TEST PLAN FOR REMOTE SENSING INFORMATION SUBSYSTEM PRODUCTS: TEST SITES 2 AND 5 (HIGH PLAINS AND TRANS-PECOS TEXAS)

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1.0 INTRODUCTION

1.1 Scope and Objectives

This plan describes map products to be generated from Landsat imagery, airborne multispectral scanner imagery, and aerial photography of test sites in the High Plains of the Texas Panhandle and in Trans-Pecos Texas. The objectives in producing these maps are (1) to determine the methodology necessary for developing each type of product, and (2) to designate the size, scale, level of detail, and final format of each map within an initial phase of development of remote sensing products.

The map products and data analysis procedures outlined here are based on (1) objectives outlined in the Applications System Verification and Transfer (ASVT) Project Plan (McCulloch and McKain, 1978), (2) state agency information needs and listings of possible products developed in conjunction with the User Advisory Group, and (3) the Remote Sensing Information Subsystem (RSIS) Level I Design and Design Review documents. The descriptions contained herein are primarily conceptual and are derived from limited hands-on experience with Landsat imagery and digital image processing hardware and software. Analysis of the High Plains region will make maximum use of experience gained in the coastal test site using ISOCLS for unsupervised classification of land cover/land use. The image enhancement techniques to be used for geologic applications in the Trans-Pecos region have not previously been applied as part of RSIS.

1.2 Project Summary

The goal of the ASVT Project Plan (McCulloch and McKain, 1978) is the development of a Texas Natural Resources Inventory and Monitoring System (TNRIMS) consisting of three main parts: (1) the Remote Sensing Information Subsystem, (2) the

Geographic Information Subsystem (GIS), and (3) the Natural Resources Analytical Subsystem (NRAS). These Subsystems represent analytical capabilities that are designed to assist agencies of the State of Texas in carrying out their statutory responsibilities in the areas of natural resources and the environment. These Subsystems will offer, respectively, the capability to manage (1) data derived by remote sensing from satellite and aircraft platforms, (2) geographic data derived from a variety of files of spatial information, and (3) models and assessment routines. TNRIMS will provide these capabilities within the framework of an existing 13-member consortium of state agencies, the Texas Natural Resources Information System (TNRIS) Task Force.

Primary funding for the development of TNRIMS comes from the National Aeronautics and Space Administration (NASA) and from Texas state agencies under a cooperative agreement between NASA and TNRIS. Project objectives, management, and responsibilities of each participant (NASA and TNRIS) are outlined in a Memorandum of Understanding dated March 1978. This document, together with the Project Plan, provides further details on the organization of all elements of the project and recounts previous experience with remotely sensed data among Texas state agencies.

1.3 Development and Configuration of RSIS

The prototype Remote Sensing Information Subsystem (RSIS) of TNRIMS, as outlined in the ASVT Project Plan, has been established for testing, evaluation, and refinement using data from five test sites within the State of Texas. RSIS is designed to become a fully operational system in the areas where RSIS is a real and direct benefit to state agencies in carrying out their responsibilities. The Subsystem must include the following capabilities (McCulloch and McKain, 1978):

1) Digital data manipulation and data enhancement procedures will allow maximum information extraction from Landsat multispectral scanner (MSS) imagery and airborne MSS imagery. Such procedures should include, for

example, removing image defects, correcting atmospheric effects, band ratioing, contrast stretching, density slicing, and creating mosaics from more than one scene of imagery. Time for testing and software refinement must be allowed as each procedure is integrated into RSIS.

2) Interactive, computer-assisted procedures for classification of data on digital tape will permit scaled and registered maps to be generated faster than by batch mode processing. The interpreter is to have a more direct role in guiding analysis based on the user's knowledge of natural processes, human activities, and the known spectral response of land cover in the area being analyzed.

3) The Subsystem must support manual image interpretation of Landsat imagery, aircraft photography, and auxiliary data to supplement the computer-assisted classification products. The generation of map products to be used with other data on a light table or with a Zoom Transfer Scope is an example of such manual interpretation techniques.

4) The Subsystem should ultimately permit automatic correlation of classification results from established ground truth locations with the results of unsupervised analytical techniques, if this can be proven feasible through testing and evaluation.

5) The Subsystem should handle a mix of Landsat data, aerial photography, airborne multispectral scanner data, and ground data to support specific needs of user agencies. Types of data and the time span during which they are collected will be evaluated as RSIS is developed using data from test sites in different physiographic regions of the state.

6) Products that meet specific user needs and are appropriately scaled and formatted hard-copy maps must be available from RSIS. Alternatively, digital tapes containing results of classification procedures, enhanced imagery, or

unconventional false-color composite images must be available for further processing by the user or for conversion to hard copy by other systems.

The capabilities listed above are to be implemented through a specific combination of hardware, software, and analytical procedures composing RSIS. Details of the system to accomplish data input, preprocessing, processing, and data output are given in Brown and others (1979a and 1979b) and include software narrative descriptions, a glossary of terms, and a detailed functional design describing all software components.

The flow of data through this system is outlined in figure 1, which shows three of the principal hardware components: the Univac 1100/41 computer, the Interdata 7/32 minicomputer and the interactive graphics terminal, a Ramtek keyboard and cathode ray tube (KCRT) display device. Most processing of digital Landsat data will require the capabilities of the Univac 1100/41. Presently data are transferred by tape between the Univac 1100/41 and the Interdata 7/32. Ultimately, results will be transferred to the Interdata 7/32 by hard-wired connection for subsequent display on the Ramtek KCRT. When completed, the system will be totally interactive but development will likely need to continue as new techniques and data sources become available.

Actual digital image processing requirements are listed in table 1, and were the basis for the Functional Design Review held on July 19-20, 1979. Software modules corresponding to each requirement are included in Brown and others (1979a). Many of the preprocessing procedures are not yet included in TNRIMS RSIS. Some processing procedures are functioning and have proven very useful.

1.4 User Advisory Group

A User Advisory Group has been established as part of the ASVT Project Plan to ensure that state agency input regarding the definition, testing, and evaluation of RSIS is incorporated into project work. One of the major responsibilities of the User Advisory Group is to define specific Subsystem output products as the basis for

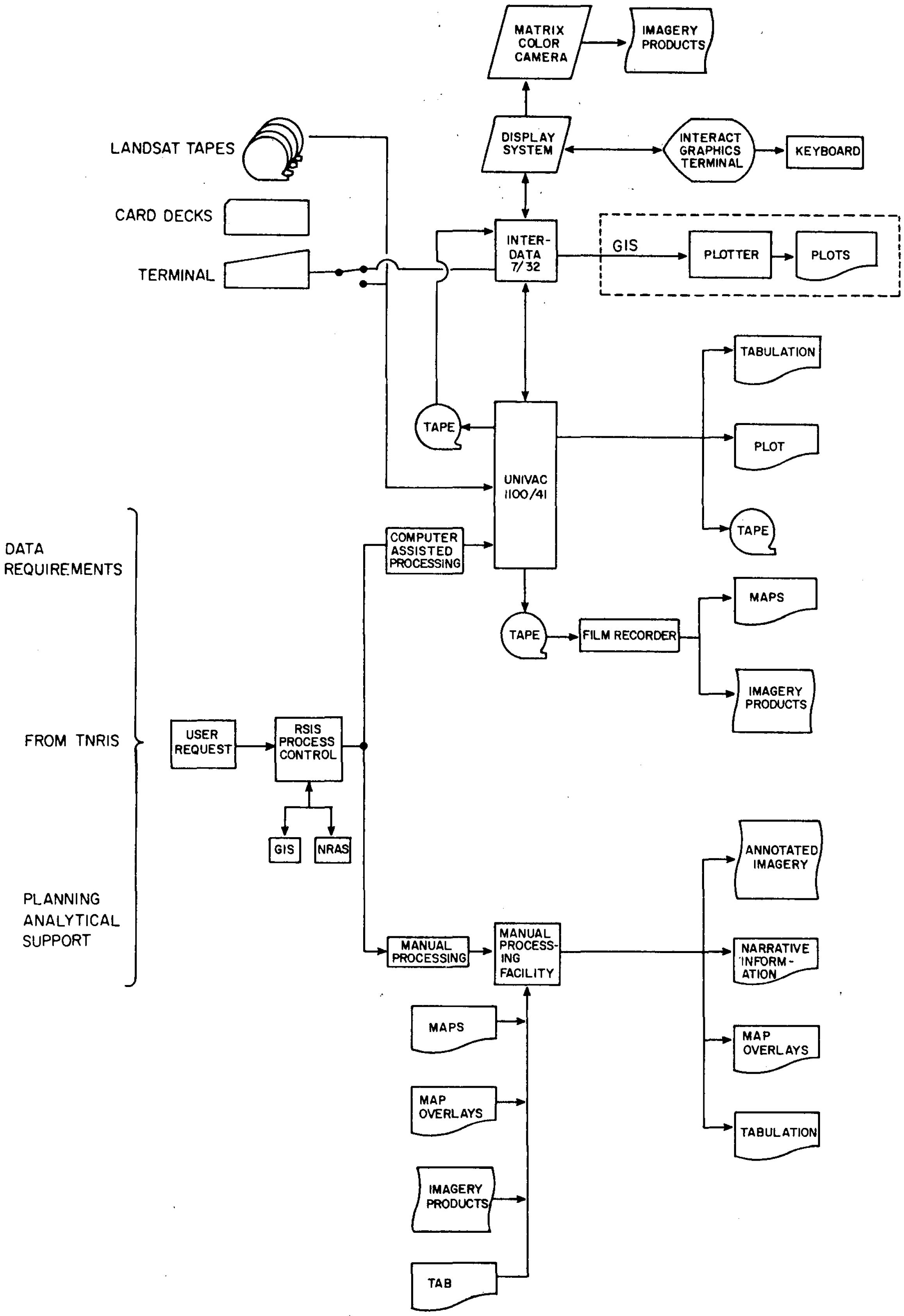

Figure 1. Physical facilities, data flow and products of the Remote Sensing Information Subsystem.

Table 1. Digital image processing requirements for the TNRIMS RSIS.

A. PREPROCESSING

1. Contrast "stretching" and related enhancements (e.g., cumulative distribution function data stretch)

2. Radiometric corrections for effects of sun angle, atmosphere, and sensor calibration (to the extent these corrections are not made at EDC on standard products)

3. Geometric corrections for such factors as sensor attitude variations, Earth rotation, image projection, and relevant sensor parameters (to the extent these corrections are not made at EDC on standard products)

4. Creating mosaics from two or more digital images and removing overlap

5. Band ratioing

6. Eliminating/reducing noise such as bad scan lines and other "cosmetic" defects

7. Accurately registering digital image to ground control points

8. Edge enhancement

9. Inputting airborne and Landsat digital image data for subsequent processing

10. Rotating the digital image to north-south orientation (or through some specified angle)

B. PROCESSING (through "interactive mode")

1. Density slicing, ratioing, and false color image displaying

2. "Supervised" multispectral analyzing of up to six bands, including selection of training fields by cursor

3. "Unsupervised" or "clustering" multispectral analyzing of up to six bands, including

    a. Selection by cursor of areas for collection of statistics

    b. Histogram generation

4. Automated correlating of spectral "clusters" with surface information at pre-selected locations

Table 1. (continued)

5. Digital image enhancement during viewing, including color (hue, saturation, and intensity) enhancement

6. Change detection through comparison of two digital images and display/output of differences

7. Adding alphanumeric annotations to image

8. Expanding and reducing image size

C. <u>POSTPROCESSING</u>

1. Video displaying of multispectral image classification results in false color

2. Generating black-and-white hard-copy film images, disk storage, line-printer, and magnetic tapes of classification results and enhanced images of individual bands

D. <u>OPERATION</u>

1. One complete interactive display and analysis station is initially required. Utilization will rotate among Project Team members assigned to generate the various products. Full operational use of the RSIS may dictate the need for multiple stations with the possibility of many support processing functions being accomplished at a single site.

2. Resolution and other Subsystem requirements will need to be determined by analysis of the information needs and output products to be generated by the RSIS.

Subsystem evaluation and potential refinement or modification. Establishment of this group will help ensure that RSIS products are scrutinized for real value in meeting specific operational needs of participating agencies (McCulloch and McKain, 1978).

1.5 State Agency Applications

In addition to the specific types of products which RSIS should be capable of generating, as identified by the User Advisory Group, a primary objective of the Project is to evaluate TNRIMS' capabilities for directly supporting the decisionmaking process in the participating agencies. To this end, TNRIS member agencies have identified selected applications from among their operational responsibilities that can potentially be used in developing, testing, and evaluating the System on a statewide basis. An Applications Coordinator within each agency guides the Project activities relating to their particular applications.

2.0 TEST SITE DESCRIPTIONS AND DATA AVAILABILITY

2.1 High Plains

The test site covers all or part of 17 counties in the Texas Panhandle and spans parts of three major physiographic provinces: the Canadian Breaks, the Southern High Plains, and the Rolling Plains (fig. 2). Two areas of grassland in Randall County and one area in Briscoe County were selected as test areas for vegetation studies, and the area covered by the aircraft flight line from the city of Lubbock through Swisher County was also used for a crop inventory (fig. 2).

The High Plains surface is typically very flat, sloping gently southeast at a gradient of about 2 m/km (10 ft/mi). Most runoff collects in playas, and, if not used for irrigation, either evaporates or percolates into the underlying sediments. The amount of water in a playa is a function of the size of its catchment, the permeability of the bottom sediments, evaporation, and precipitation.

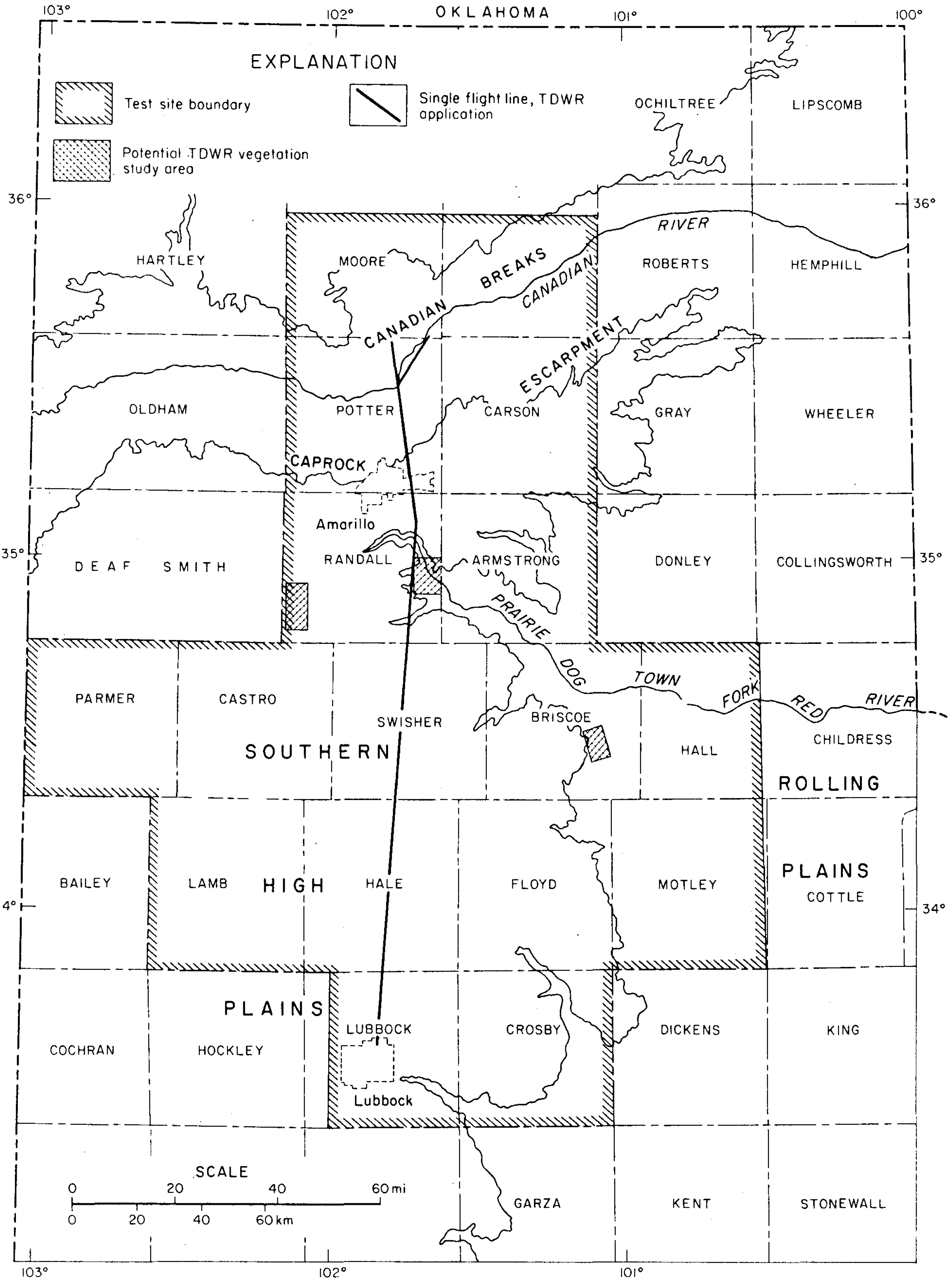

Figure 2. The High Plains test site and vicinity.

Most of the region's precipitation, which varies from 380 to 530 mm (15 to 21 in) annually, falls from April to September (Gould, 1969). During this time, most rain falls during thunderstorms. Native vegetation on the High Plains is dominantly grasses. However, much of the region has been converted to agricultural use for raising row crops such as cotton and corn, and small grains, such as wheat.

Along the escarpment native vegetation is predominantly juniper. Sandy lands, such as the sand hills in Lamb County, are populated with shinnery oak and sage, and yucca and mesquite have invaded some of the High Plains (Gould, 1969).

Soils of the region range from loamy fine sand on uplands to clay in playa bottoms. Soil thickness ranges from less than 1 to more than 2.1 m (less than 3 to more than 7 ft) (Blackstock, 1979).

Color infrared and natural color aerial photographs were taken on June 16, June 26, and July 8, 1980, along a flight line extending from Lubbock to Lake Meredith, north of Amarillo (table 2). Crop mapping was done on July 8 and 9 and August 13 and 14, 1980, along the same transect, from the city of Lubbock to northern Swisher County. Landsat data from overpasses on July 14 and 15, 1980, will be used as the remote sensing data base for this study. It should be noted from table 2 that none of the ancillary data were collected during the satellite overpass.

2.2 Trans-Pecos Region

The Trans-Pecos test site trends NW-SE through parts of five counties in West Texas (fig. 3). The long dimension of the site is approximately 307 km (190 mi), and the approximate width varies from a minimum of 51 km (32 mi) to a maximum of 67 km (42 mi). Physiographically, the test site is within the Trans-Pecos Basin and Range Province (Kier and others, 1977) and is characterized by mountain ranges and intervening basins of alluvial fill. The mountains within the test site are primarily composed of fine-grained volcanic rocks, generally of rhyolitic, trachytic, or basaltic composition (Garner and others, 1979). Both extrusive and intrusive volcanic igneous

Table 2. Landsat and aircraft data covering the High Plains test site.

LANDSAT IMAGES

Path/Row	Date	Identification No.	Sun Elevation	Comments
32/35	14 Jul 80	22000-16392	58°	0% cloud cover
32/36	14 Jul 80	22000-16395	58°	0% cloud cover
32/37	14 Jul 80	22000-16401	58°	0% cloud cover
33/35	15 Jul 80	22001-16451	58°	10% cloud cover, mostly in New Mexico
33/36	15 Jul 80	22001-16453	58°	5% scattered cloud cover, mostly over rangeland

AERIAL PHOTOGRAPHS

Date	Mission	Roll	Scale	Film	Comments
16 Jun 80	425	4	1:30,000	Color IR	5% cloud cover on 9 frames; very dark; Lubbock-Lake Meredith
26 Jun 80	425	17	1:30,000	Color	0% cloud cover; good quality; Lake Meredith to Randall Co.
7 Jul 80	425	24	1:30,000	Color	5% cloud cover on 8 frames; good quality; Lake Meredith to Randall Co.
7 Jul 80	425	25	1:30,000	Color IR	5% cloud cover on 8 frames; good quality; Lake Meredith to Randall Co.

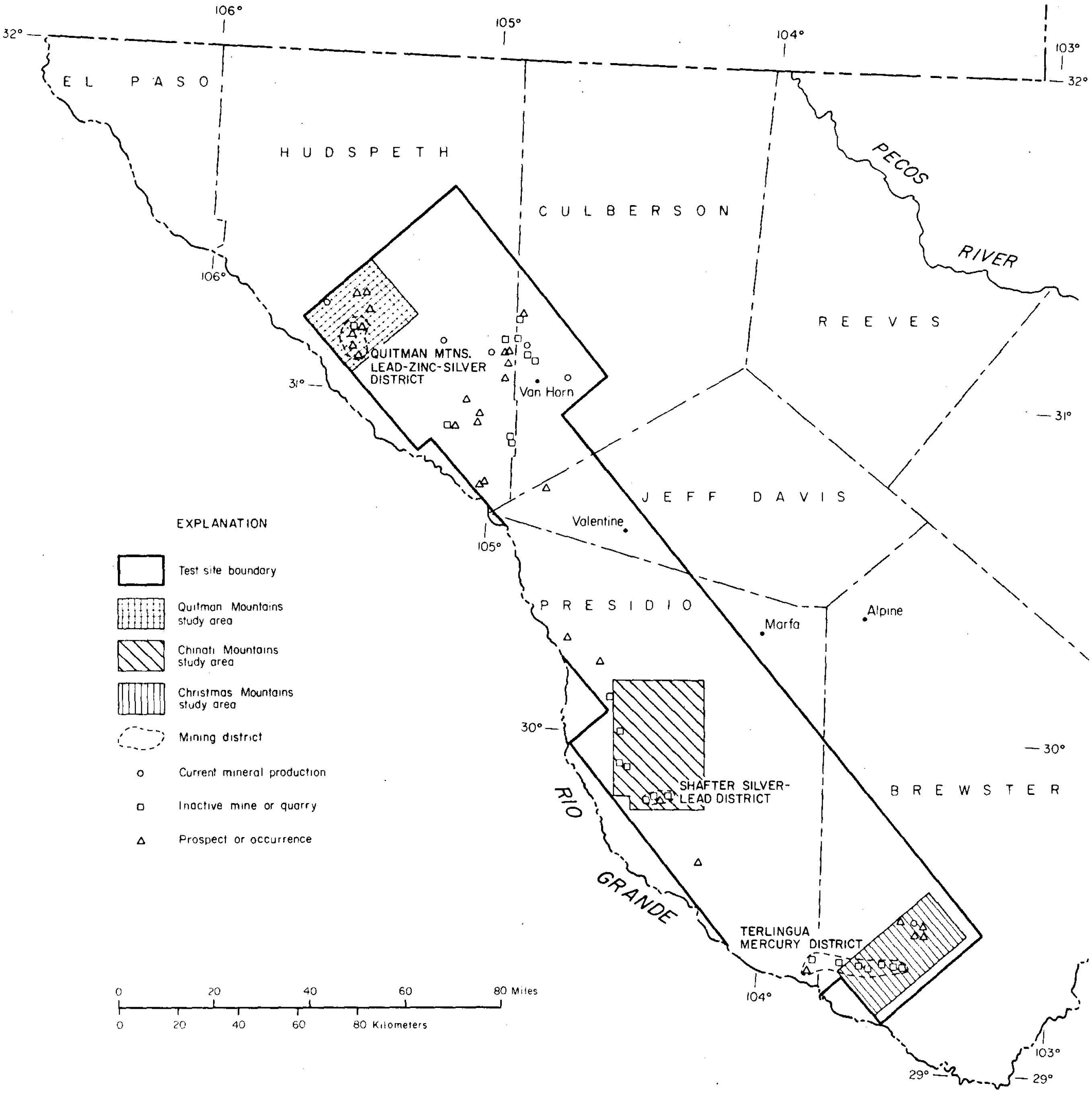

Figure 3. Trans-Pecos test site and vicinity; mineral production and occurrences from Garner and others, 1979.

rocks are present, often in complex associations developed during multiple stages of volcanic activity. Structurally, the test site is part of the Diablo Platform, an area of past moderate uplift, except for the southeastern end of the site that overlies part of the buried Ouachita Mountains front.

Mean annual rainfall over the test site is 305 mm (12 in) or less per year, and the natural vegetation is a desert shrub savanna (Kier and others, 1977). Bailey (1978) classifies the region as the tarbush-creosotebush section of the Chihuahuan Desert Province. Characteristic vegetation includes thorny shrubs in open stands to closed thickets and some short grass in association with the shrubs. All climax vegetation is drought tolerant. Perennial grasses include black grama, threeawns, and burrograss; shrubs include creosotebush, tarbush, fourwing saltbush, acacias, and mesquite. Overall, the vegetative cover is sparse, except toward the interior of the interrange basin fills where more extensive grass cover is present, such as on the Marfa Plain near Marfa in Presidio County.

Soils of the region are light reddish-brown to brown sands, clay loams and clays, most of which are calcareous and some of which are saline. Rough, stony lands are also present (Kier and others, 1977). Many soils in the region are shallow to very shallow.

As a result of sparse vegetation and thin soils, bedrock is reasonably well exposed to airborne and satellite remote-sensing devices. The area is therefore suitable for attempts to detect altered and unaltered rock types without relying strictly on geobotanical methods, as must be done in areas of heavy vegetative cover. Some interference from vegetation is expected, however, in relating spectral signatures to specific rock types. A combination of data types (aerial photography and multispectral scanner imagery) from platforms at several different altitudes may be most helpful in overcoming this problem. To this end, three areas of intensive study have been selected within the test site (fig. 3) wherein ground data collection and collection of data by aircraft will be concentrated.

Landsat images of the Trans-Pecos test site were obtained from July 1980 overpasses (table 3), when a high sun elevation angle minimized shadowing in the rugged terrain of the intensive study sites. These data will be used during digital processing; the cloud cover is absent over critical areas within the test site. Additional images from June and August 1980 and October 1979 overpasses were acquired as 1:250,000-scale standard products only. These prints are required to complete parts of the manual interpretation of Landsat products pertinent to the test site. The lower sun elevation angles of the October 1979 data result in shadowing, which enhances subtle topographic lineaments within the test site.

The 1:30,000-scale color aerial photographs are of excellent quality and are being used to expand detailed geologic mapping of the Chinati Mountains intensive study site, to help interpret results of digital Landsat image analysis, and to plan ground data collection in support of digital Landsat image analysis. The 1:30,000 color-IR data are being used for the same purposes, and especially to document the distribution of iron hydroxides, which have a unique response on this film type, and to verify the distribution of vegetation along lineaments. Lines of vegetation mark what are probably fault traces within the alluvial fill of the Rio Grande Valley southwest of the Chinati Mountains.

Collection of 1:120,000 aerial photography has been hampered by cloud cover over the test site. The two dates of this coverage (table 3) provide nearly complete cloud-free coverage of the intensive study sites, but not of the entire test site. These data will be used for lineament analysis, and, in conjunction with side-looking airborne radar imagery, for structural geologic analysis of the Chinati Mountains.

3.0 OBJECTIVES OF TEST SITE STUDIES

3.1 High Plains

The economy of the region within this test site (fig. 2) is based to a large extent on agriculture. The productivity of much of the croplands is dependent upon irrigation

Table 3. Landsat and aircraft data covering the Trans-Pecos test site.

LANDSAT IMAGES

Path/Row	Date	Identification No.	Sun Elevation	Comments
33/39	15 Jul 80	22001-16465	58°	10% cloud cover
33/40	15 Jul 80	22001-16471	58°	0% clouds in U.S.
34/38	16 Jul 80	22002-16521	58°	30% cloud cover
34/39	16 Jul 80	22002-16523	58°	0% clouds in U.S.
33/39	27 Jun 80	21983-16463	59°	0% cloud cover
34/38	30 Aug 80	30909-16422	50°	0% clouds, but lacks data at left side of image due to line start problem
33/39	28 Oct 79	30602-16455	38°	0% cloud cover
34/38	29 Oct 79	30603-16510	37°	0% cloud cover

AERIAL PHOTOGRAPHS

Date	Mission	Roll	Scale	Film	Comments
25 Jun 80	425	15	1:30,000	color	excellent quality
25 Jun 80	425	16	1:30,000	color-IR	reprocessed due to original poor exposure; good quality
21 Jan 81	435	3	1:120,000	color	incomplete site coverage
21 Jan 81	435	4	1:120,000	color-IR	incomplete site coverage
30 Jan 31	435	7	1:120,000	color	scattered clouds
30 Jan 81	435	8	1:120,000	color-IR	scattered clouds
23 Mar 81	TNRIS-GLO		1:15,000	color	fair quality

water (Blackstock, 1979, table 3). Dryland farming does not use irrigation water, and can be severely affected by drought; thus, the Texas Department of Water Resources (TDWR) must have current information regarding the acreage of irrigated crops and the severity of droughts in the region.

Most crops grown in the region belong to one of two categories: row crops or small grains. Information regarding area and location of these crop types could be used for monitoring land use changes and water requirements. Therefore, three objectives have been identified for study in the High Plains region: (1) identification of irrigated cropland; (2) definition of the spectral signature of drought-stressed vegetation; and (3) identification of broad crop categories. These objectives are part of the Texas Department of Water Resources' (TDWR) effort to gather and use timely, accurate information regarding water usage and requirements in northwest Texas (table 4).

3.2 Trans-Pecos Region

The ASVT Test Site 5 in Trans-Pecos Texas includes four mining districts, mostly active in the past, as well as numerous prospects and occurrences. Mineral resources known to occur within the test site include silver, fluorspar, lead, manganese, copper, zinc, barite, and uranium. Many of these metallic and nonmetallic mineral resources are spatially related to Tertiary volcanic calderas. Three centers of intrusive and extrusive volcanic rocks have been selected for intensive study within a larger area of volcanic rocks. These are the Chinati, Quitman, and Christmas Mountains, all of which contain known areas of mineralization.

There is currently renewed interest on the part of industry in the mineral potential of the Trans-Pecos region. The State of Texas has a considerable economic interest in the region because over 2.4 million ha (6 million ac) of land in the nine Trans-Pecos counties are state fee land or Relinquishment Act acreage. Relinquishment Act land (exclusive of mineral rights) was sold by the state in the early part of

Table 4. Summary of potential information needs of the Texas Department of Water Resources for the High Plains test site (from Finley and Baumgardner, 1981).

<u>Man-made features</u>

- General land use inventory
- Reservoirs

<u>Active processes</u>

- Changes in land use

<u>Hydrology</u>

- Playa inventory
- Lake level inventory
- Rainfall distribution
- Drought conditions

<u>Agriculture</u>

- Broad crop type
- Irrigated fields

this century. Proceeds from these lands are dedicated to the Permanent School Fund. In 1978 mineral royalties amounted to approximately $3.5 million (Beard, 1978).

The Bureau of Economic Geology is conducting basic geologic and tectonic mapping along with specialized studies on the volcanic stratigraphy in the Trans-Pecos region. Much of this work is continuing under the Mining and Mineral Resources Research Institute, an administrative unit of the Bureau.

Because ground access to much of the rugged terrain in Trans-Pecos Texas is limited, remote sensing technology can be an asset to understanding the geologic relationships of the region. Such technology may also provide information that might not be available using more conventional mapping techniques.

The following objectives are part of the analysis of the Trans-Pecos region:

1) determine the regional distribution of lineaments within the entire test site;
2) determine the distribution of lineaments in greater detail within the intensive study sites;
3) define the structural relationships of a newly recognized, older, volcanic caldera to the younger Chinati caldera complex within the Chinati Mountains intensive study site;
4) detect alteration zones of various types (limonitic, silicic, etc.) and map them as indicators of prospective areas for mineral deposits; and
5) determine which combinations of remotely sensed data, not previously utilized in geologic mapping by the Bureau of Economic Geology, contribute to improved geologic mapping in a geologically complex area.

In line with the defined information needs of the Bureau of Economic Geology (table 5), the objectives for the Trans-Pecos test site will increase both our understanding of the basic geology of the region and our familiarity with digital data processing for geologic applications.

Table 5. Summary of potential information needs of the Bureau of Economic Geology for the Trans-Pecos test site (from Finley and Baumgardner, 1981).

Geology

- Rock type
- Geologic structure
- Topography
- Substrate characteristics
- Mineral sources (potential type and location)

4.0 REMOTE SENSING INFORMATION SUBSYSTEM PRODUCTS

4.1 Types of Products: High Plains

Products resulting from this study include photographic prints of selected windows from Landsat images and maps of land cover/land use generated with a flatbed plotter. The scale of each product will be determined by its intended use, usually established by the scale of a pre-existing map base.

The image analyst generates hard-copy images from data that have been processed with an unsupervised classification routine called ISOCLS. The data are displayed on a Ramtek cathode ray tube, and the analyst makes any necessary color changes to enhance the features he or she is interested in. Irrigated fields, surface water bodies, and general land cover/land use categories (irrigated cropland, unirrigated rangeland) may be delineated on the Ramtek screen and assigned specific colors.

When the analyst is satisfied that the image shows what is necessary, a photographic print is made using the Matrix Color Graphic Camera. The Matrix photographs are essentially geometrically registered when produced from data using a control network. To be used as map products, local best fits must be made with existing base maps or photographs. The scale of the photographic image is 0.592 times the scale of the image on the Ramtek screen. A Matrix print can be generated at scales ranging upward from about 1:33,800 (Ramtek scale of 1:20,000) to 1:422,500 (Ramtek scale of 1:250,000).

The Geographic Information Subsystem (GIS) can use data supplied from the Interim Interactive Graphics Subsystem (IIGS), of which RSIS is a part, to produce geographically accurate map products at various scales. Maps can be produced using any or all of four colors: red, green, blue, and black. Information regarding cultural features can be combined with information from the IIGS. For example, county boundaries can be overlain on the land cover/land use data, enabling the analyst to determine the area within a county occupied by a given land cover.

4.2 Types of Products: Trans-Pecos Region

Study of the Trans-Pecos test site using Landsat data and aerial photography will result in development of enhanced images for further manual interpretation and in the compilation of geologic data on existing topographic base maps. Unsupervised digital classification routines, such as ISOCLS, have generally met with limited success in geologic applications and therefore will not be included in this study. The wavelength bands included in Landsat are considered unsatisfactory for automated lithologic classification, either by supervised or unsupervised methods (Siegal and Abrams, 1976). Bands included in the airborne multispectral scanner, however, have been used successfully for discrimination of rock types (Goetz and Rowan, 1981). Reformatting these data, taking 4 bands at a time, will allow processing using RSIS software.

The enhanced images for manual interpretation will be produced as prints from the Matrix Color Graphic Camera. Color density slices of single bands, band ratios, and custom false-color composites will be generated using capabilities of the Detection and Mapping (DAM) package. Displays will be reviewed on the Ramtek cathode ray tube and final color adjustments made before producing Matrix prints. Interpretation of the prints and study of supporting data will lead to a geologic explanation, either as a legend attached to the print or as an overlay.

Analysis of standard Landsat products (1:250,000-scale paper prints), high-altitude aerial photographs (1:120,000 scale), and side-looking airborne radar will result in structural geologic interpretations compiled on existing topographic base maps. A regional lineament analysis has been completed using Landsat data over the entire test site, and the lineaments will be transferred to 1:250,000-scale topographic maps. Within the intensive study sites 1:120,000-scale aerial photographs (paper prints) will be utilized for lineament detection and results will be compared to the regional lineament analysis and to previous geologic mapping. Results of lineament studies and of a structural geologic analysis of the radar data obtained over the Chinati Mountains intensive study site will be compiled on a 1:125,000-scale base map.

The 1:30,000-scale color photographs of the Chinati Mountains have been utilized in conventional geologic mapping of volcanic rocks within small areas in the intensive study site. These photographs have been much more useful than black-and-white photographs previously used in mapping this area, and an assessment of the two data types will be made.

5.0 TEST PRODUCTS

5.1 Description: High Plains

Test products will be generated for each of the three tasks identified in Section 3.1 for this test site. In each case, geometrically-corrected Matrix camera prints will be produced at scales compatible with other data bases. A standard 6 by 8 inch Matrix print at a scale of 1:48,000 covers an area of 71.3 km^2 (27.6 mi^2), and at a scale of 1:250,000, it covers an area of 1,934 km^2 (747 mi^2). Where appropriate, maps will be generated using the GIS's capabilities to combine cultural features from other map bases and digital Landsat data into a single map. The scale of such a map will be compatible with pre-existing maps (e.g., 1:63,360-scale county highway maps or 1:250,000-scale topographic maps).

5.1.1 Irrigated Cropland Maps

Matrix prints will be generated at scales compatible with color infrared aerial photography at a scale of 1:30,000. This aerial photography, flown during June and July 1980, is the primary source of information on the extent of irrigation near the time of the satellite overpass. Inventories of total irrigated acreage per county made by the Soil Conservation Service during the summer of 1980 are available.

A set of ISOCLS parameters will be developed that identifies irrigated cropland, as it appears on the aerial photography. Identification of irrigated croplands in areas where no aerial photography is available should be possible with the same or similar ISOCLS parameters. Irrigated acreage will be tabulated in a selected county and compared with the acreage for that county measured by the Soil Conservation Service in the summer of 1980.

5.1.2 Definition of Spectral Signature of Drought-Stressed Vegetation

An area in the southwestern part of the test site will be used for definition of the signature of drought-stressed vegetation. Palmer Index (Palmer, 1968) records for the week of July 12, 1980, show moderate drought conditions existing only in the southwestern part of the Texas Panhandle. The rest of the study area had nearly normal moisture conditions.

The Matrix print of this area will identify unirrigated lands that have vegetative cover experiencing drought. The lack of ground truth and aerial photography concurrent with the satellite overpass may prevent complete success in the identification of drought-stressed vegetation.

5.1.3 Identification of Broad Crop Categories

Crop types were mapped along a transect parallel to the flight path of the aerial photography taken in June and July 1980. Strip maps at a scale of 1:63,360 and block maps of 2.59 km^2 (1 mi^2) areas at a scale of 1:12,670 are available. Matrix prints will be produced at scales compatible with these scales. Only broad crop categories (row crops, small grains, permanent pasture) will be identified. No attempt will be made to distinguish between crops within each category such as soybeans vs. cotton or rye vs. wheat.

5.2 Description: Trans-Pecos Region

Test products will be generated to fulfill each of the objectives outlined in Section 3.2. Digitally processed Landsat and airborne multispectral scanner data will be displayed on the Ramtek KCRT and copied using the Matrix Color Graphic Camera. Displays will be generated to produce Matrix prints at scales of 1:125,000 and 1:62,500; in some instances scales of 1:250,000 or 1:48,000 will also be utilized. The two smallest scales will likely be used in production of custom false-color composites in order to avoid the blocky appearance of large individual pixels.

5.2.1 Regional Lineament Analysis

A regional lineament analysis has been completed using standard Landsat products at a scale of 1:250,000. Lineaments will be transferred from image overlays to a topographic map base of the same scale (National Map Series, 1° x 2° sheets), and an appropriate legend will be developed. A published tectonic map of Trans-Pecos Texas (Henry and Bockoven, 1977) will be used to determine which lineaments correlate with known geologic structure.

5.2.2 Detailed Lineament Analysis

A detailed lineament analysis will be conducted within the three intensive study sites of the Trans-Pecos test site. Individual frames of 1:120,000 color or color-IR photographs will be analyzed stereoscopically and lineaments transferred to a 1:125,000 base map. Base maps at this scale have been made for each of the intensive study sites by enlarging the 1:250,000 National Map Series sheet(s) for each site. The lineament distribution will be compared to detailed geologic mapping completed and underway in the Chinati Mountains intensive study site, to published maps of the other intensive study sites, and may be field checked. However, lack of permission to enter private property and rugged terrain may limit field checking.

5.2.3 Structure of the Infiernito Caldera

The Infiernito caldera is located northwest of the Chinati Mountains, and is older than the Chinati caldera complex. The Infiernito caldera has been partially obscured by younger volcanic units associated with the Chinati complex and is now being mapped in detail for the first time (Duex and Henry, in press; C. D. Henry, personal communication, 1981). The ring-fracture zone of the Infiernito caldera is not as well defined as that of the Chinati caldera, and mapping of the zone needs to be completed. The faults comprising the ring-fracture zone are potential pathways for mineralizing fluids, although the most extensive hydrothermal alteration is associated with intrusion of a pluton (the Ojo Bonito intrusion) and resurgent doming of the caldera complex. Analysis of side-looking airborne radar and lineament analysis should help define the structural relationships between the Chinati and Infiernito calderas, including the ring-fracture zone of the older volcanic complex.

5.2.4 Detection of Alteration Zones

Mapping surface alteration zones is a standard procedure in the search for mineral deposits. Regional surveys of altered rock provide the explorationist with a starting point in the development of specific mineral prospects, and the presence of altered rock is an important indicator of local and regional geologic history. The Bureau of Economic Geology, as provider of informational services relating to the geology and resources of Texas, researches local and regional geology throughout the state but does not focus on development of individual prospects.

Mineralization is known to be associated with volcanic centers, and a comparison of the geology of Trans-Pecos Texas with areas of known mineralization suggests that the Trans-Pecos region could contain more mineral occurrences than are presently known (Duex and Henry, in press). Emplacement of metalliferous minerals may occur as metal-bearing hydrothermal fluids migrate from a magma chamber, or part of the magma itself may be metal-bearing. Contact with hydrothermal fluids often alters surrounding rock, producing clay minerals or quartz; therefore the latter minerals may be indicators of hydrothermal activity when found in the proper geologic context. The presence of non-economic metal sulfides, such as pyrite, frequently results from hydrothermal activity. Weathering of iron sulfide minerals produces distinctive red, orange, and brown iron-oxide minerals. These minerals may form a unique surface cap, known as a gossan, over a potential mineral deposit. The gossan then becomes a target for detection by remote sensing methods as an indirect indicator of possible mineral occurrence (Rowan and Lathram, 1980).

The gossan over Red Hill in the Chinati Mountains intensive study site is one of the best developed in the Trans-Pecos test site. Procedures for gossan detection using RSIS will be developed using Red Hill as a known example, and these procedures will then be applied to the area of the Infiernito caldera (table 6). Two areas of limonitic staining were noted during initial field work in the Infiernito volcanic complex, one of which is associated with unoxidized iron sulfide mineralization in the Ojo Bonito intrusion. Other areas may be detected during the analysis program.

Table 6. Red Hill (RH window) analysis program: detection of limonitic staining of the Red Hill gossan.

1) Verify location of Red Hill at center of window using C42 CHAN 2 output.
2) Generate a sharpened density slice of CHAN 2 at a Matrix-print scale of 1:125,000 to assist in location of larger scale output. Evaluate scaling in relation to 1:125,000-scale topographic map of intensive study site.
3) Generate sharpened density slices of all 4 channels at a Matrix-print scale of 1:62,500. Compare to 1:125,000 product for location. Previous work indicates that the most classes are needed at the high-reflectance end of the data range. At least 3-4 of the major low-reflectance classes in density slices already produced are primarily the product of shadowing.
4) Generate stretched band ratio displays for bands 4/5, 5/6, 6/7 at a Matrix-print scale of 1:62,500. Overlay with single-band density slices for geographic registration. Also compare directly to 1:125,000 map using Zoom Transfer Scope. Determine which individual ratios, combination of ratios, or combination of band ratios and individual band density slices best characterize the known limonitic alteration. Evaluate other band ratios.
5) Allow individual bands to control individual color guns and generate custom false-color composites. Evalute these for best depiction of limonitic alteration. Produce at Matrix-print scales of 1:125,000 and 1:62,500. Check registration by comparison with maps.
6) Allow band ratios to control individual color guns and generate custom false-color composites at Matrix-print scales of 1:125,000 and 1:62,500. Evaluate depiction of limonitic alteration and check scaling. Evaluate entire technique and choice of ratios.

Table 6. (continued)

7) Incorporate field spectral measurements and data from the literature into the design of the above analyses.

8) If non-registered output is significantly distorted, generate most useful products again using fully registered data.

9) Apply best techniques to less evident limonitic outcrops in Infiernito caldera area.

10) Evaluate results against results obtainable with the several different channels of the airborne multispectral scanner if processing of the latter data becomes feasible using RSIS facilities.

Table 7. Infiernito caldera (IC window) analysis program: detection of altered volcanic breccia and weak limonitic alteration.

1) Generate a sharpened density slice of CHAN 2 of a Matrix-print scale of 1:125,000 to assist in location of larger scale output. Evaluate scaling in relation to 1:125,000-scale topographic map of intensive study site.

2) Generate sharpened density slices of all 4 channels at a Matrix-print scale of 1:62,500. As in Red Hill study, divide data into the largest number of classes at the high reflectance end of the digital number range.

3) Generate stretched band ratio displays for bands 4/5, 5/6, and 6/7 at a Matrix-print scale of 1:62,500. Overlay with single-band density slices and determine which displays best characterize altered volcanic breccia. Compare discrimination of all rock types on the products developed and determine optimum techniques.

4) Allow individual bands to control individual color guns and generate custom false-color composites. Evaluate for discrimination of all rock types and especially the altered breccia. Utilize Matrix-scale prints at 1:125,000 and 1:62,500. Consider use of larger scale, such as 1:48,000, if results are good at smaller scales.

5) Allow band ratios to control individual color guns and follow same procedures as in 4 above.

6) Incorporate field spectral measurements and data from the literature into the above analyses.

7) Determine necessity for fully registered data, as in Red Hill study.

8) Evaluate results against results obtainable with the several different channels of the airborne multispectral scanner if processing of the latter data becomes feasible using RSIS facilities.

A density slice of band 5 Landsat data over the Infiernito caldera revealed highly reflective areas of possible alteration. Field checking indicated that most of these areas consist of a white to lightly limonite-stained volcanic breccia that has been baked and somewhat silicified, with a few associated small areas of argillic alteration. The high reflectance areas are not a unique lithology, however, in that two of the areas checked were outcrops of white to light tan tuffaceous sediment. The significance of the altered volcanic breccia as an indicator of mineralization is very uncertain (J. G. Price, personal communication, 1981), but the breccia should be evaluated, especially in relation to the position of the ring-fracture zone. A program has therefore been designed to develop test products best suited for depicting the altered and silicified volcanic breccia and for detecting limonitic staining (table 7).

5.2.5 Data Evaluation for Geologic Applications

With the availability of many types of remotely sensed data for the Trans-Pecos test site, an evaluation of each can be made for purposes of structural geologic studies, rock-type discrimination, and the detection of alteration zones. Prior to this applications test as part of the ASVT, black-and-white aerial photographs had been primarily relied upon for geologic mapping. The complexity of the Trans-Pecos volcanic terrain and difficulty in gaining access to much of the area suggest that other types of data could help advance geologic investigations. The final objective in this analysis of the Trans-Pecos region is to review data types not generally used by the Bureau of Economic Geology and to determine which types have contributed most to the study.

6.0 EVALUATION OF TEST PRODUCTS

6.1 Purpose

Evaluations of cost, accuracy, and utility of selected products generated using RSIS will result in specific instructions for improving the individual products themselves to meet the user's needs. The evaluation results will also provide a basis for improving the various RSIS components (hardware, software, procedures) which in turn should enhance the quality of products to be generated from the Subsystem in the future. For both the High Plains and Trans-Pecos test sites a qualitative review will be undertaken. Comparison products resulting from alternate analysis methods will not be generated for either site.

6.2 High Plains Test Site

Personnel of the Texas Department of Water Resources (TDWR) will review the test products to determine their utility. Recommendations regarding image scale, precision (number of clusters), and types of clusters identified will be useful for improving future generations of Landsat-derived maps. Accuracy checks will be limited owing to the lack of concurrent ground truth and aerial photograpy and the ephemeral quality of the phenomena involved (i.e., irrigation and drought stress).

6.3 Trans-Pecos Test Site

Imagery and map products to be evaluated for the Trans-Pecos test site include: (1) Landsat lineament analysis; (2) lineament analysis based on aerial photographs; (3) structural geologic mapping based on side-looking airborne radar data and lineament analyses, and (4) delineation of alteration zones and discrimination of rock types based on Landsat imagery. The scope of the latter effort will be considerably expanded when analysis of airborne multispectral scanner data is incorporated into RSIS. The evaluation will focus on the contribution of each product type to our understanding of volcanic stratigraphy, geologic structure, and the potential for mineralization in the Trans-Pecos volcanic terrain.

Evaluations will be largely based on a qualitative comparison to the results obtainable using black-and-white aerial photographs and conventional photointerpretation procedures. The evaluations will be made by Dr. C. H. Henry and Dr. J. G. Price of the Bureau of Economic Geology. The final objective of studies in the Trans-Pecos test site will be fulfilled by compiling results of the product evaluations into a set of recommendations for future geological remote sensing activities at the Bureau of Economic Geology.

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