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APPLICATION OF REMOTE SENSING IN THE STUDY OF VEGETATION AND SOILS IN IDAHO (MMC#313-3)

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APPLICATION OF REMOTE SENSING IN THE STUDY OF VEGETATION AND SOILS IN IDAHO

INTRODUCTION

This project represents a first effort, in Idaho, to assess the value of satellite and high elevation aircraft imagery for the evaluation of land resources. This study was based on a considerable accumulation of ground truth concerning the non-forested vegetation of southern Idaho, primarily the sagebrush-grass zone and associated types of vegetation and soils. The study emphasized an ecosystem approach to resource analysis.

The primary objective of the project was to determine and map the major vegetation types of the study area and to identify the soils associated with this vegetation. Secondary objectives included the following:

a. To determine the relation of soil patterns to seasonal changes in plant growth and development.
b. To determine the distribution of soils affected by Pleistocene periglacial climates.

Previous ground study over a 15-year period by an interdisciplinary team of range ecologists and soil scientists had revealed much about the nature of vegetation and soils in this range area of some 25 million acres. It had also shown the slowness and difficulty of covering such a large and varied area by ground methods, and the resulting difficulty in recognizing and mapping similar ecological units either within the state or in adjacent parts of the Intermountain region. We were anxious to see what part remote sensing could play in capitalizing on the extensive, yet incomplete, knowledge gained from many seasons of ground study.

STUDY AREA

Although some ERTS imagery interpretation substantiated by ground truth data was made in various parts of southern Idaho, the southwest portion was selected for intensive interpretation. This area (100 x 115 miles) was selected for several reasons, including the limited amount of time and the fact that the area includes great variability in natural resources and that much ground truth information had previously been obtained in this area. In addition, it was anticipated that problems in ERTS imagery interpretation for this area would be representative of those to be encountered elsewhere in the region.

Southwestern Idaho (Fig. 1) contains great variability in vegetation, soils, physiography and climate. Since natural vegetation is the product of climate, soil, relief and time, the pristine vegetation in this area varied from salt-desert shrub communities of the shadscale zone to dense spruce-fir forests in the mountains. Man's manipulation has affected nearly all of the original vegetation through varying degrees of disturbance by grazing, logging, cultivation, fire and the introduction of exotic plant and animal species. These influences have greatly increased the variation in vegetation. Precipitation in this area ranges from about 5 to more than 30 inches annually. Elevation varies from 2200 feet to more than 10,000 feet above sea level. Soil parent materials include loess, lacustrine deposits, basalts, rhyolites, granites and alluviums all over extensive areas.

In addition a smaller area in eastern Idaho (60 x 80 miles) was selected for the determination of accuracy with which soil associations could be mapped by ERTS imagery interpretation. The vegetation over the major portion of this study area was sagebrush-grass and a small portion of the area supported lodgepole pine and Douglas-fir forests. Precipitation ranges from 8-20 inches with an elevational gradient of 5,000 feet to over 6,000 feet above sea level.

PROCEDURES

The ERTS imagery used was bulk processed black and white positive transparencies in the 70 mm format. MSS bands 4,5,6, and 7 were viewed singly and in combination with a Spectral Data viewer/projector. The combination of bands 5 and 7 with various filters provided as much enhancement for our current interpretation needs as did the use of additional bands.

The high flight imagery used to aid in interpretation of ERTS materials was black and white transparencies (475-575 nm, 580-680 nm, and 690-760 nm), and color infrared transparencies all taken from the 65,000 feet elevation. Only a portion of the study area was covered by high flight imagery.

The basic scale for the mapping of vegetation and soil features was 1:250, 000. This was accomplished by end projection with the color compositor. The projected color enhanced imagery was viewed and all observed images except roads and highways were delineated. Because the major highways were sketchily

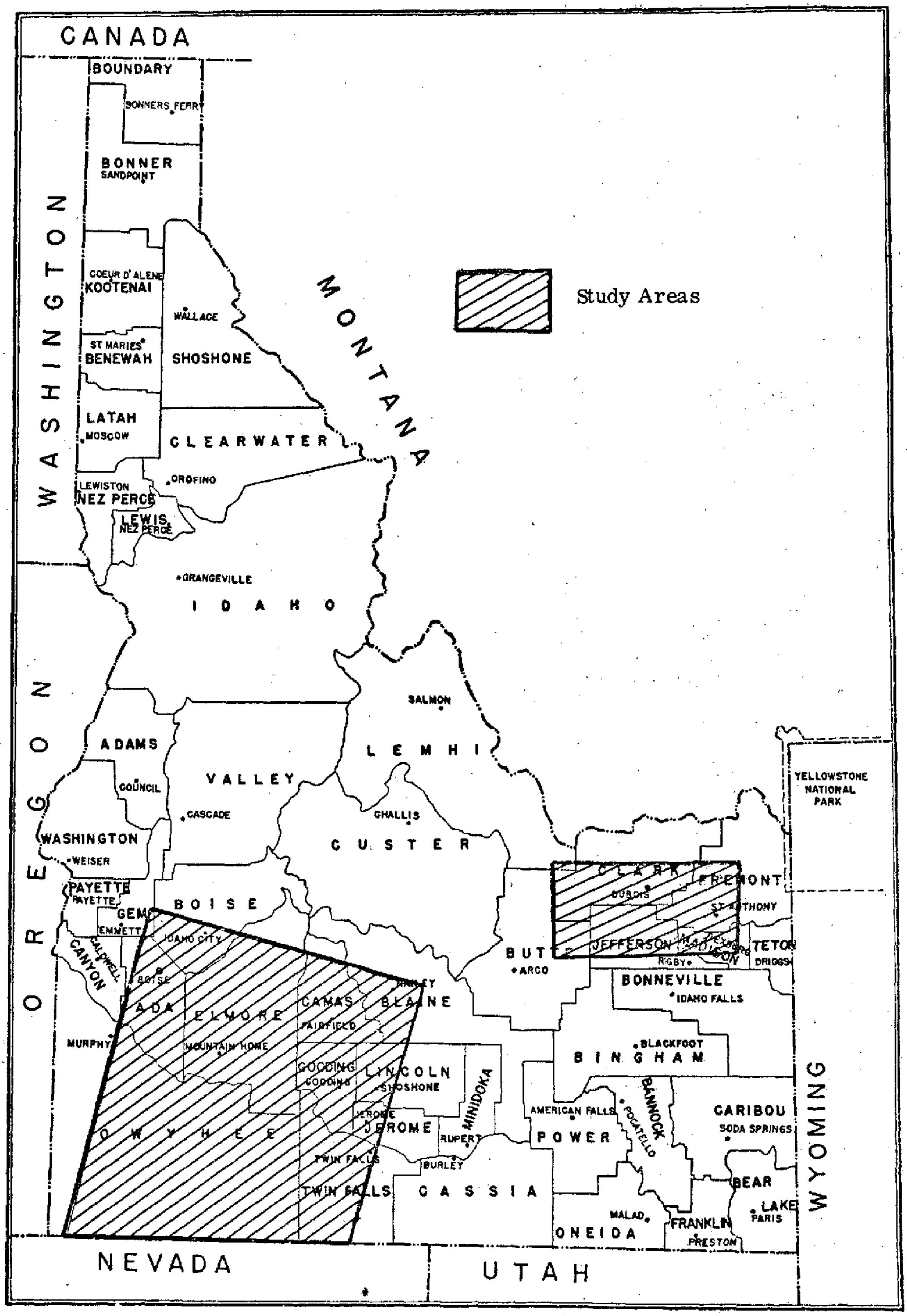


Fig. 1. Primary areas of intensive imagery interpretation.

detected and in some areas not observable, the road network was transferred from U.S.G.S. topographic maps even though errors were known to exist. Errors in the topographic maps were detected when corresponding triangles formed by the locations of prominent landmarks such as dams, confluences of rivers and larger water bodies on ERTS imagery and topographic maps were found to be incongruent (Tisdale et. al. 1973). Errors in the topographic maps for road locations were not considered serious for our purpose.

While in the process of interpreting images in relation to roads, it was found that the latitudinal markers on the ERTS chips were in error corresponding to as much as 5 miles on the ground. The 42°00' north latitude markers on the chips were located at a corresponding point 5 miles farther north than the southern boundary of Idaho which borders on Nevada and Utah.

Regardless of the errors encountered in the latitudinal locations or in the topographic maps, overlays of delineated images were reproduced by blue printing process for field and laboratory use. Some of the images were tentatively classified and later compared with ground truth data previously gathered or obtained during the summer of 1973.

Enlarged prints from black and white transparencies were also used to great advantage in the field. This low cost technique was easily done locally without special equipment and was of great value in locating and interpreting images in the field. The scale used was 1:500,000 which gave good image definition.

Ground truth inspections of numerous delineated images were made. Selection of images to be verified was not random but were in areas where we had few prior ground truth data. At each inspection site, the vegetation was characterized primarily by species abundance. Abundance ratings of 1 to 5, corresponding to the descriptive terms rare to dominant, were used to designate the relative importance of individual species in the plant community. In addition to its present cover, the site was classified as to its probable potential vegetation. Soils information included a description of the soil profile in accordance to the standard procedures established for soil surveys. A microprofile sample was collected for later verification and documentation. Each soil was classified in accordance to procedures established in the 7th approximation.

To supplement the ground truth data, a road log of vegetation was recorded with use of a tape recorder. Over 1200 miles of vegetation traverse were logged in this manner. This information was used to help determine distribution of vegetation types.

The classification of delineated images for the development of a vegetation map followed the scheme proposed by Poulton (1973) up to the tertiary level. At the tertiary level adjacent images that were classified alike were coalesced into a single image and are presented in this report as a second generation map.

The soils association map was developed in a different manner because interpretation relied less on direct evidence than for vegetation identification. The color composited imagery was projected at the same scale as for vegetation interpretation, i.e. 1:250,000, and ground truth stations were plotted (Fig. 2). Ignoring land use and small image patterns, major soil bodies were delineated on the basis of land form, geologic parent material, gross vegetation features and image color and density. The resulting soils map was developed independently of the vegetation map and is a first generation product.

Map overlays of areas receiving similar amounts of precipitation annually in increments of 5 inches and elevational contours at 500 foot intervals were superimposed on the image overlay to help identify and interpret images for the development of the vegetation map. Use of surface geological maps helped greatly in the development of the soil maps.

All color reproductions in this report were filmed on Kodacolor -X. Color enhanced images were photographed from the viewer screen of the color compositor.

IMAGE INTERPRETATION FOR VEGETATION MAPPING

The number of objects and images identifiable from ERTS imagery without special interpretive experience was considerable. This was brought out during the image viewing and delineation phase of our work. Many of the easily identifiable geologic features were rather large and conspicuous such as volcanic cones, recent lava flows, craters, canyons, cirques, lineations, and sand dunes. Other land features were man made, such as highways, large reservoirs, urban areas, agricultural lands, large airports, and large clear-cut logged areas to cite a few examples.

Most native vegetation and soil bodies were less obvious and were more difficult to identify and interpret without considerable acquaintance with the area.

Considerable information was obtainable from individual bands of the black and white transparencies. Projected images of band 5 alone showed considerable detail

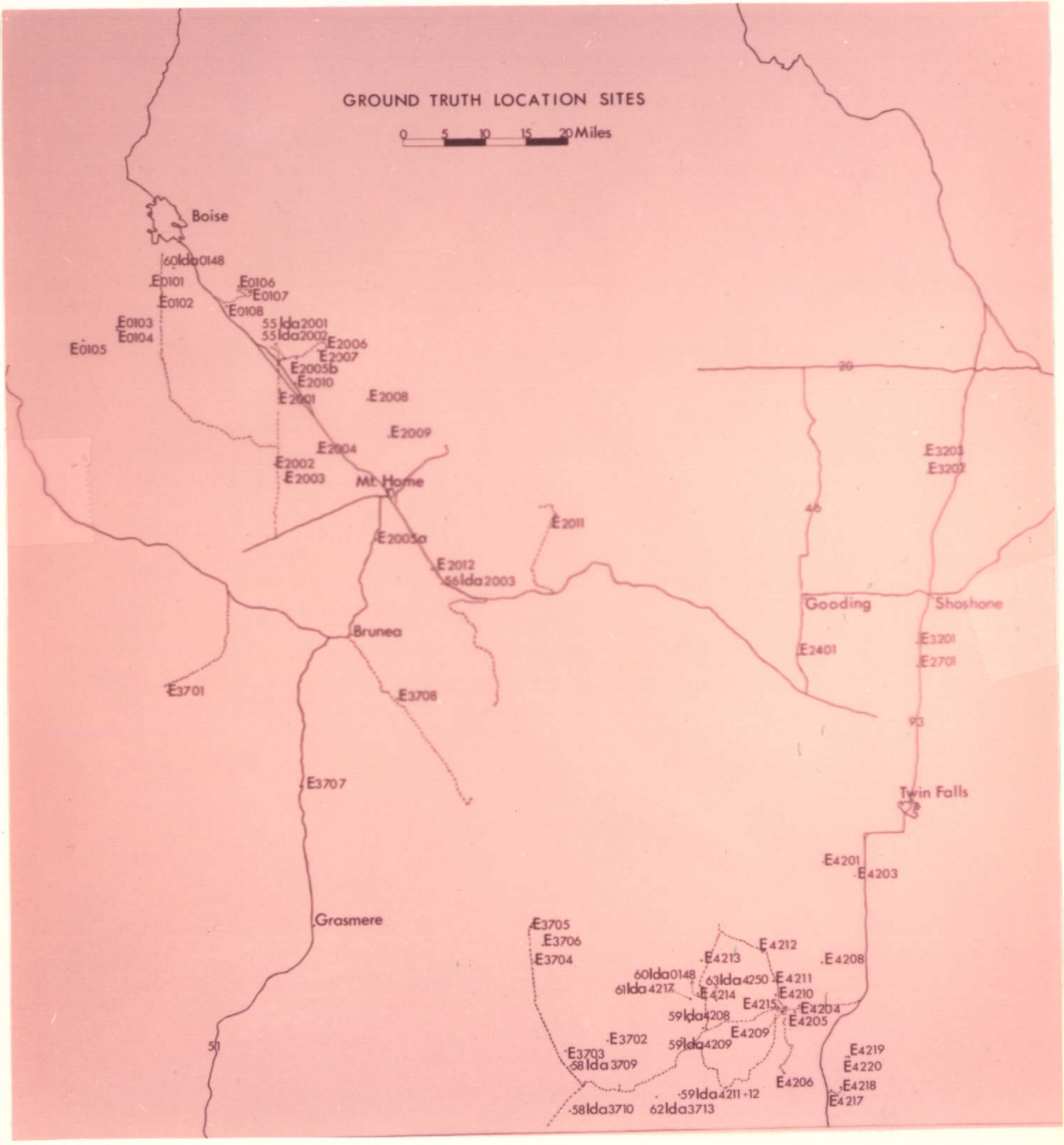


Figure 2 - Ground Truth Location Sites

on major vegetation distribution (Fig. 3). Separation of cultivated agricultural lands from forest and range areas was readily obtained. Fallow fields in the agricultural areas were also distinguished easily. Band 7 on the other hand, was more useful for distinguishing water bodies and drainage systems from the surrounding landscape (Fig. 4). Vegetational features were greatly subdued and details often lacking due to the high reflectance in the second infrared band (band 7) in areas where plants were actively growing. In general, if one were restricted to a single black and white band, film sensitive to the wave length of band 5 (600-700 nm) would be of greatest value for vegetation interpretation, particularly during the growing season. During the non-growing seasons the image differences between different kinds of vegetation was at a minimum in both bands 5 and 7. For interpretation of soil bodies, band 7 proved to be more interpretive if only a single band was used because this band enhanced land form and geologic features more than did band 5.

Single band interpretation of multispectral imagery proved to have distinct limitations compared to the multiband approach. For manual interpretation of multispectral imagery, the combined imagery of bands 5 and 7 with false color enhancement yielded considerably more information for interpretation of vegetational and soil features than single band interpretation. Vegetational features subdued or obscured in black and white transparency projection were shown as sharply contrasted by color enhancement. Forest vegetation was readily separated from agricultural areas, by the straight field boundaries of the latter, and the intensity of reflectance in infrared of agricultural crops (Fig. 5). Higher plant coverage and/or higher photosynthetic activity per unit area evidently produced this difference in reflectance.

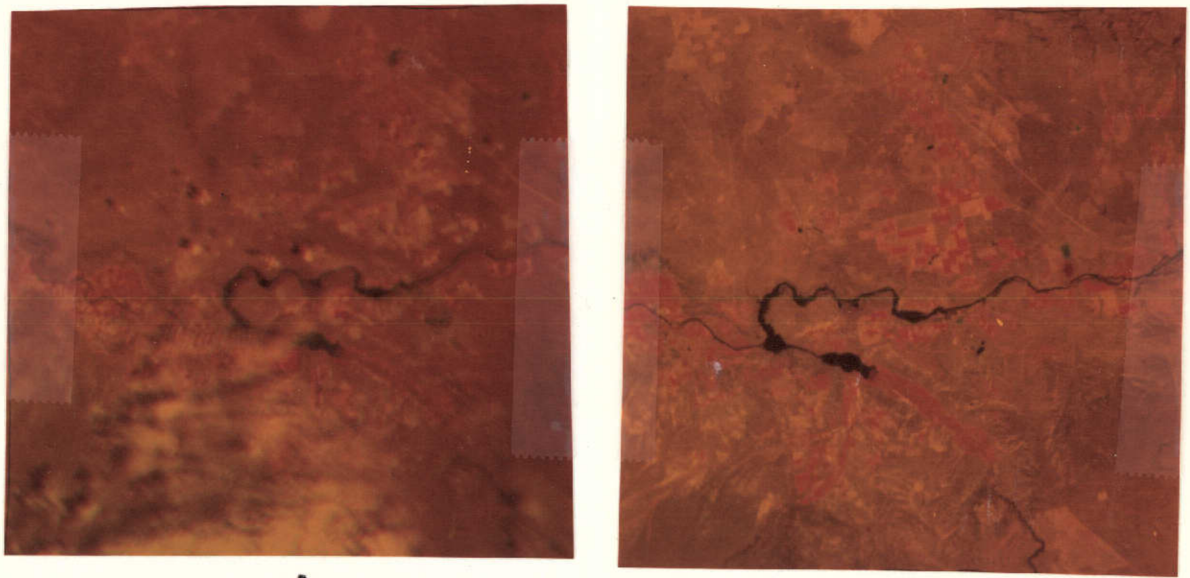
Although infrared reflectance in multispectral imagery permitted extraction of considerable information concerning vegetation, much additional information became available when sequential imagery was viewed. The combination of color enhanced multispectral imagery and temporal sequence during the growing and non-growing seasons allowed maximum interpretation of vegetation for a given resolution.

The identification of cheatgrass as compared to sagebrush dominated ranges from ERTS imagery was made relatively easily because of differences in infrared reflectance in the spring. Cheatgrass is a winter annual and highly active photosynthetically in the early spring. Separation between the two types of range was not apparent in the fall imagery because the dormant, cured vegetation did not register differently (Fig. 6). Sagebrush was found to respond very little in the infrared region throughout the season. This reaction has been observed by others, (Carneggie 1971; Driscoll and

Fig. 3. Black and white print of band 5 ERTS-1 imagery of southwestern Idaho, October 1972. This band was found to be useful in viewing vegetational features. Dark images were identified as areas of actively growing vegetation or crops. Various shades of grey were of areas dormant, sparse vegetation or harvested croplands. Recent lava flows and wildfires occurred as dark images in all bands.

Fig. 4. Black and white print of band 7 ERTS-1 imagery of southwestern Idaho, October 1972. Band 7 defined water bodies and land form well and vegetation poorly. Small resevoirs used for irrigation and stock watering were detected in this band but not in band 5.

Fig. 5. Color enhanced ERTS-1 imagery from bands 5 and 7 using green and red filters, respectively. This combination yielded highly interpretable imagery of vegetation, water bodies, landform, geology and soils.



A B

Fig. 6. Viewing of imagery of repeated coverage is highly useful and in some cases essential for identification of vegetational types. Annual vegetation such as cheatgrass is readily separated from sagebrush in imagery taken in April (A) because infrared reflectance contrast is maximum. Summer (B) and fall imagery do not differentiate the two vegetation types well.

Francis, 1972). This low reflectance of infrared on film has not been supported by spectral reflectance measurements, however. Our preliminary data indicate that spectroreflectance of sagebrush in the 800 to 1100 nm wavelength was higher than would be suspected from a species that registers only a faint light reddish purple on color infrared film (Driscoll and Francis 1970). The relatively high spectroreflectance of sagebrush was reported by Roberts and Gialdini (1971) also. It has been suggested that the pubescence on sagebrush foliage may contribute to this anomaly. This phenomenon of sagebrush reflectance needs further investigation. In any event, the differential infrared registration on film of sagebrush and cheatgrass during the spring made separation of ranges dominated by these species fairly consistent.

Throughout southern Idaho extensive range improvement programs have been undertaken by land management agencies and ranchers. Most of these programs have included range rehabilitation by means of artificially reseeding ranges to adapted perennial grasses, particularly crested wheatgrass, with a minimum of seedbed preparation. In most projects, the sagebrush or other species was destroyed by a shallow plowing, spraying with herbicide or burning and followed by drilling of a grass species. Attempts to reseed areas dominated by cheatgrass have resulted in far fewer successes than where reseeding was made in depleted sagebrush ranges. Locating and identifying seedings in Idaho on ERTS imagery has been only a qualified success to date. Some seedings were readily identified while others were difficult to discern (Fig. 7). None of the ERTS or high flight imagery showed high infrared reflectance for crested wheatgrass even in the spring months. Seedings were identified indirectly by the boundary of the seeded areas contrasting sharply with the surrounding range rather than by a unique signature for crested wheatgrass. None of the imagery showed high infrared reflectance for the seeding which is contrary to results of closeup color infrared photography. This discrepancy may be related to the high percentage of bare ground generally associated with seeded areas, particularly those less than 10 years old. Older seedings or poorly established ones dominated by annuals were difficult to identify and delineate. Our success in identifying range seedings has not been as great as reported in Nevada by Tueller (1973).

The shadscale zone occurs in areas that receive less than 6 inches of precipitation annually. The low amount of precipitation results in the development of soils that contain high concentration of salts and very low percentage of organic matter. The vegetation in this zone is generally so sparse that its presence is masked by bare ground reflectance on ERTS or high flight imagery. Identification of other salt desert shrub

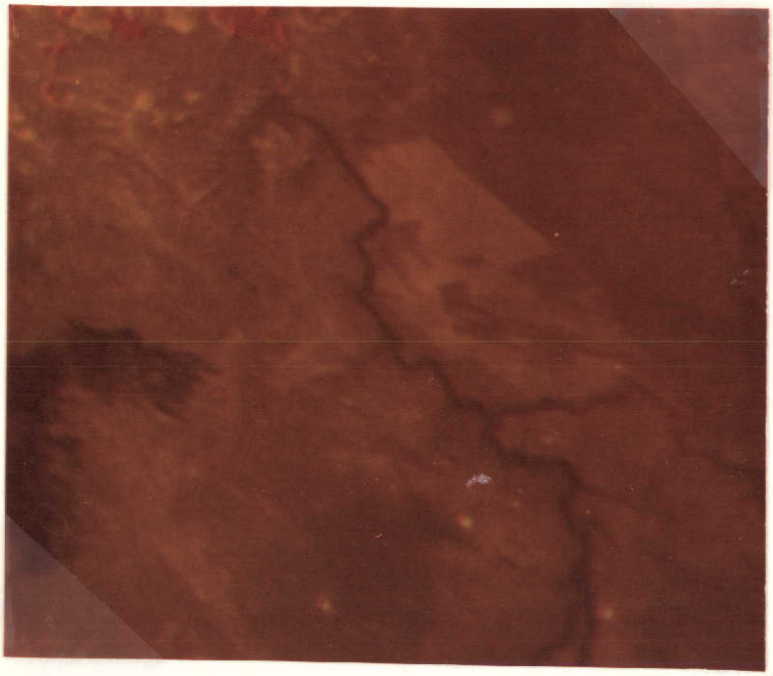


Fig. 7. Color composited ERTS-1 imagery showing a large seeding project on federal range in southwestern Idaho. Dark areas within the light colored seeding are areas of sagebrush that were left intact because of rockiness or ownership (a state school section is shown as a dark square). Infrared reflectance of crested wheatgrass seedings has been minimal regardless of season. The high amount of bare ground is probably responsible for minimal infrared response of seedings. The dark image to the left is a large burned area.

communities within the shadscale zone was not possible. Separation of the shadscale zone from the adjacent sagebrush zone in this low precipitation area was interpreted by the general occurrence of small playas and high soil reflectance in the shadscale vegetation. This method of segregation was found to be fairly accurate.

Separation of two major sagebrush types was accomplished by means of the infrared reflectance of associated species, particularly Idaho fescue. The Basin big sagebrush/Bluebunch wheatgrass vegetation was separated from the Mt. big sagebrush / Fescue by differential reflectance in the spring and summer imagery. Efforts to separate Mt. big sagebrush/Fescue from Mt. big sagebrush/needlegrass vegetation types have not been successful so far. Analysis of fall imagery separated the mountain brush and aspen communities from the high elevation mesic sagebrush communities.

Delineation of juniper vegetation in spring and summer imagery was difficult because of the high photosynthetic activity of the adjacent of intermingled mesic sagebrush and mountain brush communities. Analysis of fall imagery segregated out the sagebrush communities and late fall-early winter imagery separated the mountain brush vegetation due to its deciduous nature, except for buckbrush . Delineation of curl-leaf mahogany stands from juniper has not been successful.

From the land use viewpoint the development of new agricultural land under the Desert Land Entry Act is active in parts of the study area and can be readily monitored by ERTS imagery. In previous fall imagery, an area south of the Snake River near Glenns Ferry, Idaho showed cheatgrass range with no hint that it was to be converted to irrigated cropland. The first subsequent imagery received was April 17. Within this four month period 6000 acres of this land had been plowed and prepared for potatoes (Fig. 8).

In irrigated farm areas, as in Boise and Twin Falls valleys, land cultivated for row crops such as potatoes, beans, corn and sugarbeets were readily differentiated (in early spring imagery) from that used as pasture or haylands. Fields being prepared for row crops during this time of the year were clearly distinguishable because of their exposed bare ground. Interpretation of imagery in relation to time of ground preparation, planting date, and harvest period for individual crops for various areas in the state could be used to identify these crops and their acreage.

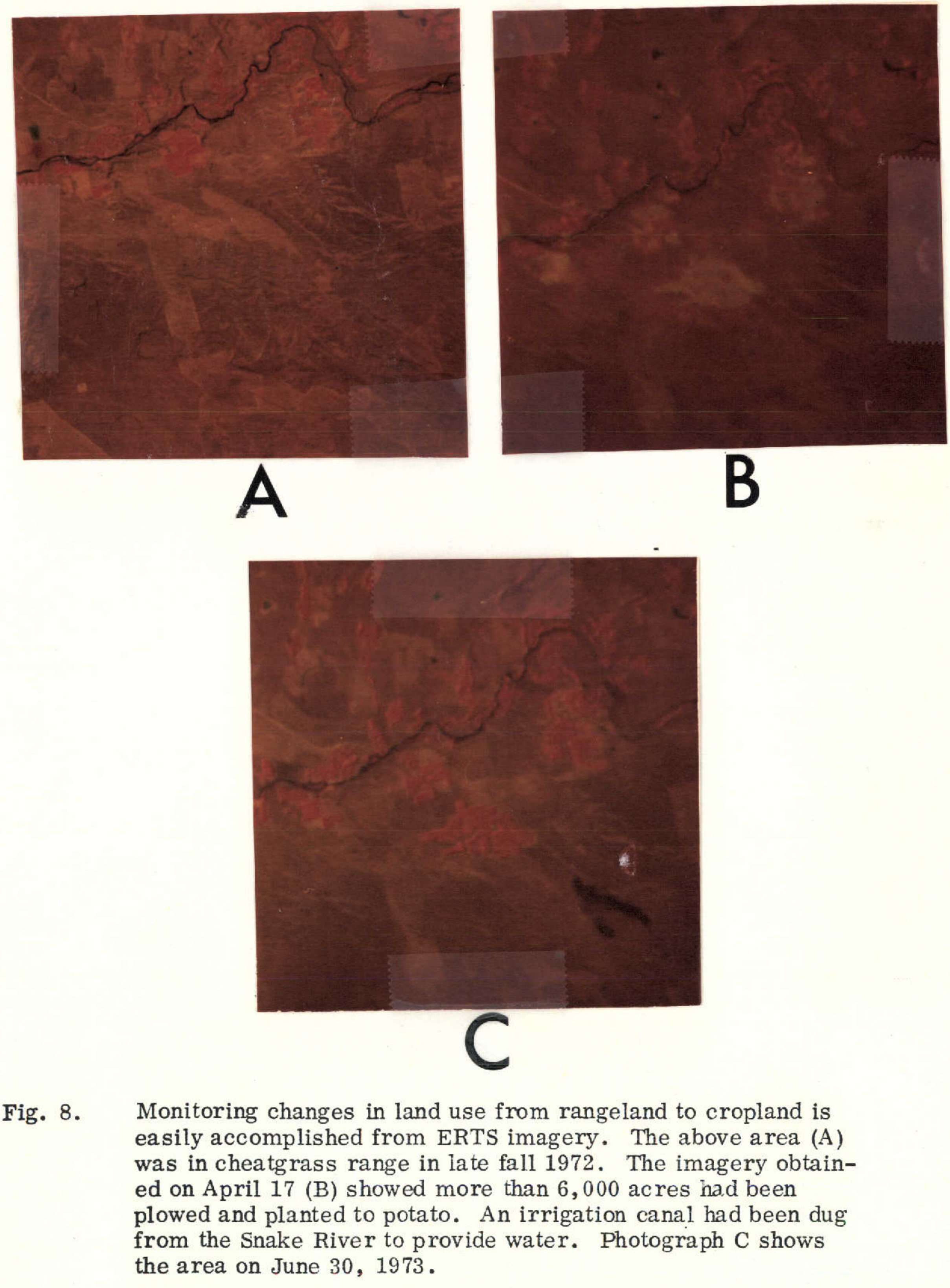


Fig. 8. Monitoring changes in land use from rangeland to cropland is easily accomplished from ERTS imagery. The above area (A) was in cheatgrass range in late fall 1972. The imagery obtained on April 17 (B) showed more than 6,000 acres had been plowed and planted to potato. An irrigation canal had been dug from the Snake River to provide water. Photograph C shows the area on June 30, 1973.

VEGETATION MAP

The vegetation type map of the Mountain Home-Jarbidge area produced from ERTS imagery is presented in Figure 9. This is a second generation map and the vegetation types include numerous complexes of images that were originally delineated from ERTS imagery at a scale of 1:250,000. Each image inclusion represented one or more plant communities. There were considerable differences in the appearance of some plant communities from one image to another but these were included within the same vegetation type because of the relatively small areas involved or the fact that the plant communities were considered sufficiently similar. The kinds of variability between plant communities included both species presence and relative abundance. The designated vegetation type is based on the predominant species that occur repeatedly over the landscape and are responsible for the vegetational aspect. Detailed description of vegetation types is presented in Appendix A.

All vegetation type lines were not observed in any imagery acquired on a particular date but were the result of interpreting imagery acquired from repeated passes. The images of the base map were outlined from imagery obtained in the fall of 1972. The delineation of the cheatgrass type was best observed in the April and May imagery. The vegetation types with Idaho fescue were best identified in the imagery acquired in late June.

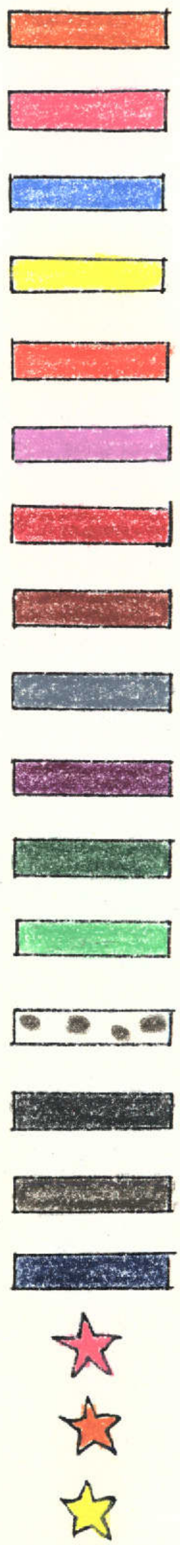
Instances where some areal coverage with U-2 imagery was available, the location of vegetation type lines were compared for agreement. Where a discrepancy was noted, the type line was adjusted to conform with the interpretation of the high flight imagery. The additional detail that was present in U-2 imagery was not included in the vegetation type map, other than for adjustment of type lines.

The vegetation and soils map presented in this report were prepared independently by a range ecologist and soil morphologist. Both individuals had some experience and training in the other's professional field. A comparison of the two maps showed a great deal of similarity in location of major vegetation type lines and soil association lines. This was not unexpected due to the interpretive ability of the mappers, who used evidence interpreted from the other's field to help map his own resource. Some obvious differences in delineation of type lines for both vegetation and soils still need to be resolved however.

VEGETATION TYPE MAP

Mt. Home - Jarbidge Mt. Area

Legend



Cheatgrass (Bromus tectorum)

Shadscale (Atriplex confertifolia)

Basin big sagebrush/Thurber needlegrass (Artemisia tridentata subsp. tridentata/stipa thurberiana)

Basin big sagebrush/Bluebunch wheatgrass (Artemisia tridentata subsp. tridentata/Agropyron spicatum)

Mt. big sagebrush/Fescue (Artemisia tridentata subsp. vaseyana/Festuca idahoensis)

Low sagebrush/Fescue(Artemisia arbuscula/Festuca idahoensis)

Juniper/sagebrush (Juniperus occidentallis/Artemisia spp.)

Meadow

Forest (Douglas-fir/Aspen)

Range seedings

Irrigated cropland

Dryland cropland

Playas

Recent lava

Sand dune

Rivers and large water bodies

Boise

Mt. Home

Twin Falls

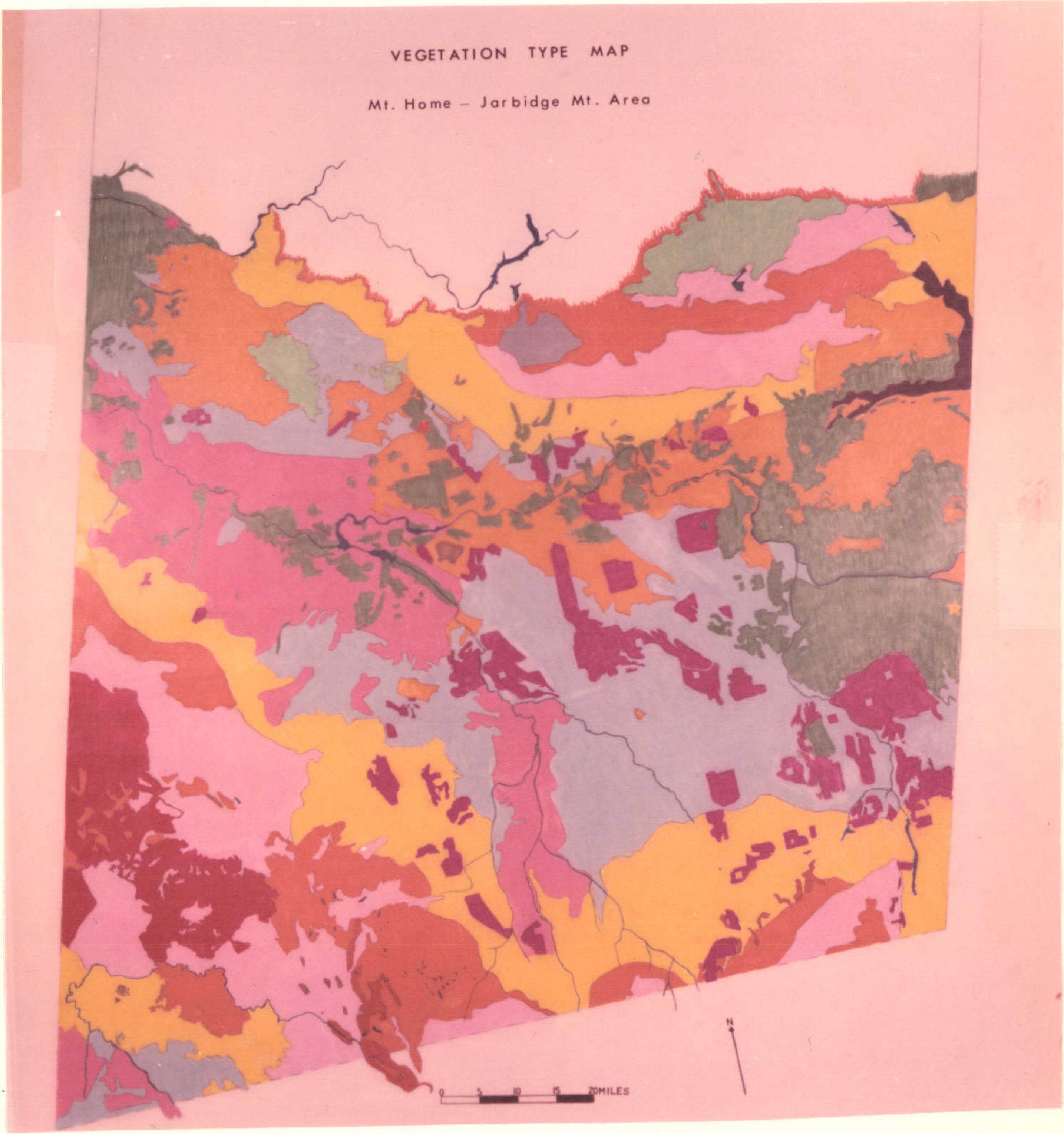

VEGETATION TYPE MAP
Mt. Home – Jarbidge Mt. Area
N
0 5 10 15 20 MILES

Figure 9

IMAGE INTERPRETATION FOR SOILS MAPPING

Different kinds of soils develop from different combinations of climate, vegetation and parent material. These three soil forming factors are modified by different landforms. Therefore, we have broad zones of soils related to specific units of climate and vegetation superimposed over kinds of parent materials that are further modified by topographic features. Thus, different patterns of soils show up on color composited ERTS imagery in different colors and tones. These are mapped as soil associations. The soil association represents a group of soils classified at the subgroup level of soil classification. Results of the soil mapping study are basically given in the two soils association maps, Figures 10 and 11. These results are supplemented by color positive photographic prints that illustrate and show images that correspond to soil association mapping units.

Figure 12 is an overall color print of the June 3 ERTS imagery corresponding to the upper two-thirds of the Mt. Home-Jarbidge Mt. (Figure 10) soil association map. Figure 13, an enlargement of the lower left one-quarter, illustrates vegetational and soil zonational patterns as a result of changes in climate due to elevational differences from the Snake River to the southwest into the Owhyee Mountains. Soil associations 1a, 13a, 11r, and 10r are in order from dry to more mesic conditions. The light colored patterns in 1a are eroded surfaces as contrast to the darker areas that support salt-desert shrub vegetation.

Soil units 13a and 11r show gradual changes in greyish color indicating sagebrush vegetation and more pronounced topography. The reddish color corresponding to 10r is related to the more actively growing plant communities at higher elevations and darker soils. Figure 14 shows the same area from an October 1972 ERTS imagery. There is less color because of decreased photosynthetic activity and the topographic relief features are much more pronounced.

The right central portion of Figure 12 also illustrates zonation but more strikingly shows changes in land forms as a result of different geologic formations. The large dark grey arc shaped image designated unit 2br corresponds to the silicic volcanic rock formation on the Idaho geologic map (Ross and Forrester 1947). Adjacent to silicic volcanics is the Idaho Batholith formation which corresponds to soil association 3g in the western one half of the unit. The contrast in color is very evident between these two geologic formations. The 2br soil association also represents the middle zone of the Mollisol soils. This grades to light colored Mollisols on the

SOIL ASSOCIATION MAP

Mt. Home - Jarbidge Mt. Area

Legend

Map Colors

Light colored aridosols

Dark colored aridosols

Light colored mollisols

Medium colored mollisols

Dark colored mollisols

Playas

Forest areas

Mapping Unit Symbol

Number	=	soil unit eg. 8b
Letter	=	parent material

Mapping units with two symbols, second symbol composed of letter and number are reference symbols from soils map of Owhyee County, e.g. H3

Parent Material Symbols

a = alluvium
b = basalt
d = dune sand
g = granite
r = rhyolite
l = loess

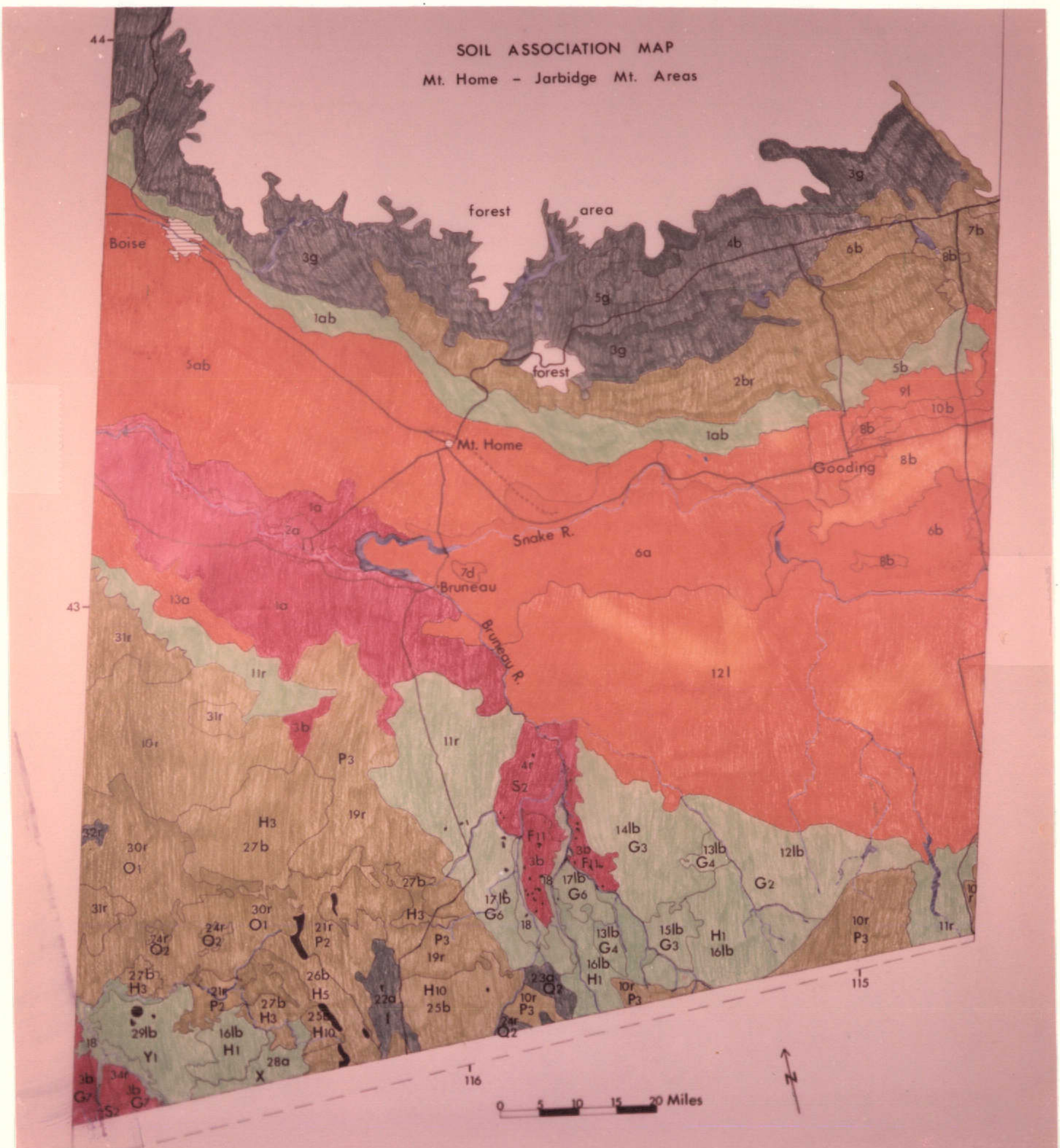

SOIL ASSOCIATION MAP
Mt. Home - Jarbidge Mt. Areas
forest area
forest
Boise
Mt. Home
Gooding
Snake R.
Bruneau
Bruneau R.
0 5 10 15 20 Miles
115
116
N
44
43

Figure 10

SOIL ASSOCIATION MAP

St. Anthony Dunes Area

Legend

Map Colors

Light colored Aridosols

Dark colored Aridosols

Light colored Mollisols

Medium colored Mollisols

Dark colored Mollisols

Sand dunes

Forest areas

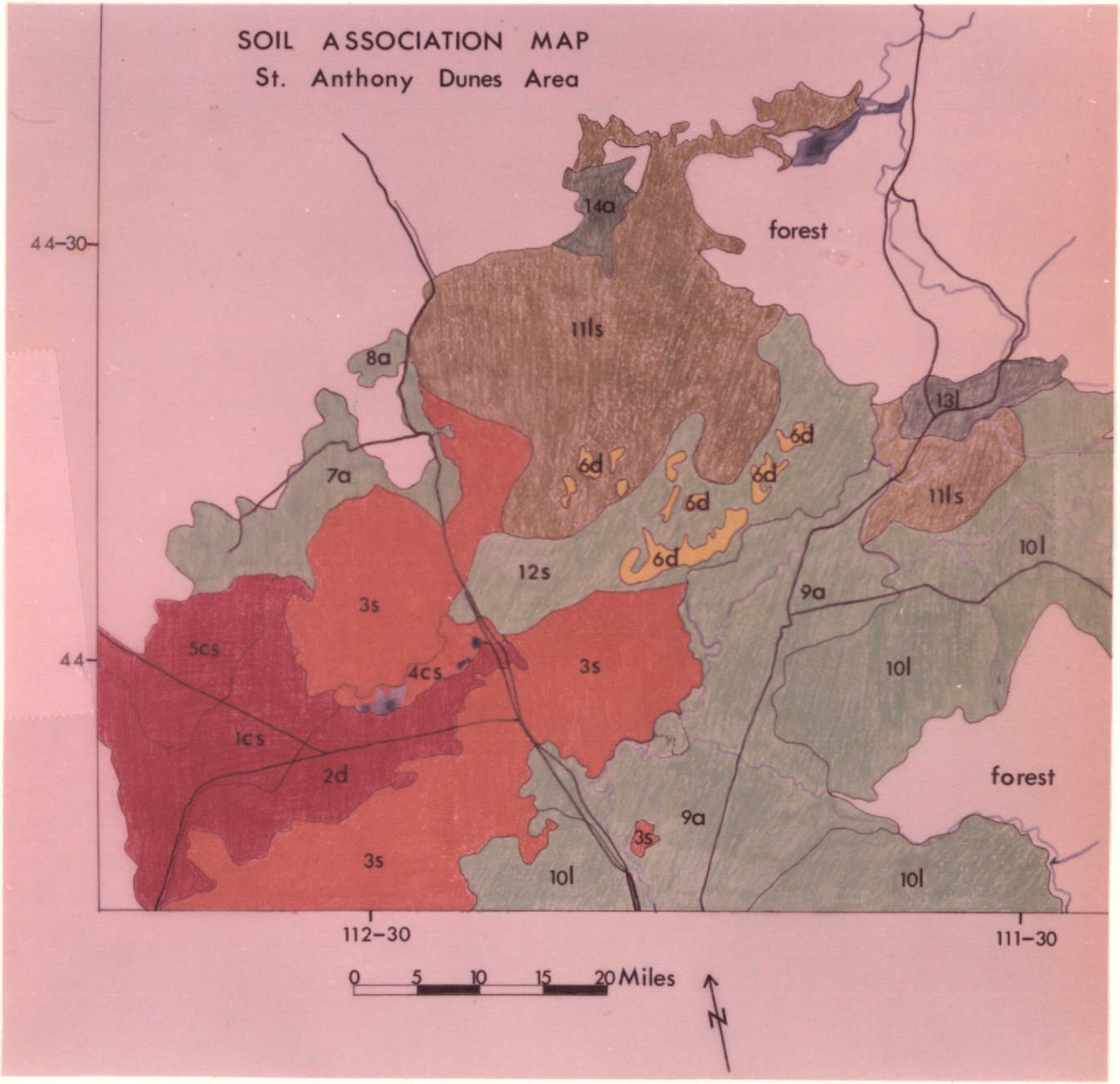
Mapping Unit Symbol

Number = soil unit e.g. - 1a

Letter = parent material

Parent Material Symbols

a = alluvium
b = basalt
c = locustrine
d = dunes
l = loess
r = rhyolite
s = sands


SOIL ASSOCIATION MAP
St. Anthony Dunes Area
44-30
44
112-30
111-30
0 5 10 15 20 Miles
forest
forest
14a
11ls
11ls
8a
7a
13l
6d
6d
6d
6d
6d
6d
12s
10l
10l
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10l
9a
9a
3s
3s
3s
3s
5cs
4cs
1cs
2d

Figure 11

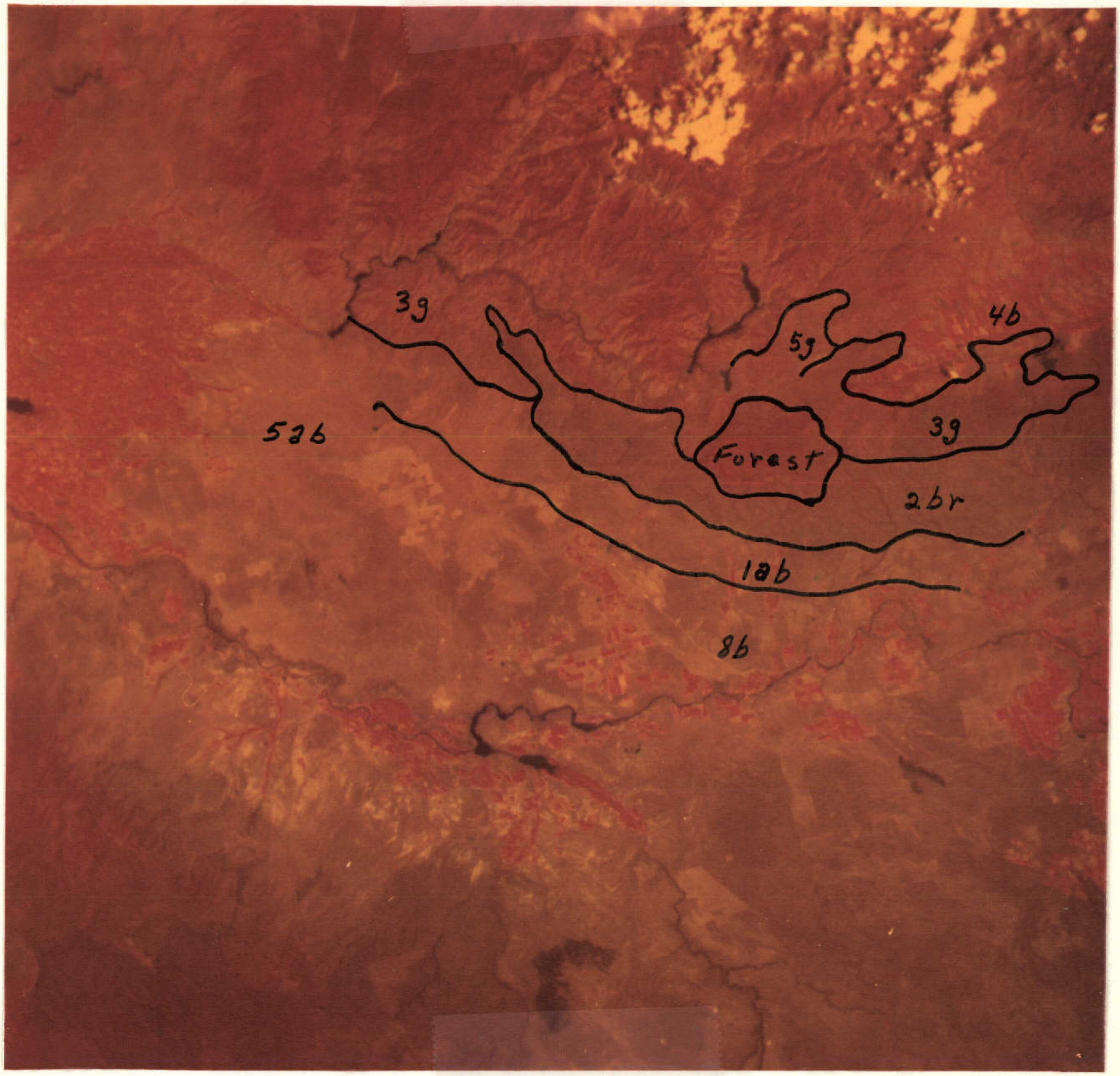

Fig. 12. Color composited photograph from ERTS imagery, bands 5 and 7, June 3, 1973 used to map the upper two-thirds of the Mountain Home-Jarbidge soil association map. Mapping symbols 2br is the silicic volcanics and the western half of 3g is the Idaho Batholith. Zonational changes progress from drier Aridosols to the more moist Mollisols as shown by symbols 5ab, 1ab, 2br, and 3g. The unit is cropland (nonirrigated).

Fig. 13. This photograph is an enlarged portion of lower left quarter of the photograph used in Figure 12. Color patterns caused by zonational changes from the Snake River to the Owyhee Mountains. Symbol and boundary lines correspond to those found on the soil associations map. Soil associations 1a, 13a, 11r and 10r are in order from dry to increasing moisture.

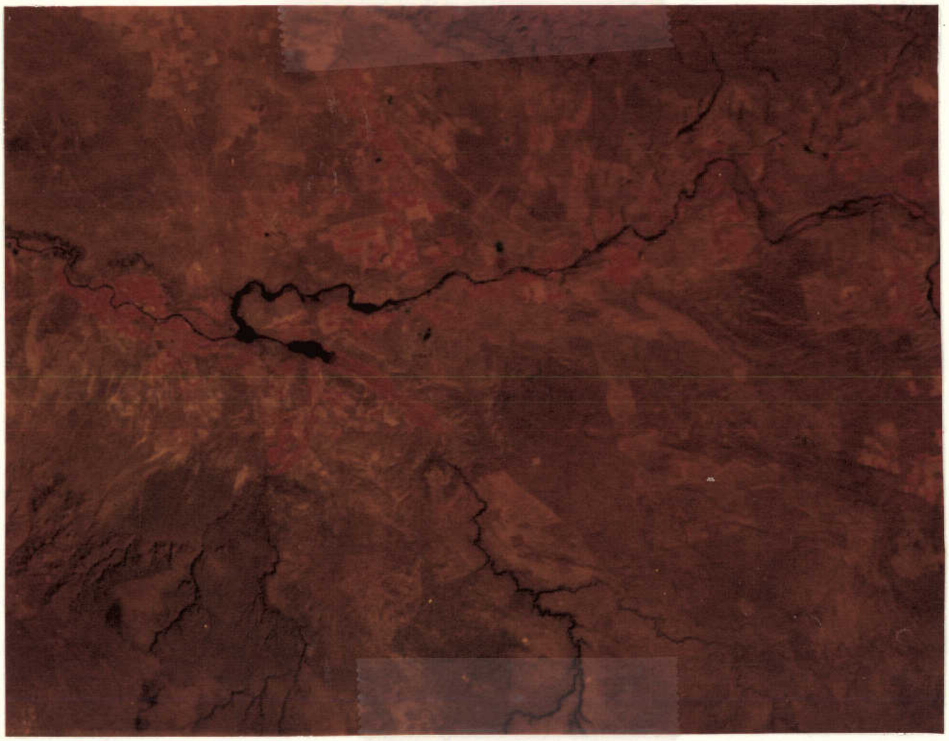

Fig. 14. October 1972 ERTS imagery shows a portion of the Mountain Home-Jarbidge area. At this date there is less color because of decreased photosynthetic activity and the topographic relief features are much more pronounced.

Snake River basalt and continues into the drier Aridosol soils represented by soil associations 1b and 5ab, respectively. North of soil associations 2br is unit 3g which occurs on the same silicic volcanics but contains more pink colors in combination with grey tones. This corresponds to a more mesic vegetation, northerly aspect and darker Mollisol soils. Soil unit 5g has lighter color tones and also occurs on the granites of the Idaho Batholith. Unit 4b is dominated by colors related to crop lands and dark colored soils developed on a basalt formation. The forested area in Figure 10 has more intense red colors than the surrounding non-forested vegetation. The contrasting colors and tones within the forested areas are related to steepness of topography, vegetation and geology. The soils of this forested area are primarily Inceptisols and Mollisols.

Relationships between soil depths, vegetation and age of basalt flows are well illustrated in Figure 15. Contrasting shades of grey tones separate five distinct ages of basalt flows. Soil depths range from no soil to soil mantle depths of 4 or 5 feet and are related to the age of flows. These basalts are associated with the Craters of the Moon area but are very representative of conditions found throughout the Snake River.

The St. Anthony dune area contains two landforms not found in the lower Snake River Plains and are illustrated in Figures 16 and 17 as soil associations 2d and 6d. The 2d unit in Figure 16 is characterized by elongated, low profile sand dunes that are not readily apparent from the ground but are conspicuous from the air. The height of these low dunes are less than one foot, often less than 6 inches, and are sparsely vegetated. These appear as light colored streaks in the imagery. The areas between the elongated dunes support normal vegetation on clay soils, over which the dunes are slowly creeping. In contrast to the elongated dunes are the large, active hilly transverse dunes designated 6d in Figure 17. These dunes are 20 to 30 feet in height and overlay shallow basaltic soils. The basalt soil area surrounding the dunes, mapping unit 12s, has an uneven grey color pattern in the color composited imagery. The lighter colored areas correspond to stabilized sand dunes and support some vegetation.

SOIL MAPS

The mapping units that make up the soil association maps in Figures 10 and 11 are groups of soils resulting from image interpretation of above discussed factors of soil formations. They were mapped from visual images which reflect various com-

Fig. 15. Black and white print of ERTS image from band 5, October 2, 1972 of the Snake River Plains area near Craters of the Moon shows contrasting patterns of four different aged basalt flows and related soil depths and vegetations.

Fig. 16. Color print from photograph of ERTS composited bands 5 and 7 in St. Anthony dunes area. Unit 2d shows elongated dunes as light colored lineations with sparse vegetation and interspaced with grey areas supporting normal vegetation on clay soils.

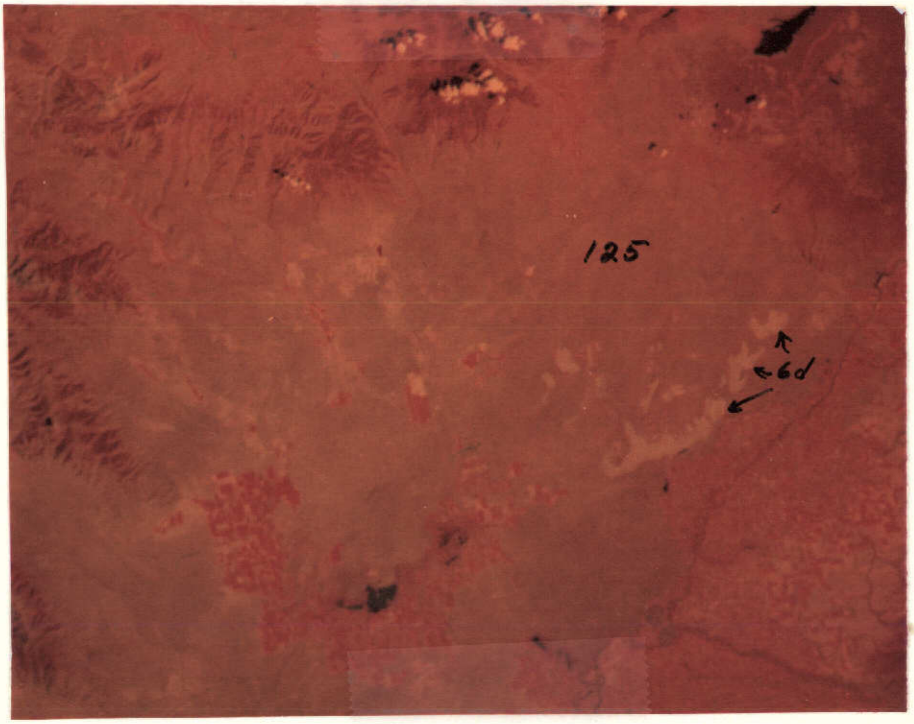

Fig. 17. Color print from photograph of ERTS composited bands 5 and 7 in the St. Anthony dunes area shows large hilly transverse sand dunes in unit 6d and the surrounding thin basaltic soils with stabilized vegetated dunes as slightly lighter shaded areas in unit 12s.

binations of soil-forming factors and are often related to physiographic and geologic units. Each color in the maps of Figures 10 and 11 correspond to the suborder level of classification and contains one or more subgroups. It appears that the agreement is only fair between the subgroup level of classification and vegetation types. Correlation between soils and vegetation should improve considerably when compared at the soil family level of classification.

After much of the mapping was completed in fairly broad patterns or units, it was found that as interpreting experience was gained, more tonal images were visible than were being utilized in mapping. This was particularly true of the lower left one-fourth of Figure 10. A soil reconnaissance map (Chugg et al. 1968) was used to interpret unidentified images in this area. Close agreement was found between the color and tonal patterns on the ERTS images and the reconnaissance map. It was also found that the ERTS images could be used to correct location of soil boundaries on the reconnaissance map.

The soil association map of the St. Anthony Dunes area, Figure 11 was made in cooperation with the Soil Conservation Service. The soil scientist of this area interpreting color composited projected imagery was able to delineate most soil associations previously mapped by standard mapping procedures. The soil association map (Figure 11) was completed in one day's time and another day was used to write the mapping unit descriptions.

The legends for the soil maps contain brief descriptions and soil classifications of major soils (Appendices B and C). The soil associations in the Mt. Home-Jarbidge map that were correlated with the Owyhee reconnaissance map contain two symbols. One of these symbols corresponds to the legend in the Owyhee soils reconnaissance map and the other is the conventional symbol used throughout this study.

DISCUSSION

Our experience with ERTS-1 imagery interpretation for wildland resource inventory purposes was limited to manual interpretation with aid of a color additive viewer/projector. This first hand experience has given us some awareness of the benefits, problems and limitations of utilizing this particular kind of imagery for remote sensing of earth's resources.

The synoptic view provided by a single ERTS-1 chip is a feature that has not been available previously. A view of 8 million acres of landscape without the distraction of artificial lines produced by a mosaic of several pieces of imagery is a highly desired feature. It is not only of value for the production of small scale maps of vegetation, soil and land uses but also permits a better interpretation of the total integrated effects of the primary factors that affect the distribution of major vegetation and soil types.

The 18-day orbital cycle is probably the most important feature of ERTS-1 imagery. Without repeated viewing of the same piece of landscape, a much higher level of imagery resolution would be required to obtain the same amount of information. The frequency of repeated passes is adequate to observe most phenological changes in vegetation, if not obscured by clouds. Information on differences in phenological development is heavily relied upon to differentiate between some vegetation types. The value of repeated passes for the purpose of monitoring and interpreting changes in vegetational development, land use and subsequent changes following short-term events such as fires, floods and earthquakes is immense.

Needless to say, greater resolution would be desirable. ERTS-1 imagery would have greater value if we were able to identify different land use practices such as clear-cutting, row crop vs pasture, and other identifiable land uses on an area of 10 acres or less as compared to the present minimum of 25-30 acres by manual interpretation. The resolution of ERTS-1 imagery was not quite adequate to permit recognition and delineation of habitat-types of natural vegetation. There has not been sufficient time to explore more fully the possible detection of habitat-types by combined interpretation of U-2 and ERTS-1 imagery. The vegetation mapping units that we were able to achieve represent a level of classification slightly above the habitat-type level, which is extremely useful for wildland management purposes. Habitat-type classification is based on the occurrence or potential occurrence of specific species or groups of species and not on life forms alone. However, the level of vegetation mapping achieved from ERTS-1 imagery contains far greater detail and accuracy than is presently available for any small scale map of Idaho.

Detection of differences in range condition, particularly heavily or overgrazed ranges as compared to lightly grazed ranges was not achieved. Only a single example of a fence line contrast was observed on ERTS-1 imagery. Heavily utilized ranges were readily apparent in U-2 imagery, however.

It was found that ERTS multispectral imagery is very useful for preparation of soil association maps made at the subgroup level of classification and at a scale of

1:250,000. The value of larger scale image projections has been demonstrated in other studies (Frazel et al. 1973). ERTS imagery is particularly valuable for mapping rough, inaccessible terrain characteristics of much of this study area and of the western United States. This is possible because image color and tonal characteristics can be related to topography, geological formations, native vegetation types, erosion patterns, drainage systems and land use. It was also found that with colored prints certain land use and other features were recognized that were not evident with color enhanced projection.

Based on accomplishments in this project use of ERTS multispectral imagery would accelerate inventory and mapping of natural resources and land use. The soil scientist from the Soil Conservation Service who used these materials to map the soils in Figure 11 stated that ERTS imagery would be very useful for delineating many of the soil boundaries for a detailed soil survey prior to going into the field, and would accelerate soil surveys which use the more detailed series level of mapping units.

More research and experience is needed in Idaho to determine the maximum use of this type of remote sensing. A better understanding is needed of the significance of certain color and tonal qualities observed with difference in geologic formation and with different soil-vegetation combinations. Likewise a better understanding is needed on changes in color tones with zonation related to elevation and climatic changes. It is believed that soil surface colors have less value in the areas of dry summer climate in contrast to the areas with summer rainfall where soil moisture causes greater soil color variations.

ERTS-1 imagery interpretation alone appears to have limited application for land management purposes on an individual ranch or allotment basis, but small scale vegetational, soil and land use maps could be produced with a minimum of ground truth. Once a base of reference has been established, changes in shape, color or texture of image as viewed on subsequent passes would indicate that a change has occurred and an investigater could be dispatched to the scene if it could not be interpreted otherwise.

We have not had much experience with multistage sampling but it would appear that ERTS-1 imagery assisted by compatible imagery from high and low flights would provide the best combination to satisfy the needs of most users of multispectral imagery for monitoring renewable resources and their uses.

This project has demonstrated that the interpreter of ERTS imagery must be familiar with the resource that is being inventoried and ground truth data are indispensible. It also demonstrated that ERTS type imagery can be interpreted with a minimum of equipment. More sophisticated equipment would accelerate and improve interpretative ability, however.

SUMMARY AND APPLICATION

The synoptic view of large areas, multiband viewing and repeated coverage provided by ERTS-1 imagery proved well suited for identifying and mapping vegetation, soils and other natural resource features in southern Idaho. High elevation aircraft imagery was found to be a valuable supplement in cases where greater definition and detail were required.

MSS bands 5 and 7 both singly and used in conbination to produce false color images were the most useful of the 4 wave lengths provided by ERTS-1. Band 5 was best of the individual bands for delineating vegetation types, while band 7 was best for showing geological and physiographic features and bodies of water. Color composites produced by bands 5 and 7 were particularly useful in distinguishing vegetation types. Use of images from both growing and dormant seasons was necessary to distinguish certain types. The use of color images was useful for identification of soil associations also, particularly in cases where vegetation was an important indicator of soil type.

The vital importance of the interpreter's experience and knowledge of ground truth for efficiency and accuracy of delineation and mapping of vegetation and soil types was demonstrated repeatedly in our study. Optical identification and mapping of vegetation types which showed only subtle tonal differences proved feasible for persons with adequate field experience. Success in such cases was due not so much to recognizing unique signatures as in the ability to interpret the observed image with the aid of supplemental information on climate, soils and landform. Similiarly, data on geology, landform, climate and vegetation were essential for interpreting soil types.

ERTS-1 imagery also proved very useful for monitoring changes in land use. Current conversion of semi-desert range to irrigated cropland was easily detected and mapped, as was loss of agricultural land to urban use. Identification of major cultivated crops would also be feasible, requiring mainly the development of a crop calendar.

The work accomplished in this short term project, starting as it did from a minimal base in remote sensing experience, has not been adequate to test fully the capabilities of ERTS-1 imagery for land resource appraisal. Particularly in the recognition and delineation of vegetation and soil types, where differences are often subtle, we have not satisfactorily established the limits of capability for ERTS imagery. Further, while we think that U-2 imagery will be highly valuable in supplementing the ERTS products, we have only begun to explore this phase of the problem. More investigation is needed to resolve the issues stated above, and thus to increase the applicability of remote sensing to inventory and management of land resources in our study area.

APPENDICES

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Vegetation Types

Cheatgrass 312.1 This is an annual vegetation type dominated principally by cheatgrass. In localized areas cheatgrass may be scarce or lacking and replaced by summer annuals such as annual sunflower, Russian thistle, willow herb, and mustard. Sandburg bluegrass is an ever present species in this type as well as most others. Scattered basin wildrye and squirreltail is common as is basin big sagebrush and rabbitbrush. Evidence of recent and past fires is conspicuous.

Shadscale 314.1 This is a diverse halophytic shrub type. It occurs in a low precipitation, high temperature area with saline and alkaline soils. Shadscale is the predominant species over the upland portion but in lower lying positions, greasewood is common. Winterfat communities as well as salt sage communities occur, also. Herbaceous species are not abundant in this type. Principal herbs are cheatgrass, peppergrass, tansy mustard and in some areas, halogeton. Shrubs that occur in localized areas include hopsage, smooth horsebrush, spiny horsebrush and bud sagebrush. Inclusions of sagebrush communities often occur as the sagebrush zone is neared.

Basin big sagebrush/Thurber needlegrass 325.2 In some areas the separation of this type from the cheatgrass type may be questionable because portions of the cheatgrass type was derived from this type. The shrub component is Basin big sagebrush with localized areas of green rabbitbrush and/or scatterings of hopsage. In addition to species that are associated with the cheatgrass type, Thurber needlegrass and needle and thread grass are generally present if disturbance has not been excessive. In areas of higher precipitation, bluebunch wheatgrass occurs but is definitely subdominant to Thurber needlegrass. A vegetation type characterized by the dominance of Sandburg bluegrass and the absence of bluebunch wheatgrass or needlegrass is also included in this type because of the limited areal extent of the Basin big sagebrush/Sandburg bluegrass type.

Basin big sagebrush/Bluebunch wheatgrass 325.3 This vegetation type is probably the largest recognized type in the sagebrush grass region and the most abused and altered. The dominant understory species are bluebunch wheatgrass and Sandburg bluegrass. Perennial forbs include phlox, balsam root, lupines and milk vetches, particularly in areas of higher precipitation. Annual forb species are generally the same as found in the drier vegetation type. Cheatgrass is widely distributed in this type. In higher precipitation areas other annual bromes replace cheatgrass. Medusahead replaces cheatgrass in natural secondary succession in this vegetation type. Bitterbrush is sporadically found in this vegetation zone and its distribution becomes more uniform in areas where moisture conditions are more favorable.

Mt. big sagebrush/Fescue 325.6 The presence of Fescue and mt. big sagebrush indicates that the area receives considerable precipitation and the temperatures are relatively cool due to higher elevation or northerly aspect. Associated species are numerous and perennial forbs are fairly rich in this vegetation type. Lupines, paint brushes, balsam root, milk vetches, arnicas, and hawksbeard are some of the more prominant species. Bitterbrush and rabbitbrush occur throughout the type whereas snowberry, serviceberry and spirea are found in areas of higher precipitation in this vegetation type. Annuals are relatively scarce in this zone although annual forbs do occur. Annual grasses are not important except in localized areas where the native vegetation has been severely abused.

Low sagebrush/Fescue 325.7 The occurrence of low sagebrush indicates that the soils are shallow, have strongly developed clay pans and/or are shallow, rocky and exposed to high winds in the fescue zone. The productivity of this vegetation type is less than surrounding or adjacent types supporting big sagebrush that occurs on deeper and better drained soils. Many of the associated understory species are the same but their abundance is generally less. Often intermingled or occurring is pure alkali sagebrush, a closely related species to low sagebrush. Both alkali and low sagebrush occupy the same kind of site. Bluebunch wheatgrass is an important herbaceous component and is often co-dominant with fescue. In this type there are often numerous fingers and islands of soils supporting big sagebrush.

Juniper/sagebrush 340.1 This is a highly varied type dominated by western juniper but often mixed with curl-leaf mahogany trees. Understory is varied with low sagebrush and mt. big sagebrush communities depending on soil depth. Bitterbrush and ocean spray are often associated with this type. Idaho fescue and bluebunch wheatgrass are the principal perennial grasses and numerous perennial forbs occur in this type. The shrub understory vegetation is sparsely developed where the tree cover is dense. The juniper is slowly spreading into adjacent mt. big sagebrush and low sagebrush communities due to lack of fires.

Douglas fir-Aspen type 343. This is a mixed forest type that has not been adequately sampled to characterize the type at present.

Crested wheatgrass seeding 414.1 This introduced perennial grass was seeded for the purpose of improving forage quantity and quality on depleted rangelands. These seedings are primarily single species until invaded by sagebrush in 10 to 20 years, or infused with annual weeds due to poor establishment of crested wheatgrass.

Mapping Unit Symbols and Description

Mt. Home - Jarbidge Mt. Area

Light Colored Aridosols: 1a Area dominated by moderately deep and deep, well-drained soil on gently sloping to steep, lacustrine sediments on dissected lake terrace and terrace escapement. They are classified Typic, Torriorthents and Urollic Calciorthids.

2a Medium textured, deep, somewhat poorly drained soils on nearly level to very gently sloping mixed alluvium on stream terraces. They are classified as Typic Haploquolls and Typic Torriorthents and Calciorthids.

3b Stony medium textured, shallow well-drained soils on nearly to very steep thin loess covered basaltic plains and rockland escarpments. Classified as Mollic Durorthids.

4r Stony and medium textured surface soils over calcareous loamy subsoil from thin loess covered rhyolitic hills. Thin moderately dark colored aridosol.

5ab Medium textured surface soils and claying subsoils over calcareous parent material from nearly level to gently sloping alluvial fans and stream terraces. Dominant soils are classified as Typic Durargids.

6a Deep loamy well-drained soils having loamy calcareous subsoils from wind worked sandy alluvium occurring on gently sloping stream terraces and basaltic plains. Classified as Xerollic Camborthids.

6b Moderately deep loamy and medium textured well-drained soils with calcareous subsoils from wind work sands and silty loess over basaltic plains. This area is typlified by its Calciorthids.

7d Moderately deep and deep excessively to well-drained soil on steep to nearly level aeolian sand and dunes. This area is characterized by Torripsamments.

8b Shallow, thin loess and residual basaltic material over basaltic flows.

91 Shallow to moderately deep residual and loess material over basalt flows.

10b Bare basaltic lava flow.

121 Medium textured moderately deep to deep loess over calcareous loess on basaltic plains. Characterized by Xerollic Calciorthids and Xerollic Durorthids.

13a Medium textured well-drained soils with calcareous subsoils derived from lacustrine sediment and alluvial fans. Characterized by Calciorthids.

Light Colored Mollisols: 1ab Medium textured well-drained soils over claying and calcareous subsoils over basaltic flows and alluvial fans. Characterized by Durixerolls and Argixeroll.

5g Medium and coarse textured soils with some clay subsoils developed from granitic material.

11r Medium textured moderately deep well-drained soils over calcareous susboils formed over rhyolitic rock formations.

121b This loess covered and residual basaltic material from basaltic plains characterized by Durixerolls.

131b Thin, dark colored stony medium textured surface soil over nearly level to steep volcanoes.

141b Medium textured thin loess covered, nearly level to steep basaltic plains and escarpments characterized by Durixerolls.

151b This area is probably similar to 141b but had a different tonal reflectance on ERTS image on Owhyee soils map.

161b Medium and stony medium textured surface soils that are shallow to moderately deep, well-drained soils with calcareous subsoils over basaltic plains. Characterized by Durixerolls.

171b Medium and stony medium textured shallow and moderately deep soils with calcareous subsoil on nearly level to steep basaltic plains. Characterized by Durixerolls.

18 Steep canyons dissecting basalt formations.

28a Medium textured, deep well-drained soils with calcareous subsoils developed from lacustrine sediments - Xerollic Haplargids.

29b Medium textured moderately deep well-drained soils with calcareous subsoils over thin loess covered basaltic plains.

Moderately Dark Colored Mollisols: 2br Medium textured shallow to moderately thick and frequently stony soils clay subsoils over basaltic and rhyolitic lava formations occurring on moderately steep mountain slopes. Many of these soils vary in thickness due to influence by past periglacial climate causing solifluction.

6b Medium textures surface soil with clayey subsoils over basalt bed rock-Argixeroll.

7b Medium textured mollisol over basaltic bedrock. Area not well investigated.

8b Nearly level area with medium textured soils which are somewhat poorly drained. This area not well investigated, separated mainly by zonal color pattern.

10r Medium textured stony surface with clayey noncalcareous subsoils that are shallow to moderately deep to rhyolitic welded tuff-Argiborolls.

19r These soils are similar to 10r but probably have weak calcareous subsoils, occur in dryer position and probably are Calcic Argixerolls.

21r Soils very similar to mapping unit 10r but with more shallow soils - Argiborolls.

24r Cobbly and stony medium textured surface soils moderately deep with clayey subsoils over rhyolitic welded tuff - Argriborolls.

25b Medium and stony medium textured soils over clay well-drained moderately deep to shallow developed from basaltic residuum. Typic Argiborols.

26b Very similar to mapping unit 25b.

27b Shallow soils on nearly level to sloping basaltic residuum - Lithic Mollic Haplargids and Argiborolls.

30r Moderately deep and deep well-drained stony medium textured soil over loamy noncalcareous subsoil-Cumulic Cryoborolls.

31r Similar to 30r but shallow soil from rhyolitic residuum.

Dark Colored Mollisols: 3g Medium textured moderately deep soils from granitic materials occurring on moderately steep to steep mountainous slopes -Cryoborolls.

4b Moderately deep and deep medium textured soils from alluvial fans and basaltic residuum occurring on gently sloping valley landform.

5g Similar to 3g but occurring on more gently sloping landforms.

22a Fine to medium textured deep, nearly level poorly drained soils with loamy and clayey subsoils from mixed alluvium in stream bottoms - Aquic Argiborolls.

23g Medium cobbly and stony moderately deep well-drained mixed alluvium on stream terraces and terrace escarpments - Argiustolls.

32r Mountainous area not investigated.

Mapping Unit Symbols and Description

St. Anthony Dunes Area

1cs Soils of this unit are well-drained. They formed in lacustrine material on playas in the 8-11" ppt zone. Surface and underlying layers to a depth of greater than 60", are silty clay loam and silty clay.

They are classified as Xeric and Aquic Torriorthents.

2d Soils of this unit are well-drained. They formed in lacustrine material on playas in the 8-11" ppt zone. The surface layer is loamy sand and sandy clay loam. The underlying layers are silty clay to a depth of greater than 60".

They are classified as Xeric Torriorthents.

3s Soils of this unit are well-drained. They formed in wind blown material on basalt plains in the 8-11" ppt. The surface and underlying layers are silt loam and sandy loam. Basalt bedrock is at depths of 10 to 40 inches.

They are classified as Calciorthids and Camborthids.

Lithic Xerollic Camborthids, Xerollic Camborthids, Xerollic Calciorthids

4cs Soils of this unit are poorly and somewhat poorly drained. They formed in windblown and lacustrine material on playas in the 8-11" ppt zone. Surface layers are loa my sand and sandy clay loam. Underlying layers are clay to a depth of more than 60".

They are classified as Aquic Camborthids and Xeric Torriorthents.

5cs Soils of this unit are well-drained. They formed in alluvium on alluvial fans in the 8-11" ppt zone. Surface and underlying layers are loam and gravelly loam with sand and gravel beginning at 10 to 20 inches.

They are classified as Xerollic Calciorthids.

6d Active sand dunes.

7a Soils of this unit are well-drained. They formed in alluvium, on alluvial fans and terraces in the 8-11" ppt zone. Surface layers are silt loam. Underlying layers are loam, silt loam and gravelly loam over sand and gravel at 10 to 60 inches.

They are classified as Camborthids, Calciorthids and Haploxerolls.

Xerollic Cambiorthids, Aridic Calcixerolls, Xerollic Calciorthids

8a Soils of this unit are well-drained. They formed in wind blown material and alluvium in the 11-13" ppt zone. Surface and underlying layers are loam. Basalt bedrock or sand and gravel begin at 20 to 40".

They are classified as Aridic Calcixerolls.

9a Soils of this unit are well-drained. They formed in mixed alluvium on river terraces in the 8-14" ppt zone. Surface layers are loam and silt loam. Underlying layers are loam, silt loam and gravelly loam with sand and gravel beginning deeper than 20".

They are classified as Aridic Calcixerolls, Aquic Haploxerolls, Aquic Xeroflurents, Xeric Torriorthents.

10L Soils of this unit are well-drained. They formed in wind blown material on loess foothills in the 11 to 19" ppt zone. Surface and underlying layers, to a depth greater than 60" are silt loam.

They are classified as Calcic Haploxerolls, Calciorthidic Haploxerolls and Pachic Cryoborolls.

11Ls Soils of this unit are well-drained. They formed in windblown material on basalt plains in the 12-19" ppt zone. Surface and underlying layers are very sandy and extremely rocky loam. Basalt bedrock begins at 20 to 40".

They are classified as Pachic Cryoborolls.

12s Soils of this unit are somewhat excessively drained. They formed in wind-blown material on basalt plains in the 8-16" ppt zone. Surface and underlying layers are sand and loamy sand. Basalt bedrock begins at depths of 40 to over 60".

They are classified as Haploxerolls - Typic, Calcic and Calciorthidic.

13L Soils of this unit are well-drained. They formed in glacial till in the 16-19" ppt zone. Surface and underlying layers, to a depth of greater than 60" are silt loam.

They are classified as Pachic Haploxerolls and Pachic Cryoborolls.

14a Soils of this unit are well-drained. They formed in alluvium and glacial outwash on terraces, fans and glacial topography. The precipitation zone is 16-19". Surface and underlying layers are loam. Sand and gravel begin in the profile deeper than 20 inches.

They are classified as Cumulic Cryaquolls and Pachic Cryoborolls.

15Lr Mountainous regions with forest vegetation. Soils are complex but the gentle slopes are loess covered and soils are Typic Cryoboralfs.

SPECIES LIST

Alkali sagebrush	Artemisia longiloba
Annual sunflower	Helianthus annuus
Arnicas	Arnica spp.
Aspen	Populus tremuloides
Balsamroot	Balsamorhiza sagittata
Basin big sagebrush	Artemisia tridentata tridentata
Bitterbrush	Purshia tridentata
Bluebunch wheatgrass	Agropyron spicatum
Bud sagebrush	Artemisia spinescens
Cheatgrass	Bromus tectorum
Crested wheatgrass	Agropyron desertorum
Curl-leaf mahogany tree	Cercocarpus ledifolius
Douglas-fir	Pseudotsuga menziesii
Fescue	Festuca idanoensis
Greasewood	Sarcobatus vermiculatus
Green rabbitbrush	Chrysothamnus viscidiflorus
Halogeton	Halogeton glomeratus
Hawksbeard	Crepis spp.
Hopsage	Grayia spinosa
Idaho fescue	Festuca idahoensis
Indian paintbrush	Castilleja spp.
Juniper	Juniperus spp.
Low sagebrush	Artemisia arbuscula
Lupines	Lupinus spp.
Medusahead	Taeniatherum asperum
Milkvetche	Astragalus spp.
Mt. big sagebrush	Artemisia tridentata vaseyana
Mustard	Sisymbrium spp.
Needlegrass	Stipa columbiana
Needle-and-thread grass	Stipa comata
Oceanspray	Halodiscus spp.
Pepperweed	Lepidium perfoliatum
Phlox	Phlox spp.

Rabbitbrush	Chrysothamnus spp.
Russian thistle	Salsola kali tenuifolia
Sandburg bluegrass	Poa sandbergii (secunda)
Salt sage	Atriplex nuttaliii
Serviceberry	Amelanchier alnifolia
Shadscale	Artiplex confertifolia
Smooth horsebrush	Tetradymia glabrata
Snowberry	Symphoricarpos spp.
Spiny horsebrush	Tetradymia spinosa
Spirea	Spiraea spp.
Squirreltail	Sitanion hystrix
Tansy mustard	Descurainia pinnata
Thurber needlegrass	Stipa thurberiana
Western juniper	Juniperus occidentalis
Wildrye	Elymus cinereus
Willow herb	Epilobium paniculatum
Winterfat	Eurotia lanata