations and identifications) were done by stereo interpretation of CIR prints (see Figure 1). The mapping has been transferred to an overlay on an uncontrolled photo mosaic which was constructed from the same imagery. A written descriptive narrative has been completed for each mapped unit. Mapping delineations, identifications and descriptions were drawn from photo interpretation, ground familiarization and ground truth records previously assembled (forest type maps, range type maps, flight index mosaics, narrative reports, graduate student theses, and additional aerial photography).

The mapping and descriptions are considered to be close to final form. Anticipated changes are refinement of the delineations and additions or deletions within the descriptions upon attaining more detailed ground truth. The basic mapped units should remain as they are now described.

The legend to be used for the final product is complete except for refinements in the narrative for the floristic levels (Appendix).

Figure R-1. Vegetation/land-use mapping of Prineville Reservoir area,
Crook County, Oregon.
NASA U-2 Highflight 72-114 color infrared.
Scale   1:120,000
Note: Numerator is vegetation/land-use and denominator
is landform.
See Appendices G and R.

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The mapping for this ground truth base on the highflight was accomplished at sufficient detail to meet all anticipated needs for interpretation and verifications on ERTS scales (~1:1,000,000 and 1:250,000).

Digital Analysis

    Objective 9, Pattern Recognition
    Objective 2, Delineation of ERTS
    Objective 4, Repeatability of Image Identification

Upon receipt of the first digital products from NASA, we worked with our co-investigators in Electrical Engineering and the Computer Center in developing a vegetation classification. The first step was to select an area in which there was enough diversity in plant communities to assure at least a broad classification and also an area where additional vegetation information would be desirable. Using these criteria, an area in the Ochoco Mountains known as Big Summit Prairie was selected.

Using data from frame 1021-18151, a gray scale print out of band 5 was produced. This was done by using vegetation type mapping on NASA highflight (Acc. No. 72-134, ~1:30,000, CIR transparency, 24" fl, 9" x18" format) and overlaying it on the gray scale printout using a zoom transfer scope. Test sets were chosen for water, Ponderosa pine forest, sagebrush scabland and wet meadow vegetation. Statistical analysis of each class was computed and a classification using all four ERTS bands was generated. This classification matched the photo interpretation mapping closely but left much of the area unclassified.

While this work was being conducted, ground truth data were collected at Big Summit Prairie. New and more refined training classes (Table 2) were located on topographic maps and NASA highflight (72-114 ~1:30,000). These training classes were located on the gray scale printout in the same manner as was previously used. Statistics were calculated for each class. This analysis showed there was no significant difference between each member of four pairs of the classes (Table 2). Consequently, each of these class pairs was combined into a single class. One class (bare ground) was found to have a great amount of variance and was broken into two classes which were significantly different (1. Lava and 2. Other rock).

The second classification was based on the ten classes resulting from the statistical analysis. This classification was seen with no threshold so all units were classified. This classification was analyzed using a zoom transfer scope and overlaying the NASA highflight (No. 72-134, ~1:30,000) on the printout. Close correlation was found between the photo interpretive mapping and the computer classification. Upon this comparision it was decided that the mixed conifer class more closely represented Ponderosa pine stands which were dense and had greater crown closure as the mixed conifers

Table R-1 Performance of Training Sets Transferred from Big Summit Prairie
to Prineville Reservoir Area

Big Summit Prairie Training Sets	Occurrence[1] at Prineville Reservoir	Prineville Reservoir Classes[2]
Water	+	Water
Low Sagebrush Scabland	+	Low Sagebrush Scabland
Pine	+	Juniper-Sagebrush
Mixed Conifer	-	Pine
Big Sagebrush	-	
Forbs	-	
Moist Meadows	-	
Riparian	-	
Lava	-	
Rock	-	

[1] + = did occur; - = did not occur

[2] This column indicates into which Big Summit Prairie class the Prineville
Reservoir area classes were placed.

were of very limited distribution in the area and in very small patches. Also, the Riparian class more closely represented a density class of Ponderosa pine as the Riparian vegetation occured as such narrow stringers associated with the pine. Misclassification was noted along class boundaries where broad ecotones exist. No assessment was made of omission--commission errors because of the arbitrariness of type boundary locations in ecotonal areas at the highflight scale (~1:30,000).

Additionally, ERTS frame 1004-18210 was selected for classification to determine if the training sets from one date of imagery could be transferred to another for the same area (Big Summit Prairie). A classification printout based on these previously used training sets was generated. This classification was not as accurate as the first when compared to the mapping of like units on highflight 72-134 (~1:30,000). These classification errors may be attributed to phenological changes, changes in sun angle and errors in location of the training sites on the digital imagery between dates. The communities most consistently classified in the multidate digital data were pine *(Pinus ponderosa)* moist meadows *(Juncus* and *Carex* spp.), big sagebrush *(Artemisia cana* and *A. tridentata)* and low sagebrush scabland *(A. arbuscula* and *A. rigida)*.

Using ERTS scene 1040-18210, another site for computer classification was selected which was within the same scene area as the previous classifications. The area was between the Ochoco and Prineville Reservoirs. Selection was based on a need for intensive information within this area due to subdivision development pressures within a fragile ecosystem.

A first run classification of the area was based on the training sets, which were used in the Big Summit Prairie area. The result was a gross misclassification (juniper-sagebrush as pine). This error was attributed to transferring training sets from one ecological zone to another, i.e., pine zone to juniper-sagebrush zone. Another contributing factor was the change in scene date.

Due to the gross errors in the classification, training sites within the test area were selected from the highflight 72-134 (~1:30,000) photography and transferred by zoom transer scope to the digital imagery as accurately as possible. Classes selected were: low sagebrush scablands *(Artemisia rigida* and *A. arbuscula)*, juniper/sagebrush *(Juniperus occidentalis/ Artemisia* spp.), pine *(Pinus ponderosa)*, and water.

The first run classification using these training classes was very poor due to a programming error. Subsequent classification produced more promising results. Accuracy of classification of the water and pine was highly reliable but juniper/sagebrush and low sagebrush scablands were confused with no consistent misclassifications. The latter classes are areas of very sparse vegetation in which the exposed soils contribute an

overwhelming amount of reflectance to the image's spectral signature. Therefore, since the soils are of very nearly the same color, these two classes overlap, which accounts for classification errors.

Diazo Process

In this reporting period, the Environmental Remote Sensing Applications Laboratory has obtained an Ozalid machine. This machine is available for use by the investigators on the Oregon ERTS research team. By using Diazo projection film in yellow, magenta, and cyan on MSS bands 4, 5 and 7, respectively, we have been able to produce false color infrared reconstitutions in 70 mm and 9" x 9" (~1:1,000,000 scale) formats.

At this time, there has been no detailed mapping done on these products, but they appear to be of sufficient quality for photo-interpretation and delineations suitable to the scales being reproduced. Some of the most interpretable color reconstitutions that we have are diazo. There are several advantages of these inexpensive and quickly produced reconstitutions: (1) Gives a quick-look capability of examining recently acquired imagery to aid in deciding if more intensive evaluation is needed; (2) Gives the investigators the capability of giving special emphasis to desired bands to emphasize features of particular interest simply by varying exposure time or multi-layering of the diazo film from the band of interest; (3) Makes possible the comparison of multi-date imagery in color to give maximum information on seasonal variations to aid in deciding upon further evaluations and comparisons as well as additional products required; and (4) Enables investigators to make quick-look evaluations of change, either seasonal or cultural, on multi-date imagery by the technique of negative masking.

Problems encountered with the Diazo process of producing reconstitution products have been minimal. The variables which were most troublesome were the varying density of the positives for each band and obtaining accurate registration when "sandwiching" the various bands into a final product. Both of these problems were minimized by the technician becoming familiar with the machine's capability and operation and maintaining accurate records of exposure times and relative densities of the film.

To date, 70 mm color products have been made of several frames for use as latern slides. Greatest emphasis has been placed on producing 9" x 9" color reconstitutions at a scale of approximately 1:1,000,000 of suitable quality for photo interpretation and mapping of resources. Enlargements (4X) have been ordered from the Diazo reconstitution of frame 1076-18211 so that a critical evaluation may be made. If the print proves satisfactory, we may be able to produce enlarged color prints of desired frames within a much shorter time than these kinds of products are available to us now.

This process gives us a wide latitude for experimentation in attempting to produce images which weill emphasize specific resource features. One such attempt has been the addition of band 6 exposed to black film to give emphasis to old growth forest and clear cuts. (See forestry illustrations.)

Visual quick-look comparisons of these Diazo products with similar products from NASA and several commercial sources indicate the resolution may be slightly degraded with the Dizao. The consensus of the local users is that the advantages of quick reproduction outweigh the degradation of the resolution in terms of having the added information of a color product available for use as quickly as possible.

Program for Next Reporting Interval

Essentially, the program involves completion of work on all objectives.

Objective 1, Development of Ground Truth Base

Within the next reporting period, it is projected that the vegetation/land-use map and narrative descriptive legend will be finalized and put into a form which will be suitable for the information needs of planning personnel in Crook County. Additional overlays will be produced which will match ERTS scale mapping intensities. Finally, the resource information from this vegetation/land-use map will be integrated with the other resource base maps being produced by the co-investigators on our multi-discipline team (Forestry, Soils, and Geology). This final integrated product will give a total comprehensive resource information base for the use of land-use planners as an aid in decision making.

Objective 2, Delineation, Interpretation, and Comparison of ERTS Imagery
             with the Highflight Mosaic

Comparison of intensity and accuracy of vegetation mapping on ERTS imagery with highflight will be done following completion of work on Objective 1.

Objective 3, Assessment of Monitorable Changes

Land-use changes and degree of change which can be assessed from ERTS will be determined. The diazo technique of negative masking[1] will be evaluated for this use. Phenological changes of vegetation are more difficult to monitor because we do not have adequate representation of all seasons due to cloud cover.

---

[1] To use this technique, a diazo is made of a positive of a band for one date, then a second diazo is made of a negative of the same scene and same band for a subsequent date. The diazos are then overlaid. Appearance should be uniform except for change which will show up a light or dark spots.

Objective 4, Repeatability of Image Identification

Because of our experience with the digital data, we will make this assessment initially within ecological zones. The primary approach will utilize photographic products rather than digital data due to time and cost constraints.

Objective 7, Evaluation of Resource Inventory Information

This work will necessarily follow completion of work on Objectives 1 and 2. In addition to other discipline teams this will involve participation of the Crook County Planning Department and the Extension Service.

Objective 9, Pattern Recognition in Digital Data

Further classifications of the Ochoco-Prineville Reservoir area are pending. We will collaborate with Geology to develop vegetation-geologic classes for this area.

Diazo Process

Conditional on satisfactory outcome of a trial run, we will produce color reconstitutions of ERTS frames for enlargements to service all co-investigator's needs. Of particular emphasis will be use in change detection as previously described.

SOILS APPLICATIONS

Current Progress

Compilation of a soil association map of Crook County Oregon is nearly complete. This map is based on a 1:120,000 CIR photography and will serve as ground-truth for the soil association map previously prepared at a scale of 1:250,000 using ERTS frame 1076-18211 (illustrated in previous Type II report). Figure S-1 shows a portion of the 1:120,000 soil association map for the vicinity of Prineville Reservoir. A preliminary legend is contained in appendix S-1. In its present state of development, this map differs from that made with ERTS imagery mainly by the greater cartographic detail which can be shown at the larger scale. The legend used for the larger scale map is not much more detailed than that which applies to map made with ERTS imagery (25 versus 19 units).

A digital soils legend was constructed, as contribution to the computer compatible Comprehensive Ecological Legend. Figure S-2 shows an example of the digital soils legend applied to a map of the same area depicted in Figure S-1. Addition of these four digit numerical designators, plus their geological counterparts (Appendix G Fig. 1) to the symbols appearing in figure R-1 would constitute a complete example of a comprehensive ecological symbol.

Soil colors observed on ERTS frame #1075-18150-5, at the eastern end of the Columbia Basin, correlate very well with those described from that area. Due to uniform moisture conditions and widespread wheat-fallow agriculture, the gradual change of surface soil color from light brownish-gray to dark grayish-brown along a 30 mile east-west transect is readily apparent.

Program for the next reporting interval

During the next reporting period, soils making up the mapping units for Crook County will be correlated with existing soil series recognized by the Soil Conservation Service (USDA) in cooperation with personnel from that agency as well as with those of the US Forest Service and Bureau of Land Management. Use and management interpretations for mapping units of both 1:250,000 and 1:125,000 soil association maps will be made largely in terms of these established soil series.

Figure S-1. Soil-landscape map of the Prineville Reservoir area, Crook County, Oregon. NASA flight 72-114, frame 3200, color infrared. See appendix S.

35
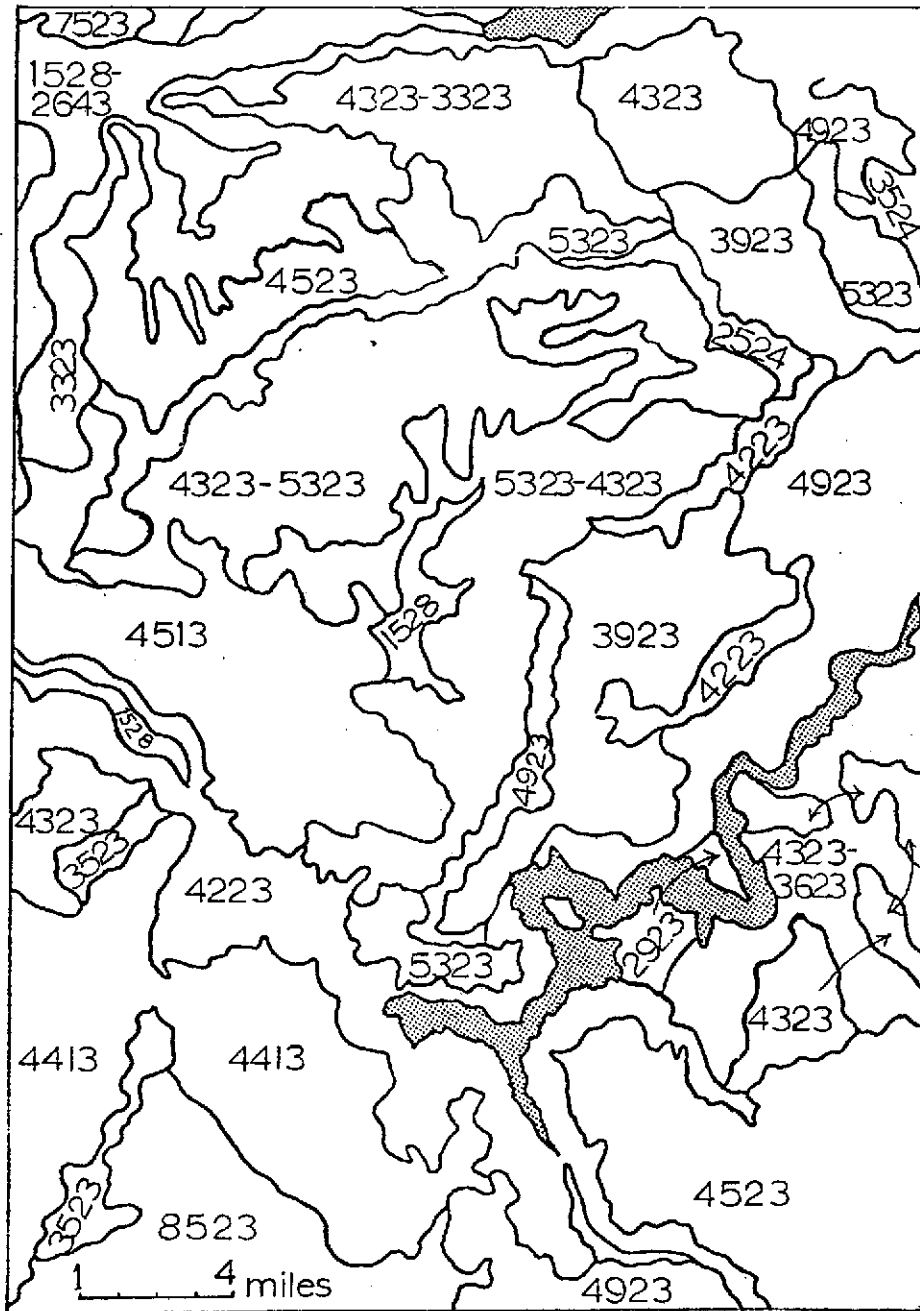
Figure S-2. Example of the digital soils legend applied to a portion of frame 3200, flight 72-114

Table S-1   Digital Legend of Soil Characteristics for Figure S-2

The digits used to denote these four categories occupy four spaces immediately to the right
of those discussed in Appendix A.

This version of the soils portion of the Comprehensive Ecological Legend is designed primarily
for application to the present study area (Crook Co., Oreg.)

Depth	Texture, of control section or Bt horizon	Drainage and reaction	Soil climate and epipedon
1. very deep, >60"	1. sandy skeletal	1. excessive	1. aridic, ochric, mesic
2. deep, 40-60"	2. loamy skeletal	2. good	2. aridic, ochric, frigid
3. mod. deep, 20-40"	3. clayey skeletal	3. mod. good	3. xeric, mollic, mesic
4. shallow, 10-20"	4. sandy	4. somewhat poor	4. xeric, mollic, frigid
5. very shallow, >10"	5. coarse loamy	5. poor	5. xeric, ochric, frigid
6. rockland	6. fine loamy	6. very poor	6. xeric, pachic, mesic
7. mod. deep to hardpan	7. coarse silty	7. peat and muck	7. xeric, pachic, frigid
8. shallow to hardpan	8. fine silty	8. alkaline	8. xeric, cumulic, mesic
9. shallow to soft rock	9. fine	9. strongly alkaline	9. xeric, cumulic, frigid
10. shallow to gravel	10. very fine	10. very strongly alkaline	10. xeric, mollic, cryic

COMPUTER APPLICATIONS

Additional Error Detecting Routines

Several routines to detect and summarize variations within scanner sweeps have been added to a program for unpacking and reformatting NASA-supplied tapes. In addition to checks which list the high, low, and mean intensity values for each scan line, a summary of the number of times a high and low value occurs within a group of 24 scan lines for each of the four bands is generated. The grouping of 24 lines is somewhat arbitrary, but it enables the detection of repeating patterns more readily seen than a grouping of every six lines and may show any recurring patterns between mirror sweeps. An example of the output is shown in Table C1 for the second from the left 25 x 100, N mile strip of frame 1006-18322. The distribution of high and low intensity values is also compacted into an overall summary based on six scan lines as shown in Table C2.

Some indication is shown in a high/low pattern occurring at the high end of the intensity scale between mirror sweeps, but this tend has not been as noticeable in other scenes.

A routine to calculate the raw and normalized frequency distributions and accumulative sums of the intensity values for each six scan lines has also been implemented.

If a reasonable number of scan lines (<200 by 1/4 frame) are unpacked, these routines should give a measure of the internal consistency and provide a guide for applying corrections. Currently no adjustment of the scanner data is undertaken, and it may be that the most economical procedure may be to wait until submitting the imagery to a classifier before correcting. For instance, when a more accurate classification is needed, a "sub band" class could be introduced for scan lines one and two of band four in Tables C1 and C2. Using this approach, those classifications that warrant additional processing may be selected, and more importantly, the original, not corrected scanner data used; it has the disadvantage that larger training sets are required.

Coordinate Transformation System

A series of programs to transform map coordinates and digital imagery elements from one scale to another has been implemented. The purpose of these routines if twofold: 1) use a computer-driven plotter to produce overlays for maps or photographs from classified digital imagery, 2) to produce the resolution element coordinates enclosing areas delineated on photographs or maps. Input not in digital form is obtained from an x-y digitizer which encodes the outline of a region at 0.01 inch increments and records the resulting x, y coordinates on magnetic tape. The transformations used are of the form:

$$\bar{x} = a_0 + a_1 x + a_2 y$$

$$\bar{y} = b_0 + b_1 y + b_2 x$$

where $\bar{x}$, $\bar{y}$ are the transformed coordinates, and x, y are the original coordinates. For landmarks (points) that can be accurately located in both coordinate systems, a set of linear equations is solved for the a's and b's; and for systems that are less well defined, a least squares fit is used to obtain the coefficients. When using the least squares method, if additional points are obtained, they can be added to the original set to obtain a better estimate of the transformation parameters.

The first pass output from a CALCOMP drum plotter showing digitized section lines, U.S. Highway 26, and Ochoco Reservoir is reproduced in Figure C1. Some areas classified as water or pine stands from ERTS imagery have been overlayed onto the base map together with the general outline of one pine stand as shown on approximately 1:120,000 U-2 imagery. Thus, three sources of information have been incorporated into the same map which in turn has been scaled to fit the 8 1/2 x 6 inch format for NASA reports.

With respect to the highflight photographs and topographic maps, a similar transform can be used to obtain the ERTS resolution element coordinates and is of considerable value in locating training sites--particularly for a person not familiar with a gray scale or test representation of digital imagery.

Data Display and Presentation

In order to present the results of processed and classified digitial imagery in a more readily interpreted and condensed form, two methods of information display are being investigated. The first is the use of multi-film diazo color composites to show different classifications. Each of the classes making up the composite is printed separately with the resolution elements blacked out by printer overstrikes, and the output copied onto diazo film. By assigning different colors to each of the printer outputs and then stacking the film, a good quality hard-copy color composite of a computer classification is produced. The production of the diazo composite has been carried out in close cooperation with the staff of the Environmental Remote Sensing Applications Laboratory.

The second method of information display currently being investigated is the use of perspective plots which give a three-diminsional effect. This type of plot should be valuable when elevation and slope are important considerations in displaying the data. A copy of some preliminary perspective views of approximately the same geographic area depicted in Figure C1 is shown in Figure C2.

In addition to forming the data base for the perspective view, the matrix of elevation values can be used as an additional information source for classifying digital imagery. By interpolation estimates of slope and elevation can be obtained for an ERTS resolution element, and these estimates used in a manner analogous to a crop calendar, e.g., the elimination of vegetation types not found above a certain elevation.

Table Cl. Distribution of Band 4 High and Low
Intensity Values Within Groupings of
24 Scan Lines

Relative Scan Line	Number of Values		Average Value			Number of 24 Line Groups
	Highs	Lows	Highs	Means	Lows	
1	3	69	49	20	16	97
2	3	25	48	21	16	97
3	2	16	49	21	16	97
4	2	12	51	21	17	97
5	8	5	51	22	17	97
6	6	3	50	22	17	97
7	4	67	49	20	16	97
8	4	25	51	21	16	97
9	4	17	50	21	16	97
10	9	12	51	21	16	97
11	8	2	51	22	17	97
12	12	1	52	22	17	97
13	0	71	49	20	15	97
14	3	78	50	21	16	96
15	6	16	50	21	16	96
16	5	7	51	21	17	96
17	5	4	51	22	17	96
18	8	3	52	22	17	96
19	6	68	49	20	16	96
20	5	23	49	21	16	96
21	1	15	49	21	16	96
22	11	10	52	21	16	96
23	5	10	51	22	17	96
24	14	4	51	22	17	96
TOTAL	134	453	1206	508	393	--
AVERAGE	6	19	50	21	16	--

Table C2. Distribution of Intensity Values
in Band 4 for Every Six Scan Lines
by Groups of 24

Relative Repeating Scan Line	Number of High Values Within Line Groups				Total
	1-6	7-12	13-18	19-24	
1	3	4	0	5	13
2	3	4	3	6	15
3	2	4	6	1	13
4	2	9	5	11	27
5	8	8	5	5	26
6	6	12	8	14	40
TOTAL -	24	47	27	42	134

Relative Repeating Scan Line	Number of Low Values Within Line Groups				Total
	1-6	7-12	13-18	19-24	
1	69	67	71	68	275
2	25	25	28	23	101
3	16	17	16	15	64
4	12	12	7	10	41
5	5	2	4	10	21
6	3	1	3	4	11
TOTAL -	130	124	129	130	453

41
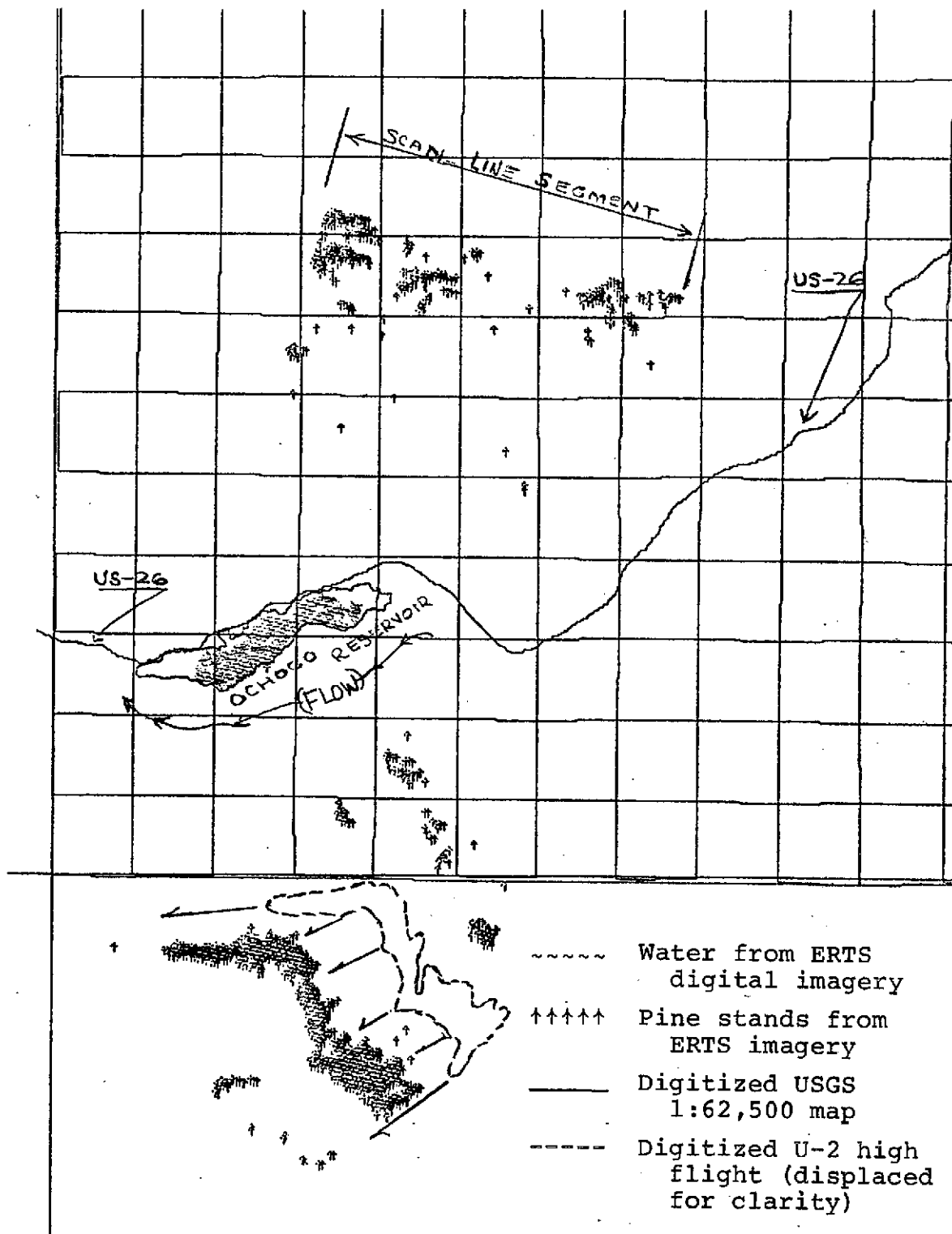
Figure C1. Composite Map of Ochoco Reservoir Area
(~1:120,000)

The legend on the figure reads:
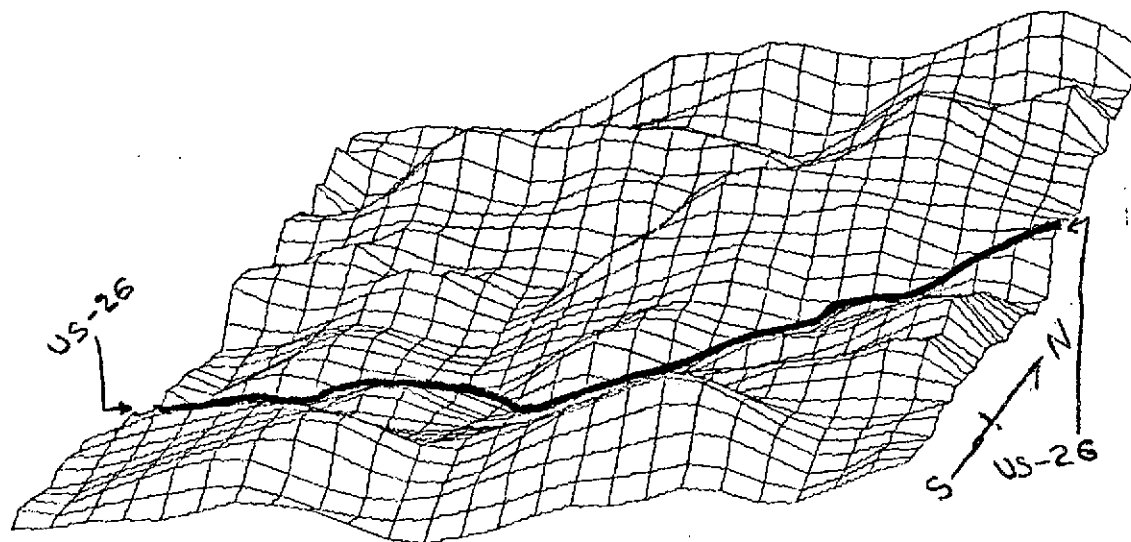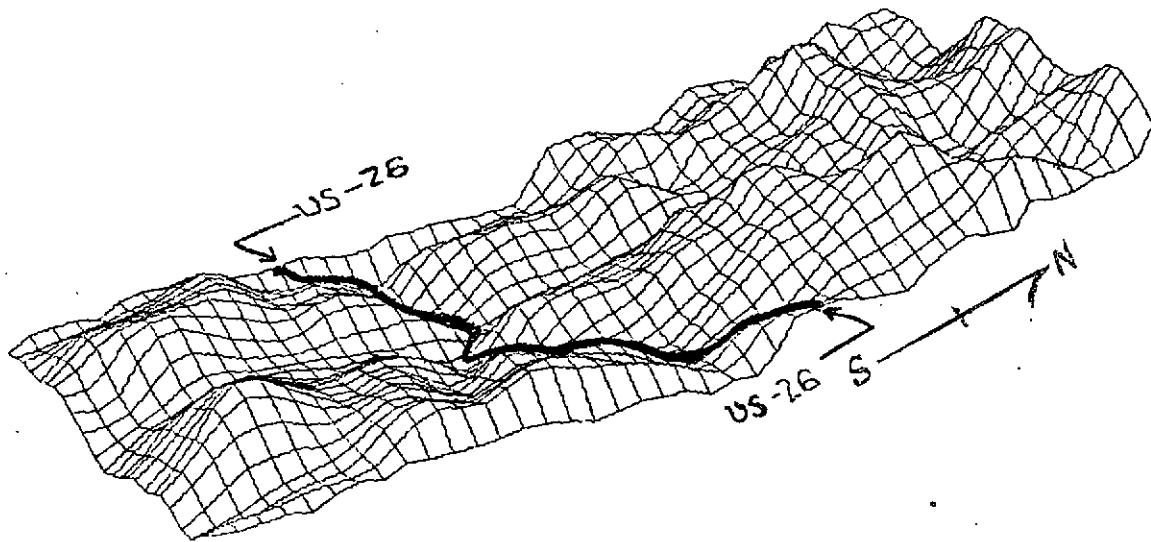
~~~~~ Water from ERTS digital imagery

↑↑↑↑↑ Pine stands from ERTS imagery

_____ Digitized USGS 1:62,500 map

- - - - - Digitized U-2 high flight (displaced for clarity)

Figure C2.   Two perspective views of the OCHOCO Reservoir
             area of Crook County (cf. Figure C1).

PICTORIAL INFORMATION EXTRACTION AND ENHANCEMENT LABORATORY

This report covers the activity of PIXEL (Pictorial Information Extraction and Enhancement Laboratory) in the Department of Electrical and Computer Engineering for the six month period ending September 1, 1973. During this period the PIXEL director (Dr. James Herzog) and two graduate students in Electrical and Computer Engineering received partial support.

Analysis Techniques Development

An operational computer analysis system has been written and successfully used in all of the projects described in this report. It may be used in a time share mode from remote terminals under the Oregon State Open Shop Operating System.

The OSU Automatic Classification System for ERTS Digital Data consists of three componenet programs: *PIXOUT, for obtaining gray scale computer printouts, intensity histograms; *SEL, for selecting training sets and determining training set statistical measures; *CLASSIFY, which contains a distance to prototype classifier.

Additional details and examples of the classification system are included in the following paper, "An Automatic Classification System For ERTS Digital Data".

An Automatic Classification System for

ERTS Digital Data

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1. Introduction

This paper is intended to provide an overview of an automatic classifica-
tion system developed at Oregon State University for use with data from the
NASA ERTS satellite. It provides the basic overall system philosophy and
examples of operational parts of the system.

Automatic classification involves the application of three disciplines sel-
dom completely understood by a single individual.

Problem Oriented Specialist - This is the individual that presents the
initial classification problem. Often he alone has the experience to judge the
eventual success of the results. His continual interaction is necessary to
provide selected test sites and ground truth information. Such a specialist
might, for example, be a range ecologist interested in a vegetation map of a
large region of several types of natural vegetation. He must have examples of
the vegetation he wishes to classify and accurate locations of these samples
(test sites).

Computer System Analyst - This individual has the skills necessary to
assemble the vast quantity of digital data relevant to the problem. He provides
an operating system in which the problem oriented specialist can effectively
interact with the appropriate digital programs. He works closely with the
problem oriented specialist to insure satisfactory results.

Classification Techniques Specialist - This individual assembles his skills
in pattern recognition, artificial intelligence, computer hardware, and pro-
gramming to provide a series of processing techniques which can be integrated
by the computer system analyst into the operating system. He must frequently
interact with the problem oriented specialist and the computer system analyst.

II. Data Processing

Figure E-1 shows the overall data flow and data products generated by the
OSU Automatic Classification System.

The PIXEL (Pictorial Information Extraction and Enhancement Laboratory)
contribution to the system is contained in three operational, interactive
programs called *PIXOUT, *SEL, *CLASSIFY. The programs are written in FORTRAN
to run on the Oregon State Open Shop Operating System (OS-3) from remote tele-
type terminals. These programs have been sucessfully used in several auto-
matic classification problems.

Figure E-1

OSU Automatic Classification System for
ERTS Digital Data

Data File Source
Data Location

*PIXOUT

Gray Scale Printout of
Selected Region

Histogram of Entire File

PIXEL Developmental
Version of Automatic
Classification System

Location of Training Sets

*SEL

Training Set Data

Training Set Hist.

Training Set Stat.

Classification Symbols
Thresholds
Statistics from *SEL

NASA → Tape Reformatting (Computer Center) → OS3 Data File Generation → *CLASSIFY

Classification Map

Classification Summary

Data File Source

Data Location

OSU Computer Center Operational
System for interactive processing
of ERTS Data (will eventually
include PIXEL Classification System)

*NASA

Gray Scale
Data Printout
Interactive Selection of
Training Sets

Continue with *SEL

A Problem Oriented Specialist desiring to use this system would proceed as follows.

1. Formalize the classification objectives. Obtain ground truth data for selected areas (test sites).

2. Contact the appropriate Computer System Analyst for data acquisition and file management. This specialist would also provide aid in completing the remaining items.

3. Use *PIXOUT to generate gray scale printouts to aid in locating test sites.

4. Specify test sites and their known classification. Determine appropriate line and point numbers from the gray scale print out. Verify ground truth.

5. Use *SEL to inspect test site data (training sets) and calculate statistics and histogram for each class to be automatically classified.

6. Create a statistics file to be used by *CLASSIFY.

7. Use *CLASSIFY to produce a classification map.

III. Program Descriptions

*PIXOUT

*PIXOUT is composed of two parts which may be used individually or in tandem. The first part calculates statistics and produces a histogram of an ERTS original data file. The second part produces a gray scale image of a selected area. The latter part uses data produced in the earlier part of the program or data supplied by the user himself.

INPUT The only input necessary is the ERTS original data file and the user's responses. (line numbers, point numbers, file names, etc.)

OUTPUT Output is on two scratch units which PIXOUT later saves under the file names supplied by the user. One of the outputs is a histogram of the ERTS data together with mean values, standard deviations, and threshold values.

The second output is the gray scale image of the selected area from the first ERTS data.

The user must, after completely running the program, use OS-3's COPY routine to get a hard copy of the output on any terminal or the line printer.

Sample Program Run

The following is an example of a PIXOUT program. User responses are underlined.

*PIXOUT

PIXOUT VERSION 1.0

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PIXOUT USES TWO SCRATCH FILES INCLUDING LUN 20 FOR THE BINARY INPUT.
(LUNS 10 AND 11 HOLD ALL STATISTICAL AND PICTORIAL OUTPUT.)

DO YOU WANT STATISTICS CALCULATED?
YES

WHAT IS THE INPUT FILE?
*J2SEP2

IS THE FILE NAME CORRECT?
YES

STATISTICS HAVE BEEN CALCULATED.
DO YOU WANT STATISTICS OUTPUT?
YES

WHAT BAND WOULD YOU LIKE STATISTICS ON?
7

WHAT FILE WOULD YOU LIKE STATISTICS SAVED ON?
T1

DO YOU WANT MORE OUTPUT?
NO

DO YOU WANT A PICTURE?
YES

WHAT BAND?
7

WHAT IS THE INITIAL POINT?
7

NUMBER OF POINTS?
50

WHAT IS THE INITIAL LINE?
30

NUMBER OF LINES?
25

PICTURE IS COMPLETED. WOULD YOU LIKE IT SAVED ON A FILE?
YES

WHAT FILE WOULD YOU LIKE IT SAVED ON?
P1

WOULD YOU LIKE TO START AGAIN?
YES

DO YOU WANT STATISTICS CALCULATED?
NO

DO YOU WANT A PICTURE?
YES

48

THRESHOLDS   7   11   12   13   14   15   16

MEAN   11.471

STANDARD DEVIATION   3.70c

Figure E-2   Typical Histogram for one band of MSS date. The thresholds
             are calculated to allow approximately equal use of each
             gray scale intensity.

Sample Output

EXAMPLE 2

```
FRAME I.D.        10 41-18265
DATE              2SEP72
STRIP NUMBER         0003
POINTS           385-  512
STARTING SCAN LINE 1001
NUMBER OF SCAN LINES  300
```

```
                    1           2           3           4           5
                    0           0           0           0           0

1001   OXXXOOXX88888888888+--    X8MMM8X8O+ //OOOXXXX//
1002   XOOXO?OX8888X888M888/+-    8MMM8/++O++//-XXX/+-
1003   /O8XOOXXX88888880++       OMMM8X//OOO/+-O8/   +/
1004   OX88XXXXXX?O8888/+       /MMMMX+OXOOXO888+   /O/
1005   X888XXXOXXOXOOX8+/O+     -8MMM8OXOOXOOOOOX/  +-+
1006   X8XO/OOO/OOO/+++ -+/     /XOOXOOO///++//---   -
1007   88OO88XXOX8XXOX8XOXXO   ++    -   -XXXOXX/+-+    /
1008   X8/O888XXXOOX8O         ++    /OO/OOOX8X/O     ++
1009   /OXXXXX8XXXOOO/-        /+//      OO/++-+-     ++
1010   X8XO8888XOXOOO/OX/-     +OO8X   ++   OO//     //+
1011   XOXXXXXXXOXX/OOOO/+     OXOOOX/+       /-     +O
1012   88XX//O/OO//OXX//       -O/OX//OO//+      -     //
1013   X88XOX8X//88XXXX-      /XOXXXXXOXX/++//-     +/OO
1014   XOXXX88X8/+/XXXX/     --OO/OXXX/O//+-- --  -+++/OO
1015   X88XXXXX//+O++/+    -OXOXXXXOOOOXO/++O+/X//+/O/+O
1016   OX8XXOO/OOXO+   + +OXXXX8XX88OOXX88XXO/OOOOXX/OO/
1017   OOXO//+-    +/-//++/XXXX88XOOOXOXXX//OOOxOOXOXO/+
1018   O////OO/OXXXXOO////8X88/+/XXX8X//O/+ OXO/O/+----
1019   XO//XXXX88XXXOX8XOOOOOXXO/+-+/+/OX///O/++  -----
1020   888/ +////XX8XXXOO////OXXO++X///+++++/+XX/++/++
```

Figure E-3 Typical gray scale output from *PIXOUT

50

```
WHAT IS INPUT FILE?
*NCAT

IS THE FILE NAME CORRECT?
NO

WHAT IS INPUT FILE?
*N7OCT3

WHAT BAND?
7

WHAT ARE THE THRESHOLDS?
7 11 12 13 14 15 16

WHAT IS THE INITIAL POINT?
35

NUMBER OF POINTS?
60

WHAT IS THE INITIAL LINE?
25

NUMBER OF LINES?
25

PICTURE IS COMPLETED.  WOULD YOU LIKE IT SAVED ON A FILE?
YES

WHAT FILE WOULD YOU LIKE IT SAVED ON?
P2

WOULD YOU LIKE TO START AGAIN?
NO
```

*SEL

The purpose of the *SEL program is to select training sets and provide descriptive statistics for them. The user has essentially three options. He may

1. Select training sets.
2. Select training sets and generate descriptive statistics for them.
3. Generate descriptive statistics of training sets previously selected.

INPUT The inputs for parts 1 and 2 above are the ERTS data files and user responses. The input for part 3 is a file previously generated by parts 1 or 2 above.

OUTPUT There can be two outputs realized from this program. The first is a list of the ERTS data values for all four bands and their locations. This output is realized whenever training sets are selected and is used by the second part of the program to generate descriptive statistics. The second output supplies a histogram, mean and standard deviation of the four bands of a given training set. A histogram mean and standard deviation is also calculated for

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the sample distances to their mean to facilitate setting thresholds for input to the *CLASSIFY program.

Sample Program Runs

The following example shows the selection of two training sets. The first training set is located entirely on a single ERTS data file. The second set is selected from two different data files showing that training sets are not restricted to a single data file. The training set for the first selection is saved under file name SAMPS. The statistics describing the data in SAMPS is saved under file name STATS. The data on any files generated may be analyzed by use of standard OS3 display units and control mode instructions. In general statistics should be output to the line printer since the records are too long for teletype use. The underlined lines are user responses.

```
#*SEL
SELECT VERSION 1.0

DO YOU WANT TO SELECT POINTS?
YES

WHAT IS INPUT FILE?
*P1SEP1

IS FILE NAME CORRECT?
YES
```

INPUT SAMPLE LOCATIONS

    1 1 5 1

    2 4 5 0

Enter four values separated by at least 1 space
1. Line number
2. Point number
3. Number of points
4. 0 data this line incorrect
   1 data this line correct

WHAT?
2 1 5 1

When all sample locations entered depress teletype keys CTRL W at same time

```
DO YOU WANT TO SELECT POINTS?
NO

DO YOU WANT STATISTICS?
YES

ENTER FILE NAME TO SAVE SAMPLES UNDER
SAMPS

IS FILE NAME CORRECT?
YES

ENTER FILE NAME TO SAVE SAMPLE STATISTICS UNDER
STATS

IS FILE NAME CORRECT?
YES
```

DO YOU WANT TO DO MORE?
YES

DO YOU WANT TO SELECT POINTS?
YES

WHAT IS INPUT FILE?
*N7OCT3

IS FILE NAME CORRECT?
YES

INPUT SAMPLE LOCATIONS
10 6 3 1

14 14 9 1

DO YOU WANT TO SELECT POINTS?
YES

WHAT IS INPUT FILE?
*N7OCT4

IS FILE NAME CORRECT?
YES

INPUT SAMPLE LOCATIONS
19 32 12 1

23 12 2 1

DO YOU WANT TO SELECT POINTS?
NO

DO YOU WANT STATISTICS?
YES

ENTER FILE NAME TO SAVE SAMPLES UNDER
SAMPS2

IS FILE NAME CORRECT?
YES

ENTER FILE NAME TO SAVE SAMPLE STATISTICS UNDER
STATS2

IS FILE NAME CORRECT
YES

DO YOU WANT TO DO MORE?
NO

END OF FORTRAN EXECUTION

The following example shows the calculation of descriptive statistics from a file, SAMPS, previously generated by *SEL. This feature is used in the event samples are included which are not typical of the training set being developed. It is suggested that training set data values be inspected before statistics are calculated. Single point data values which are very different from all other members of the class may not correctly belong in the training set. In this event it is suggested either a new training set is selected deleting the non-typical elements or the OS3 on line editor, EDIT, be used to delete the incorrect values from the training set already selected.

```
#*SEL
SELECT VERSION 1.0


DO YOU WANT TO SELECT POINTS?
NO


DO YOU WANT STATISTICS?
YES


WHAT IS INPUT FILE?
*SAMPS


IS FILE NAME CORRECT?
NO


WHAT IS INPUT FILE?
SAMPS


IS FILE NAME CORRECT?
YES


.ENTER FILE NAME TO SAVE SAMPLE STATISTICS UNDER
STATS3


IS FILE NAME CORRECT?
YES


DO YOU WANT TO DO MORE?
NO


END OF FORTRAN EXECUTION
```

*CLASSIFY

The purpose of the *CLASSIFY program is to provide an automatic classification of ERTS digital data based on descriptive statistics of known samples previously selected by the user. the current version is designed to run only from a standard OS3 teletype device.

INPUT The program will request the names of 2 input files. One should contain the original ERTS data, the other a file containing descriptive statistics of the training sets. The training set file may be generated either by using the on-line OS3 editor, EDIT, or by copying a card deck to a file. One line should be provided for each class in the following format.

TEST SAMPLES

Band 4	Band 5	Band 6	Band 7	Scan Line	Point
11	9	13	15	1	1
9	6	13	14	1	2
9	6	13	15	1	3
10	7	14	15	1	4
11	8	14	16	1	5
11	8	13	14	2	1
10	8	14	15	2	2
11	9	14	16	2	3
11	10	15	16	2	4
11	9	14	16	2	5

Figure E-4. Typical training set selected by use of *SEL.

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BAND   4

```
 0        0
 1        0
 2        0
 3        0
 4        0
 5        0
 6        0
 7        0
 8        0
 9        2    * *
10        2    * *
11        6    * * * * *
12        0
13        0
14        0
15        0
16        0
17        0
18        0
19        0
20        0
21        0
22        0
23        0
24        0
25        0
26        0
27        0
28        0
29        0
30        0
31        0
32        0
33        0
34        0
35        0
36        0
37        0
38        0
39        0
40        0
41        0
42        0
43        0
44        0
45        0
46        0
47        0
48        0
49        0
50        0
51        0
52        0
53        0
54        0
55        0
56        0
57        0
58        0
59        0
60        0
61        0
62        0
63        0
```

MEAN   10.40

STANDARD DEVIATION   .84

NUMBER OF SAMPLES   10

Figure E-5   Typical statistics and Histograms of selected training sets.

BAND   5

```
 0    0
 1    0
 2    0
 3    0
 4    0
 5    0
 6    2    * *
 7    1    *
 8    3    * * *
 9    3    * * *
10    1    *
11    0
12    0
13    0
14    0
15    0
16    0
17    0
18    0
19    0
20    0
21    0
22    0
23    0
24    0
25    0
26    0
27    0
28    0
29    0
30    0
31    0
32    0
33    0
34    0
35    0
36    0
37    0
38    0
39    0
40    0
41    0
42    0
43    0
44    0
45    0
46    0
47    0
48    0
49    0
50    0
51    0
52    0
53    0
54    0
55    0
56    0
57    0
58    0
59    0
60    0
61    0
62    0
63    0
```

MEAN   8.00

STANDARD DEVIATION   1.33

NUMBER OF SAMPLES   10

Figure E-5 cont'd   57

BAND   6

```
 0        0
 1        0
 2        0
 3        0
 4        0
 5        0
 6        0
 7        0
 8        0
 9        0
10        0
11        0
12        0
13        4    ****
14        5    *****
15        1    *
16        0
17        0
18        0
19        0
20        0
21        0
22        0
23        0
24        0
25        0
26        0
27        0
28        0
29        0
30        0
31        0
32        0
33        0
34        0
35        0
36        0
37        0
38        0
39        0
40        0
41        0
42        0
43        0
44        0
45        0
46        0
47        0
48        0
49        0
50        0
51        0
52        0
53        0
54        0
55        0
56        0
57        0
58        0
59        0
60        0
61        0
62        0
63        0
```

MEAN   13.70

STANDARD DEVIATION   .67

NUMBER OF SAMPLES   10

Figure E-5 cont'd   58

BAND   7

```
 0    0
 1    0
 2    0
 3    0
 4    0
 5    0
 6    0
 7    0
 8    0
 9    0
10    0
11    0
12    0
13    0
14    2   * *
15    4   * * * *
16    4   * * * *
17    0
18    0
19    0
20    0
21    0
22    0
23    0
24    0
25    0
26    0
27    0
28    0
29    0
30    0
31    0
32    0
33    0
34    0
35    0
36    0
37    0
38    0
39    0
40    0
41    0
42    0
43    0
44    0
45    0
46    0
47    0
48    0
49    0
50    0
51    0
52    0
53    0
54    0
55    0
56    0
57    0
58    0
59    0
60    0
61    0
62    0
63    0
```

MEAN   15.20

STANDARD DEVIATION   .79

NUMBER OF SAMPLES   10

Figure E-5 cont'd

SAMPLE DISTANCES FROM MEAN

```
 0    1    *
 1    3    ***
 2    3    ***
 3    0
 4    0
 5    0
 6    2    **
 7    1    *
 8    0
 9    0
10    0
11    0
12    0
13    0
14    0
15    0
16    0
17    0
18    0
19    0
20    0
21    0
22    0
23    0
24    0
25    0
26    0
27    0
28    0
29    0
30    0
31    0
32    0
33    0
34    0
35    0
36    0
37    0
38    0
39    0
40    0
41    0
42    0
43    0
44    0
45    0
46    0
47    0
48    0
49    0
50    0
51    0
52    0
53    0
54    0
55    0
56    0
57    0
58    0
59    0
60    0
61    0
62    0
63    0
```

MEAN   3.21

STANDARD DEVIATION   2.72

Figure E-6 A histogram of the "distance to prototype" for each data point within the training set. This indicates the homogeniety of the training set

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Characters	Contents
1-8	Class Name
9-12	Number of Samples in the Training Set
13-18	Mean for Band 4
19-24	Mean for Band 5
25-30	Mean for Band 6
31-36	Mean for Band 7
37-42	Standard Deviation for Band 4
43-48	Standard Deviation for Band 5
49-54	Standard Deviation for Band 6
55-60	Standard Deviation for Band 7
61-66	Threshold for Class
68	Character to Represent Class

The Program has the facility to weight each band by the values entered in the standard deviations. Our experience has shown entries of 1.00 in these locations produce the most accurate classification. The numerical entries for means, standard deviations, and threshold should be accurate to 2 places right of the decimal. For example, 12.14, 3.12, etc.

The last line in this file should contain 4 entries which are the correction factors to apply to training sets from one frame which are to be used on a different frame. If the training sets are selected from the same frame that is to be classified, then these values should all be 1.00.

Characters	Contents
1-6	Correction Band 4
7-12	Correction Band 5
13-18	Correction Band 6
19-24	Correction Band 7

Sample file

ARRI	124	12.89	12.50	12.79	12.63	1.00	1.00	1.00	1.00	3.00	.
JUNIPER	183	12.74	11.90	12.92	12.68	1.00	1.00	1.00	1.00	30.00	/
PINE	97	9.86	6.99	12.94	14.71	1.00	1.00	1.00	1.00	12.00	P
WATER	156	10.72	5.89	3.00	1.19	1.00	1.00	1.00	1.00	6.00	W
	1.00	1.00	1.00	1.00							

OUTPUT The program supplies a point by point display of the classification which is saved on the OS3 file system for future analysis. It can be saved under any name which is not currently in use. A user should take special care to insure he does not attempt to use a name already in use, as this results in termination of the program.

The output may be displayed on any of the standard OS3 display devices. Following is the instruction and results of the classification made under the example run described later using a standard teletype.

    # COPY,I=CLASSED,S=O

    FRAME I.D.   1 40-18210
    DATE   1SEP72
    STRIP NUMBER   0003

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```
POINTS          129- 256
SCAN LINES        1- 2340
                  1           2           3
                  0           0           0

 1  PPPPP///PPPPPPP///////          //
 2  PPP/PPPPPP///P///////           /
 3  PPPPPP/P///PP/PPPP////          P
 4  PPPP////////PP/PP/////          P
 5  P///////PPPPPPPPPPPPP/          /
 6  ////////PP///////////////
 7  PP/////////////////////////
 8  ////////  //  //////
 9  P///PPPPPPPP////////
10  ///PPPPP///PPPPPPPP//
```

NUMBER OF SAMPLES FOR EACH CLASSIFICATION

.	ARRI	SAMPLES	0
/	JUNIPER	SAMPLES	131
P	PINE	SAMPLES	85
W	WATER	SAMPLES	0
	UNCLASSIFIED	SAMPLES	84
	TOTAL	SAMPLES	300

If the classification is unsuitable for display on a teletype unit it may be displayed on the line printer.

Sample Program Run

The following example was run with intentional user mistakes to indicate correction procedures. The underlined entries are those supplied by the user.

```
*CLASSIFY
CLASSIFY VERSION 1.0

ENTER FILE NAME TO BE CLASSIFIED
*P1SEP1

CORRECT:
YES

ENTER FILE NAME WITH CLASSES
*TEST

CORRECT?
NO

ENTER FILE NAME WITH CLASSES
TEST

CORRECT?
YES

ENTER STARTING LINE
<>1
```

CORRECT?
YES

ENTER NUMBER OF LINES
<>10

CORRECT?
YES

ENTER STARTING POINT
<>1

CORRECT?
YES

ENTER NUMBER OF POINTS
<>30

CORRECT?
YES

ENTER NUMBER OF CLASSES
<>5

CORRECT?
MO

WHAT?
CORRECT?
NO

ENTER NUMBER OF CLASSES
<>4

CORRECT?
YES

ENTER FILE NAME TO SAVE RESULTS ON
*CLASSED

CORRECT?
NO

ENTER FILE NAME TO SAVE RESULTS ON
CLASSED

CORRECT?
YES

DO YOU WANT TO CLASSIFY ANOTHER AREA?
NO

If an error is made prior to the question "Enter file name to save results on" which results in termination of the program, the user must insure LUN 10, 20,21 used by the program are unequipped, then call *CLASSIFY to start again. Should an error be made after the above question (for example the name to save

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the classification under is already in use) one may type

SAVE,10= name to save file under

since LUN 10-contains the classification then UNEQUIP, 10,20,11 prior to making another run.

COMPLETED PROJECTS

The following short papers represent application of the OSU classifier to problems relevent to the PacificN orthwest region. In most of these applications significant contributions were made by other members of our interdisciplinary Oregon ERTS Research team.

AUTOMATIC CLASSIFICATION OF NATURAL VEGETATION

BIG SUMMIT PRAIRIE, CENTRAL OREGON

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Oregon State University
Corvallis, Oregon

INTRODUCTION

The ERTS I Satellite was launched by NASA in July 1972 into a 500 mile sun synchronous orbit. The satellite is equipped with a variety of sensors which for the first time allow scientists and engineers to freely experiment with the potential for high quality digital data procured from a stable space platform.

The primary data collection device on board the satellite is multispectral scanner which accepts reflected ground radiation in four distinct bands: green (0.5 - 0.6 µm), red (0.6 - 0.7 µm), infrared (0.7 - 0.8 µm), and infrared (0.8 - 1.1 µm).

The optics of the satellite scan across the surface of the earth in a direction perpendicular to the flight path. A vertical raster is provided by the forward motion of the satellite. Each frame of ERTS data covers 100 by 100 nautical miles. The ground resolution of the digital data is approximately 5/6 of an acre.

The variety of applications of this data to land use classification and natural resource inventory is very large. This paper will consider the problem of classifying natural vegetation communities.

Big Summit Prairie is located in the high desert country of central Oregon approximately 100 miles northeast of Bend, Oregon. The region of approximately 100 square miles contains a diverse assortment of sages, grasses, trees, and water resources. This area is typical of many portions of the Western United States in which large acreages must be managed with respect to timber production, cattle grazing, mineral production, and recreation.

Satellite observation offers a cost affective means of obtaining data relevant to the management of these regions. The repeated coverage every 18 days allows the possibility of monitoring seasonal changes in these natural resources.

The research described in this paper represents a coordinated activity between experienced personnel in natural resource and vegetation management and the PIXEL (Pictorial Information Extraction and Enhancement Laboratory) group at Oregon State to test the feasibility of digital classification of several communities of natural vegetation.

BIG SUMMIT PRAIRIE

Big Summit Prairie, at a mean elevation of 4500 feet, contains the following predominant vegetation communities.

Shrub Dominant Vegetation

a) Artemisia rigida/Poa secunda - Tri folium macrocephalum.
   Rigid sagebrush scattered with Sandberg's bluegrass and big headed clover in understory.

b) Artemisia arbuscula/Poa secunda - scabland sagebrush dominant with Sandberg's bluegrass in understory.

c) Artemisia cana - Hoary Sage on old flood - plains with many weedy forbs.

d) Artemisia tridentata/Festuca idahoensis - Big sage with Idaho foscue as dominant understory. Some scattered Purshia tridentata.

Forest Vegetation

e) Abies grandis/Calamagrostis rubescens - Mixed Conifer, Grand Fir, White Fir, Douglas Fir, Western Larch.

f) Pinus Ponderosa/Festuca idahoensis - Cerocarpus ledifolius - Scattered Ponderosa Pine with a fringe of Mountain Mahogany.

g) Pinus Ponderosa/Festuca idahoensis - Scattered Ponderosa Pine without Mountain Mahogany.

h) Riparian Vegetation/Alnus sinuata, Populus tremuloides, Salix - Streamside vegetation.

Herbaceous Vegetation

i) Wyethia - rocky scablands with smooth dwarf sunflower.

j) Lava deserts - rock scablands with some Lomatium, Trifolium macrocephelum, no Wyethia.

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k) Moist Meadows - Sedges and rushes.

Water Resources

1) Water

The automatic classification problem is burdened by two major considerations not normally encountered in classification of agricultural vegetation.

Nonhomogeneity

Natural plant communities seldom have the abrupt demarcation lines associated with agricultural vegetation. Since vegetation is often nonhomogeneous, it is difficult to get "pure" samples for use in training an automatic classifier.

Geologic Considerations

The region around Big Summit contains changes in elevation from a maximum of 5000 ft. to a minimum of 4500 ft. The sloping land tends to affect the reflection characteristics of the vegetation. Volcanic activity in the area leads to a wide variety of soil types and textures. In natural vegetation communities the vegetation is strongly affected by the soil type and available moisture.

THE CLASSIFIER

The features used in the investigation were the data magnitudes provided by the multispectral scanner. This gave a four element vector for each ground resolution element. No normalizing was done to the vectors. It was later noted that some improvements in the data could be achieved by correcting for gain differences in the sensors on the satellite. Because of the large amount of data, these corrections were not made.

A prototype vector was constructed for each of the classes indicated in the section titled BIG SUMMIT PRAIRIE. Each element of the prototype vector was the mean of the corresponding training set for that class.

Classification of unknown feature vectors was performed based on the euclidian distance between the unknown vector and each of the prototype vectors. Classification was determined by the smallest distance. A threshold distance was included to allow a "none of these" classification if the distance was larger than expected for a given class.

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For prototype vector of class P

$$F_P = \begin{bmatrix} f_{p1} \\ f_{p2} \\ f_{p3} \\ f_{p4} \end{bmatrix} \qquad (1)$$

An unclassified vector

$$F_X = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{bmatrix} \qquad (2)$$

$$D_p = (f_{p1}-f_1)^2 + (f_{p2}-f_2)^2 + (f_{p3}-f_3)^2 + (f_{p4}-f_4)^2 \qquad (3)$$

$$D = \text{Min } D_p \qquad (4)$$

T_p = Threshold for class P

if $D \leq T_p$ assign F_X to class P $\qquad (5)$

if $D > T_p$ assign F_X to "none of these"

An alternative classifier involving normalization by the standard
deviation of the class was also considered. For this the calculation
for D_p became:

$$D_P = \frac{(f_{p1}-f_1)^2}{\sigma_{p1}^2} + \frac{(f_{p2}-f_2)^2}{\sigma_{p2}^2} + \frac{(f_{p3}-f_3)^2}{\sigma_{p3}^2} + \frac{(f_{p4}-f_4)^2}{\sigma_{p4}^2} \qquad (6)$$

σ_{pi}^2 = Variance of the ith component of the training set
for class P

Use of the variance as a normalizing factor proved to be unsatis-
factory. This was due to the nonhomogeneity of the training sets.
Large variances were associated with training sets containing diverse
vegetation. Use of equation 6 tended to incorrectly make false assign-
ments to classes with large variances.

The same conclusion regarding the use of variance and standard
deviation can probably be extended to include maximum liklihood classifiers.
Again the statistical behavior of training sets is strongly influenced
by nonhomogeneity of the vegetation community.

It may also reasonable be argued that the prototype vector for the distance metric should not be the mean vector for the class because of the biasing effects of secondary plant vegetation. If it can be reasonable determined that the desired species dominates the training set, the statistical mode of the region offers the best estimate of the "pure" vegetation. Our data sets indicated that the median, mean, and mode of the data were approximately equal.

EXPERIMENTAL PROCEDURE

Using photographic reconstruction of the red band of the ERTS data, the approximate location of Big Summit Prairie was determined in the digital data. A gray tone computer output of the region was then constructed using overstrike characters on a line printer.

A team of vegetation specialists vistited the 100 square mile region to determine appropriate training sets for the vegetation of interest. These sets were marked directly on the digital "picture" for subsequent work. An approximate overall vegetation map was prepared for selected parts of the region.

Using the specified training sets, an elementary statistical analysis was performed to yield the mean, standard deviation, and a histogram.

Classification was performed on the entire prairie. Discrepancies noted were used to modify test site location and variables in the classification algorithm.

RESULTS

Figure E-7 is a reproduction of a U.S.G.S. topographic map of the Big Summit region. Figure E-8 is a computer classification of the ground vegetation. The overall classification was judged to be very accurate by vegetation experts with first hand knowledge of the area. The size of the region, approximately 100 square miles, prohibited a quantitative evaluation of the vegetation classification. Figure E-8 was prepared by shading in the computer printout with colored felt tip pens. Distinction between the four sagebrush classes was not possible due to the similarity of their spectral signatures.

Figure E-7 USGS Topographic Map of Big Summit Prairie

Figure E-8 Computer Classification of the Vegetation in
         Big Summit Prairie

Color	Class
Red	Artemisia rigida/Artemisia Arbuscula
Green	Ponderosa Pine
Orange	Mixed Conifer
Blue	Artemisia Cana/Artemisia Tridentata
Brown	Meadow
Gold	Brush
Pink	Dry Meadow
Black	Lava
Gray	Rock
Dark Blue	Water

AUTOMATIC CLASSIFICATION OF GEOLOGIC FEATURES

MT. WASHINGTON REGION, CENTRAL OREGON

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INTRODUCTION

The high cascades region of Central Oregon contains a diverse landscape of timber resources, lakes, natural meadows, and volcanic activity. The purpose of this research was to identify and map the patterns of volcanic activity from Belkap Crater near Mt. Washington. The region has had two periods of volcanic activity. The older flow has had some timber and brush regrowth. The newer flow has only very sparse vegetation.

The region surrounding the volcanic activity is primarily forest region of Ponderosa Pine and mixed Conifer (Fir, Larch). A major forest fire (the HooDoo burn) raged through the area in 1967.

DATA SOURCE

The NASA ERTS 1 Satellite was used as the data source for this investigation. Some high flight imagery was also available and was used to locate test sites for the automatic classifier.

EXPERIMENTAL PROCEDURE

Using a photographic reconstruction of the red band of the ERTS data, the approximate location of the region was determined. Using the *PIXOUT program a grey scale computer reconstruction of the region was prepared. Dr. Robert Lawrence, an Assistant Professor of Geology at Oregon State University isolated and verified test sites using his firsthand knowledge of the area.

The *SEL computer program was used to determine the statistical characteristics of the selected test sites. *CLASSIFY was then used for a preliminary classification. Refinements were made in the test sites based on incorrectly classified regions and nonclassified regions.

RESULTS

The results of this classification give a remarkable geologic overview of a large and complex region. Figure E-9 shows the computer classification of the area. The computer classification of each resolution element has been shaded in with a felt tip pen to provide the color image.

The present analysis is primarily from a geological point of view and demonstrates several satisfactory results from this perspective. The recent basalt lava flows are easily distinguished. They can be separated according to age, which cannot be done by visual photointerpretation. This distinction is based on the degree of weathering and the small vegetation cover. The flow pattern closely matches that established by field geologic mapping. In addition to the detail of the basalt flows, it is possible to separate ash from flow material. A major disappointment in the work is the difficulty so far experienced in differentiating cinder cones from other features. These are a distinctive landform, but not a distinct material. They vary from barren to vegetated, from north slopes to south slopes, and in other ways. Thus no specific signature is present, even though they are an important feature.

The HooDoo burn of 1967 is easily identified, and shown in brown at the top of the image. Big Lake is the body of water in the upper portion of the center panel. The unclassified areas in the forested parts of the left panel are clear-cut timber harvesting. (This class was not included in the original training sets.) The unclassified portions of Figure E-9 were principally brush lands. Some of the regrowth in the forest fire area had a similar spectral signature to the clear-cut areas. The bare rock and snow at the mountain peaks were also unclassified. Ground truth has now been obtained on the vegetation types and ages of clearcuts in the area, and a new analysis will be made which incorporates this additional information. The second classification of this area should considerably improve the vegetation treatment.

The classification of this region based on geologic considerations has provided information unattainable from any other source.
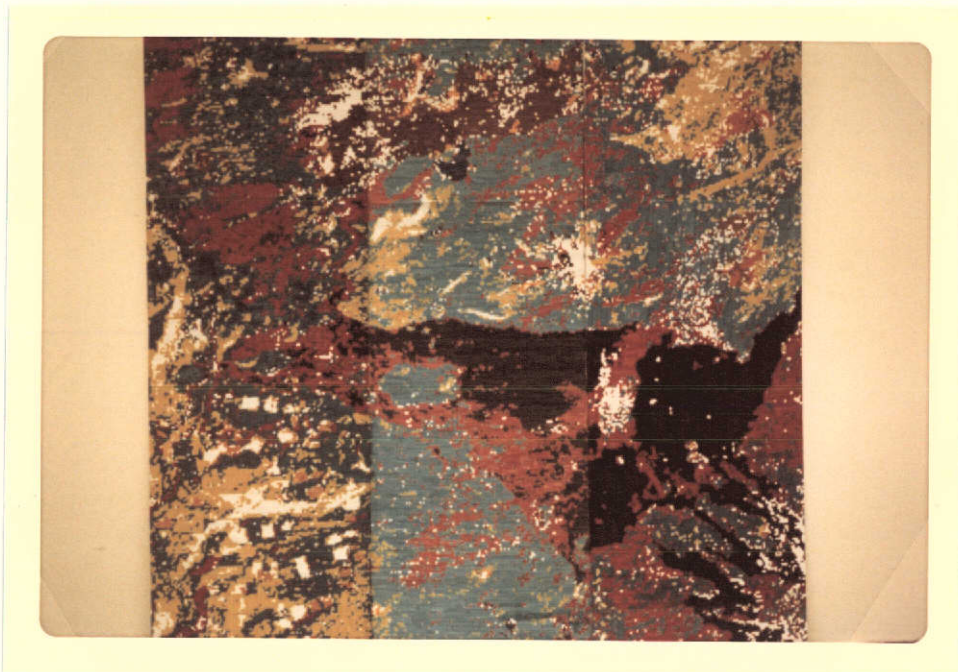
Figure E-9 Computer Classification of the Geologic Structure
         of the Mt. Washington Region of Central Oregon.
         ERTS Frame 1041-18265

Color	Class
Dark Blue	Water
Yellow	Old Lava Flows
Black	New Lava
Blue	Young Lava (a subclass of new lava)
Red	Volcanic Ash
Orange	Brush
Brown	HooDoo Burn of 1967

MONITORING OF EROSION AND SEDIMENT TRANSPORT

SALISHAN SPIT, CENTRAL OREGON COAST

INTRODUCTION

Salishan Spit is located at the mouth of the Siletz river approxi-
mately 5 miles south of Lincoln City, Oregon on the Pacific Ocean. The
Spit forms a long slender finger which nearly blocks the entrance to
Siletz Bay.

The Spit is in private ownership and has been developed for private
homesites. Prior to Winter, 1973, approximately 20 high quality
dwellings had been built on the Spit.

In the Winter of 1973, wave action and tidal erosion caused a
breech of the Spit and caused one of the houses to be destroyed. Oregon
Governor McCall commissioned a committee to make recommendations con-
cerning the future of the Spit. The data products in this paper were
presented to the committee for their use in Summer, 1973. The committee
was not active at the time of presentation and the data products will
probably not be used unless another crisis develops.

The purpose of this investigation was to classify the predominant
terrain features of the Spit and Bay for comparison with similar
classification in Winter, 1974. Differences will provide information
for possible action such as riprapping the beach area or dredging
operations.

DATA SOURCE

The NASA ERTS 1 Satellite was used as the data source for this
investigation. Digital data from the July 29, 1972, coverage frame
1006-18315-5-0 was entered into the Oregon State Automatic Classifi-
cation System for ERTS digital data.

EXPERIMENTAL PROCEDURE

Using the *PIXOUT program a grey scale "map" of the region was
prepared. There was a low tide at the time of satellite data
acquisition. Test sites were selected for ocean water, bay water
(brackish), mud flats, wet sand, dry sand.

RESULTS

The following figure shows the computer classification of the Salishan Spit area. The classifier clearly delineates the shoreline. The narrow Siletz River is also partially classified as it curls up into the heavily vegetated coastal mountains.

Because of the wide publicity gained by the erosion problems at Salishan, this investigation was used as a demonstration for a travelling poster which explains the activities and capabilities of PIXEL and the ERTS Satellite.
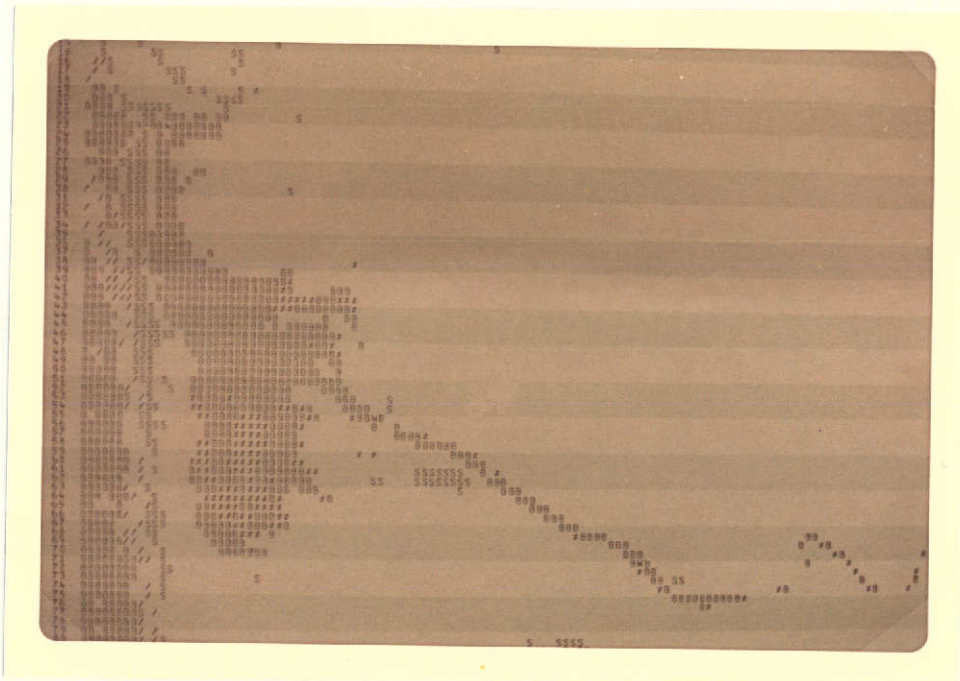

Figure E-10   Computer Classification of Salishan Spit for Monitoring
              Erosion and Sediment Transport

Symbol	Class
1	Wet Sand
s	Dry Sand
≠	Mud Flat
B	Bay Water (Murky)

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SIGNIFICANT RESULTS

1. A digital classification of the Newberry Cauldera area, according to 7 classes, that successfully separates rock materials by compostion and texture.

2. A table of the geologic units of Crook County that shows their land use capabilities.

3. A preliminary map of lineaments in the forested area of Western Oregon.

4. A study of the reproductibility of lineament mapping which suggests strongly that stereo viewing is essential to the production of a reproducible result. Comparisons are made between mapping on band 5, band 7, color reconstitutions, and stereo combinations in any order, which are qualitative at present and from which quantitative results are being prepared.

5. Reclassifying vegetation of the same area using digital data from subsequent imagery was less accurate than the original. Errors are attributed to phenogical changes in vegetation, changes in sun angle, and mislocation of training sites on digital imagery.

6. Misclassification of vegetation types resulted when training sets chosen in one area were used to classify vegetation in antoher, even though several types were common to both areas. Occurrence of similar vegetation on contrasting slopes, due to climatic differences between the two areas, was a strong contributor to this error in computer classification.

APPENDIX F

TARIF TABLES (3)

A. <u>What</u> are tarif tables?

A <u>tarif table</u> is a local volume table that gives tree volume by diameters for trees of the same general height class. They are particularly suited, but not limited, to even-aged stands.

The tarif table <u>system</u> provides for a series of harmonized, related local volume tables covering a <u>range</u> of height classes.

<u>Comprehensive</u> tree-volume tarif tables (4, 5) provide the added features of tree volumes in several units of measure and utilization limits, as well as volume/BA ratios, all within a related system. Each separate tarif table (i.e., local volume table) with its parallel relationships in differing units of measure, is identified by a tarif number. The tarif number assigned is the cubic foot volume for a tree of one square foot of basal area within each individual tarif table in the system.

B. Tarif system is not limited to "tables" per se. Discussion of the tarif system is more clear when thought of in terms of "tables" of information. However, formula versions of the relationships render easy application of the system to computers.

C. Theory of application of local volume tables.

In almost all cases where the volume of a stand or plot is desired, we select a limited sample of trees, measure them some way, smooth the relationships, and then apply the smoothed results to the total stand or plot population.

D. When would you use the tarif system?

The tarif system proves especially useful in measuring <u>marked timber in young growth stands</u>. We use a tree tally together with a sample of marked trees for average tarif. The system is useful in computing volume for timber inventory and for projections of inventories over time. It is also very useful in determining volume and volume growth for permanent and research plots.

E. Use of tarif system in uneven-aged stands.

Since the late 1800's, Europeans have managed selection forests (all aged stands) of both conifers and hardwoods. Series of local volume tables, to which they applied the term "tarifs", are used to determine volume.

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The builders of the tables recognized different volume trends for close
intervals among age (height) classes within all aged stands which readily
transform into straight lines. Thus separate tarif lines adequately
describe the volume of trees in separate age (height) classes within all
aged stands.

F. Advantages of the comprehensive tarif table system (1)

1. Volume estimating procedures are simplified. Tarif number identifica-
   tion is reduced to sampling a few trees, and the need for curve fit-
   ting of local volume tables is eliminated.

2. Standardized forms of curves are contained within the tarif table.
   This factor is especially important when estimating growth on per-
   manent plots, inasmuch as apparent differences in volume could be
   the result of error derived from different methods of curve fitting
   at each remeasurement.

3. Tree volume is listed in several units of measure and for differing
   top diameter limits, providing a simple, accurate means of conversion.

4. Volume/basal area ratios are provided which make the system equally
   convenient for Bitterlich's variable plot or point sampling as well
   as fixed plot sampling.

5. Growth multipliers in each table provide a real convenience.

6. The data are expressed in convenient measurements and convenient
   units familiar to foresters.

7. The method is adaptable to both office calculators and computers.

8. The tarif tables are applicable in both coniferous and hardwood
   stands.

9. The methods have been proven statistically sound and lend themselves
   to statistical analysis.

APPENDIX G

Geologic Analysis of Frame 3200, Flight 72-114

Figures included:

1. Geologic Map
2. Digital Geology Legend
3. Landforms Map
4. Digital Landforms Legend
5. Lineament Map
6. Susceptibility to Mass Movement Map
7. Erodibility Map
8. Ease of Excavation Map

Appendix G , Figure 1, Geology Map

81

A Digital Geology Legend

1st = Major material class
2nd = Minor material class
3rd = Material type

0_ _   Thick unconsolidated materials (more than 10')
1_ _   Thin unconsolidated materials (less than 10')
2_ _
3_ _
4_ _   Unknown thickness unconsolidated materials

The classes "0" to "4" above use unconsolidated subclasses

5_ _   Consolidated materials with thick regolith (greater than 10')
6_ _   Consolidated materials with thin regolith (6" to 10')
7_ _   Consolidated materials with little or no regolith (less than 6")
8_ _
9_ _   Consolidated materials with unknown depth of weathering

The classes "5" to "9" above use consolidated sublcasses

UNCONSOLIDATED SUBCLASSES

_0_ ·Valley and plain materials

    _00 Floodplain alluvium
    _01 Terrace alluvium
    _02 Bajada and alluvial fan gravels
    _03 Fine clastics, muds
    _04 Medium clastics, sands
    _05 Coarse clastics, gravels
    _06 Mixed fine and medium clastics
    _07 Mixed medium and coarse clastics
    _08 Mudflow and laher deposits
    _09 Mixed or undifferentiated

_1_   Valley side materials

    _10 Saprolite
    _11 Colluvium
    _12 Landslide materials
    _13 Talus and scree
    _14 Solifluction deposits

    _19 Mixed or undifferentiated

_2_   Lake and marine materials

    _20 Lake beds
    _21 Evaporite and playa deposits
    _22 Deltaic sands and muds
    _23 Estuarine sands and muds
    _24 Beach, bar, and spit sands
    _25 Marine sands and muds
    _26 Beach gravels
    _27 Marine gravels

    _29 Mixed or undifferentiated

_3_   Aeolian materials

    _30 Pumice and air fall ash
    _31 Sand dunes, hills, plains
    _32 Loess

    _39 Mixed or undifferentiated

_4_   Glacial materials

    _40 End moraine
    _41 Ice-contact gravels (eskers, kames, etc.)
    _42 Ground moraine

    _49 Mixed or undifferentiated

CONSOLIDATED SUBCLASSES

_0_ Clastic Sedimentary rocks

   _00 Siltstones and mudstones
   _01 Shales
   _02 Poorly consolidated tuffaceous sediments
   _03 Well consolidated tuffaceous sediments
   _04 Poorly consolidated sandstones
   _05 Poorly consolidated congolomerates
   _06 Well consolidated sandstones
   _07 Well consolidated conglomerates

   _09 Mixed or undifferentiated

_1_ Non-clastic sedimentary rocks

   _10 Gypsum and anhydrite
   _11 Halite and evaporites
   _12 Poorly consolidated limestone
   _13 Well consolidated limestone
   _14 Dolomite
   _15 Mixed carbonates
   _16 Chert

   _19 Mixed or undifferentiated

_2_ Intermediate volcanic rocks

   _20 Fragmental, including pyroclastics, breccias, and
       non-welded tuffs
   _21 Vent rocks
   _22 Flows
   _23 Welded tuffs
   _24 Mixed fragmental and flow rocks
   _25 Dikes, sills, and other shallow intrusives

   _29 Mixed or undifferentiated

_3_ Silicic volcanic rocks

   _30 Fragmental, including pyroclastics, breccias, and
       non-welded tuffs
   _31 Vent rocks, domes
   _32 Flows
   _33 Welded tuffs
   _34 Mixed fragmental and flow rocks
   _35 Dikes, sills, and other shallow intrusives

   _39 Mixed or undifferentiated

_4_ Basaltic volcanic rocks

   _40 Vent rocks (commonly cinder cones or low shield volcanoes)
   _41 Fragmental, including breccias, etc.
   _42 Basalt flows
   _43 Mixed fragmental and flow rocks
   _44 Dikes, sills, and other shallow intrusives

   _49 Mixed or undifferentiated

_5_ Mixed volcanic rocks

   _50 Fragmental
   _51 Flows
   _52 Shallow intrusives
   _53 Vents

   _59 Mixed or undifferentiated

_6_ Coarse-grained intrusive rocks

   _60 Serpentinite
   _61 Ultramafic rocks, often including serpentinites
   _62 Mafic intrusives
   _63 Intermediate intrusives
   _64 Silicic intrusives
   _65 Pegmatite

   _69 Mixed or undifferentiated

_7_ Metamorphic rocks

   _70 Slates and phyllites
   _71 Schists
   _72 Metavolcanics (Greenstones and Greenshists, blueschists)
   _73 Marbles
   _74 Hornfels
   _75 Gneisses, migmatites, granulites
   _76 Quartzites
   _77

   _79 Mixed or undifferentiated

_9_ Combined units (defined for each specific problem except "_99")

   _90 Pre-Tertiary rocks
   _91 Basalt flows and thin alluvium, mixed

   _99 Unknown but photo identified unit that needs field checked

Appendix G , Figure 3, Landform Map

Appendix G   Figure 4

A Digital Landform Legend

1. Major descriptive classes
2. Minor
3. Slope angle classes
4. Aspect classes

Note: If 4th digit is missing no significant aspect is
indicated. Usually this implies areas of diverse topography
with no dominant orientation.

0-   Flat lands (0-10% slopes, 0-10' local relief)

    00   with smooth microrelief
    01   with rough microrelief

    09   Mixed or undifferentiated

1-   Uniformly flat lands

    10   Smooth with no significant microrelief
    11   Smooth with little microrelief, low drainage density,
          dendritic drainage pattern
    12   Smooth with little microrelief, low drainage density,
          parallel drainage pattern
    13   With moderate microrelief in mounds, biscuits, or other
          patterned ground
    14   Rough with intricate, non-integrated microrelief, very low
          drainage density, and no pattern.
    15   Rough with integrated microrelief, moderate drainage density,
          and dendritic pattern
    16   Rough with integrated microrelief, moderate drainage density,
          and parallel pattern
    17   Smooth with moderate drainage density, and dendritic
          drainage pattern
    18   Smooth with moderate drainage density, and parallel drainage
          pattern
    19   Mixed or undifferentiated

2-   Incised flatlands

    20   Smooth with dendritic drainage patterns to incised channels
    21   Smooth with parallel drainage patterns to incised channels
    22   Showing patterned ground and dendritic pattern to incised
          channels
    23   Showing patterned ground and parallel pattern to incised
          channels
    24   Rough with dendritic drainage patterns to incised channels
    25   Rough with parallel drainage patterns to incised channels

    29   Mixed or undifferentiated

3-   Sloping lands (10-30% local slopes, 0-10' local relief,
          significant regional slope)

    30   Smooth with little or no drainage pattern
    31   Smooth with drainage parallel to the regional slope
    32   Smooth with patterned ground, especially stone stripes
    33   With irregular rough microrelief
    34   Incised with deeper drainage parallel to regional slope
    35   Broken with local breaks that cross the regional slope (fault
          scarps, etc.)
    36   Dip slopes (stripped structural surfaces)

    39   Mixed or undifferentiated sloping lands

4- Rolling lands (10-30% slopes, 10-100" local relief)

40   With low to moderate drainage density and dendritic drainage
     pattern
41   With high drainage density and dendritic drainage pattern
42   With low to moderate drainage density and parallel drainage
     pattern
43   With high drainage density
44   With irregular surface pattern (landslide topography)

49   Mixed or undifferentiated rolling lands

5- Uniformly rolling lands

50   With low drainage density and dendritic drainage pattern
51   With moderate drainage density and dendritic drainage pattern
52   With high drainage density and dendritic drainage pattern
53   With low drainage density and parallel drainage pattern (below)
54   With moderate drainage density and parallel drainage pattern
55   With high drainage density and parallel drainage pattern
56   With irregular surface pattern (landslide topography)
57   Dip slopes (stripped structural surfaces)

59   Mixed or undifferentiated

6- Incised rolling lands

60   With low to moderate drainage density and dendritic pattern
     to incised channels
61   With moderate to high drainage density and dendritic pattern
     to incised channels
62   With low to moderate drainage density and parallel pattern
     to incised channels
63   With moderate to high drainage density and parallel pattern
     to incised channels
64   Dip slopes (stripped structural surfaces) with dendritic
     pattern to incised channels
65   Dip slopes (stripped structural surfaces) with parallel
     pattern to incised channels

69   Mixed or undifferentiated

7- Hilly lands (10-50% slopes, 100-1000' local relief)

70   With low to moderate drainage density and dendritic drainage
     pattern
71   With high drainage density and dendritic drainage pattern
72   With low to moderate drainage density and parallel drainage
     pattern
73   With high drainage density and parallel drainage density
74   Incised with deeper drainage in dendritic pattern
75   Incised with deeper drainage in parallel pattern
76   With irregular surface pattern (landslide topography)

79   Mixed or undifferentiated

8- Mountainous lands (10-100+% slopes, more than 1000' local relief)

80   With low drainage density and dendritic drainage pattern
81   With moderate drainage density and dendritic drainage pattern
82   With high drainage density and dendritic drainage pattern
83   With low drainage density and parallel drainage pattern
84   With moderate drainage density and parallel drainage pattern
85   With high drainage density and parallel drainage pattern

89   Mixed or undifferentiated

9- Escarpments and Canyons

90   Linear Escarpments
91   Irregular escarpments
92   Fault scarps of fault-line scarps
93   Antidip slopes
94   Canyons
95   Undrained depressions (e.g., sinkholes, kettles)

Slope and Aspect

Slope angle classes

0   0-5%
1   5-15%
2   15-30%
3   30-50%
4   50-100%
5   over 100%
6   0-30%
7   0-50%
8   0-100+%
9   15-50%

Aspect classes

0   No significant aspect (absent = 0)
1   North facing
2   Northeast facing
3   Northwest facing
4   East facing
5   West facing
6   Southeast facing
7   Southwest facing
8   South facing

Appendix G

Legend to Lineament Map

Line Weight

    Features younger than Danforth Formation
        (about 5 million years)

    Features of unknown age
        (do not cut young units)

Kinds of features

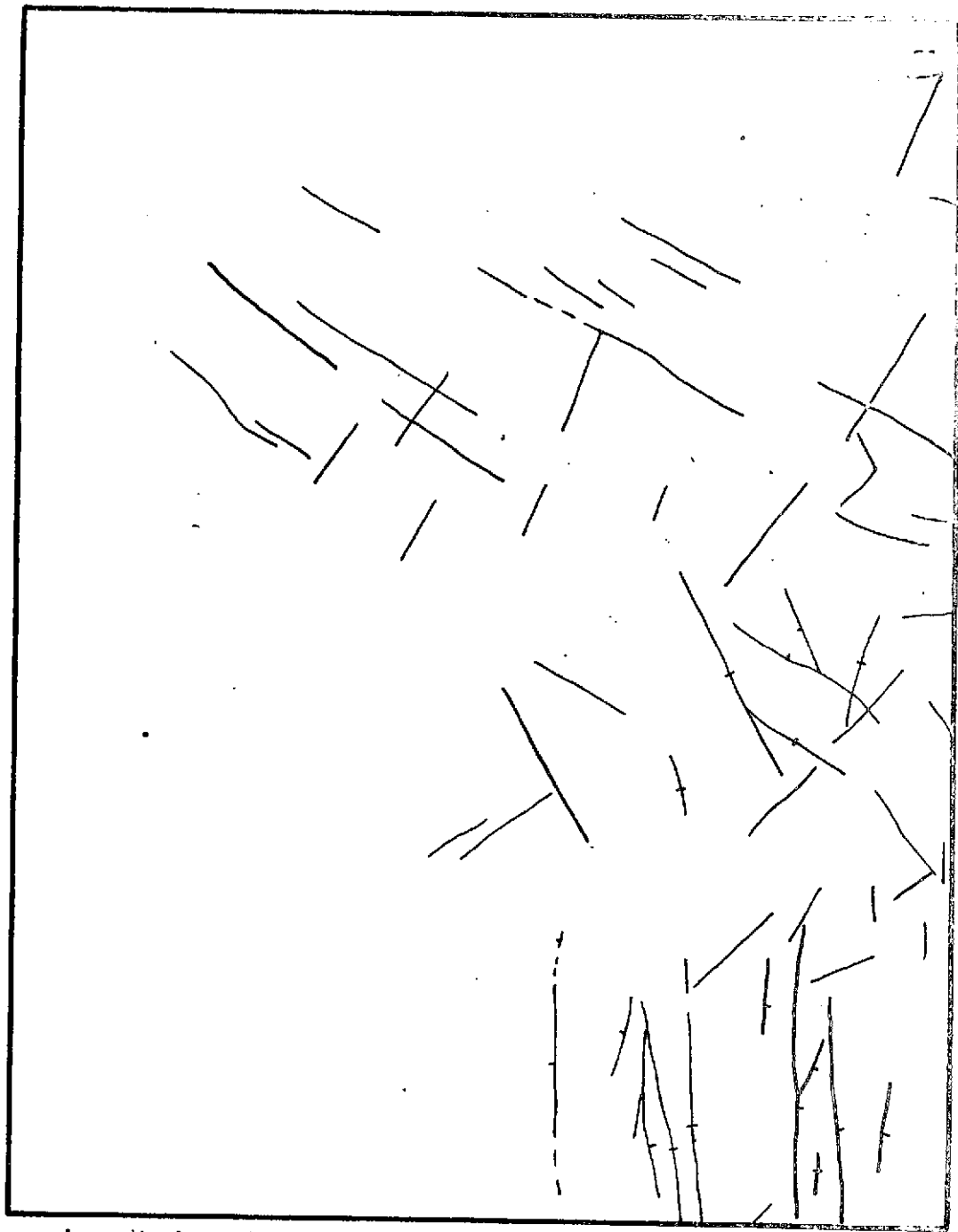   Known faults, tic on downthrown side

    Known faults, unknown motion

    Other features including faults and joints both

Appendix G. 1. Figure 5, Lineament Map

Appendix G

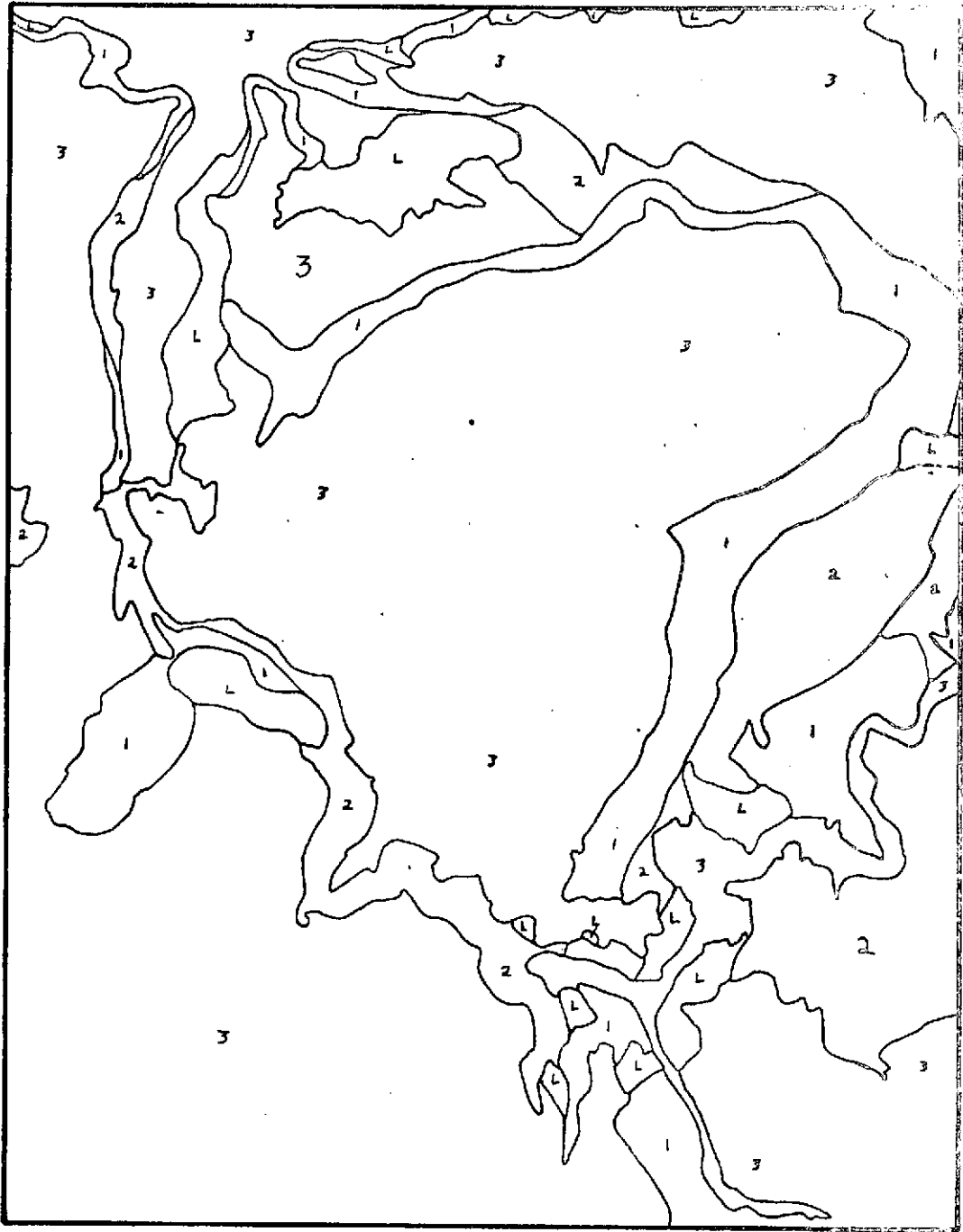Legend for Figure 6, Susceptibility to Mass Movement

    L = Identified landslides
    1 = Highly unstable ground
    2 = Moderately unstable ground
    3 = Relatively stable ground

Legend for Figure 7, Erodibility

    W = Subject to Wind erosion
    1 = Highly erodible
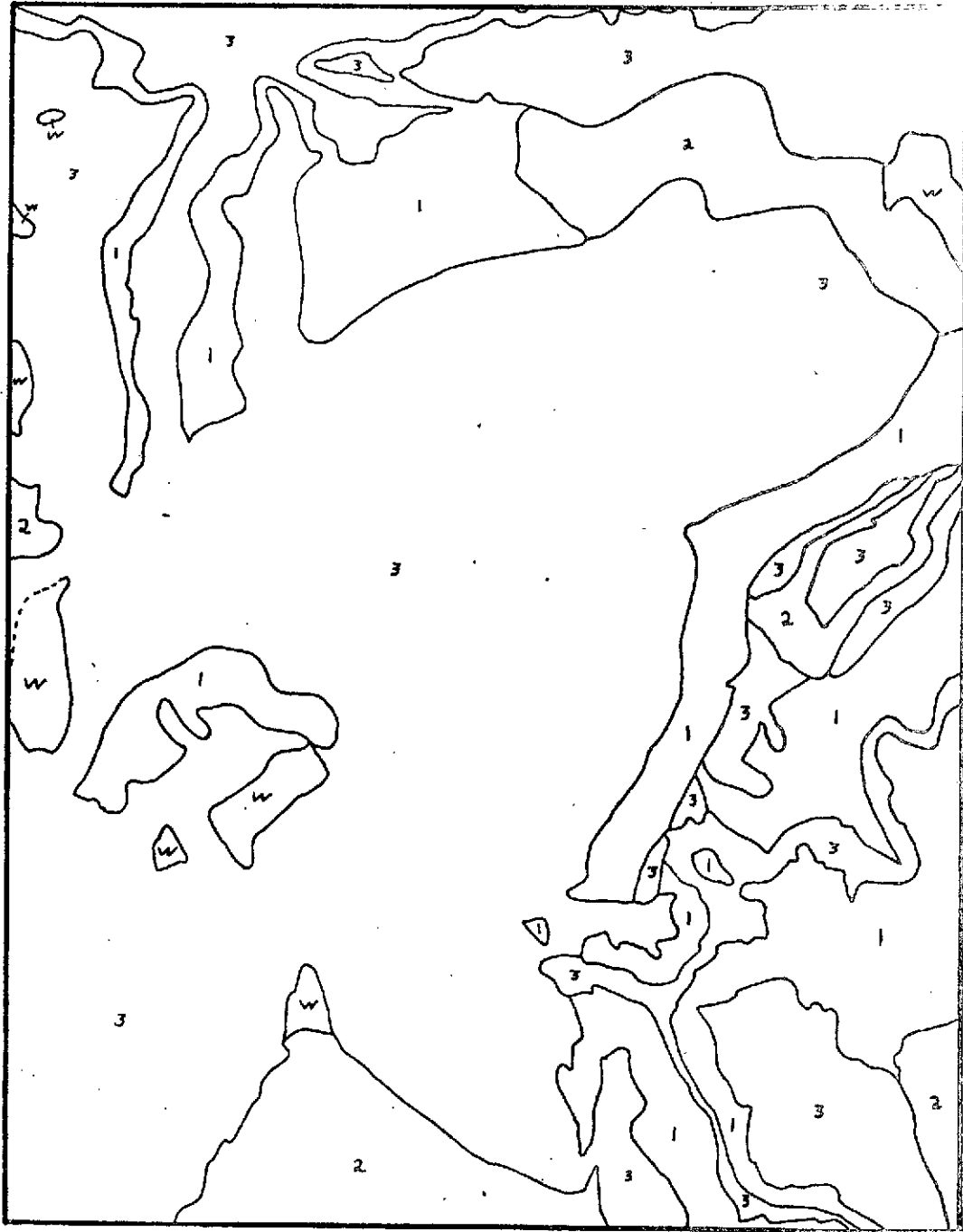   2 = Moderately erodible
    3 = Relatively stable

Legend for Figure 8, Ease of Excavation

    1 = Very easy, power equipment not essential
    2 = Easy, minimal power equipment needed
    3 = Moderate, major power equipment needed
    4 = Difficult, major power equipment and local blasting needed
    5 = Very difficult, much blasting required
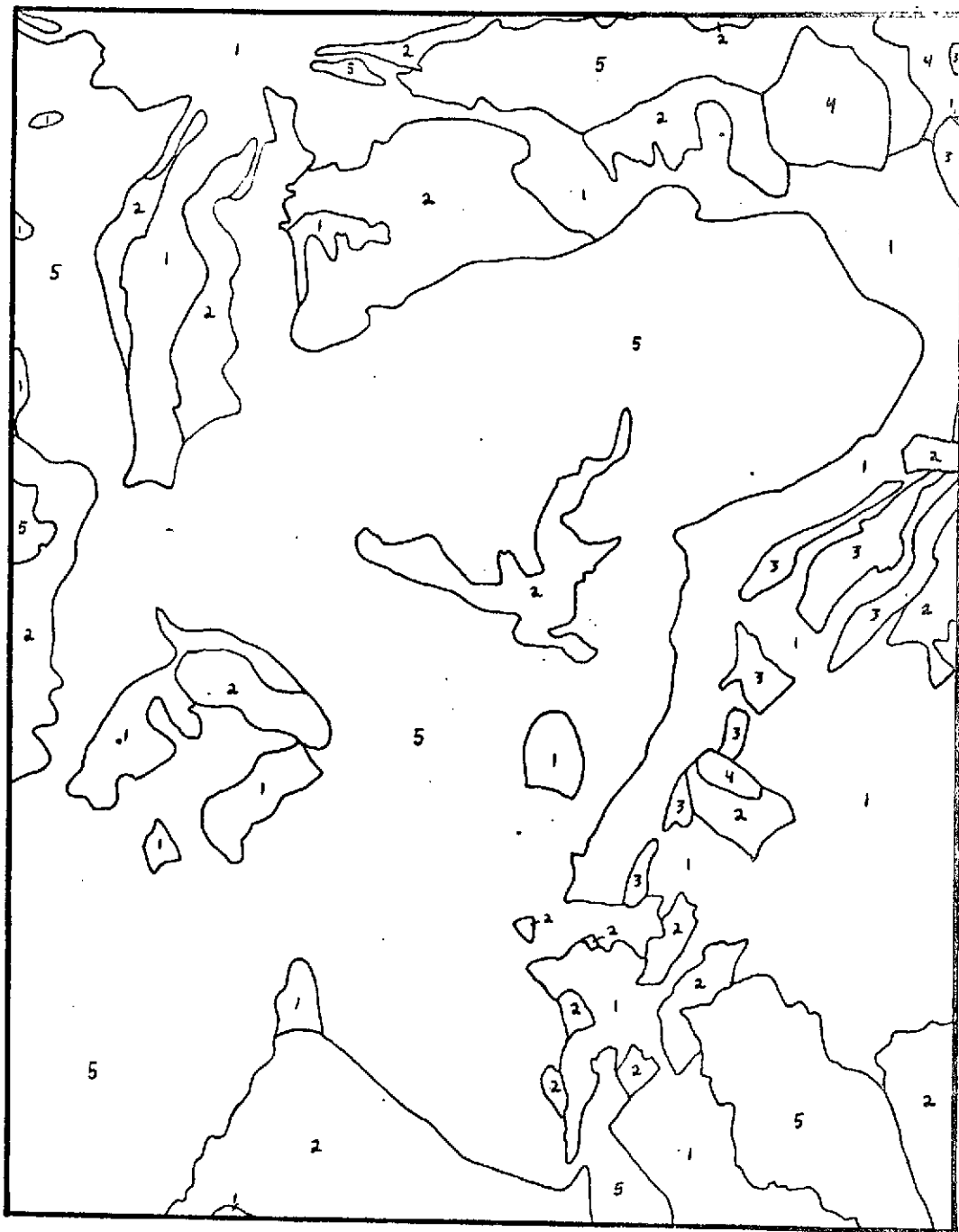
Appendix C   Figure 6, Susceptibility to Mass Movement Map

Appendix G   Figure 7, Erodibility Map

Appendix G   Figure 8, Ease of Excavation Map

Appendix R

VEGETATION/LAND-USE TECHNICAL LEGEND

Crook County

100 - BARREN LAND

 110 - Playas, Dry, or Intermittent Lake Basins
 130 - Rocklands
 180 - Man-Made Barrens

200 - WATER RESOURCES

 210 - Ponds, Lakes, and Reservoirs
  211 - Natural Lakes and Ponds
  212 - Man-Made Reservoirs and Ponds

 220 - Water Courses
  221 - Natural Water Courses
  222 - Man-Made Water Courses

 230 - Springs, Seeps, and Wells
 290 - Undifferentiated Complexes of Water Resources

300 - NATURAL VEGETATION

 310 - Herbaceous Types
  314 - Grassland, Steppe, and Prairie
   314.1 - Tussock Grasses or Bunch Grasses *(Agropyrons,*
     Sporobolus, Aristidas)
   314.2 - Rhizomatous or semi-rhizomatous or giving a single
     layered low stature appearance
   314.3 - Tall Grasslands *(Elymus cinereus)*
  315 - Meadows
   315.1 - Dry Graminaceous Meadows *(Deschampsia, Poa, Agrostis,*
     Phleum, Agropyron)
   315.2 - Wet Mixed Graminaceous - Cyperaceous Meadows or
     Juncus
  317 - Tule Marshes
  319 - Undifferentiated Complexes of Herbaceous Types

 320 - Shrub-Scrub Types
  324 - Halophytic Shrub
   324.3 - Greasewood *(Sarcobatus* - including *S. baileyi* types)
  325 - Shrub Steppe
   325.1 - Low Sagebrush Types *(A. arbuscula, nova, rigida)*
    325.11 - Arar-Arlo2/Agsp etc.
    325.12 - Arri/Pose scablands
   325.2 - Big Sagebrush Types *(A. tridentata, tripartita)*
    325.21 - Artr/Agsp xeric uplands
    325.22 - Artr/Feid mesic N slopes
    325.23 - High altitude
    325.24 - Artr/tall grass (Elci)

325 - Shrub Steppe (continued)

    325.3 - Silver Sagebrush Types *(A. cana)*
    325.4 - Rabbitbrush Dominant Types *(Chrysothamnus)*
    325.7 - Mixed Shrub Steppe *(Artemisia, Purshia, Symphoricarpos,*
        Amelancher but always with *Artemisia)*
    325.9 - Undifferentiated Shrub Steppe
326 - Sclerophyllous Shrub
    326.4 - Curlleaf Mountain Mahogany Shrub
    326.9 - Undifferentiated Sclerophyllous Shrub

330 - Savanna-like Types (only ones in Oregon are:)
    333 - Coniferous Tree Over Herb
        333.1 - Juniper Over Grass
            333.11 - Juoc/Agsp
            333.12 - Juoc/Feid
    336 - Coniferous Tree Over Low Shrub
        336.1 - Juniper over *Artemisia, Purshia*
            336.11 - Jouc/Low Sagebrush
            336.12 - Juoc/Big Sagebrush

340 - Forest and Woodland Types
    341 - Conifer Forests
        341.1 - Juniper and Pinyon - Juniper Types
            341.11 - Juoc/Artr
                341.111 - Juoc/Artr/Agsp
                341.112 - Juoc/Artr/Feid
        341.3 - Ponderosa and Jeffrey Pine Types
            341.31 - Pipo-Juoc
            341.32 - Pipo-Psme
        341.4 - Lodgepole Pine Types
        341.5 - Douglas Fir Types
        341.6 - Mixed Conifer Types
        341.7 - Spruce-Fir Types
            341.71 - Abla
        341.9 - Undifferentiated Forest and Woodland Types
390 - Undifferentiated Natural Vegetation

400 - CULTURAL VEGATATION

    410 - Cultural Herbaceous Types
        414 - Cultural Grassland, Steppe, and Prairie
            414.1 - Range Seedings-exotic spp.
        419 - Undifferentiated Complexes of Cultural Herbaceous Types

    420 - Cultural Shrub-Scrub Types
        425 - Cultural Shrub Steppe
            425.1 - Overstory Clearings or Shrub Control
        429 - Cultural Undifferentiated Complexes of Shrub-Scrub Types

    490 - Undifferentiated Cultural Vegetation Types

500 - AGRICULTURAL PRODUCTION

    510 - Field Crops
        511 - Cereal and Grain Crops
        512 - Forage Crops
        514 - Drug, Flavoring and Spice Crops
        519 - Other Undifferentiated Field Crops
            519.1 - Dry-land Field Crops
            519.2 - Irrigated Field Crops

    540 - Pasture
        541 - Herbaceous Pasture

    560 - Non-Producing Fallow, Transition, or Idle Land
        561 - Fallow Cropland
        562 - Plowed Cropland
        564 - Harvested Stubble Fields

    590 - Undifferentiated Agricultural Production

600 - URBAN AND EXTRACTIVE INDUSTRY

    610 - Residential
    620 - Commercial and Services
    640 - Industrial
    650 - Transportation, Communications and Utilities
    660 - Resource Extraction
        661 - Sand and Gravel
        665 - Chemical, Fertilizer, and Non-Metallic Minerals

    670 - Open Space and Recreational Facilities
        671 - Designated Natural Open Space
        672 - State Parks

900 - OBSCURED LAND

Appendix S

Preliminary

Legend for Generalized Soil-Landscape Map of
Crook County, Oregon

Frame 3200 NASA Flight 72-114

1:125,000

Symbol

1. a. Deep and moderately deep, medium textured soils on floodplains.
        Alkaline soils occur in some poorly drained areas.

    b. Poorly and somewhat poorly drained, medium and fine textured
        soils, some of which are alkaline.

2.   Moderately deep, medium textured soils, with partially cemented
        pans, on old alluvial terraces.

3.   Shallow and moderately deep, medium textured, gravelly soils
        with strongly cemented pans, on slightly disected alluvial fans.

4. a. Shallow, very shallow and moderately deep, medium textured soils,
        some of which are stony, on nearly level to gently rolling older
        lava flows.

    b. As above, on rolling, moderately dissected terrain.

5. a. Shallow and moderately deep, medium and coarse textured soils in
        nearly level and concave areas of younger lava flows. Bare rock
        predominates on convex portions.

    b. As above, but bare rock predominates.

6. a. Very shallow and shallow, stony and very stony soils, many of
        which have clayey subsoils, on gently rolling to nearly level
        volcanic plateaus.

    b. Similar to 6a, but on rolling, somewhat dissected topography.

    c. Similar to 6a, but on steeply rolling, dissected topography.

7. a. Moderately deep, shallow, and deep clayey soils, on moderately
        dissected rolling terrain.

    b. Similar to (a) but with numerous exposures of unconsolidated rock.

8.   Shallow and moderately deep clayey soils in steeply rolling, dis-sected terrain. Moderately deep, loamy soils occur on north slopes and in concave places. Rock outcrops are common.

9.   a.   Shallow and moderately deep, stony and very stony, medium and fine textured soils predominate. Moderately deep, stone-free, medium textured soils occur on some north slopes. Steeply rolling, dissected terrain predominates, and rock outcrops are common.

      b.   Similar to (a) but north slopes make up >25% of the area.

10.   A complex landscape consisting predominantly of very shallow, stony and very stony, sparsely vegetated soils on nearly level to rolling plateaus. Moderately deep and deep, medium textured, tim-bered soils occur on northern slopes and in canyons.

11.   A complex landscape consisting predominantly of moderately deep and deep, medium textured, timbered soils; with sparsely vegetated, very shallow and stony soils on south facing slopes.

12. a.   Moderately deep and deep, fine-textured, timbered soils in mod-erately dissected, rolling terrain, primarily above 5000 feet elevation.

      b.   Similar to (a) but north slopes predominate.

13.   Moderately deep and deep, medium and fine-textured, stony, tim-bered soils in steeply rolling, dissected terrain. South slopes may have shallow, stony soils and lack timber.

14. a.   Moderately deep and deep, medium textured, timbered soils formed from volcanic ash over a variety of buried soils, primarily on north slopes above 4500 feet elevation.

      b.   A mixture of units 14a and 13.

15 a.   Very steep, shallow and moderately deep, stony and rocky soils predominate. Canyons with more than 500 feet of local relief.

      b.   Similar to 15a, but includes areas of more gentle relief resulting from landslides.

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