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USE OF ERTS-1 DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (UN314)

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USE OF ERTS-1 DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (UN314)

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16. Abstract

Many of the features of the Southern California environment, both physical and cultural, are of diffuse nature. Development of methodologies for study of large areal phenomena has focused on remote sensing techniques. Research has been directed toward: 1) new applications of existing photo-interpretive and statistical methods; 2) development of new methods in image enhancement as well as data reduction and graphic display; 3) correlation of variations and co-variations of physical and/or cultural features of the landscape in an attempt to better understand their nature. Throughout, an eye was given toward minimizing cost of various techniques to facilitate their adoption by potential users. Test sites were selected from both the Los Angeles Basin and the California Desert (Mojave and Colorado Deserts).

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1 INTRODUCTION

The research effort at UCR, associated with this integrated study, has consisted of attempts to determine the value of ERTS-1 and similar data for analysis of environmental problems in a variety of regions in Southern California. Initial investigations dealt mainly with general land use patterns and changes, but advanced methods of displaying and enhancing the imagery have made it possible to conduct more detailed studies of specific environments.

1.1 Data Acquisition

The latest ERTS-1 imagery which our group has received was that of May 5, 1973. Preliminary evaluations have been made of all frames, and some color combinations have been produced. Acquisition of a Mini-Addcol Viewer from International Systems Inc. (I^2S) has made it possible to perform color combinations to simulate true color and CIR images as well as a variety of other color combinations. The Mini-Addcol Viewer allows better image registration and a greater variety of color combinations than the Diazochrome method which we previously have used, though image and color qualities vary according to the phenomena under study.

The data from the U-2 flights were of significant value for detailed interpretation and verification of patterns extracted from ERTS-1 data. The detailed studies were limited, however, to the areas covered by U-2 flights. This restricted us to making a less detailed analysis of most of the desert areas, based primarily on ERTS-1 imagery, because very little U-2 imagery exists for coverage of the northern Mojave Desert in which these studies were made.

1.2 Relationship to Non-ERTS-1 Research and Science

1.2.1 Information and Application Assistance

The receipt of ERTS imagery has generated considerable interest throughout the public and scientific community in Southern California. The number of weekly visits by prospective users has doubled in the past six months. It is, of course, a major function of the University, in addition to research, to help disseminate new information and technology to the public and other scientific groups. The expertise and the data file that have been accumulated at Riverside over the past six years provide a natural attraction to researchers. Appendix A lists some of the universities, colleges, public agencies, and private industries which have been assisted within the last six months here at UCR. The list briefly describes the kinds of projects which have brought to us the research groups in question.

1.2.2 Integration with NASA NGL 05-003-404 Grant

The acquisition of ERTS-1 satellite and high altitude aircraft (U-2) data has assisted in the NASA funded "Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques." Two particular studies under this contract have been: (1) the development of an environmental data base for Southern California, and (2) a study of urban-regional land use in the Riverside-San Bernardino-Ontario standard metropolitan statistical area.

Environmental Data Base

The major objective is to generate a data base reflective of the conditions, processes and important features present within the coastal environment. The development of an information base requires that two functions be performed: (1) image (data) interpretation, and (2) interfacing of data with a geographic information system. The interpretation function is currently being undertaken in the area of Orange and northern San Diego Counties. (See Section 2.2.)

The initial data source used in this study was the high altitude imagery from NASA Mission 164. Since the receipt of the recent U-2 imagery, secondary interpretation and sequential analysis have proved useful in verifying and modifying previous evaluations.

Urban Regional Land Use

The metropolitan area of which Riverside and San Bernardino form the core, has been selected by USGS as one of 26 sites for study of urban land use under the Urban Atlas Project. The basic data gathering system, of mapping land use information on USGS 1:24,000 sheets, is being continued until its completion. Computer maps are being prepared from the base data. Five quadrangles have been finished and are mosaicked together (Figure 1).

This large scale data base, while useful in its present condition, also allows rapid and useful correlation with ERTS-1 and ERTS-B imagery. The sequential nature of ERTS-1 imagery fits in well with the requirements of the project, including those of monitoring urban and regional land use changes. The conversion of conventionally mapped data into a format for computer storage and manipulation allows quick comparisons of several dates, and thus rapid assessment and calculation of urban changes.

Present plans include the production of a technical report summarizing all the work of the project at UCR. It will include details on the methodology and techniques as well as analysis of data from selected sites in the study area. This paper will provide local county and city planners with quantitative data and adaptable techniques for their use

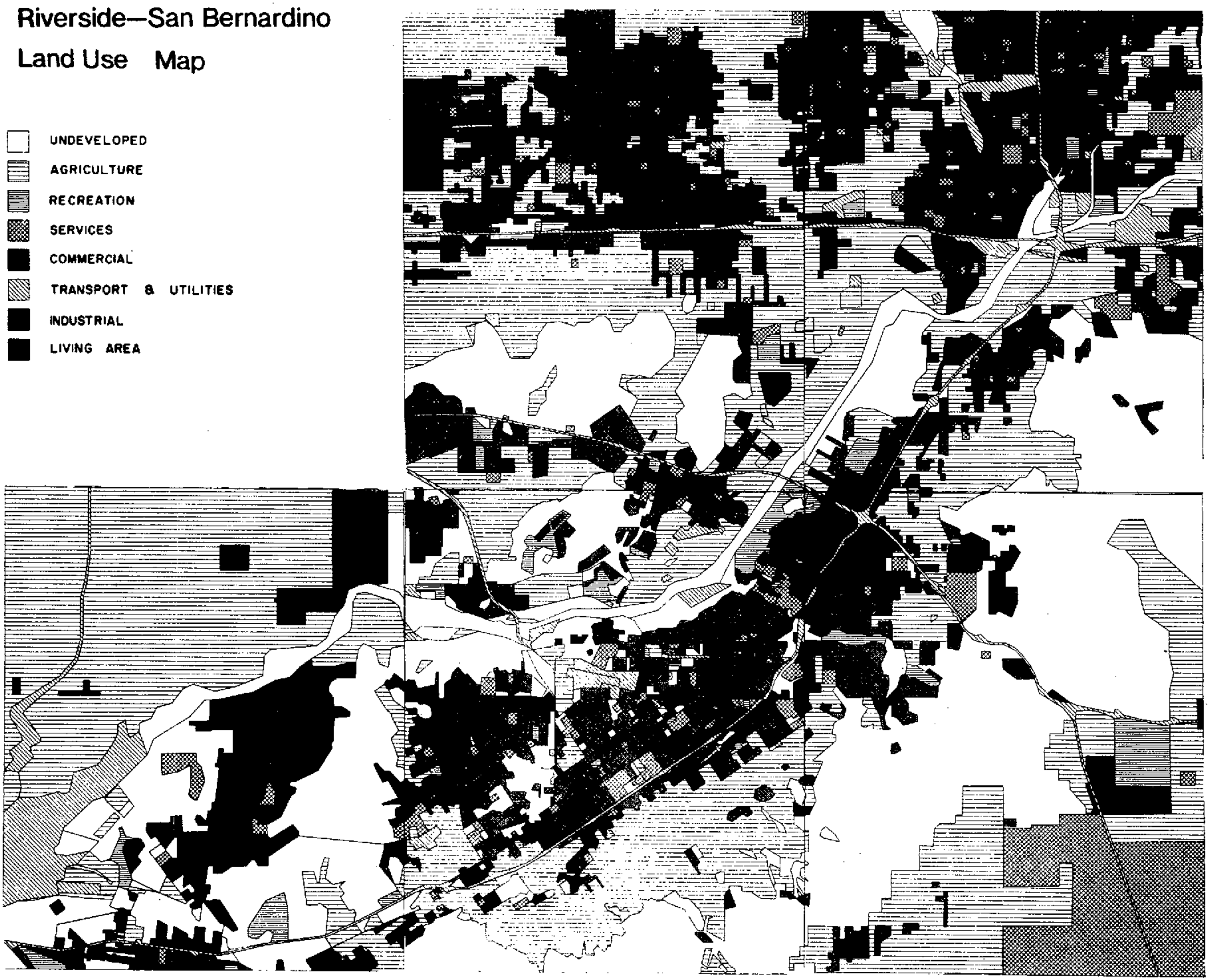


Figure 7.1. Riverside-San Bernardino land use map.

in evaluating land use changes and processes occurring in the area. It also reflects the ability and intention of this research program to go beyond the limited objectives stipulated by USGS and make information available for practical, local agency utilization.

2 ACCOMPLISHMENTS

The general objectives of the investigations conducted by UCR under the ERTS-1 program are listed as: (1) mapping of general land use patterns in rural and urban regions of Southern California; (2) monitoring of changes in land use, particularly in urban and rural/urban locations and with additional emphasis placed upon analysis of wildland areas coming under urban and/or agricultural pressures; (3) monitoring environmental pollution in Southern California basins; and, (4) developing models defining "environmental quality."

Out of these goals have grown a series of specific studies. In some cases, the concepts of these individual studies are included under more than one of the four prescribed goals, lending greater importance to the studies and demonstrating greater utility of ERTS-1 data.

The synopses of three studies are described first in the following three sub-sections. The studies represent the kind and scope of effort initiated during the first part of the contract year and consequently are the three studies which are closer to completion. The first is the monitoring of cyclic crop production with the objective to develop a semi-automated system of identification of specific crop types in the Imperial Valley. The second study was designed to create a vegetation classification system, functional with ERTS-1 data, and to produce a map of the floral distributions of Orange County. The last study focuses upon land use changes in the Coachella Valley.

Included also in this section are reports of projects presently underway which require not only high altitude imagery (U-2), but also good quality ERTS-1 imagery as well. The lack of a refined method of multi-spectral color combination and enhancement forced a delay in the research efforts for these studies. These summaries represent the extent of significant results gained from the research conducted thus far. These projects vary widely in subject matter and location, although most are contained within the Desert regions.

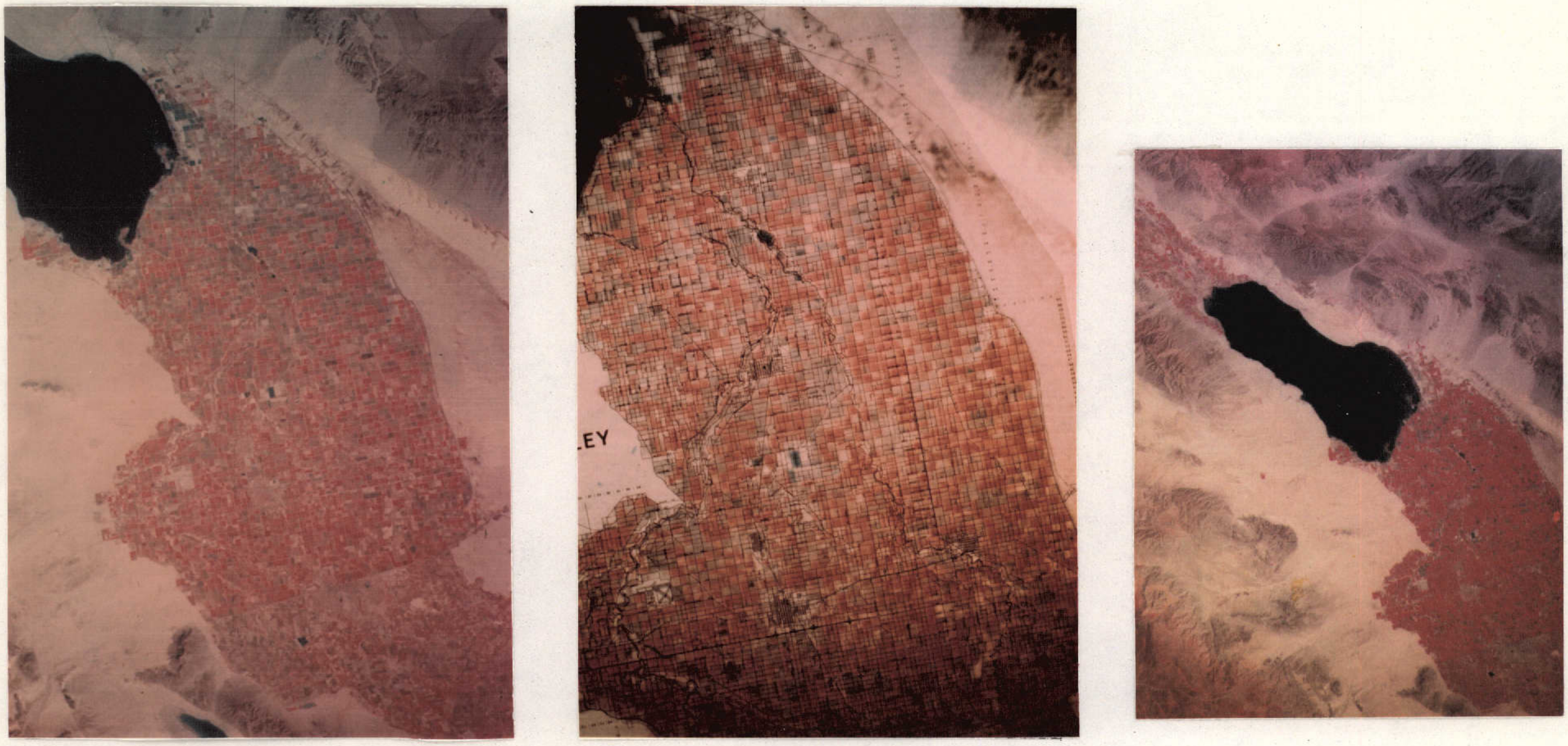
2.1 Monitoring Crop Changes in the Imperial Valley from ERTS-1 Data

Based on our studies to date, sequential satellite imagery can provide sufficient data to determine specific field conditions with 97 percent accuracy, and specific crop identification for any one field can be achieved with a 92 percent accuracy. Techniques being developed at the University of California, Riverside, utilize the color infrared returns from an ERTS-1 color combined image of multispectral bands 4, 5, and 7 (Figure 2a). Combining the interpretation procedures of the imagery with a computerized program that compares the data to the actual crop calendar of the region, each field of 20 acres or more can be monitored over a minimum of four sequential 36 day cycles and subsequently identified by the computer as to the most probable crop that is growing within that field.

ERTS-1 images of 1972 of 26 August, 1 October, 6 November, and 12 December were interpreted for the experiment and results compared to approximately 10 percent of the total field population (biased sample) that had been ground surveyed. The results discussed in this report are based on this comparison. Although the ground survey fields were biased by accessibility to hard surfaced roads, the percentage breakdown by total number of crops by field and by acreage are almost identical to the Imperial Irrigation Report percentage breakdown of crops growing as of December 31, 1972.

Initial interpretation of the first complete ERTS-1 image of the Imperial Valley (26 August 1972; 1015-17440M) showed that the quality and resolution of the image is better than that of Apollo 9. Superimposition of the color combined ERTS image onto a base map controlled by USGS topographic maps (Figure 2b) enables field conditions to be interpreted for fields as small as ten acres and a few even smaller five acre plots. However, because of the uncertainty of detection (or identification) of all fields below twenty acres the project was limited to monitoring fields of twenty acres and greater. Preliminary computer processing of the data from the first image indicates the objectives of the research will be attained successfully. The primary objective is to develop a semi-automated system that will enable the identification of specific crops in each field and subsequently produce thematic computer maps for the Imperial Valley on a regular basis. A valuable and anticipated "spin-off" has already resulted from the analysis. The original categorization of field conditions into fields with growing crops, wet fields, plowed fields, and dry fields makes it possible to assess the irrigation requirements both currently and for the next two or three weeks. The assessment may be made within one to two days after receipt of the imagery.

The first thing noted on the imagery was the existence of four distinct colors within agricultural fields (Figure 2c). Growing crops with good ground cover are readily identifiable by the red color. Completely bare (fallow) fields present a distinctive white or "sand" color. Two other colors show a deep purple and a very light purple. The darker color proved to be irrigated or wet bare fields that have just been seeded. The lighter lavender color is an indication that the field has been freshly plowed. To these four categories it soon became obvious that a "no data" category was required for those instances where it is impossible to distinguish the field condition due to imperfections, cloud cover, or other causes. We have found that further refinements



A B C

Figure 2. Color infrared images of the Imperial Valley, California. Figure 2A (October 1, 1972) shows the relatively small number of growing crops indicated by the red return (33 percent). Figure 2B is a combined image of December 12, 1972, with a super-imposed grid map for locating each of the more than 8,000 fields. Figure 2C is the image of March 30, 1973, indicating almost 85 percent crop cover within the fields.

can be added in late spring or summer due to the bronze color of mature small grains, the yellow color of grain stubble and the black color of burned grain stubble. These later indicators will be categorized as harvested crops. Within the boundaries of the study area are a variety of "permanent" crops (e.g., asparagus and citrus) as well as beef feeder lots. As these areas are identified by ground survey they will be located and eliminated from the interpretation process. Urban areas and the changes in their boundaries are detectable and excluded from the total agricultural acreage. Experience has shown that within the legal survey limits of each field approximately 10 percent of the area is devoted to off-site improvements which includes highways, roads, field access roads, canals, and farm equipment and hay lots. Therefore, in the compilation of the statistics an automatic 10 percent is deducted from each field. It is anticipated that ten categories will be sufficient to provide data input for the automatic identification system.

To facilitate the interpretation process as well as the computer mapping process, the valley was subdivided into seven arbitrary regions. These divisions were separated by boundaries that more or less divided the valley into regionalized agriculture. Regions 1 and 2 are primarily vegetable crops with most of the asparagus grown in region 1 and carrots in region 2. Regions 3 and 4 act as a transition from vegetable crops to field crops. The other three regions (5, 6, and 7) are predominantly large acreages (160 acres) of field crops. Crop regionalization will be one factor used in the automatic identification system.

Table 1 summarizes the field conditions interpreted from the 26 August ERTS-1 image. Approximately six man hours was required to determine the condition of the 8,861 fields of the Imperial Valley. Considerably more time was involved in transferring the data to machine cards. Future research will concentrate on making this process more automatic. The total of 464,496 agricultural acres agrees to within 1 percent with the farmable acres reported by the Imperial Irrigation District annual summary. Some difference is found in the decision to eliminate fields of less than twenty acres. Another point of difference may be found in the method of computing the acreage (e.g., different percentage used to compute off-site improvements). The total acreage of growing crops (154,429) representing one third of the farmable lands is expected for the month of August when daily temperatures rise above 110° almost every day of the month. Reference again to the Imperial Irrigation District Report of July 1972 and the crop calendar shows that the three major crops growing in August are: (1) alfalfa (over 100,000 acres); (2) cotton (30,000 acres); and, (3) sorghum (over 20,000 acres). Other minor crops (no more than 2,000 acres) which are in production on 26 August are: Sudan grass, Bermuda grass, onions, and fall melons. Although there are only seven crops to consider at this time of year it is still impossible to distinguish specific crops from a single image.

TABLE 1. IMPERIAL VALLEY -- FIELD CONDITIONS AUGUST 26, 1972.

REGION	TOTAL ACRES	NO DATA	GROWING CROPS	WET BARE FIELD	PLOWED BARE FIELDS	DRY BARE FIELD	HARVESTED CROPS	PERM CROP	FEED LOTS	AGRICUL OFFSITE	URBAN
1	58,255	2,047	23,211	4,846	11,371	9,180	342	27	243	5,698	1,290
2	54,455	968	19,014	4,361	8,327	13,367	1,300	324	720	5,379	695
3	111,771	2,380	33,087	1,728	28,233	26,876		288	562	10,352	8,265
4	119,629	1,390	37,603	3,510	37,048	22,461	220		301	11,396	5,700
5	74,203	689	22,599	805	17,415	24,627			287	7,381	400
6	78,131	594	15,503	1,075	28,364	23,877			309	7,749	660
7	38,047	1,189	3,412	99	5,089	23,228				3,670	1,360
TOTAL	534,491	9,257	154,429	16,424	135,847	143,616	1,862	639	2,422	51,625	18,370
Less URBAN	18,370										3.45%
	516,121										
Less OFFSITE	51,625									10%	
TOTAL AGRI ACREAGE	464,496	2.0%	33.3%	3.5%	29.2%	30.9%	0.4%	0.14%	0.5%		

Initial work with specific crop identification involved field condition data from four 36 day cycles between August 26 and December 12, 1972. Table 2 summarizes these findings. From the 8,000 plus fields in the Imperial Valley, 1,164 fields were studied, and their data used to test different approaches to crop identification. The 1,164 fields used were specifically selected because ground truth surveys were available for these fields, thus making it possible to check tentative conclusions about the crop growing in any one field, and facilitating perfection of the crop identification process. A computer card was made for each field, and each time more imagery was received, the condition of each field was coded and punched on the card.

The Imperial Valley Crop Calendar was used as a guide; however, it was found that the field condition code sequences obtained from ERTS-1 imagery differed from the idealized crop calendar because of the extremely wet fall and winter in the Imperial Valley in 1972. Therefore, it was necessary to depart from the idealized crop calendar. In order to devise a system for crop identification applicable to the time period in question, we examined carefully the code sequences of the sample fields, and recorded them. Then, we matched each field's code sequence, ground truth, and acreage. This allowed us to note several trends in the data, and to determine which crops would fit any particular sequence. Two significant things were noted at this time: (1) for any one sequence, crops varied if the field in question was over 80 acres or 80 acres or less, because field crops are more common in fields of over 80 acres, and (2) some crops could not be positively identified from only four periods because of similar code sequences and acreage sizes as other crops.

Steps were taken to incorporate the above two findings into a computer program designed to automatically identify crops from the input data. The first step was to divide fields with a certain sequence into fields with over 80 acres and fields with 80 acres or less. The second step was to establish "weights" relating to the probability of a particular crop growing under any code sequence. The weights were obtained by computing percentages of different crops in each code sequence. For example, a very common code is 1 1 1 1, indicating that the crop in that field was identified on ERTS-1 imagery as growing during each of the four periods considered. We determined that, for fields of over 80 acres and for that code sequence, the weighted values are:

Alfalfa 92 Sugar Beets 3 Cotton 3 Barley 2

Using only four cycles, uncertainty of identification for some sequences results. For example if the sequence is 1 1 1 2, with 80 acres or less, the identification and weights are:

Alfalfa 40 Cotton 38 Sorghum 13 Sudan Grass 6 Lettuce 3

TABLE 2. SUMMARY OF IMPERIAL VALLEY FIELD CONDITIONS DETECTED FROM ERTS-1.

Field Condition / ERTS Color Code	GROWING CROPS (Red) (1)	WET PLANTED (Purple) (2)	DAMP PLOWED (Lavender) (3)	DRY BARE (White) (4)	HARVESTED STUBBLE (Yellow) (5)	PERMENENT AGRICULTURAL (8)	NO DATA (0)
	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)	(Acres) (%)
August 26	153,528 (33.3)	40,374 (8.8)	128,219 (27.8)	123,025 (26.7)	2,636 (0.6)	3,640 (0.8)	9,599 (2.1)
October 1	142,047 (30.9)	69,115 (15.0)	150,351 (32.7)	83,642 (18.2)	787 (0.2)	3,640 (0.8)	10,470 (2.3)
November 6	199,197 (43.3)	120,330 (26.2)	48,736 (10.6)	80,221 (17.4)	315 (0.1)	3,640 (0.8)	7,627 (1.7)
December 12	213,233 (46.3)	116,426 (25.2)	55,542 (12.0)	62,262 (13.5)	1,075 (0.2)	3,640 (0.8)	8,270 (1.7)

	TOTAL PRODUCING ACRES	FEED LOTS	FARM ASSOCIATED	OFFSITES (Roads, Canals)	TOTAL AGRICULTURAL	URBAN	TOTAL ACRES
	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)
August 26	461,021	2,698	180	51,508	515,407	14,640	530,047
October 1	460,052	2,703	184	51,467	514,405	15,140	520,546
November 6	460,066	2,747	463	51,442	514,718	15,350	530,068
December 12	460,448	2,734	486	51,489	515,157	14,850	530,007

In this case, the addition of more code sequences would permit definite identification of the crop.

In the process of reviewing the fields and determining the weights, it became apparent that some codes fit no known crops. We designed the computer program to note all the fields with code sequences other than those of known crops. The irregular code sequences can then be checked to determine if human error in initial interpretation of the imagery occurred. If so, the error can be corrected, and the code identified. Another possibility with an irregular crop code is that a new crop is being grown, such as was the case with Alicia grass. In a few cases, data were not obtainable from the imagery for certain fields. The crops in these fields, obviously, could not be identified.

With the system outlined above, using only four periods, accuracy of specific crop identification varies. It is not usually possible to state for certain that one particular crop is growing in a field because several crops may have the same code sequence, and four time periods are enough for only preliminary identification of the crop growing in any one field. Our findings suggest that overall, an 81 percent accuracy can be expected if one accepts the two highest weights of any code sequence. With more sequential imagery interpretation, more accurate identification of a crop can be anticipated.

Conclusions

The system being developed shows great promise of achieving the objective of more than 90 percent accuracy of crop inventory for a given agricultural region. The experiment utilized only four 36 day cycles. Many more fields could have been identified if the cycles were extended to at least 6 time frames. More importantly, the system operating throughout the entire year would have the advantage of knowing the previous crop. In the Imperial Valley the previous crop is a great aid to identification and inventory procedures because there are restraints on crop rotation. Sugar beets for example must be planted before cotton has been picked. Therefore, sugar beets cannot follow a cotton crop. Watermelons cannot be planted in the same field for a five year period. Factors such as the above can be very useful in developing an automated crop inventory system. Future investigations should consider performing the task on a year around basis.

2.2 Mapping Vegetation in Orange County from ERTS-1 Data

Vegetation mapping from high flight U-2 imagery at small scales (1:131,000) can be accomplished with proper methodological procedures. These same techniques can be applied to the ERTS-1 imagery for interpretation of (generalized) vegetation patterns of the landscape. However, the greater perspective gained from ERTS-1 at greater altitudes can both aid and hinder investigation and accuracy.

Through the use of U-2, RC-10 high flight color infrared imagery, Orange County was mapped for vegetation and wildlife patterns. Development of a functional classification scheme is of primary importance. It must be coordinated with the capability of the imagery to record information as well as with the needs of the investigation. It was felt that the best accuracy could be achieved using ten vegetation classifications, and five wildlife associations. Figure 3 is an example of the type of map produced (only 9 vegetation classes were needed). Separate maps of wildlife associations were drafted.

In formulating the classification system an intensive study of ERTS-1 imagery (band 7) and the U-2, RC-10 CIR imagery was required to determine patterns of specific tonal and texture registration. Careful attention was given to locational relationships such as slope orientation, drainage patterns, accessibility of wind systems and moisture, and elevation. Broad general patterns can be determined in the ERTS-1 photos and more specific and accurate delimitations made with the U-2 imagery.

Field checking was required to identify the specific signature pattern and determine the vegetative type characteristic of that registration. After a signature has been identified it can be applied to the entire study to delineate the vegetation type.

In this systematic development a functional classification system can be formulated based on observable data and geared to the photography. The methodology can be applied to any region for mapping vegetation and will yield accurate, comprehensive results.

Mapping of vegetation can provide a useful data base for planning, especially when introduced into a computer format with land use, landform, and hydrological data. Digital plotting of boundaries recorded from air photos can enable quantification of, heretofore, arbitrary information and quickly provide accurate, usable data.

2.3 Land Use in the Northern Coachella Valley

The initial design of this research concerned the qualitative evaluation of ERTS-1 imagery's utility as an information source for the detection of land use change. A by product, however, namely the regional perspective and relatively exact spatial relations provided by the imagery is potentially significant for regional planning and management decisions. Open space desert resources, in California, are under severe pressure to serve as a source for recreational gratification to individuals living in the heavily populated southern coastal plain. Concern for these sensitive arid environments (the Colorado and Mojave Deserts) has been expressed by both federal and state agencies. The northern half of the Coachella Valley, part of the Colorado Desert natural province, has long served

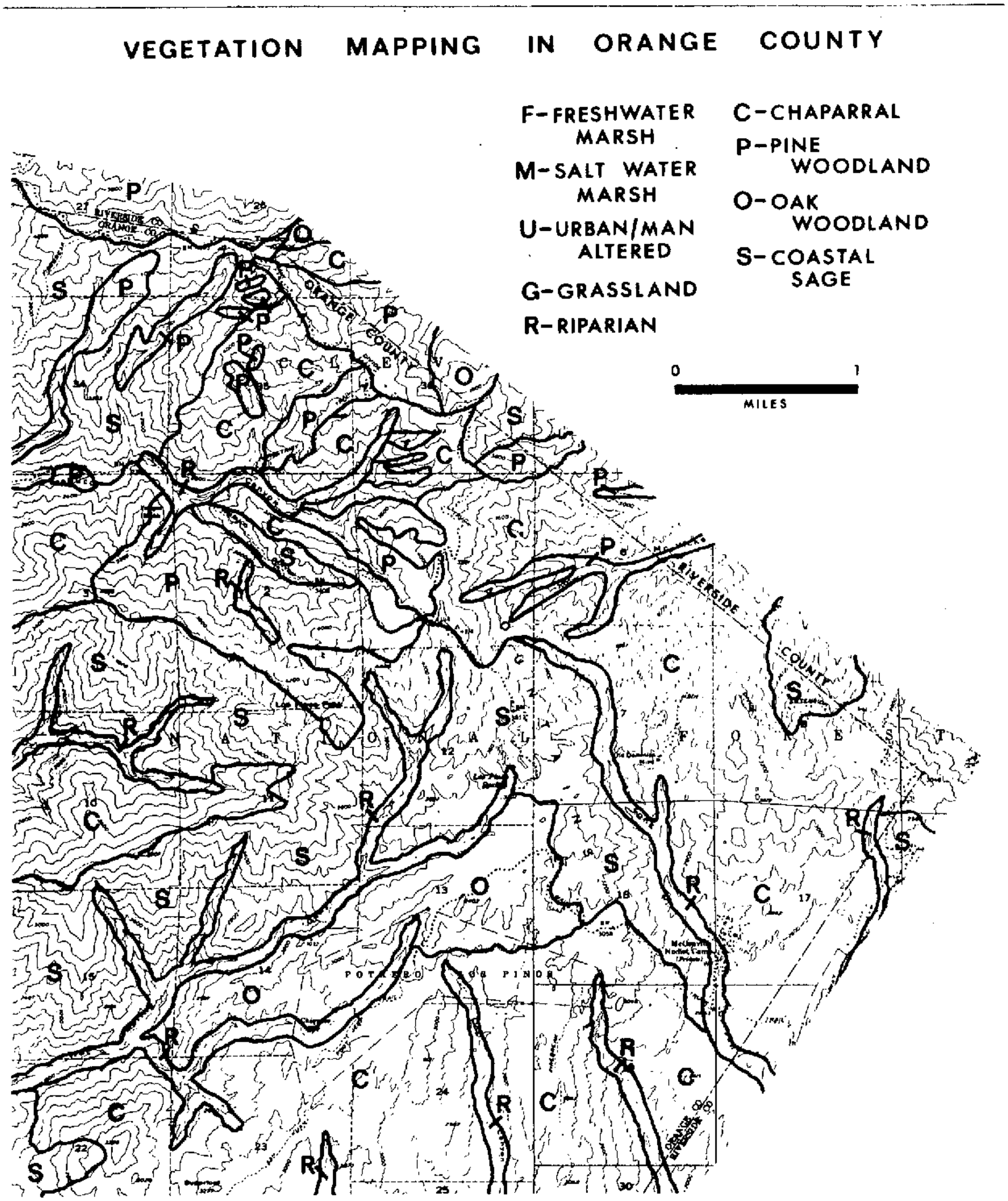


Figure 3. Vegetation mapping in Orange County.

as a focal point for weekend and seasonal (winter) recreational activity.

Area

The Coachella Valley is the northernmost extension of the Salton-Imperial Trough (Figure 4). Land use has traditionally been a contrast between agriculture and recreation. The valley is approximately 50 miles (80.5 km) long and averages less than 15 miles (24 km) in width. As a structural trough, it is bounded on both the north and southwest by the highest mountain ranges in Southern California. It terminates in the south at the Salton Sea and narrows to the north to form San Gorgonio Pass. If one wished to delimit geographic regions solely on physical characteristics, the Coachella would qualify. Dominant land use types dictate that the valley be divided into two regions (Glendinning, 1949). The northern half of the valley possesses a recreational economic base while the southern half from Indio to the Salton Sea depends primarily on an agricultural economic base. The investigation has been limited to the northern half of the valley where recent residential and recreation oriented building occurs at rates far above county averages.

Research Design

Research objectives involve the qualitative testing of ERTS-1 imagery as a data source for land use monitoring at the urban-rural fringe in the desert environment. Base land use information was obtained in 1966 and 1969. This information was then compared with the record obtained from ERTS-1 to produce a map of change. Analysis of the change, where it is concentrated, and how quickly it is occurring will provide insight into potential regional problems.

Data Sources

Although ERTS-1 imagery served as the primary data source, both U-2 and RB-57 photographs were also used. Field surveys and the aforementioned high altitude imagery allowed the information interpreted from ERTS-1 to be verified and more precisely located.

Two formats of ERTS-1 imagery were used with an I^2S Mini-Addcol Color Viewer to produce interpretable false color representations. 70 mm positives were used in their entirety, while only a portion of reproduced 9 x 9 inch (22.9 x 22.9 cm) positives were used. Diazochrome black-and-white positive transparencies were prepared from 9 x 9 inch (22.9 x 22.9 cm) ERTS positives. These were then cut to fit the 2-3/4 x 2-3/4 inch (6 x 6 cm) yoke format of the color viewer. The resulting scale, as visible on the ground glass view plate of the color viewer, was approximately 1:150,000. This technique provided more enlargement,

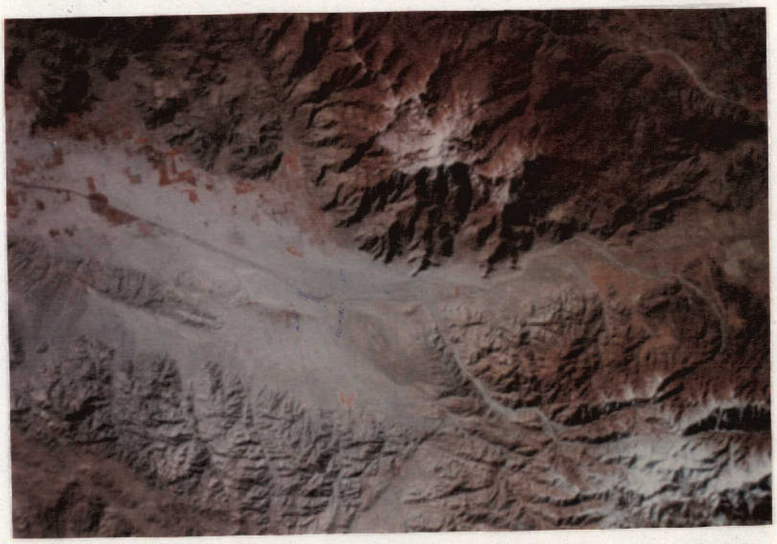


Figure 4. A portion of an ERTS-I image showing the northern Coachella Valley. (Note: north is at bottom of photograph).

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but less resolution than the enlarged 70 mm positive transparencies. MSS bands 4, 5 and 7 were used in three of the four channels of the color viewer. In order to reconstruct a false color infrared image, band 4 was projected through a blue filter, band 5 through a green filter and band 7 through a red filter. In order to enhance the image record of commercial activities along main thoroughfares the filters used for bands 5 and 7 were switched and a false color image, with green in place of red, was created.

Mapping Procedures

The largest portion of the mapping was accomplished from enlarged positives or projected slides taken off a portion of the reconstructed 70 mm image on the color viewer view plate. Projected images were worked at scales no larger than 1:62,500. Resolution usually extended to eighty-acre sections. Better resolution occurred where intense signatures associated with specific uses could be found in isolated parts of the valley. Linear features and land use arrays appeared to be more visible than other features of equal area. Such findings were expected and not in themselves surprising.

Strict procedures were established, and followed, during the mapping process. One interpreter accomplished all the mapping. Factors which influence the quality and resolution of land use information gleaned during this study include the scale of the imagery, the scale of the final map product, the availability of secondary data sources, the expertise of the interpreter, and finally, how well the interpreter knows the subject area. In evaluating the usefulness of a remote sensing system, there is no justification for faulting a mapping procedure because one interpreter, through his own knowledge of the area, is more proficient at correctly identifying land use than another equally skilled individual who does not know the area.

During this study more land use information could be extracted from the imagery because the interpreter "knew" the region, than would have been possible otherwise. Familiar areas where residential and commercial urban uses are fixed, because of high capital investment, served as a base for identifying uses in less well known areas and in areas where change had taken place. Members of any regional planning organization should be as knowledgeable about areas under their jurisdiction as was our interpreter in the Coachella Valley.

Previous land use mapping in 1966 by R. Van Curen served as a base for change comparison. An intermediate set of information was obtained in 1969 through the work of J.B. Bale and W.G. Brooner for Palm Springs. The land use classification used for ERTS-1 derived information (see table on following page) is a modification of the one used in 1966. This, of course, is necessary to maintain consistency and allow land use change identification. In most areas, the classification scheme allows more detail to be recorded than is actually visible from the imagery -- the 1966 survey was based on both a low altitude large scale photographic record and detailed field work. A less detailed classification system would inhibit interpretation processes where additional information is available on the photo.

Techniques developed in previous agricultural surveys at the University of California, Riverside and elsewhere facilitate identification of agricultural uses. Crop calendars, dependence on false color infrared film where various shades of red facilitate interpretation, and the fact that agricultural fields usually cover large areas, allow interpreters to obtain greater detail (even to the identification of specific crops) in an agricultural area than in urban areas. In the Coachella Valley, however, certain urban associated recreation uses, specifically golf courses and fairway side housing, can be easily identified (Tamarisk, Bermuda Dunes, La Quinta, Canyon Country Club, Thunderbird, etc.). This combination of residential and recreational use has its own category in the land use classification scheme.

Ground Truth

All areas where positive change was mapped within the city limits of Palm Springs were ground checked February 18, 1973. In every instance some form of positive change had taken place in or adjacent to the boundaries drawn on the map. In no instance were the boundaries which were drawn on the map exact representations of the actual area where the change occurred. Although no attempt was made to identify the new land uses as they were being mapped, it was noted in the field that all change identified consisted of residential structures or subdivisions except for one park in section 34 at the north end of town. All areas of change 1/8 section or larger were recorded. Change did occur which was not recorded, but it was from one use other than open space to another or it occurred over an area which was too small to be recorded (Figure 5).

East of Palm Springs in the unincorporated portion of the test site, land use change was monitored with similar accuracy to that which was achieved in the more densely occupied city area. Identification of land

TABLE 3. COACHELLA VALLEY LAND USE CLASSIFICATION (1972).

A. AGRICULTURAL LAND USES
   1. Field Crops
      a. grains
      b. feed
      c. vegetables
      d. truck crops
      e. other
      f. pasture
   2. Row Crops
      a. vegetables
      b. maize
      c. other
   3. Tree Crops
      a. citrus
         (1) oranges
         (2) lemons
         (3) grapefruit
         (4) limes
         (5) other
      b. vineyards
      c. palm orchards
         (1) date
         (2) ornamental
      d. other (i.e., pecans)
      a/c. palms with citrus
   4. Rural Housing and Agricultural Services
   5. Unidentified or Unknown
   6. Miscellaneous Agriculture
      a. nursery
      b. feed lot
      c. other agriculture (experiment station)
      p_p. packing plant

B. URBAN LAND USES
   1. Residential
      a. single
      b. multiple
      c. transient
      l. lot subdivisions
      m. mobile
      r. recreation
   2. Commercial
      a. sales and service
      b. recreation
   3. Industrial
   4. Institutional and Governmental
   5. Unknown

C. UNDEVELOPED AND UNUSED
   1. Vacant
   2. Abandoned
      a. agriculture
      b. urban

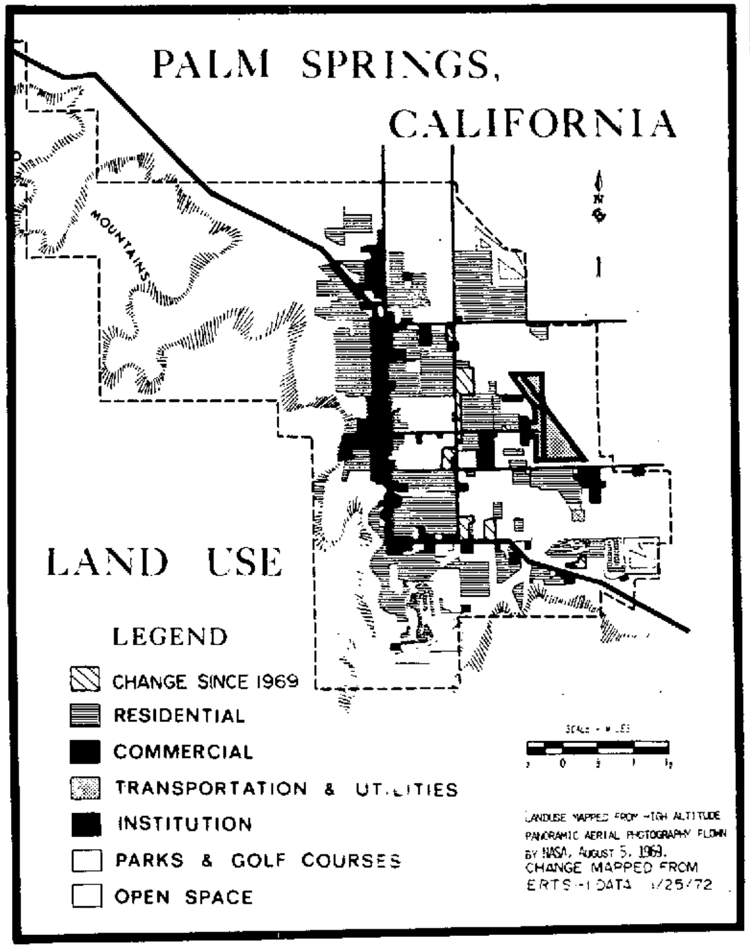

Figure 5. Palm Springs, California.

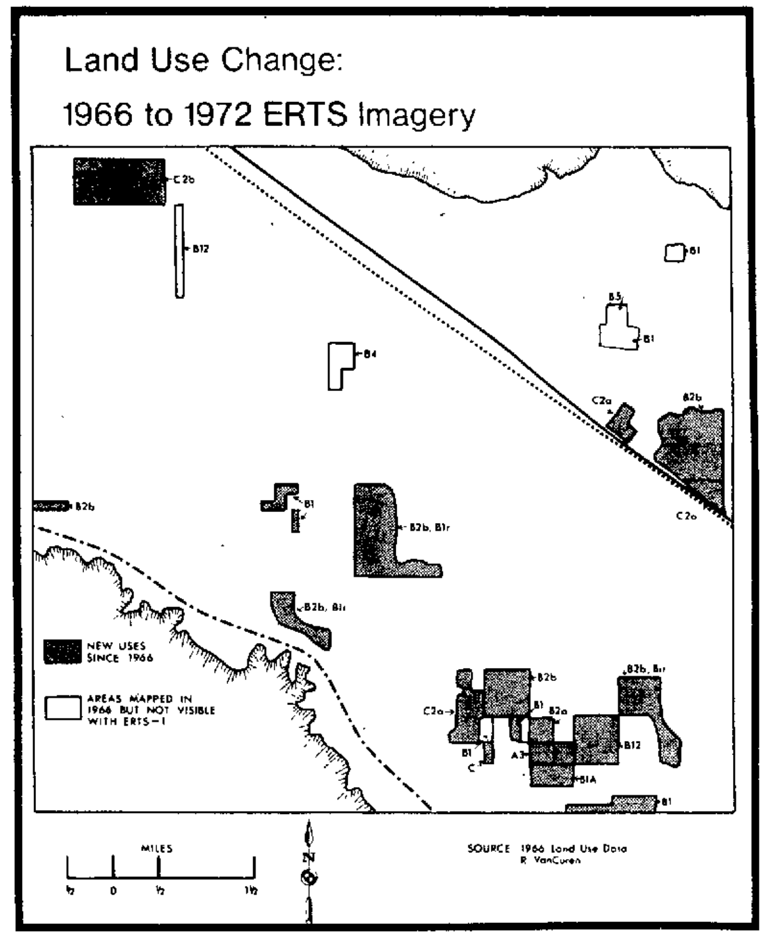

Figure 6. Land use change.

use type as well as land use change was attempted. Boundaries again could not be placed exactly, but in only two instances were land uses misinterpreted. The first case was a locational problem involving the improper postioning of a small area of abandoned vineyards in the south central part of Figure 6. Secondly, at Thousand Palms recreational residential use involving mobile homes around a golf course was not identified. Less critical problems involved the category of agricultural abandonment (C2a in Figure 6). Here, no distinction could be made between active removal of orchards or groves, and their complete removal. The difference between active agriculture, and abandonment or disinvestment was always apparent.

Results

From both maps and the ERTS-1 imagery, it is obvious that much of the urban development has occurred on the various alluvial fan surfaces that emanate from the San Jacinto Mountains. These areas, somewhat protected by spur ridges from the winds which are strongest along the axis of the valley, were developed first and still contain the most diversified urban uses (residential, parks, commercial). More recent residential development has occurred on the upper portion of some fans (Deep Canyon Fan for example) or along the south center axis of the valley at the expense of open space or agricultural uses. All agriculture will be gone from the north half of the valley within the next few years.

Change in the Palm Springs area consists primarily of the filling in of an already urban environment. Alternate sections within the city limits belonging to the Agua Caliente Indian Reservation are now being transformed from open spaces to urban uses. Problems were encountered while working in this more complex urban environment. With the present system of combining and projecting reconstructed imagery, land use boundaries within the city could not accurately be drawn. Furthermore, except for most single family residential areas, parks, golf courses, and some, specific commercial uses, a full range of urban uses including most commercial areas, multi-family residential, governmental, and other institutional uses were not discernible. Positive change however was visible where other forms of use have replaced open space.

Farther to the southeast, in what was originally a less complicated agricultural landscape, change occurs in the center of the valley. This area, originally a "blow-sand" environment, is undergoing a transformation from open space and agriculture to recreational and residential uses. What exists is perhaps the heaviest concentration of golfing facilities in any area of this size in the world. In situations where direct conversion from agriculture does not occur, fields are abandoned, left fallow or trees (either citrus or date palm) are maintained as ornamentals to residential uses. Agricultural abandonment is one form of factor disinvestment common to the rural-urban fringe in Southern California (Goehring, 1971).

Analysis

If they existed, information systems featuring rapid updating procedures and utilizing statistical data sources such as census returns, assessor's data or building permit totals could provide more accurate information concerning land use change than is available from ERTS-1 imagery. However, information developed from such sources, even if graphically arrayed (in map form) can approximate an areal perspective of the landscape or accurately convey regional spatial relationships like ERTS-1 imagery. Perspectives available from ERTS-1 imagery allow regionwide views containing information in quantities not available from composite sources (maps or photo mosaics). The sequential nature of the imagery adds to potential utility although biannual collection instead of every 18 days would suffice to monitor urban land use change in the northern Coachella Valley.

Although no regional planning agency with responsibilities in the Coachella Valley has yet to integrate ERTS-1 imagery into its resource management procedures, various members of the planning departments of Riverside County and Palm Springs City have made casual use of reconstructed images. Individuals from both organizations have, from other sources, already been made aware of problems illustrated by ERTS-1 imagery. Alarmed by what appears to be a loss of amenities in a primarily recreational urban environment, officials in Palm Springs have called a temporary building moratorium, and proposed revolutionary measures to maintain open space within the city (personal communication, Department of Planning and Development, City of Palm Springs and Proposed Open Space and Conservation Element, Palm Springs General Plan). County officials have expressed little concern over loss of open space but have been confronted by numerous local conservation organizations that have expressed concern over a number of related topics ranging from a loss of wildlife habitat to deteriorating ground water quality.

Additional building and subsequent increases of human activity will jeopardize numerous specialized natural habitats in surrounding areas. Most recent land use change suggests a loss of unique natural habitats, including fan surfaces emanating from the San Jacinto Mountains, the sand dune habitat that extends along the axis of the valley, and the Bighorn sheep habitats in the mountain slopes surrounding the valley bottom. Continued residential construction has also reduced the habitat value of the valley to man. Increased environmental pollution (air pollution, noise and visual pollution) threaten the area's economic base. Amenity loss stemming from the lack of attention to concepts of environmental design and consequent impacts of continuing development can be inferred. Sequential ERTS-1 imagery has recorded the most recent chapter of the Coachella Valley's continuing environmental alteration.

References

Bale, J. B. and W. G. Brooner (June, 1970), "Experimental Land Use Mapping from High Altitude Panoramic Photography," Paper Presented at APCG Meeting, Santa Cruz, California.

Glendinning, Robert M. (1949), "Desert Contrasts, Illustrated by the Coachella," Geographical Review, 39:221-228.

Goehring, Darryl R. (1971), Monitoring the Evolving Land Use Pattern on the Los Angeles Metropolitan Fringe Using Remote Sensing, Technical Report T-71-5, Contract No. N00014-69-A-0200-5001, NR 387-047 and NASA NGL 05-003-404, Department of Geography, University of California, Riverside.

Roos, Marvin (January 1973), Assistant Planner, Department of Planning and Development, Palm Springs, California, Personal Communication.

Van Curen, R. (1966), "Land Use Maps of the Coachella Valley," Unpublished, University of California, Riverside.

2.4 Southern California Compression Zone

The Los Angeles Basin and its several sub-basins have been blocked out by the intersections of the northwest-trending Peninsular fault structures of the San Andreas system with the east-west or Transverse structures related to the Murray Fracture Zone. Local seismic interest has been focused upon faults related to the two tectonic alignments. ERTS-1 imagery of Southern California clearly indicates a third tectonic lineation which appears more closely related to recent seismic activity than the traditionally recognized structures (Figures 7 and 8).

The ERTS-recognized lineations appear as a broad zone, some 50 miles in width, which intersects the Transverse Ranges at about a 15° angle or with an azimuth of 70°. Although a limited number of landform features appear to be solely the products of the forces responsible for this sub-transverse zone, extensive evidence is also to be found in elements of the larger structures of the Transverse Ranges. Ridges that form the northwestern edge of the San Gabriel Mountains, for example, are properly oriented and in turn align with Oak Ridge which extends in a west-by-southwest direction toward the Pacific Ocean to impart the same orientation to the Santa Clara River Valley. North of the valley, the prominent ridge of the Topatopa Mountains, similarly set obliquely to the Transverse Ranges of which it is part, delineates the approximate northern edge of the zone.

The southern edge follows a line of recognized faults which for the most part are buried under alluvial fill of the Los Angeles Basin

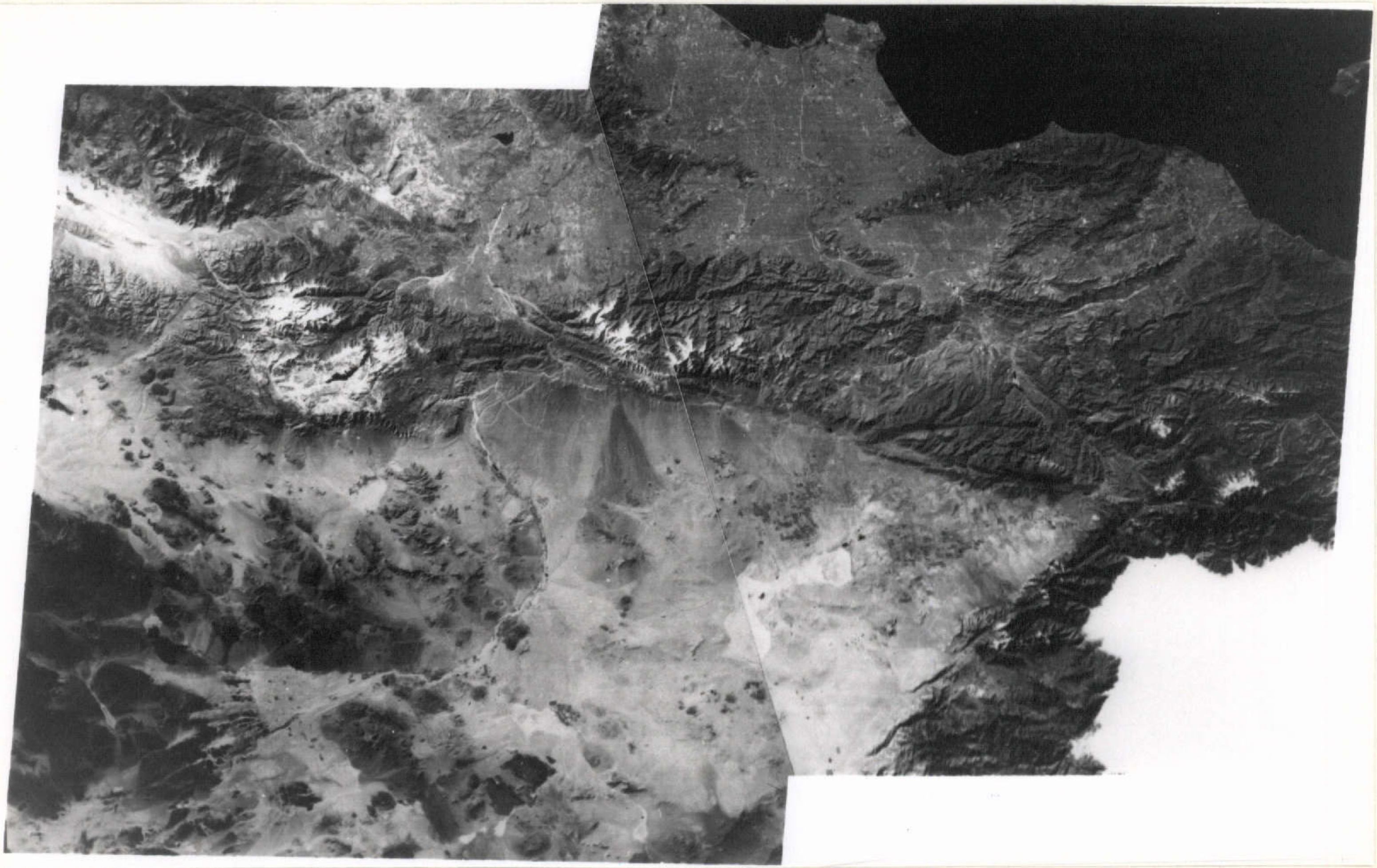

Figure 7. A mosaic of ERTS images of November 25 (RH) and November 26 (LH) showing the Los Angeles Basin, Transverse Ranges, and Mojave Desert. The zone of tectonic lineations with the 70° azimuth is located in the accompanying map.

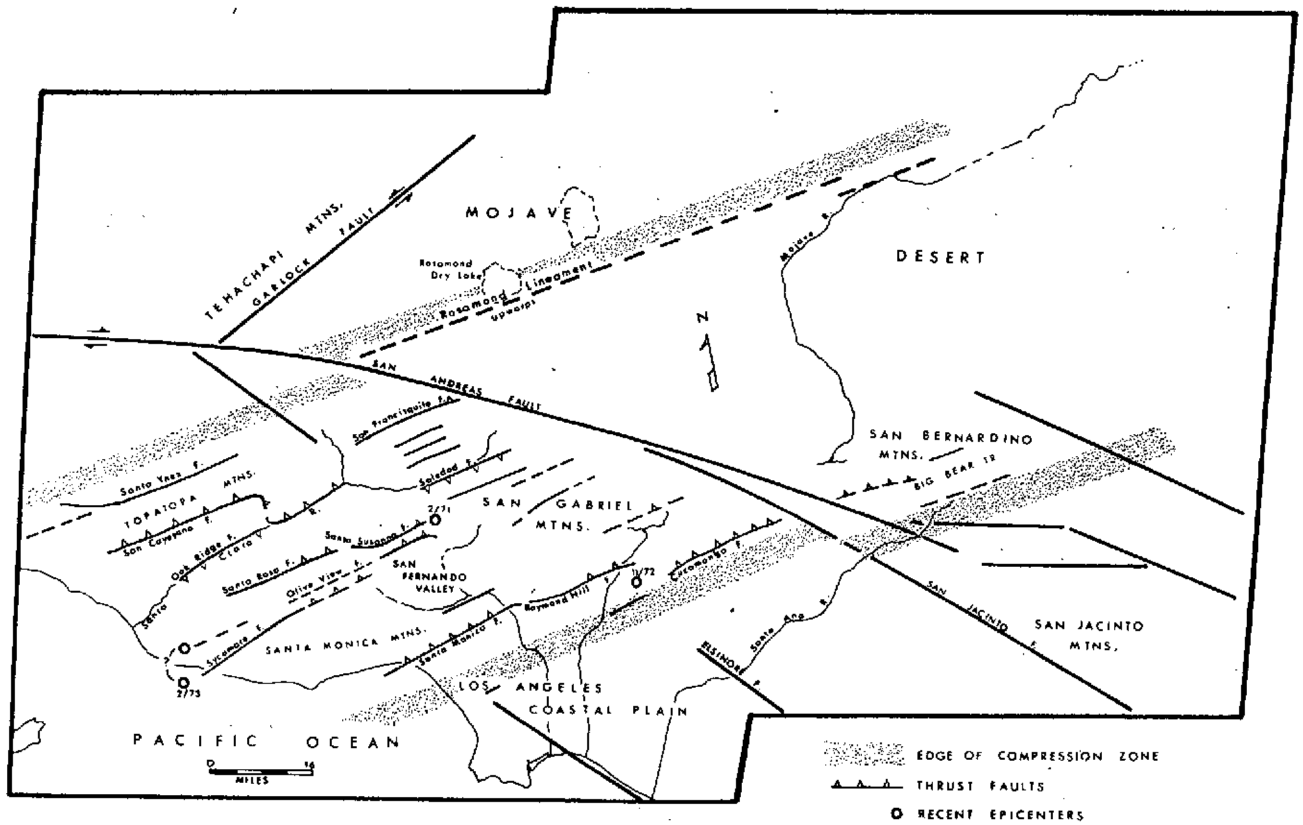

Figure 8. Zone of tectonic lineations.

(*Geologic Atlas of California*). At the western end of this alignment is the Santa Monica Fault while to the east the Cucamonga Fault facets the southeastern corner of the San Gabriel Mountains near the point where the San Andreas system bisects the Transverse Ranges at Cajon Pass. It is significant to note that at this point the ERTS-recognized alignment crosses the San Andreas Fault with less than a mile of right-lateral offset which may give some clue to its age. The tectonic trend has affected the San Bernardino Mountains east of Cajon Pass by giving landform orientations that are cross-grained to the trend of the mountain range. These include a major indentation on the southern mountain front, the trend of the Big Bear-Baldwin lakes trough, and the general trend of the Santa Ana River canyon. Although the lineation just described is taken as the southern edge of the zone, ridge orientations and recognized faults in the San Jose Hills south of the San Gabriel Mountains may indicate a slightly wider zone, but evidences on ERTS imagery for this are not definitive.

The most prominent single indicator, both for the existence of the zone as well as its orientation, is a single tectonic line that extends across the Mojave Desert along the zone's northern edge and about halfway between the San Andreas and Garlock faults. On the imagery, it is particularly conspicuous along the southern edge of Rosamond Dry Lake (Figure 9) where desert-floor alluvium has been upwarped into low knolls with sufficient drainage to permit heavy stands of trees yucca (*Yucca brevifolia*) to form dark patches on the scans (Figures 10 and 11). To the east, the tectonic line extends along the northern edge of several low domes on the desert floor to be eventually occupied by a portion of the course of the Mojave River.

The alluvium knolls south of Rosamond playa, as well as the dome landforms, suggest that the desert tectonic line has been subjected to lateral pressure from the southeast. A number of faults with the sub-transverse orientation are known to be thrust faults and the San Fernando earthquake of 1971 indicated that those buried by alluvium may well be. Recognized as thrust faults are the Santa Susanna-Santa Rosa Fault, the San Cayetano Fault, the Cucamonga Fault, and, in all probability, the Santa Monica Fault. This combination of evidence strongly suggests that the sub-transverse zone here described is a zone of active crustal compression which is absorbing much of the compressional stress being exerted by the northwestward-moving blocks of the peninsula of Baja California which intrude into Southern California.

It is of particular interest to relate the tectonics of the San Fernando earthquake of February 9, 1971, to the zone of lineations observed on ERTS imagery. Surface breaks related to the Olive View Fault (Youd, 1971) were thrust plates with strikes close to the 70° azimuth of the ERTS-recognized zone. Several feet of crustal compression occurred. The compressional component of earth movement lifted

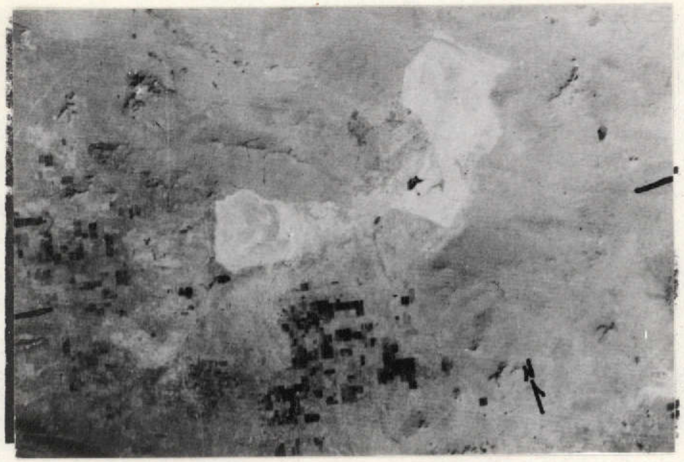

Figure 9. Rosamand dry lake and lineament. Band 5, 26 November 1972.

Figure 10. An oblique view of Rosamond playa showing groves of tree yucca along lineament.

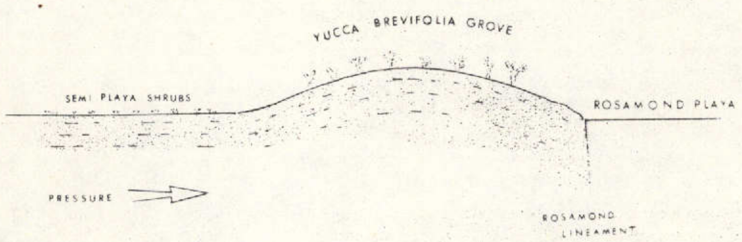

Figure 11. Cross-section diagram of knolls along the Rosamond Lineament which appear to be upwarped from desert-floor alluvium.

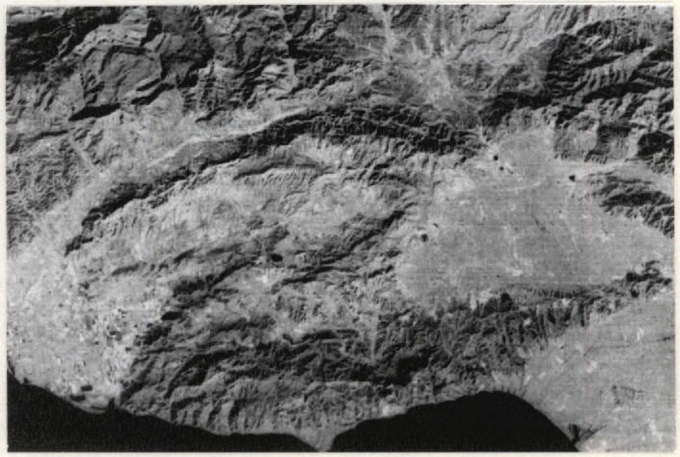

Figure 12. The lineament of olive view fault connecting two recent earthquake epicenters.

the surface north of the break approximately three feet and in so doing demonstrated that forces associated with the zone may well be responsible for much of the mountain-building in and around the Los Angeles Basin. The cause of the left-lateral movement associated with the quake can also be conjectured since the wedging of the shattered crustal block against the San Andreas Fault backed by the more intact Mojave block should eject the coastal structures westward. The indication provided by the Rosamond lineation that the Mojave block is absorbing some of the crustal stress may also indicate a lessened chance that severe slippage will occur along the San Andreas Fault adjacent to the Los Angeles Basin.

An epilogue to the San Fernando movements occurred on February 21, 1973, with a sizable tremor centered near the western end of the Santa Monica Mountains (Figure 12). An extension of the Olive View Fault southwest along the Simi Hills at an azimuth of 70° joins the Sycamore Fault which is believed to have caused the recent quake. This again demonstrates that the compressional zone is active. On November 28, 1972, a swarm of small tremors occurred, centered under the alluvium near Pomona, California. This is a location which does not fit the traditional fault network of Southern California but which would act like on a westward extension of the Cucamonga segment of the compression zone system.

In summary, ERTS-1 imagery in concert with previously recognized evidence delineates a zone of crustal compression across Southern California which is responsible for mountain building, landform orientations, and current seismic activity. The orientation of the zone can be considered "sub-gransverse". The zone thus intersects both the San Andreas system and traditional transverse structures obliquely. The existence of the broad zone of compression strongly suggests that Southern California seismic activity may be as much related to the zone as to specific faults. In other words, earthquake-producing compressions may occur anywhere within the zone and may not be related to known faults.

References

Geologic Atlas of California. California. Department of Natural Resources. Division of Mines. Scale: 1:250,000. Los Angeles, 1969; San Bernardino, 1967; Long Beach, 1962; and Santa Ana, 1965 sheets.

Youd, T. L., "Landsliding in the Vicinity of Van Norman Lakes," The San Fernando, California, Earthquake of February 9, 1971. U.S. Geological Survey Professional Paper 733, U.S. Government Printing Office, Washington, D.C., 1971.

2.5 A Remotely Sensed Examination of the Tectonic Framework of the Mojave Desert North of San Bernardino, California

The area selected for examination encompasses that portion of the Mojave Desert represented on the 1:250,000 USGS topographic sheet of San Bernardino, California. The Mojave Desert, being a distinct structural and physiographic unit was studied by itself, and only the adjacent borders of the Transverse Ranges to the south were included in the study. Thus tectonic homogeneity was preserved during the study. Because of lack of sufficient high altitude imagery for the entire Mojave region, only the south-central portion, with its complete air photo coverage, was studied.

A map showing the tectonic framework of the region was prepared using the San Bernardino sheet as a base map. The structural data were compiled from color and CIR imagery from Mission 164, recent U-2 CIR imagery, and from continuous black-and-white and color composite ERTS-1 imagery. The map records all faults, folds, volcanic features, joint systems, and surface fractures visible on the imagery. Mapping proceeded through the spring of 1973 (Figure 13).

The Tectonic Framework

The predominant trend of faulting in the area is northwest. These faults are for the most part rifts with right-lateral strike-slip displacement. These rifts display an average trend of N39°W. They are more numerous and better displayed at the surface in the eastern half of the area. The traces of many of them are striking, even when observed upon ERTS-1 imagery (Figure 14). The faults in the western half of the area are much more subtle in their surface expression and must be traced from Mission 164 and recent U-2 imagery. Very poorly developed wrench faults with an average trend of N8°E may be found in the eastern half of the area. Two were significant enough to be mapped. Others appeared with the same approximate trend in complex fault zones in the Bullion, Bristol, and Cady Mountains. These faults may represent a left-lateral set of a conjugate system composed of the northwest and northeast trending faults. Another set of better developed wrench faults with left-lateral strike-slip displacement and an average trend of N78°E occurs throughout the area, but with more frequency and longer traces in the eastern half. The best developed of these are the Cady fault, the Rainbow Canyon fault zone, and the Pinto Mountain fault.

The folds in the area are poorly developed. Most of them strike northwest, with an average axial trend of N43°W. Half of the observed folds plunge to the northwest. No plunge was observed for the others. The best developed fold is the Lenwood anticline. The Bullion Basin anticline has an axial trend of N85°W.

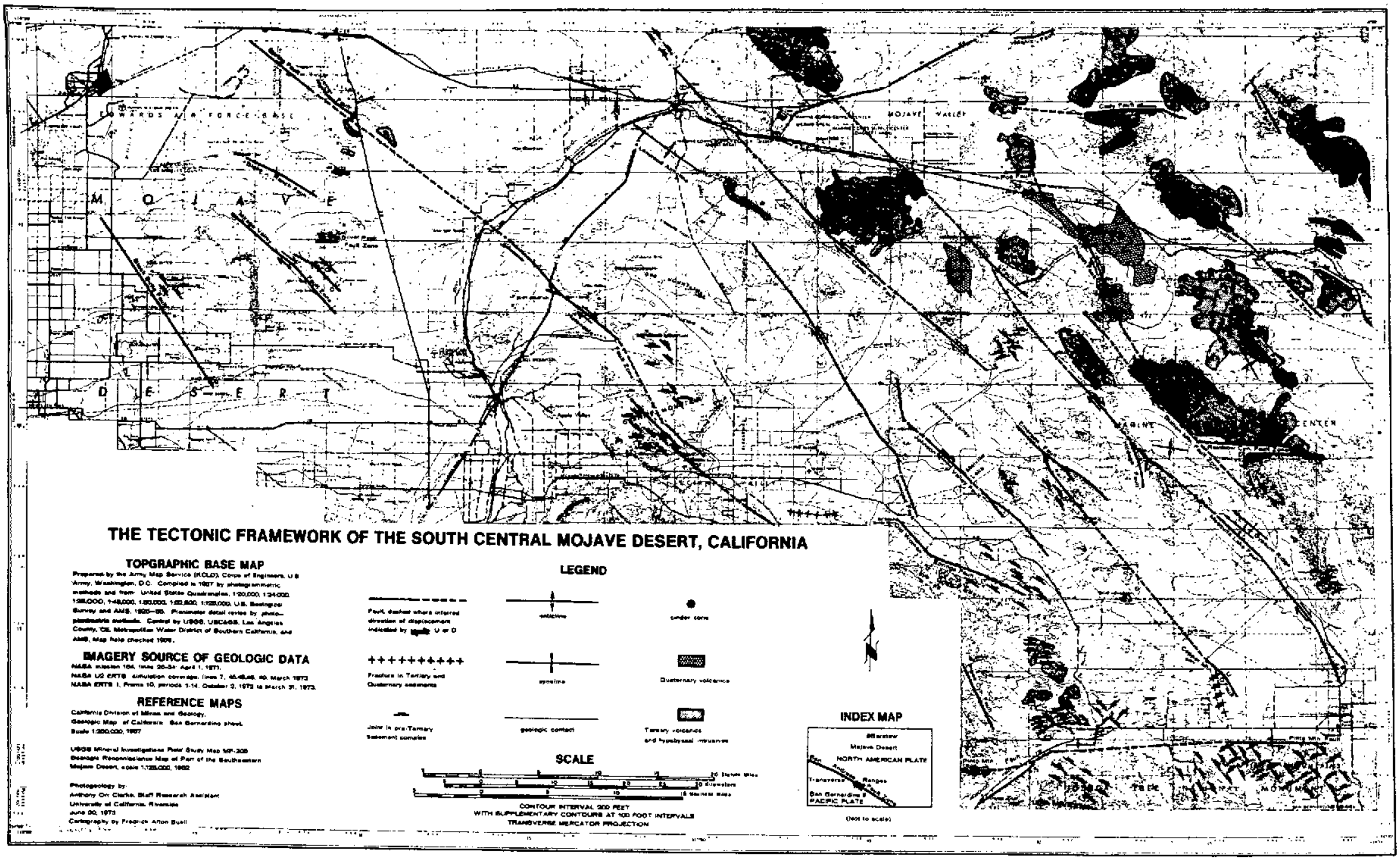

Figure 13. The tectonic framework of the south central Mojave Desert, California.

Figure 14. ERTS-1 photo (25 November 1972), 1:1,000,000. The Mojave Desert lies in the northern half of the photograph, bordered on the south by the Transverse Ranges. The Los Angeles Basin and San Bernardino Valley occupy the lower portion of the photo. Many structural lineaments are visible on satellite imagery, those which may be seen on this frame have been outlined in black.

Quaternary volcanic action has been extensive in the eastern half of the area, and is non-existent in the western half. Cinder cones possess a high degree of alignment with the rifts. Three of the five cones are within the Pisgah fault zone, and the other two are approximately three miles from exposed surface faulting. Pisgah Crater is a fairly recent feature and is remarkably well preserved. Its lava flows are by far the largest. Tertiary volcanics and hypobyssal intrusives are frequently found exposed in the eastern half of the area. These Tertiary volcanics display dominant northwest alignment and may be related to deep-seated Tertiary rifting. The most common extrusive rock in the area is basalt.

Two joint systems occur in the area. The system in the southeast corner is composed of two intersecting sets of joints, one striking northwest and the other striking northeast; both sets dip toward each other and appear to be conjugate shear joints. This system presents an imposing appearance in both Mission 164 and U-2 imagery, and is best observed in the vicinity of Joshua Tree National Monument. The second joint system is less dominant but easily observable. This system may be seen throughout the northern and central portions of the area. It is made up of two intersecting sets of joints, one striking northwest and the other striking east-west. The origin of the second set is not as clear as the first. Both systems occur in the pre-Tertiary basement complex and are best developed in the Mesozoic granitic rocks.

Surface fractures are observable in unconsolidated Quaternary deposits at two locations, an east-west trending fracture in the alluvium at the base of the Transverse Ranges north of Baldwin Lake, and two parallel northwest trending fractures in the lake bed sediments immediately west of Copper Mountain fault. These fractures or fissures may be related to dislocations in the bedrock at depth or they may be the result of surface subsidence caused by a recompaction of unconsolidated sediments following some seismic event.

The northwest trending mountain ranges of the area are low-lying and much more eroded than those of the Basin and Range to the north and east. For these reasons they must be much older. They consist primarily of folded and faulted Mesozoic volcanics, Mesozoic granitic rocks, and Paleozoic and pre-Cambrian metamorphic rocks. Locally they are intruded and overlain by Tertiary volcanics. They are for the most part fault-block mountains. Many appear to have been uplifted by rotational movement along strike-slip faults rather than by gravity faulting, creating the current rift topography. Rifting, uplift, and vulcanism occurred mutually during the Tertiary and some rifting and vulcanism continued into the Quaternary.

Stress - Strain Analysis

In the area studied, the structural fabric fits the conjugate faulting model remarkably (Figure 15). When the trends of the right-lateral rift faults are averaged, a mean shear fault trace with a trend of N39°W is computed. The rifts have a median trend of N40°W, and a mode of N45°W. In the following stress analysis the mean value of N39°W is used. Using the stress ellipsoid, the greatest principal stress axis P and the least principal stress axis R may be assumed to be perpendicular to each other, and both lying in the same near horizontal plane, somewhere at depth. The intermediate principal stress axis Q is perpendicular to P and R, and is nearly vertical. This stress arrangement will produce strike-slip faulting. Shear fractures f_1 and f_2 should develop at 30° left and right respectively to P and lie in the same plane as Q: f_1 will experience right-lateral displacement and f_2 will experience left-lateral displacement. N39°W may be assigned as the trend of f_1. This will orient the stress ellipsoid in space, and give the same approximate stress distribution as must have been present to produce the tectonic pattern observed in the area of study.

With this orientation we might expect to find left-lateral shear fractures developing parallel to the f_2 plane at N21°E. Several small faults with a mean trend of N8°E are found in the area. This is only a 13° deviation from the expected trend, and suggests a conjugate system of faults. Such a stress distribution also predicts second order left-lateral wrench faults trending N66°E. The mean trend of the ENE left-lateral wrench faults found in the area is N78°E which is a deviation of 12° from the predicted. Some of these may be thrust faults, particularly the Pinto Mountain fault. If they are thrust faults rather than second order wrench faults, there is only a 3° deviation from the predicted trend of N81°E for thrust faulting. The folds, exclusive of the Bullion Basin anticline, have a mean axial trend of N43°W. The predicted trend for second order folding is N54°W, and the deviation is 11°. The Bullion Basin anticline has an axial trend of N85°W, and the predicted trend for first order folding is N81°E; the deviation is 14°.

In all cases, the greatest deviation between observed and predicted lineaments is 14°, which is close enough to make a valid suggestion of conjugate faulting. The above analysis may also be performed using the strain ellipsoid. In this case, the greatest principal stress axis P becomes the least strain axis C, the least principal stress axis R becomes the greatest strain axis A, and the intermediate principal stress axis Q equals the intermediate strain axis B. The shear fractures f_1 and f_2 remain the same. Simultaneous shear faulting and thrust faulting may be explained by the rotation of the B axis in a vertical plane from its vertical position at depth (where, because of the greater lithostatic load, strike-slip faulting would be produced), to a horizontal B axis at a shallow position, (where, because of the decreased lithostatic load, thrust faulting would be produced).

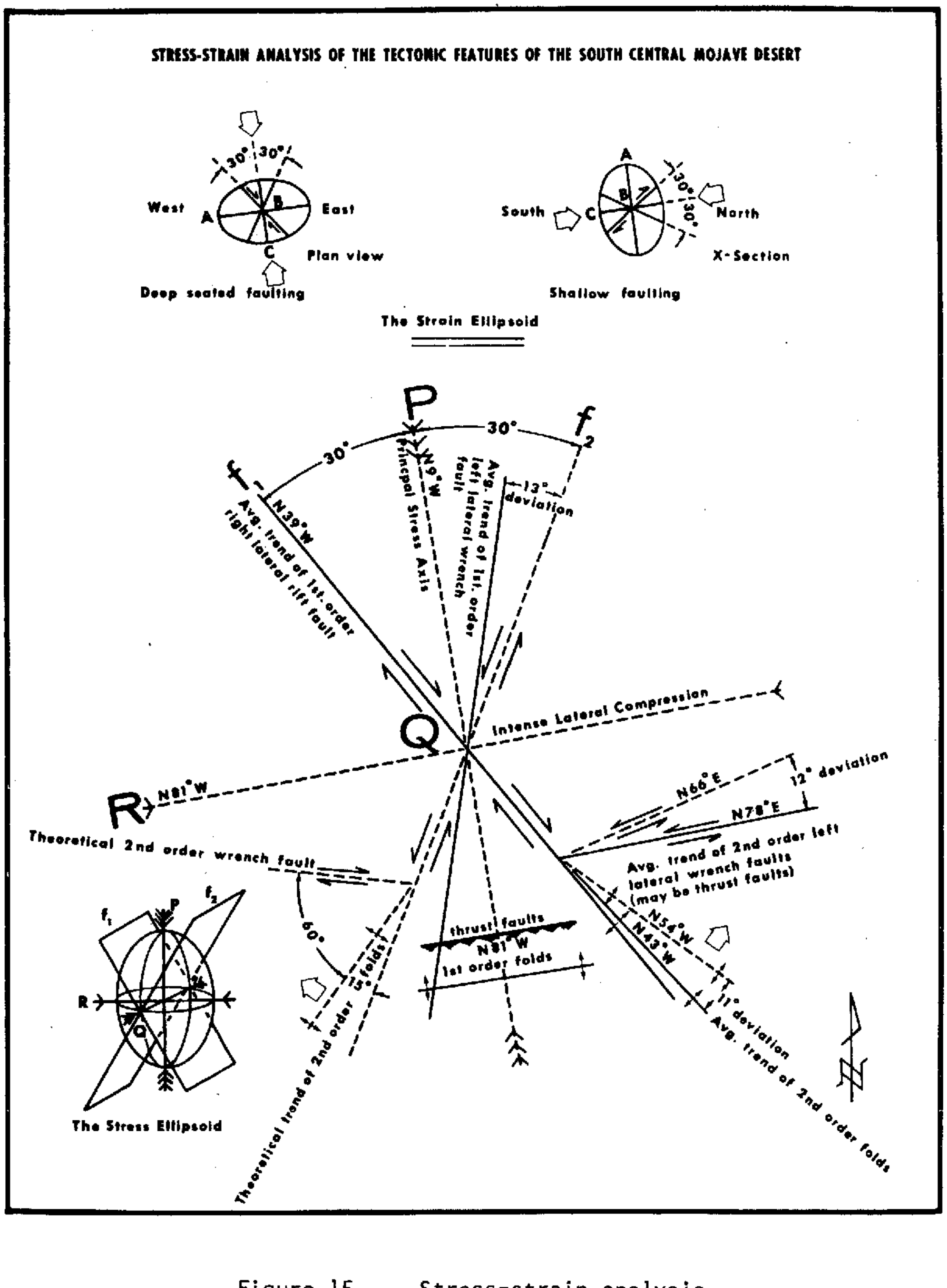

Figure 15. Stress-strain analysis.

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Conclusion

The stress and strain orientations suggest severe compressive forces having an axis of greatest principal stress trending approximately N9°W and causing intense lateral compression in a belt of easiest relief trending approximately N81°E conforming with the least principal stress axis. This near north-south compression culminated in the uplifting of the Transverse Ranges south of the area in the late Tertiary and Quaternary. These mountains have been uplifted by late Cenozoic thrust faulting along their base and have been thrown into folds possessing dominant trends oriented approximately east-west.

References

Badgley, Peter C., 1959, Structural Methods for the Exploration Geologist, New York: Haryper & Bros.

Billings, Marland P., 1954, Structural Geology, Englewood Cliffs: Prentice-Hall.

Kedar, Ervin Y., 1969, Geomorphotectonic Inferences from Earth Photographs: A Case Study of the Western and Southwestern United States, a presentation at the annual meeting of the Pacific Coast Geographers.

Kupfer, D. H. and A. M. Bassett, 1962, Geologic Reconnaissance Map of Part of the Southeastern Mojave Desert, California, Scale 1:125,000, U.S. Geological Survey Mineral Investigations Field Studies Map, MF-205

Lowman, Paul D., 1969, Apollo 9 Multispectral Photography: Geologic Analysis, Greenbelt, Maryland, Goddard Space Flight Center, X-644-69-423.

Oakshott, Gordon B., 1971, California's Changing Landscapes, New York: McGraw-Hill.

Pease, Robert W., 1969, "Normal Faulting and Lateral Shear in Northeastern California," Geological Society of America Bulletin, 80: 715-720.

Pease, Robert W. and Claude W. Johnson, 1973, New Fault Lineament in Southern California, Symposium on Significant Results Obtained from ERTS-1, Greenbelt, Maryland, Goddard Space Flight Center.

Rogers, Thomas H., 1960, San Bernardino Sheet of the Geologic Map of California, Scale 1:250,000, California Division of Mines and Geology Map Sheet.

2.6 Regional Monitoring of Atmospheric Circulation and Atmospheric Pollution

Conventional aerial photographs or small scale formats of weather satellite images seldom provide information at intermediate scales useful for monitoring atmospheric circulation in a region the size of Southern California. Research for this project is designed to visually monitor and record atmospheric pollution if possible and to record and help explain the delicate energy transfers that occur at the interfaces of dissimilar desert and marine air masses.

A system for collecting recorded atmospheric data from all stations in Southern California is now under development. Standard information including temperature, humidity and air pressure, as well as synoptic maps, can be gathered each date when there is an overflight. This information will then be compared to the ERTS-1 photography once it arrives. If pollution monitoring is possible, there will be the interesting potential of matching a visual record with measurements of ground stations. Because of sensor characteristics and atmospheric conditions, little synoptic information concerning either regional atmospheric circulation or pollutant dispersal patterns has been available from extant ERTS-1 imagery.

2.7 Impact of Off-Road Vehicles

The recreational use of off-road vehicles, especially in the arid regions of the western United States, has become an important and rewarding leisure time activity. As a result, off-road vehicular traffic, especially motorcycle traffic, has already caused considerable damage to these delicate desert environments, and this damage will certainly become more widespread unless regulatory action is taken promptly to prevent overuse and destructive uses of the terrain.

Location of damaged areas and the study of their proliferation would aid greatly in efforts to minimize the impact of this vehicular traffic. Such a study would also provide a rational basis upon which to establish regulatory policy for off-road vehicles. In this study the utility of remote sensing techniques for the dual purposes of location and study of damaged area is explored.

Through the use of imagery of California's northern San Gabriel bajada, spanning nearly three years from July 1968 to July 1972, all major areas of off-road vehicular damage within the study region were located (Figure 16). Growth of areas subject to damage, for the time period in question, was also mapped for specific locations.

Small scale imagery, particularly from the U-2 aircraft and NASA Mission 164, was found to be most desirable for purposes of initial

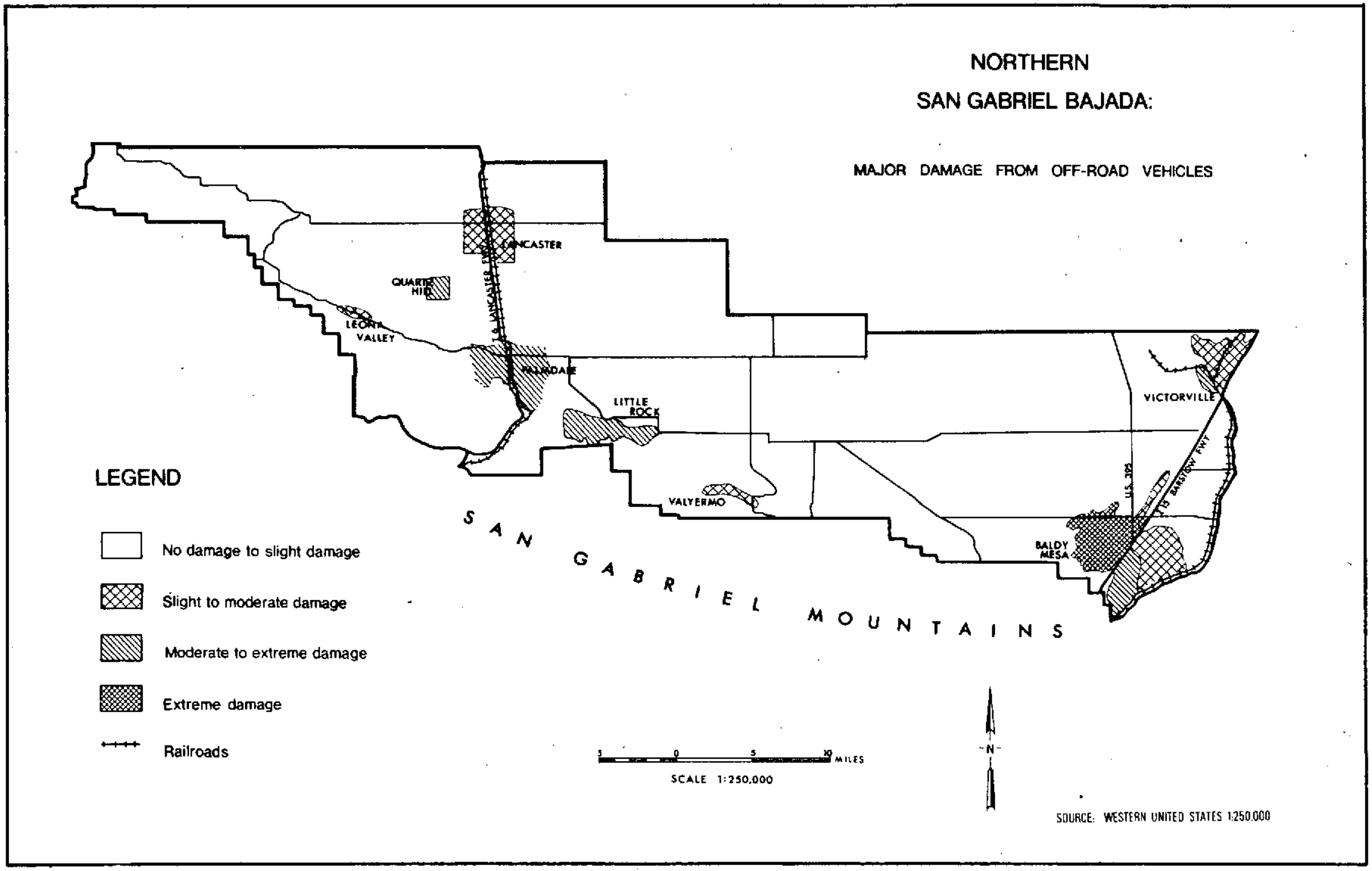

Figure 16. Northern San Gabriel Bajada.

location of damaged areas. Larger scale photography (1:24,000 to 1:30,000) was found to be more appropriate for more intensive study once damaged areas had been located. CIR imagery, particularly under a stereoscope, was found to be especially valuable in this investigation. Imagery of damaged areas from more than one date is, of course, requisite for a temporal comparison to determine expansion of damage.

Remote sensing techniques have direct application to the tasks of locating and studying off-road vehicle damage. Aerial survey is clearly superior to ground survey for these purposes for several reasons. First, the use of aerial photographs allows vast areas to be rapidly examined. Second, the perspective offered by aerial photographs allows the interpreter easily to see spatial patterns not readily visible from the ground. Finally, the number of man hours required for ground survey and mapping of damaged areas probably renders that method prohibitively expensive.

2.8 Impact of the Barstow to Las Vegas Motorcycle Race -- An Update

Off-road-vehicle (ORV) use in the desert is becoming an ever increasing activity for a large number of people, especially in Southern California. The impact of ORV operation has led to significant environmental change of the desert, often to its detriment. Initially, our study evaluated the use of U-2 underflight imagery for detecting the effects of ORV's. The annual Barstow to Las Vegas Motorcycle Race was chosen for analysis, primarily because the Bureau of Land Management (BLM) was considering suspension of approval to hold the race in future years if damage proved excessive. Damage was defined as any change that resulted in a dimunition of any of the factors that serve to make the desert environment unique (i.e. desert surfaces, soils, vegetative cover and air quality). We cooperated with the BLM in analyzing this race with our input focusing on the use of remotely sensed imagery for evaluating damage. The race was an organized event and the race route traversed a narrow and pre-determined path. Consequently, the amount of damage which the desert sustained proved minimal, especially in view of the large number of people who derived pleasure from the event (15,000 to 20,000). However, those areas which did sustain damage could have been spared if the race had been more carefully routed. The effects of this event and the results of the more common, extensive, random ORV operation in other areas of the Mojave were compared on U-2 imagery. Damage resulting from random usage was found to be the most serious and also the most easily detected on the U-2 imagery.

Ground reconnaissance both before and after the race showed that certain desert surfaces were much more able to withstand intensive ORV activity than others. For example, playa surfaces represent the local base level so that they are not susceptible to severe water erosion. Once the compacted playa surface is broken, however, dust becomes and and continues to be a major problem. In addition, many archaeological sites exist near the playa shores. Washes represent a type of ephemeral surface that is most adaptable to ORV activity; they consist of coarse and non-compactable material so that any indication of change which they incur disappears with the next significant rainstorm. Fan surfaces consist of sorted material and thus the head, consisting of the coarsest and least compactable material, is more adaptable to ORV operation than the foot of the fan, which consists of finely sorted material. The most vulnerable of all the surfaces to ORV activity are (natural) pavement surfaces. Different grades of pavement exist, varying in degree of development and particle size, and they are often somewhat indurated. Once the pavement surface is broken, it is susceptible to severe erosion by both wind and water (Figure 17).

In the attempt to determine textural composition of the various desert surfaces, ERTS-1 images were pre-enhanced and mapping done from the resultant image. The objective was to map the desert surfaces which texturally are most adaptable to ORV operation from a small scale image such as ERTS-1 (1:1,000,000). This information will provide a planning input to agencies, such as the Bureau of Land Management, concerned with recreational planning of the desert.

Unenhanced ERTS-1 images have poorly defined boundaries separating different desert features (Figure 18). Through use of the unenhanced image, it would be impossible to determine surface texture in any precise manner. One of the major problems encountered is that changes in parent material tend to greatly blur any boundaries. The technique of density slicing, reported in another ERTS-1 study, allowed for more precise boundary determination. The technique was used in order to enhance the boundary between different textural surfaces. The enhanced frame (Figure 19) showed pronounced breaks where different textural/slope conditions prevailed. The topographic sheet onto which the information was mapped (Figure 20) showed a relatively close correlation between the small scale ERTS-1 enhanced image and the large scale topographic sheet. A large degree of generalization was required, due to scale differences. Finer definition is discernible on the enhanced image so that it will be possible for us to draft a much more detailed map. The two most easily definable changes are in rock outcrops and playa bottoms. Often when a distinct break appeared, it proved, upon field checking, to correspond with a break in slope (Figure 21).

Perhaps more significantly, the "break" also corresponded with significant textural differences, determined later by laboratory analysis. For example, transects down an alluvial fan bordering Roach Dry Lake, and another bordering Mesquite Dry Lake, revealed the following textural differences:

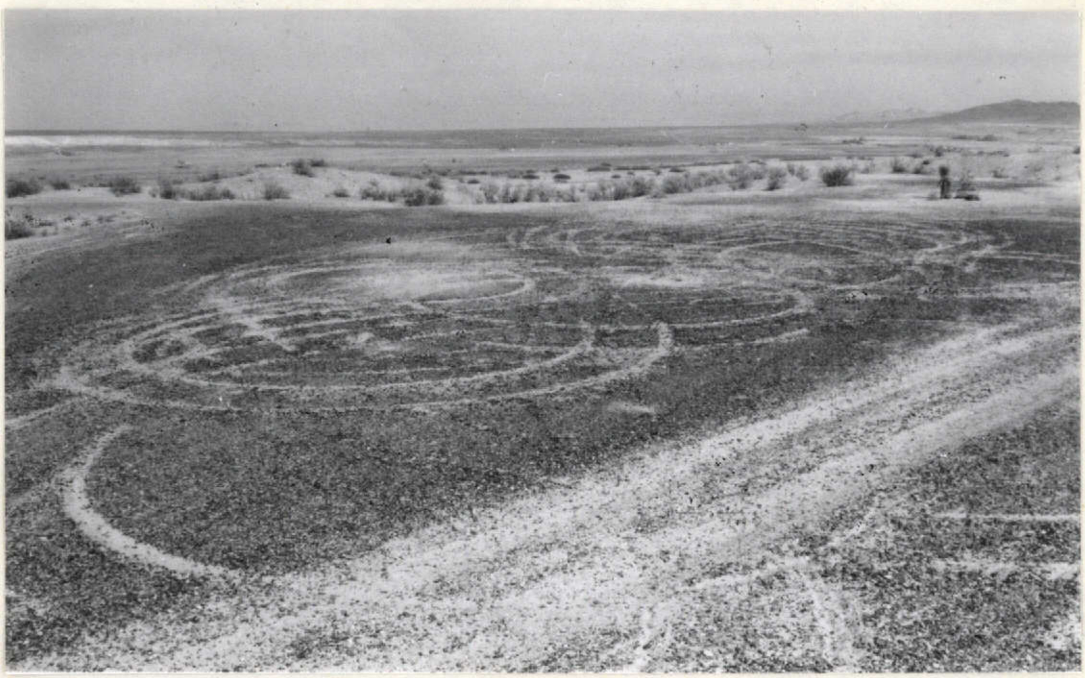

Figure 17. Broken desert pavement surface near Barstow, California. The surface is now susceptible to both wind and water erosion. Dust can also be a minor problem.

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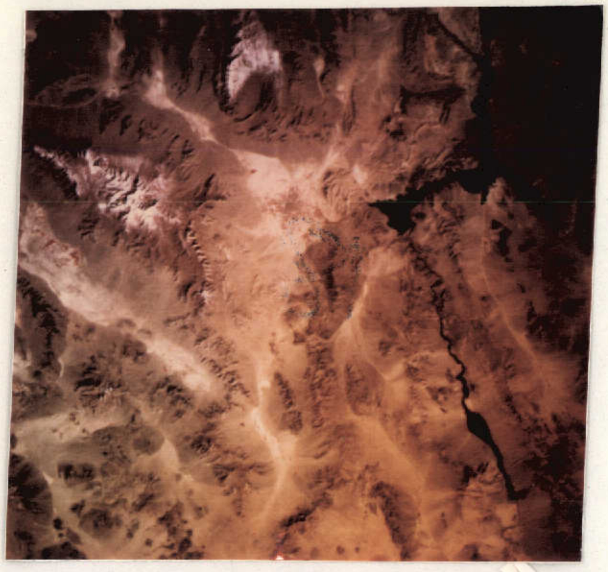


Figure 18. Unenhanced CIR simulation made from an ERTS-1 frame of Las Vegas.

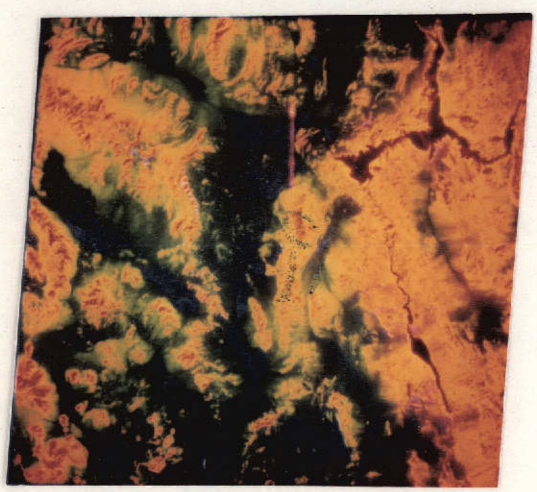


Figure 19. Density slice of the same ERTS-1 frame of Las Vegas. Textural/slope boundaries are much more easily determined.

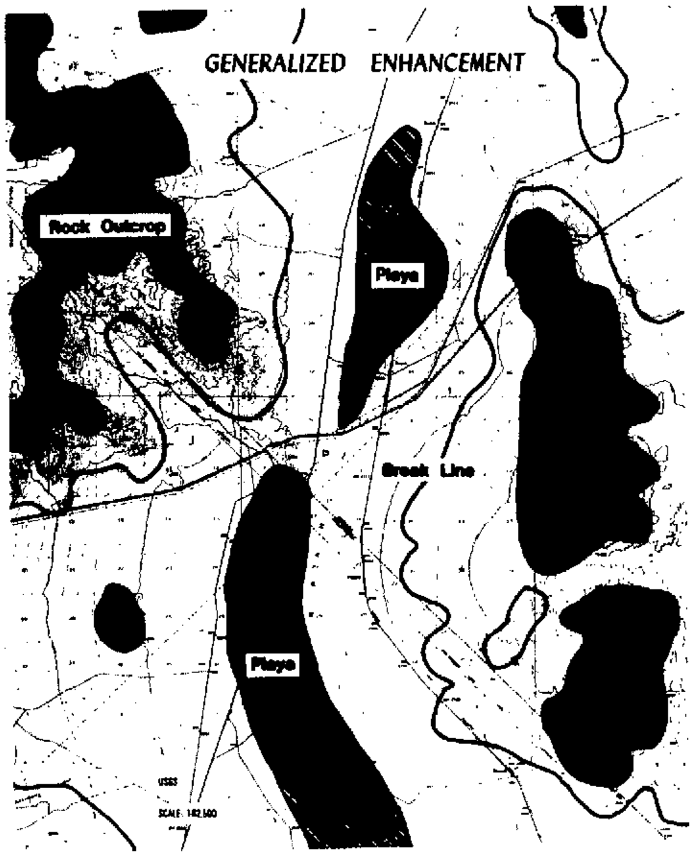


Figure 20. Mapped information placed onto a topographic map.

Figure 21. Photograph near Ivanpah Dry Lake. Break in slope occurs where IR signature changes from the darker red (front) to a lighter red (rear).

ROACH DRY LAKE

Size	Above "Break" Line Percent	Near "Break" Line Percent	Playa Bottom Percent
1/4"	21.40	2.70	0.00
Mesh 10	22.12	14.20	1.62
Mesh 30	10.76	27.48	8.39
Mesh 70	6.88	23.77	28.74
Mesh 230	17.78	22.21	47.50
pan	21.06	9.64	13.75

MESQUITE DRY LAKE

Size	Above "Break" Line Percent	Near "Break" Line Percent	Near Playa Percent
1/4"	21.70	7.72	2.10
Mesh 10	19.47	12.01	3.59
Mesh 30	18.13	12.12	5.53
Mesh 70	19.61	16.34	25.45
Mesh 230	10.55	20.39	41.73
pan	10.54	30.88	21.60

As expected, the coarsest materials are found on the highest part of the fan surface. Still, the most significant result is the fact that these changes in surface texture can be detected from ERTS-1 imagery.

The recreational planning potential of this study for the desert is great. Not only do textures have a direct relation to the adaptability of desert surfaces to withstand ORV operation, but the importance of texture in the distribution of desert vegetation is receiving increasing attention.

2.9 Use of Yucca Brevifolia as a Surrogate for Detection of Near Surface Moisture Retention

For this investigation, ERTS-1 imagery proved useful, albeit not conclusive. ERTS-1 imagery supplemented both low altitude (1:20,000) color infrared imagery and field/laboratory analysis. It also provided a regional photo mosaic of the Mojave Desert from which to work. By examination of false color Diazo transparencies made from such imagery one can detect the signature of Yucca core areas and associated vegetation.

It was our intention to isolate the major controls which govern Yucca distribution. For the purpose of this preliminary investigation, we focused upon core areas of Y. brevifolia which were within two hours driving time of Riverside, California and chose for detailed examination only those sites which appeared to have the most dense and healthy stands of Yucca. Thus, the sites studied probably possess optimal physical conditions for the Yucca's survival. The discussion centers on climatic and edaphic parameters, parameters which are felt to be of primary importance, at least within the area studied.

The primary factor governing Yucca distribution is the availability of moisture during the season of seed germination: summer. (Temperature factors are considered only secondary since the Yucca seed will germinate at warm/hot temperatures, a condition satisfied throughout the desert in summer). Precipitation, although in meager amounts, comes to the Mojave (high) Desert in both winter and summer. The Gulf of Mexico and the Gulf of California are both source regions of maritime tropical air which influences the Mojave Desert in summer. Circulation patterns and the thermal low pressure system developed over the Mojave-Colorado Deserts in summer initiate influx of this maritime tropical air. In contrast to the Colorado (low) Desert, the Mojave (high) Desert receives a greater percentage of its total precipitation during the summer season. The overall greater elevation of the Mojave complements the convective processes triggered over the strongly heated desert area in summer. Areas with the highest elevations will thus likely have more summer precipitation, usually in the form of thundershowers. This is seen in the areas of Joshua Tree National Monument and the environs of Mountain Pass-Cima Dome, for example. Consequently many stations in the Mojave exhibit a degree of bimodality in their precipitation curves, with maxima in late summer and winter.

Not all areas in the Mojave which receive summer precipitation (and would thus appear to have Yucca) do, in fact, possess Yucca. Conversely, several areas which receive a relatively small percentage of their precipitation in summer do have Yucca. In order to understand these situations, a detailed examination of soil conditions is needed, especially with reference to the moisture-retentive capability of the soil.

In the Mojave, it was assumed that the surface and near-surface soil samples were reasonably representative of soil characteristics as deep as Yucca root penetration, at least in terms of the soil parameters examined. This assumption is considered valid since no significant caliche or claypan horizons were detected in any accessible stratigraphic sections.

Within the broad ranges of pH tolerance of the Yucca, which includes the span 6.8 to 8.2, soil pH does not seem to be a critical factor governing Yucca distribution. Similarly, available soil nutrients also seem not to be significant relative to Yucca distribution. Textural analysis of soils, however, proved to be very useful and enable the determination of the edaphic factors regarding Yucca growth.

Yucca supporting soils are bimodal, with maxima in the medium-coarse sand and silty clay fractions, .75Ø and 40800, (Ø is a dimensionless unit used in soil textural analysis). The textural composition is highly moisture-retentive. This is understandable as Yucca-supporting (as opposed to the well-sorted soils) if the upper Mojave Desert is accepted as a climatically tense environment in which _Y. brevifolia_ is able to survive only where there is available sufficient soil moisture. Soil moisture, thus, becomes the limiting factor governing Yucca distribution which, in turn, is controlled by soil texture, given a certain minimum of precipitation.

The significance of optimal soil conditions for moisture retention is additionally confirmed by the fact that _Y. brevifolia_ tends not to occur on pedimented surfaces, the depth to bedrock on which very rarely exceeds one meter. There simply is insufficient groundwater to support Yucca.

Although species identification is not possible from ERTS-1 imagery, since it is now known that _Y. brevifolia_ occurs in the moistest areas in the high desert, which can be predicted from physiography, (i.e. non-pedimented surfaces, alluvial fans, wadis), these secondary physiographic surrogates, easily detectable from ERTS-1 imagery, can be used to ascertain the general distribution of _Y. brevifolia_ and, therefore, the regions in the high desert with the greatest potential for near-surface moisture retention.

2.10 Disjunct Fluvial Transport Patterns in the Colorado River Delta as Interpreted from ERTS-1 Imagery

Cursory examination of ERTS-1 imagery of the Colorado Delta for two dates, September 12 and December 29, 1972 (Figures 22 and 23) reveals differences in sediment transport patterns in the waters of

Figure 22. Colorado delta.

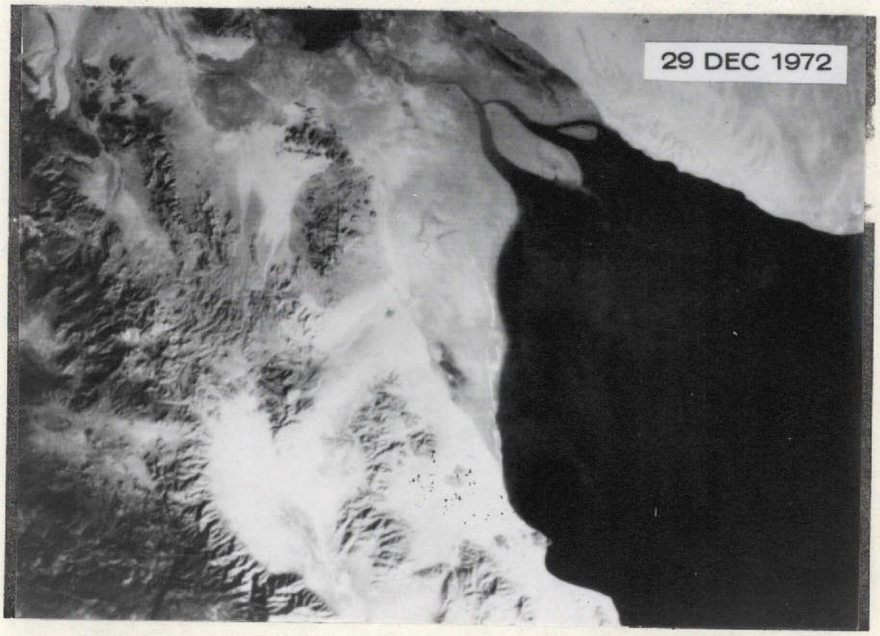


Figure 23. Colorado delta.

the Northern Gulf of the California Delta region. Initial impression of these differences leads one to believe that what is seen is either surface phenomena or the bottom configuration of the Colorado River Delta. The discontinuities might be attributed to any one or a combination of variables. These variables could conceivably be: (1) local storm activity and related precipitation; (2) agricultural activity; (3) tidal flow or stage; (4) currents in the gulf; (5) thermal mixing of the fresh and saline water at the delta.

Such examination of ERTS-1 imagery of the Colorado Delta and Gulf of California coastal region leads to certain possible generalizations about agricultural activity and, in turn, some inference can be made about relative amounts of precipitation for that region. These elements combine to modify fluvial transport patterns in the delta region significantly. Examination of sequential imagery of the delta could be used to substantiate any interpretation of agricultural activity made from ERTS imagery of the Lower Colorado River. At this time more intensive research into the variables affecting the delta sedimentation system is necessary before any extensive application of the imagery is made. Lack of access to tidal information and to data regarding temperatures of the Colorado River and the Gulf of California, and likewise to scant data available on mixing rates in the delta, makes any conclusions or statements unsupportable. Initial impressions realized from the imagery are encouraging, however, and it is felt that further research on this aspect of the Colorado River water system is warranted.

2.11 Land Evaluation Based on ERTS and High Altitude Imagery

The vital environmental economy of "Spaceship Earth" has become today's immediate concern for both layman and earth scientist. To properly manage these natural resources and to compile the necessary resource information in a speedy and comprehensive manner, has become a formidable task. The solution for this problem is now under investigation by various organizations (federal, state and private) each in harmony with two immediate goals: (1) to provide assistance to earth resource managers and (2) to develop and test inventory techniques applicable to devebping areas of the world. To benefit most from a resource inventory one should apply a holistic method: a purely holistic method implies that the environment should be studied in its entirety attuning more to remote sensing techniques in the modern sense, rather than photo interpretation which was designed as a tool used for separate evaluations of land attributes.

The assessment of the world's resources through the use of both satellite (ERTS-1) and high altitude (U-2) imagery leans naturally toward the broad perspective, thus obtaining the holistic impression of the region. Some authorities, however, believe that the retrieval of environmental information can best be accomplished by means of aerial photography (Katz, 1967). The value of combining both satellite and high altitude imagery, however, will probably reveal maximum utility in large environmental surveys. Consider for a moment the land attribute of relief which usually is not great enough to be stereoscopically visible on ERTS-1 photography, but is on the high altitude imagery. This single characteristic of land relief is an essential asset in a holistic survey.

Recognizing that the compilation of all the environmental attributes necessary to properly evaluate the usefulness of satellite and high altitude images in a holistic survey is still being made, certain preliminary observations and conclusions have been compiled and grouped into three sections: (1) the practical application of ERTS-1 in a holistic survey, (2) the evaluation of the (MSS) bands in detection of land units and, (3) the advantages of their compatibility.

Explanation of Holistic Method

The holistic survey of the environment involves an assessment of the total characteristics of the landscape, including relief, vegetation, geology, and soils, remembering to account for the technological, sociological and economic considerations as well (note land classification in Figure 24). The divergence from a separate survey which is aimed at a specific land attribute can be seen in Figure 25.

The classification of individual land units is constructed upon the converging evidence of individual attributes which appear as homogenous areas (Zonneveld, 1971). The observable units can then reveal a comprehensive view of information to scientists who have knowledge of the land.

Application of ERTS for a Holistic Survey

The need for practical evaluations of large areas of land, especially in remote underdeveloped nations, has become extremely important in the assessment of world resources. The acquisition of this information prior to ERTS-1 was usually costly because of its scale, requiring large numbers of photographs and personnel. In a holistic method of evaluation, small scales present few problems and in fact scales smaller than 1 to 100,000 in areas where little knowledge is usually known, require a holistic approach. Both ERTS-1 and high altitude images are above this scale, thereby permitting this method optimum usage. The direct advantages in doing so are: (1) more direct integration of knowledge, (2) saving in logistics, (3) less need for personnel, if team leaders are experienced and, (4) the basic data result in an integrated basis for assessment of the land.

Furthermore, the final product provides a useful data base for specific studies, when certain resources are needed in detail.

Scheme of Pragmatic Land Classification or Resources Evaluation in Integrated Survey of the Natural Environment

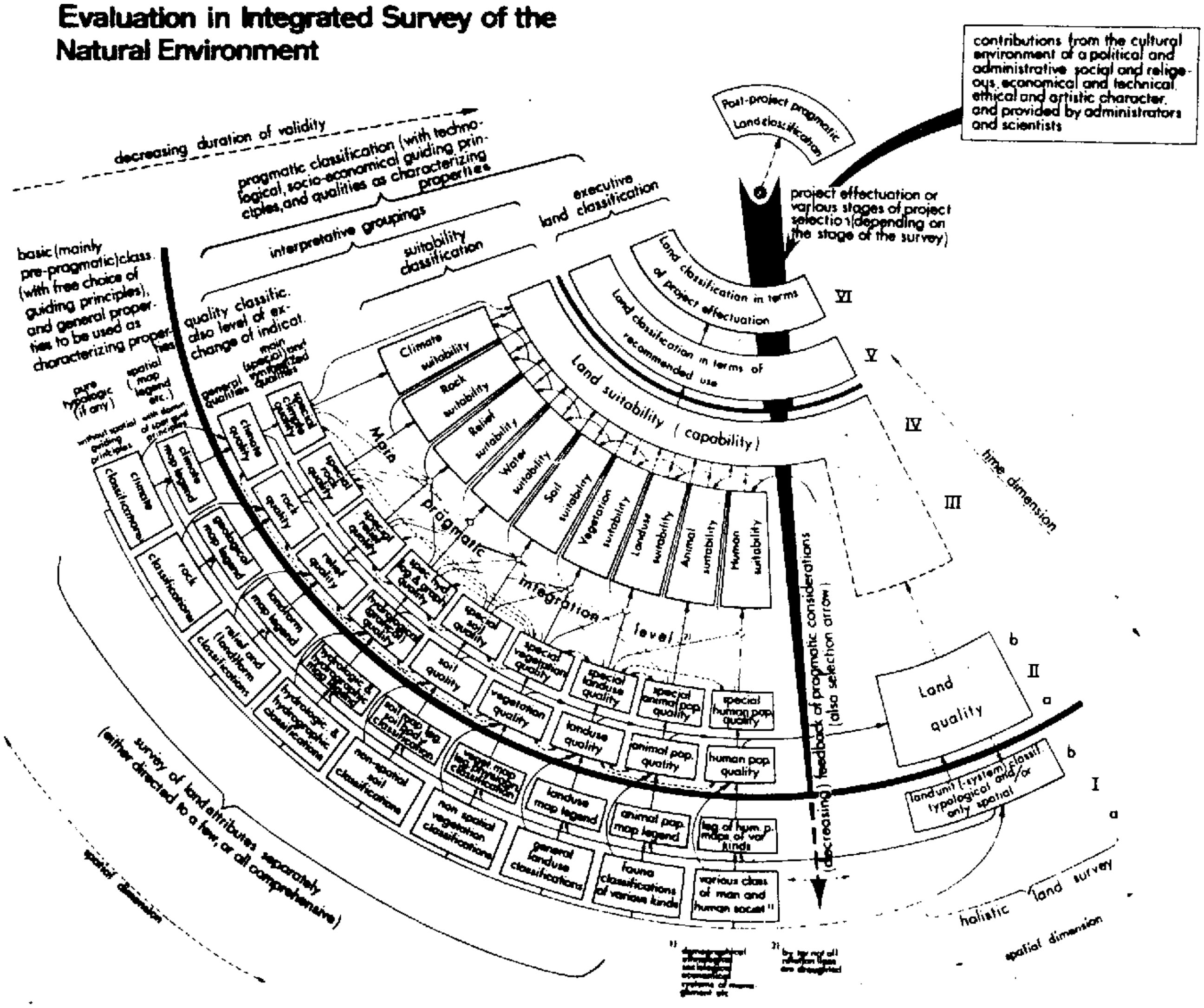


Figure 24. Land classification (source: Zonneveld, 1971).

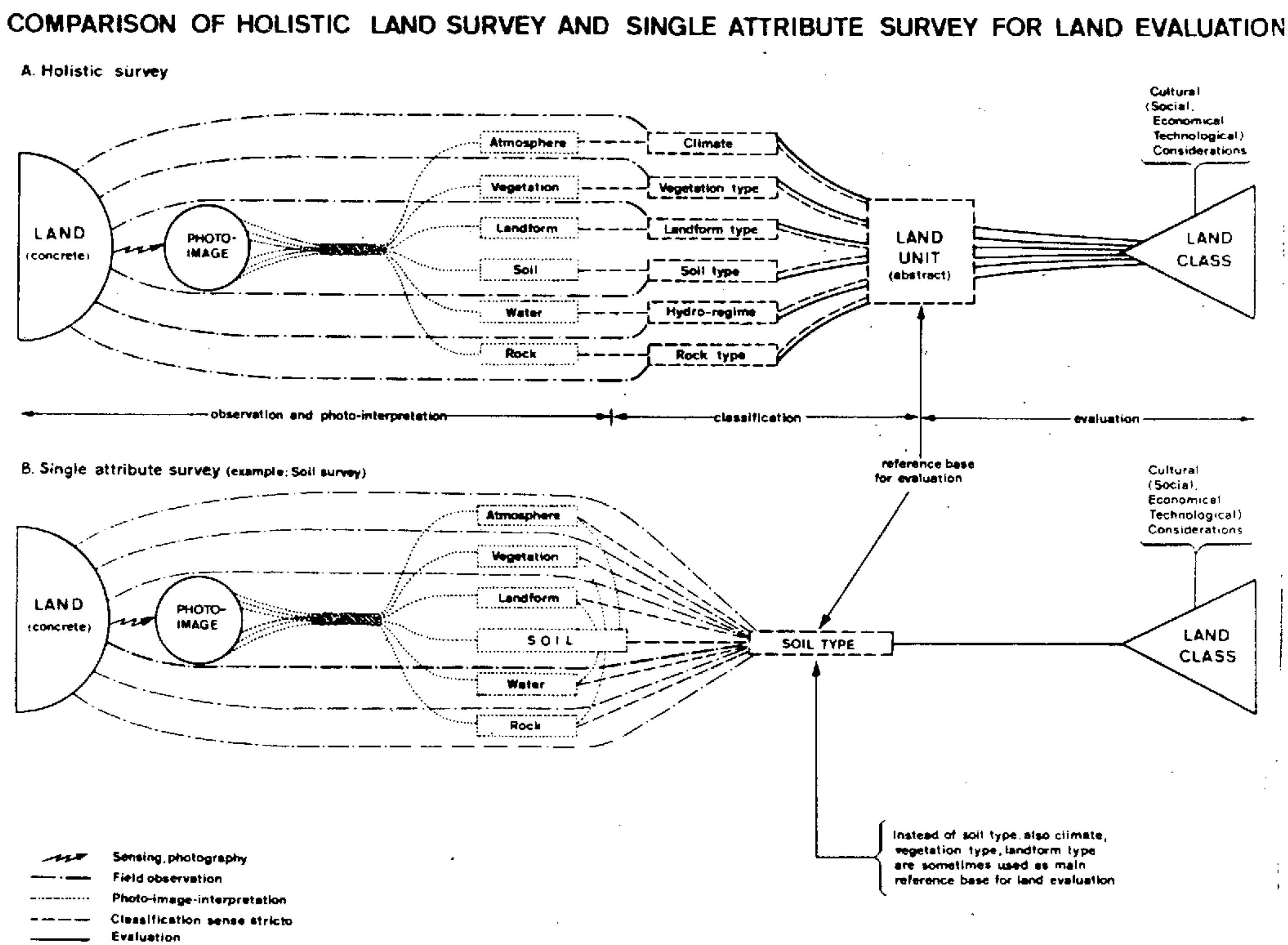


Figure 25. Single attribute survey.

Imagery and Scale

The primary set of imagery analyzed in this preliminary investigation was small scale satellite (ERTS-1) and high altitude (U-2) frames, recorded in September of 1972 and March of 1971, respectively. Analysis of the ERTS-1 imagery frame 1053-17551 generated by the Multispectral Scanner (MSS) Bands (channels 4 to 7) provided the satellite base. The high altitude photography, recorded on color infrared film because of its optimum quality in small scale interpretation, provided the aerial imagery in this interpretation.

As previously stated, survey scales smaller than 1 to 100,000 usually demand a holistic approach. Therefore, both ERTS-1 imagery having a scale of 1:1,000,000 (on 9 x 9 inched frames) and the high altitude imagery approximately 1:100,000 are acceptable in this holistic approach. However, other qualities necessitate their combined efforts in a land evaluation study.

The utility of ERTS-1 is curtailed by its lack of systematic overlapping coverage within the line of flight and consequently by the monoscopic view, thereby not permitting total reliance in a holistic survey. Numerous authors have announced that the mapping of land use categories is feasible, which is true in separate surveys concerned with one attribute. To map the total environment as a entity, however, requires an appreciation of all attributes of the landscape. Therefore to comprehensively investigate a region in a holistic method requires the sum of satellite and high altitude imagery.

Study Area

The landscape under this preliminary study is located in Perris Valley, California. This study area constitutes a surrogate for a larger regional investigation in Southern California. However, the geographic significance of this area is important due to the fact that the newly constructed Perris Dam represents the end of the California Water Project in Southern California. The area (Figure 26) geographically commences at the summit of the Box Springs grade near the intersection of Highways 395 and 60, and from there trends in a southerly direction. The end of the valley is located near Menifee Valley, approximately 25 miles distant. The western boundary parallels and is near to Highway 395, while the eastern limit is artifically delineated and extends from a point near the city of Hemet to Black Mountain.

The general topography of the area is one of denudational hills surrounding a lower peneplain which contains an occasional noticeable granitic remnant. The agriculture of this area can be divided into three categories: (1) irrigated crops, (2) non-irrigated crops and, (3) dry farmed crops. Predominantly the area is known for its

Figure 26. Preliminary study site. A portion of a U-2 frame of the Perris Valley (north at top).

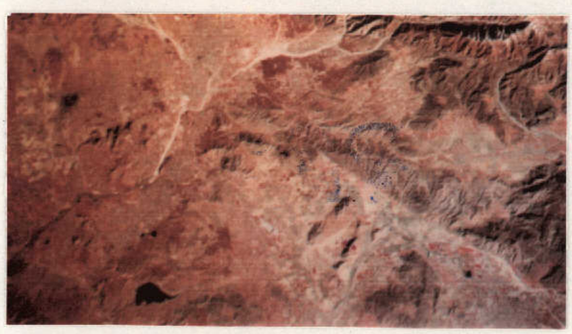


Figure 27. A portion of an enlarged ERTS-1 frame of the same area (north at top).

production of potatoes, sugar beets, onions, carrots, alfalfa, navel oranges and wheat or barley.

Interpretation

The preliminary interpretations of ERTS-1 and high altitude imagery concentrated upon the task of delineating holistic land units. The original scale of the ERTS photography was 1:1,000,000. Early observations made at this scale were achieved by using an Agafa 8X magnification loupe over a light table. Each individual MSS band was scanned in this process as well as the simulated CIR combined image. These observations allowed familiarization with the spectral characteristics which were later enhanced in an effort to delineate homogeneous land units.

The initial analysis of the 9 x 9 inches CIR high altitude imagery (Mission 164, 3/71) having a scale of 1:120,000 was accomplished on a Bausch and Lomb stereoscope which has the capability of scanning in both x and y directions. The only warranted discontent in using this device was in its limited free space beneath the lens, which caused difficulty in production of the overlays when viewing the image.

The technique of photographically enlarging a section of the ERTS image to recognize and delineate areas having homogeneous color tone was employed. The area photographed was taken from the I^2S color combiner and was enlarged to a scale of 1:125,000 (Figure 27). The emphasis upon this foremat in crop identification and other detailed investigations is still under quantitative testing but preliminary results published by various authors indicate future success (Estes, 1972).

During the preliminary investigation the four bands (channels 4 to 7) were examined manually so as to determine the attributes indicative of land use. These individual categories of urban, agriculture, rangeland, water bodies and barren land were delineated in order to evaluate the optimum band or bands for interpretation.

The urban areas of the investigation were mainly small service centers, except for the City of Riverside. The small cities of Perris and Sunnymead were difficult to interpret because the street patterns could not be observed (visible breaks or sudden bends in the transportation lines proved to be useful criteria). The larger City of Riverside is easily detectable due to the street complex and coarse texture.

Agricultural areas provide detectable signatures because of their distinct geometric shapes and spectral signatures, especially in the color combined image.

Rangeland vegetation, interpreted on band 5, was possible to differentiate, although the identification of particular communities was sometimes difficult. Chaparral had a grey to grey-black tone signature as opposed to the usually lighter grey grassland communities.

Water bodies of large proportion could always be detected owing to their low reflectance in the red band (0.6 to 0.7 microns). However, the smaller reservoirs near the agricultural fields, owing to their similar geometric shapes and tonal characteristics, were difficult to identify.

Barren land, having a light grey signature, can usually be easily distinguished. The features which cause possible confusion are large construction areas (e.g., Perris Dam) and fallow land, if not distinguishable by their geometric shape.

The preliminary observations of the MSS bands presented some problems in that the spatial resolution and tonal ranges were poor. The same areas, however, when viewed on the simulated CIR combined composite, permitted substantial information in delineating vegetation communities, a quality especially useful in a holistic evaluation.

In short, the preliminary results of the interpretation show that bands 4 and 7 allowed the greatest differentiation in urban areas. Transportation routes and agricultural areas were best observed using band 7. Convergence of evidence, necessary in the delineation of homogeneous land units, was best accomplished from the simulated CIR combined image. This fact results primarily from the sharper vegetation boundaries visible on that image.

It should be noted that in this preliminary interpetation only a single land attribute (land use) was delineated using ERTS-1 and high altitude imagery. To properly benefit from a holistic land survey all the land attributes should be known. This then would permit the convergence of evidence necessary in delineation of land units.

Conclusion

Evidence available at this time demonstrates that both ERTS-1 and high altitude imagery can be useful in a holistic approach, especially over large areas where little prior knowledge is known. To recapitulate, the advantages of a holistic survey are as follows: (1) adapted to small scale imagery; (2) provides a better integration of knowledge; (3) lowers total survey costs; (4) requires fewer experienced personnel; and (5) facilitates presenting the results in an evaluation format.

Preliminary conclusions of this study obviously point out the useful application of a holistic land evaluation. Based upon both ERTS-1 and high altitude photography, a holistic resource evaluation, whether on a regional, national or global basis, can be an asset to a resource manager in any country.

References

Estes, John E., 1972, Use of ERTS-1 Data to Assess and Monitor Change in the West Side of the San Joaquin Valley and Central Coastal Zone, NASA Technical Report No. NAS-5-21827.

Katz, A. H., 1967, Reflections on Satellites for Earth Resource Surveys, Rand Corporation P-3753, 28 p.

Zonneveld, I. S., 1971, Land Evaluation and Land(scape) Science, International Institute for Aerial Survey and Earth Sciences Press, Enschede, The Netherlands.

2.12 Impact of Linear Features

It has been accepted among geographers that linear human constructions (roads, railroad, aqueducts) have had more than local environmental impact. The question is especially timely because of the present debate over the Trans-Alaska pipeline.

ERTS and high altitude U-2 images have proven valuable as monitoring devices for the study of such impact. Moreover, such images reveal patterns of change which are not readily visible from the ground. The arid areas of the western United States provide an excellent environment within which to demonstrate the capacities of this imagery for such purposes. First, vegetation in this environment tends to be constant; therefore lithic and soil changes are readily discernible there. Second, the imagery allows for the interpretation of groundwater flow. The properties of this simulated CIR imagery are especially useful for the detection of vegetation; where groundwater is trapped and pushed nearer the surface, fluorescence of vegetation results and can be detected on the imagery. Moreover, the variability of arid basin-and-range landscapes like the Mojave Desert provides many different environments in which the effects of these linear features can be observed. Mountain passes and playa surfaces, for example, are two of the many environments common to the Mojave which show the marked impacts of road construction. Several examples of the impacts of linear features are available. Figure 28 shows, for example, the influence of road construction upon the surface of Ivanpah Dry Lake. The road at the south of the lake is of special interest because it has become the southern boundary of that playa.

Figures 29A and B are ground photographs taken on either side of a road near the margin of Lucerne Dry Lake. The effect of this road on vegetation is clear; such effects are visible on ERTS imagery.

Other influences on vegetation, soil, and other physical features are also visible on ERTS imagery. Many influences can be located and their progression studied through ERTS and U-2 sequential photographs,

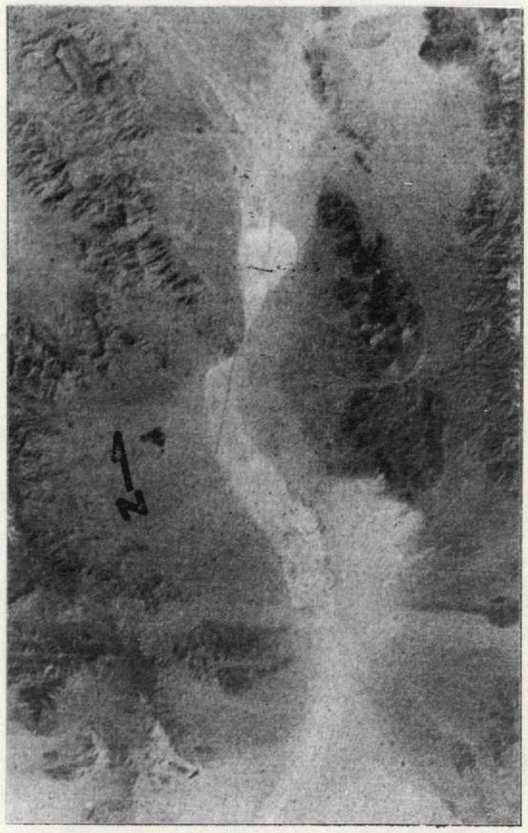


Figure 28. Enlargement of a portion of an ERTS frame of Las Vegas. Shown are Roach (top) and Ivanpah dry lakes. Note influence of highway construction.

Figure 29A

Figure 29B

given the regularity with which these kinds of imagery become available. Lower altitude imagery with greater resolution would be appropriate for more detailed study of the resultant environmental impact.

Because ERTS band number 4 has proven best for the location of linear features it has special application for the study of the environmental impact caused by roads, aqueducts, and other similar features. Band number 7, however, reflects vegetation patterns most clearly and is, therefore, also especially valuable for these purposes. Vegetation patterns are the ones most often altered by the linear constructions.

Finally, it should be noted that the broad vegetation boundaries which are often clearly discernible on ERTS imagery are not always easily observed on the surface or at low altitude. Thus, for example, the boundary effects of linear human construction are frequently more easily seen on small scale ERTS imagery than they are on the ground.

2.13 Archaeological Findings in Hidden Valley, Nevada

While observing U-2 imagery of Las Vegas, Nevada (CIR, RF 1:131,000) to gain another view of the environmental impact of linear human construction in that area, the researcher observed several odd lines around the margin of Hidden Valley, south of Las Vegas. ERTS imagery was inspected carefully for evidence of these lines but scan line and resolution problems made them impossible to see at that smaller scale.

The lines have several interesting characteristics and present indications are that they represent a major archaeological find. First, the lines, overall, extend for more than four miles, mainly on the west side of Hidden Valley, but they can also be faintly seen in the southeast. There are at least 18 lines in the best preserved series. In addition, they are evenly spaced, curving, and parallel as if they were created by design. They do not, however, follow lines of equal elevation as recessional shorelines of the lake which once filled Hidden Valley would have to do. Moreover, they can be seen to have deflected drainage in several areas. There is no natural mechanism by which these lines could have been created.

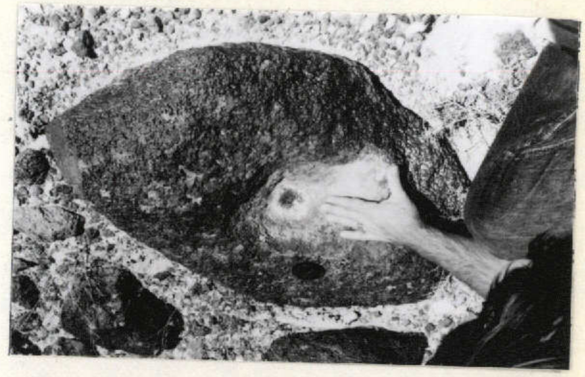
Further observation indicates that these lines end abruptly at the edges of several alluvial fans and then resume on the other side. There are only three possible ways in which this situation could have developed. The first possibility is that they never existed on these several fans, but did exist on either side thereof. This is extremely unlikely however. Ground observation has shown that these fans have not been disturbed in an extremely long time; they are covered with a deeply patinated desert pavement, indicating that they have not been disturbed for a considerable length of time. Thus, the second possibility, viz. that these lines underlie and are older than the fans, seems most likely. It is a generally held opinion among geomorphologists that fans of this type have not been growing in the southwest since the end of the Pleistocene Epoch, some ten to thirteen thousand years ago. Rather, since that time, fans in the area have been subjected to erosion. Thus, there is a considerable chance that these lines are at least ten thousand years old.

Ground observations strengthen this possibility. A stone circle which apparently was a fire ring has been found, as have several madatis. These features are patinated in such a way as to suggest great age. The lines themselves are extremely obscure, and disconnected (Figure 30). Yet they can be seen as stone lines, perhaps ten feet wide and one or two feet high at the present time. Because these stone lines are a preferred environment for certain types of vegetation, they often correspond with linear plant formations (Figure 31). They are clearly human constructions and are quite old. The lines, in fact, are much more obvious on the imagery than they are on the surface. One might make an analogy with a pointillistic painting. One must get a removed perspective before the lines become apparent. Initial observations indicate that these stone lines were part of a water conservation system the size of which is unequalled at any archaeological site in North America.

Much more work needs to be done in Hidden Valley to determine the origin and purpose of these stone lines. Nevertheless a purely speculative explanation of their origin is offered here. It may be that these lines date from the last filling of the lake which once occupied Hidden Valley; presumably the last time the lake was filled to overflowing was at the end of the Pleistocene. A relatively dense population could have developed which was economically dependent upon that lake. When the lake began to dry, however, a new food source presumably had to be found. Because wild grasses with edible seeds are presently found in the valley, these may have become the new source of food for this population. Even today, the floor of Hidden Valley supports a lush growth of flowers each spring; the valley contains fertile soil, weathered from the basalts which comprise the regolith of the area. One must assume that in times past, when the soils were not as saline, that Hidden Valley provided a rich environment for the growth of wild grasses. Moreover, the lack of salinity in the valley floor made its center a natural catchment basin where plant growth was probably lush, at least initially, after the drying of the lake.

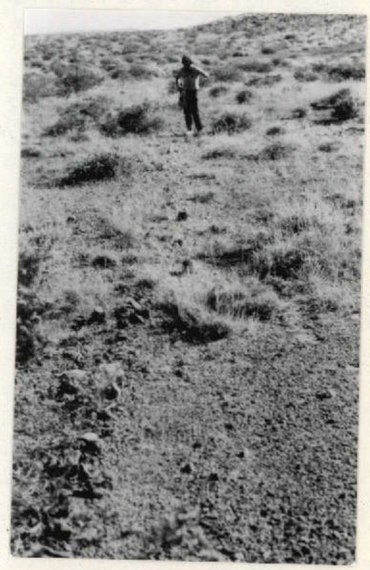
Nevertheless subsequent partial fillings and evaporation would have increased salinity on the floor to a point where grasses would no longer grow there. It is at this point that the stone lines in question may have been constructed. Their function, if this theory is correct, would have been to retard sheetwash and other runoff so as to encourage the growth of grasses with edible seeds on the less saline slopes. Hopefully the origins of these lines will be more certainly established by further field work by the author in Hidden Valley.

A



B

C



D

A -- Fire Ring
B -- Matadi
C -- Stone Line
D -- Stone Line

Figure 30. Archaeological findings in Hidden Valley, Nevada.

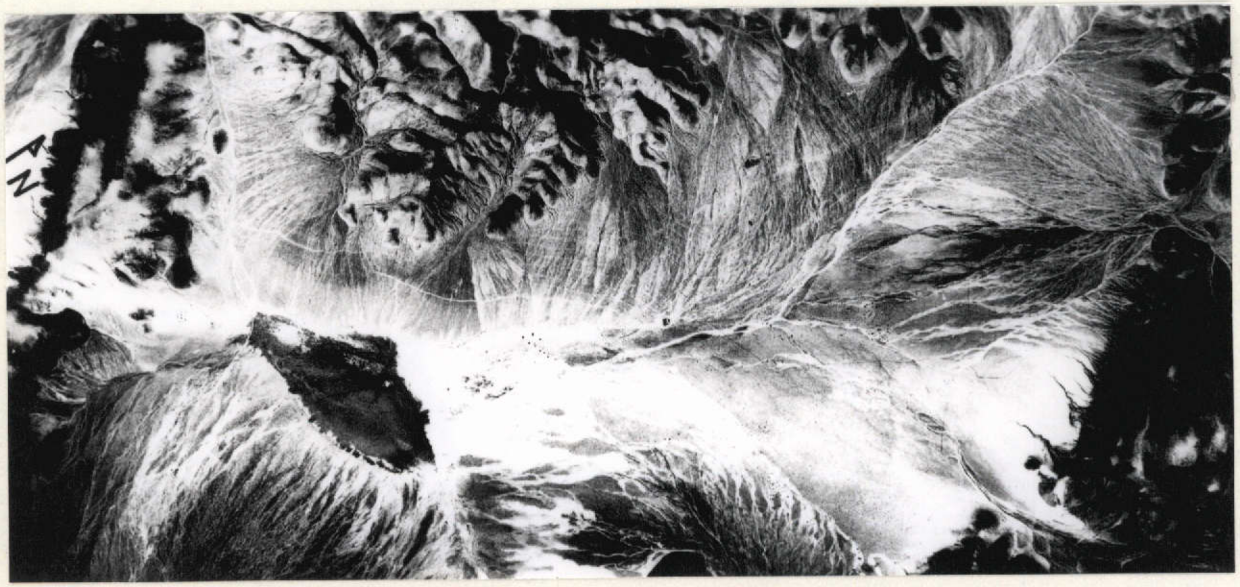


Figure 31. Enlargement of a portion of a U-2 frame of Hidden Valley, Nevada (21 November 1972). The stone lines appear as white curves.

3 NEW TECHNOLOGIES

3.1 A Recipe for "Do-It-Yourself" Color Composites of ERTS-1 Imagery: The Poor Person's Guide to Everlasting Color

Due to the shortage of color composite prints and the denseness of 70 mm bulk negatives available from early ERTS-1 imagery, the investigators at the University of California (Davis, Berkeley, and Riverside) sought alternate methods of producing "true" and "false" color images suitable for preliminary research and investigation. Several expensive "darkroom" techniques were attempted but a parallel system was developed that is cheap, practical and universally applicable. The simple, but practical, idea is presented here because any present or potential user can do it!

All you do is follow a few easy steps:

1. Use Diazochrome color proofing film. Diazochrome is purchased from most audio-visual stores as a product of Tecnifax (a subsidiary of Scott Graphics) and is supplied in fifteen colors of Pastel (P) and Dense (K).

2. Acquire 9 x 9 inch black-and-white positive transparencies in bands, 4, 5, 6, and 7 from the Sioux Falls or NASA-Goddard data processing facilities.

3. We prefer the dense (K) for the following combinations:

a. Band 7, use Cyan (KCY)
b. Band 5, use Magenta (KMG)
c. Band 4, use Yellow (KYL)
d. For edge enhancement, buy Black (KBK) and use with Band 7.

The cost is only about twenty-five cents per sheet.

4. Expose each band to the corresponding color (a subtractive process) with an ultraviolet light, i.e. a #4 photo-flood lamp, overhead projector, or use an Ozalid, Bruning or Diazo machine. Exposure times of one to three minutes are required. The longer the exposure, the less dense the image. (At Riverside, we are using a Sears Photo Lamp, over a glass plate, cooled by an office fan.)

5. Acquire a one gallon "pickle jar" to develop the Diazo image in a closed bottle. The process requires ammonia vapors and we are using a 1/2 inch "sponge" covered with a plastic sheet at the bottom of the jar with 1/3 inch of #26 blue print ammonia. (Film may also be developed in a Diazo machine.)

6. For variety you may want to experiment with various colors and change the number of layers. As a final product, sandwich the desired

layers together with double-stick tape. Use a magnifier to align and recheck the registration marks. The cost per color composite printed is usually less than $1.00.

Figure 32 shows a color composite of ERTS-1 on September 4, 1972, made by using blue in band 7 and red in band 5 for a simulated false-color image of the San Diego area of Southern California. Figure 33 shows a simulated CIR image of the same region produced on the I^2S Mini-Addcol Viewer.

3.2 Density Slicing to Enhance ERTS-1 Imagery

The technique of density slicing using a photographic film, and its application for pre-enhancing ERTS-1 imagery in preliminary testing, appears to be an effective one for mapping variegated areal phenomena. Furthermore, it provides a useful supplement to the I^2S Mini-Addcol viewing system. The test presently to be described involved enhancement of selected ERTS-1 imagery (November 1972), showing the Las Vegas, Nevada region, eastern Mojave Desert, and the Los Angeles Basin. Early difficulties in obtaining high resolution enhancements from ERTS-1 MSS imagery by use of Diazochrome composites, and initial interpretation from the 70 mm MSS chips in the viewer (Figure 34), led to experimentation with an equidensity film, Agfacontour Professional, to pre-enhance the selected ERTS-1 MSS bands.

Equidensity Film

Briefly, Agfacontour equidensity film is a black-and-white copy film, which at a specific combination of exposure and development becomes transparent, creating a band or line of isodensity (Ranz, 1970) (Figure 35). The underexposed and overexposed areas of the film adjacent to the transparent sector essentially remain black or opaque. The transparent portions of the image relate to a specific band of density on the negative and an areal representation of that density manifests itself on the positive equidensity film. The emulsion is blue sensitive, and the width of this band (i.e., the thickness of the density slice) can be varied by increasing or decreasing the amount of yellow-filtration used during the exposure process. Only first generation equidensities of the ERTS-1 imagery were used in this study. Subsequent experiments with this enhancement technique should include second generation density slicing.

The above implies a procedure whereby the first generation density slice is contacted onto a litho film and a subsequent density slice is taken from that negative. Perhaps third generation density slices might be required to further enhance the image. Initial results indicate that this technique of density slicing, using accesible darkroom facilities and procedures, allows rapid, accurate, and facile interpretation of certain areal phenomena. As seen in Figure 36, the distribution of the Joshua Tree or Tree Yucca, Yucca brevifolia (Jaeger variation; Jaeger 1968) in the Eastern Mojave Desert of Southern California and Southern

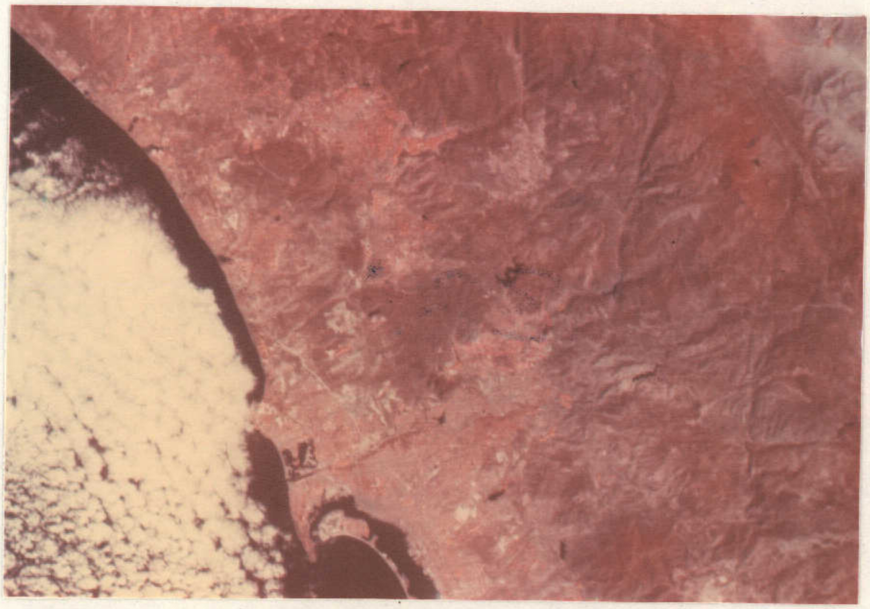


Figure 32. Simulated color infrared ERTS-1 image of the San Diego area; produced by the diazochrome technique.

Figure 33. Simulated color infrared ERTS-1 image using the I^2S Mini-Addcol Viewer.

Figure 34. Unenhanced ERTS frame of Las Vegas.

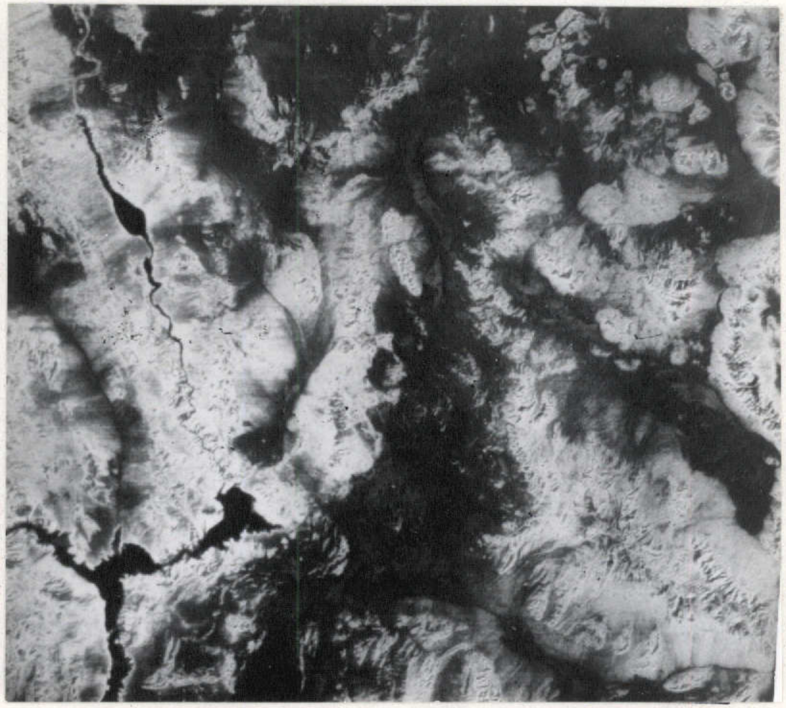


Figure 35. Density slice of the same Las Vegas frame.

Figure 36. Yucca brevifolia (Jaeger variation).

Nevada was used as an example to test the technique in terms of accurately mapping a minor element of the desert's environment. Because of difficulties experienced in obtaining the contour film no extensive experiments have as yet been conducted in the Los Angeles Basin Region.

Mapping of Yucca Brevifolia Jaegeriana

The negatives of MSS bands 5 (0.6-0.7 micrometers) and 7 (0.8-1.1 micrometers) of the Las Vegas Region were used to produce various density slices on the equidensity film. The first step in this process was to determine the negative density for a predetermined concentration of Y. brevifolia Jaegeriana (Joshua Tree). Teutonia Peak or Cima Dome, a well-known geomorphic feature in the Eastern Mojave, which is covered by a dense stand of Tree Yucca was used (Huning and Petersen, 1973). Once its image density had been determined using a densitometer with a suitably small sensing spot, the equidensity film was exposed to isolate this preselected area. A series of different density slices were also extracted from the same ERTS negatives bracketing the above key density. The resultant density slices were then viewed in the combiner using various filter combinations. The results are an enhanced and mappable signature for an environment in which the Tree Yucca is dominant (Figure 37). The enhanced density slice specifically depicting this environment was viewed through a green filter. The other three density slices used for the combination were projected through red and blue filters. It is felt that the green signature was most easily accommodated by human eyes for proper interpretive purposes. The areal expression of this environment was then mapped from the combined enhanced imagery (Figure 38).

Field Check of Yucca Environment

Over a three-day period the mapped distribution of Y. brevifolia Jaegeriana was field checked by the author. This field check of the mapped data revealed a high correlation with the environment's distribution. The field check also involved keying the vegetative community associated with it. This was done to determine more accurately the basis for the recorded signature. With the exception of two sites, the mapped signature from the enhanced imagery was a location containing Yucca. The exceptions were in areas where extremely high concentrations of another Yucca, Mojave Yucca or Yucca shidigera, were found in combination with a dense stand of Creosote Bush, Larrea divaricata. The morphology of mature Mojave Yucca (which is quite similar to the Y. brevifolia in its juvenile form) when found in a vegetative community having a high density of the Creosote Bush records as a similar signature on the imagery.

The mapped locations were all indicative of Yucca and its related community (Figure 39) but an inaccuracy was noted for the boundaries of each location. In all instances interpreter error on the boundary may result from the interaction of several related elements. Foremost of these is a change in topography from a low local relief fan surface

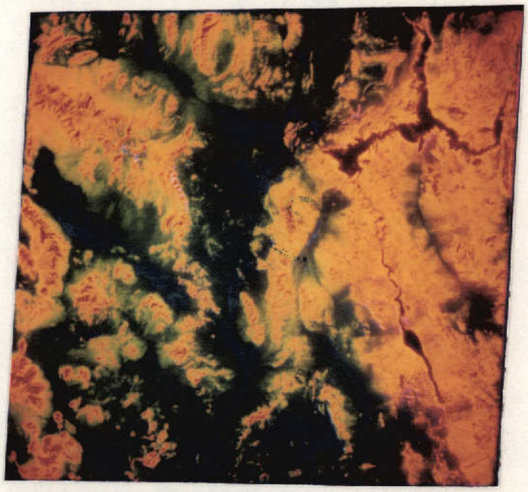
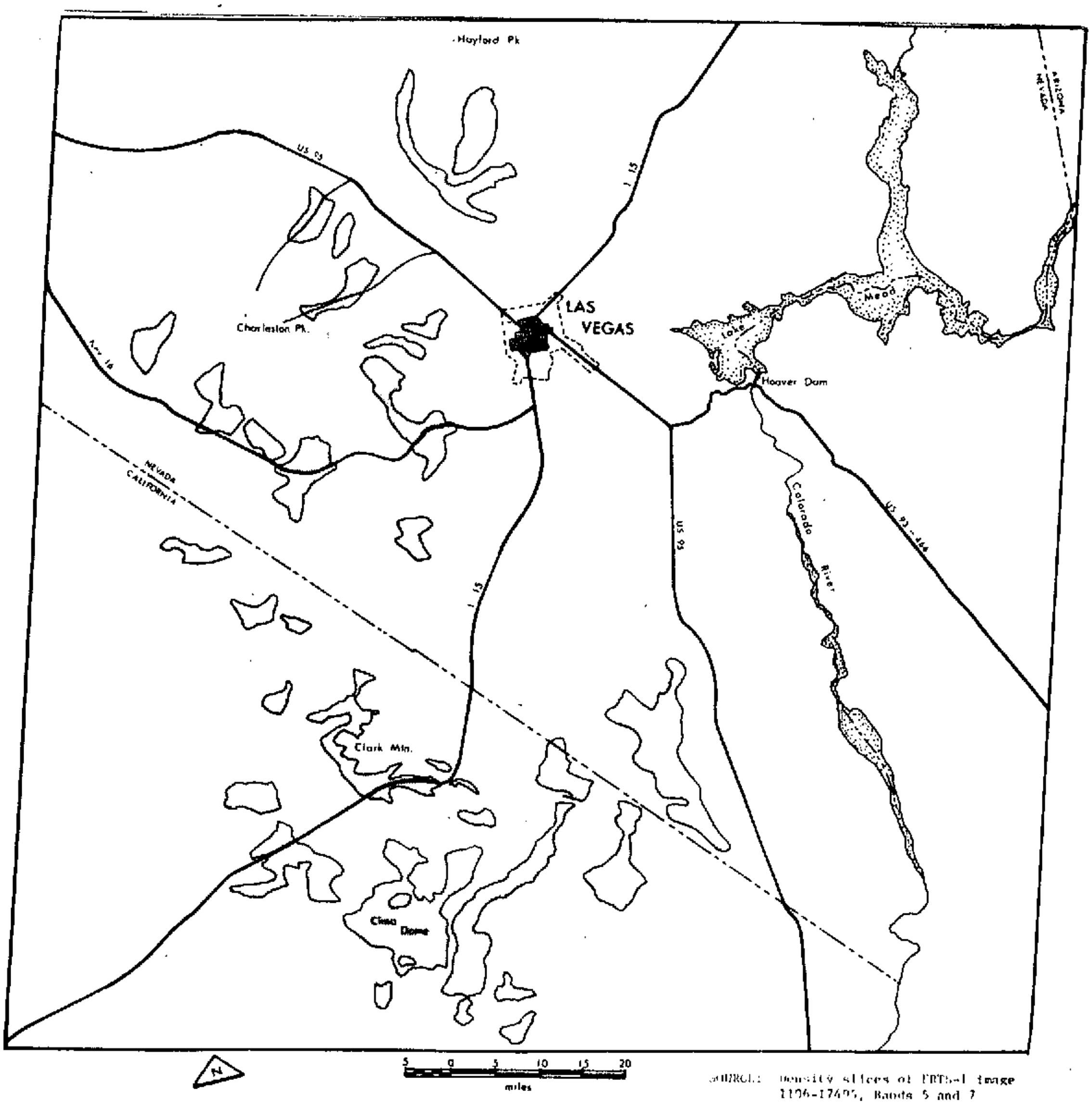


Figure 37. Density slice of the Las Vegas frame from which the Tree Yucca environment was mapped.



SOURCE: Density slices of ERTS-1 image 1106-17495, Bands 5 and 7

Figure 38. Distribution of Yucca brevifolia jaegeriana.

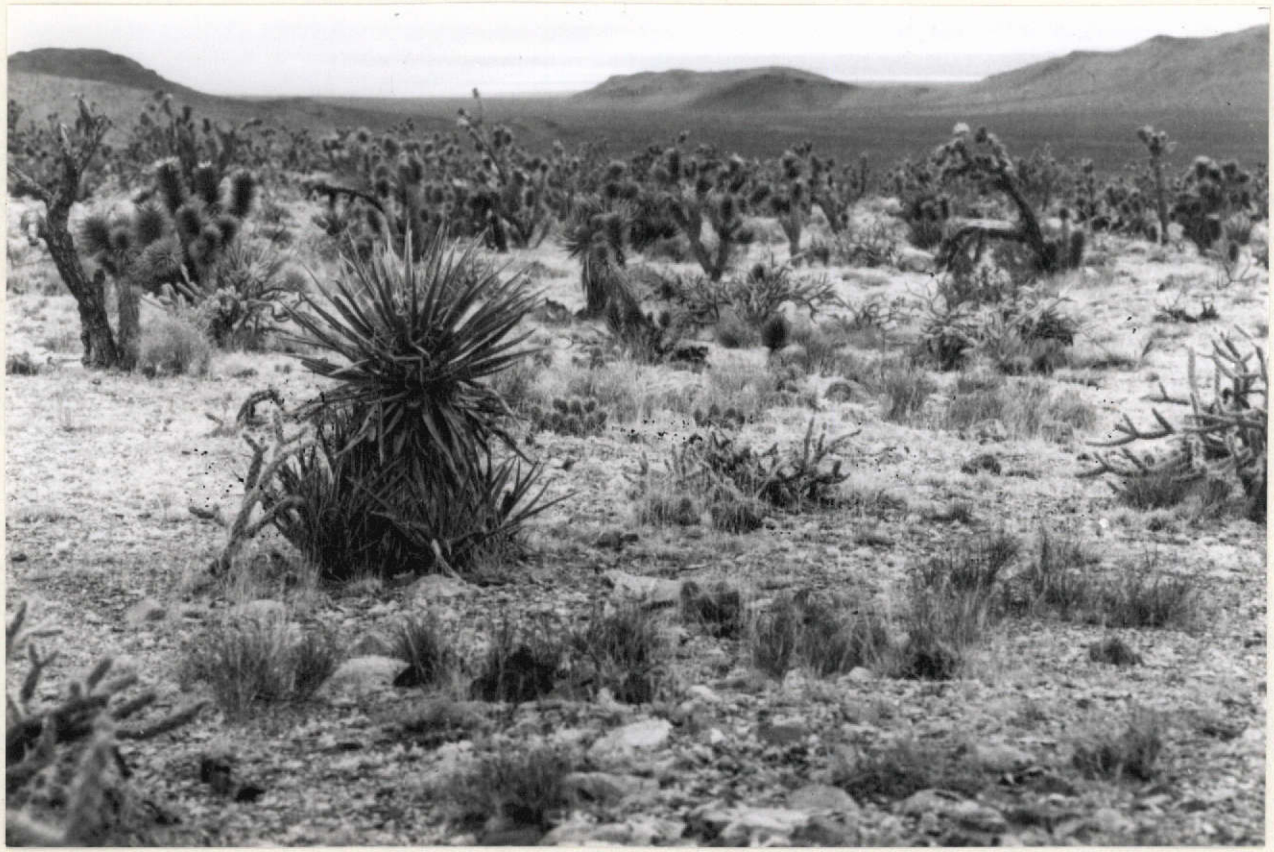


Figure 39. Type of environment mapped in the Eastern Mojave Desert.

to one of more rugged topography and high local relief. The key area, for example, Cima Dome, where the initial sample density was determined, is a feature of low surface relief on the Mojave landscape. The density of the community as isolated on Cima Dome would apply only to other low relief features where the environment is present (e.g., upper portions of alluvial fans, old pediment surfaces, and some high elevation alluvial-filled valleys). These types of surfaces where the Tree Yucca community is present would provide similar physical characteristics of albedo, texture, slope, and exposure to the sensor. Thus, they would present a similar density on the density slice. Another group of factors influencing the determination of the boundary of the community is the transition between environments of different plant communities.

Examination of Figure 40 reveals that the signature mapped there belongs to a vegetative community dominated by Joshua Tree, Y. brevifolia; Blackbush, Coleogyne ramosissima; and Burrograss, Scleropogon brevifolius. A group of minor species also are nearly always found in association with the above dominants. These are Mormon Tea, Ephedra spp.; and Cheesebush, Hymenoclea salsola. Also, in certain sites, at lower elevations of ±1,000 meters, Mojave Yucca, Y. shidigera, becomes codominant. Further tests need to be made to determine the degree to which plant associates other than the Tree Yucca contribute to the imagery signature.

Los Angeles Basin Slices

The Los Angeles Basin density slices were exposed to no specific density. They are the result of early experiments with the equidensity film to determine proper exposures. Filter packs were then combined to determine the value of the equidensity film to enhance urban phenomena.

Though no attempt was made to isolate specific densities, enhancement of certain features on the imagery results. The normal ERTS image of the Los Angeles Basin is highly interpretable and many elements of the urban environment may be discerned. Examination of comparable density slices reveals that certain features not visible on the normal false color image are readily apparent and more easily delineated. The density slice technique greatly enhances topography. The San Gabriels, Santa Monicas, Santa Susannas, Topatopas and the Simi Hills and Verdugo Hills are especially apparent. Other elements of alpine environments also become enhanced. Note, for example, the white enclosed ring pattern. This pattern is believed to closely delimit the extent of conifer vegetation in the San Gabriels, especially in the vicinity of Mt. Wilson. Re-examination of an enlarged portion of the ERTS combination of the Los Angeles Basin (Figure 41) reveals excellent information about the detail of the street and freeway network of the city. The density slice of the same scale (Figure 42) shows an obliteration of certain details of the above pattern. Harbor and coastal features, however, are greatly enhanced. The turbidity pattern of coastal waters is enhanced on the density slice. This pattern is scarcely visible on the original imagery.

Evaluation of the density slices for the Los Angeles Basin reveals

Site	Elevation	Dominant Species								Minor Species								
		Joshua Tree *Yucca brevifolia Jaegeriana*	Mojave Yucca *Yucca shidigera*	Fleshy-fruited Yucca *Yucca baccata*	Creosote bush *Larrea divaricata*	Blackbush *Coleogyne ramosissima*	Western Juniper *Juniperus occidentalus*	Piñon Pine *Pinus monophylla*	Grasses including Burrograss *Scleropogon brevifolius*	Joshua Tree *Yucca brevifolia Jaegeriana*	Mojave Yucca *Yucca shidigera*	Fleshy-fruited Yucca *Yucca baccata*	Creosote bush *Larrea divaricata*	Blackbush *Coleogyne ramosissima*	Cactii *Opuntia* spp. *Echinocereus* spp.	Mormon Tea *Ephedra funera* *Ephedra nevadensis*	Cheesebush *Hymenoclea salsola*	Unknown species (shrubs)
Ivanpah Mountains - 1	3340'	x	x		x				x			x			x	x	x	
Ivanpah Mountains - 2	3930'	x	x						x			x	x		x	x		
Ivanpah Mountains - 3	4640'	x									x	x	x		x	x	x	
Teutonia Peak - Cima Dome	5200-4100'	x						x	x		x	x	x		x	x		
Piute Valley - 1	<3000'		x		x				x					x				
Piute Valley - 2	3000-4500'	x				x			x		x				x	x	x	
Lanfair Valley	4200'	x							x		x		x	x	x	x	x	
Halloran Summit - 1	4000'	x		x		x			x		x		x		x	x	x	x
Halloran Summit - 2	3700'	x	x		x	x			x			x			x	x	x	
New York Mountains	3200-4200'	x		x	x						x				x	x		x
Nipton	3200'	x	x		x				x			x			x	x	x	
Ivanpah - 1	<3000'		x		x				x	x				x	x			
Ivanpah - 2	>3000'	x			x				x		x	x			x	x	x	
Clark Mountains - 1	>4000'	x							x		x			x	x	x	x	x
Clark Mountains - 2	4500-3200'	x	x	x	x		x	x	x					x	x	x	x	
Cottonwood Valley - 1	<3000'		x		x				x						x		x	
Cottonwood Valley - 2	3000-4100'	x				x			x		x		x		x	x	x	
Cottonwood Valley - 3	>4100'		x	x		x			x						x		x	
Lovell Wash - 1	>4500'	x					x	x	x		x		x	x	x		x	x
Lovell Wash - 2	3200-4500'	x							x		x	x	x	x	x	x	x	
Lovell Wash - 3	<3200'		x		x	x			x						x	x	x	x
Wheeler Fan - 1	3100'	x	x	x	x	x			x						x	x	x	x
Wheeler Fan - 2	3760'	x							x				x		x	x	x	
Wheeler Fan - 3	6200'	x					x	x	x						x	x	x	
Kyle Canyon Fan - 1	<3000'	x	x		x				x					x	x	x	x	
Kyle Canyon Fan - 2	3000-6000'	x				x			x		x					x		
Kyle Canyon Fan - 3	<6000'	x					x	x	x		x					x		x
Yucca Forest	4500-6500'	x				x			x		x		x		x	x	x	
Las Vegas Mountains	3500-4800'	x				x			x		x		x		x	x	x	
Pine Springs - 1	3200-3400'	x	x		x				x						x	x	x	
Pine Springs - 2	3500-4100'	x			x				x						x	x	x	x
Red Rock Valley	3000-3600'	x	x	x					x				x		x	x	x	
Goodspring Valley	3200-4400'	x	x		x				x					x	x	x	x	x

Figure 40. Yucca brevifolia jaegeriana and its associated vegetation.

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Figure 41 An enlarged color infrared ERTS-1 image of the Los Angeles Basin.

Figure 42. Density slice of the same ERTS-1 image of the Los Angeles Basin.

that certain elements of this landscape were greatly enhanced. The enhanced image is, for many sectors of this coastal basin, highly interpretable. Further experiments with the density slices could allow enhancement of any desired phenomenon in the Basin.

Conclusions

To reiterate, the technique of pre-enhancing ERTS-1 MSS 70 mm chips with an equidensity film has greatly increased the utility and application of the imagery. The density slicing technique also provides a useful supplement to the I^2S Mini-Addcol Viewing System.

The technique should not be viewed as final, however, since its full potential has not yet been realized. A further test of the technique might include mapping all the various vegetation environments in the Mojave, something which, considering the facility with which *Y. brevifolia* was mapped, could be done with small inputs of interpretation time. The technique can also be applied to the delimitation of specific urban environments as outlined for the Los Angeles Basin.

Density slicing of ERTS-1 imagery as realized from this technique has the potential for increasing the interpretability and use of the imagery and can provide the user with environmental data not easily obtained with other technology. The technique can contribute to studying various physical and cultural environments, and can be used to map their areal signatures at a high level of confidence.

References

Ranz, E. and E. Schneider, 1970, "Der Aquidensitenfilm als Hilfsmittel bei der Photointerpretation," *Bildmessung und Luftbildwesen*, 2: 123-134.

Jaeger, Edmund C, 1968, *Desert Wild Flowers*, Stanford; Stanford University Press.

Huning, J.R. and R.M. Petersen, 1973, "Use of *Yucca brevifolia* as a Surrogate for Detection of Near-Surface Moisture Retention," *NASA Technical Report N-71-1*, Department of Geography, University of California, Riverside.

4 SUMMARY

Our position as we near the end of the present contract may be summarized as follows: Imagery has been late in coming, and therefore much of the work was delayed. The first few weeks were primarily involved in developing a crude, color enhancement technique and determining the best ways of utilizing ERTS-1 data. Refinement of enhancement techniques, receipt of better imagery, and acquisition of the I^2S Mini-Addcol Viewer have allowed significant and rapid progress toward the fulfillment of the program objectives and have stimulated additional, unsupported research within the department.

Our research objectives have been generally achieved. Development of the semi-automatic crop inventory system is well on its way to fulfillment.

ERTS-1 has provided a needed regional overview of Southern California, revealing previously unrecognized physical phenomena (such as the compression zone, described in Section 2.4). In addition, the sequential coverage of ERTS lends itself to the detection of dynamic environmental change (Coachella Valley, Section 2.3). Overall, research conducted under ERTS-1 has been most rewarding.

Appendix A provides an indication of the very extensive effort made by our group during the period covered by this report in providing information to interested groups and agencies about ERTS-1 imagery and its potential applications.

5 APPENDIX A -- INFORMATION AND APPLICATIONS ASSISTANCE

I. Origin of Visitor

A. Academic

1. Faculty

(a) University of Montana

(b) University of California, Riverside

(c) University of Wisconsin

(d) University of Southern California

(e) California State University, Fullerton

(f) California State University, San Diego

(g) University of California, Los Angeles

(h) Cal Poly, Pomona

(i) University of California, Santa Barbara

(j) Rio Hondo Junior College

(k) San Bernadino Valley College

(l) Riverside City College

(m) Pierce Junior College

(n) California Institute of Technology, Jet Propulsion Lab

(o) California State University, Hayward

2. Students

(a) University of California, Riverside

(1) Anthropology

(2) Geology
(3) Business Administration
(4) Sociology
(5) Political Science
(6) Urban Studies
(7) Dry Lands Institute
(8) Biology
(9) Agriculture
(10) Soils

(b) University of California, Los Angeles

(1) Geography
(2) Meteorology
(3) Hydrology

B. Government Agencies

1. City

(a) Department of Water and Power, Los Angeles
(b) Department of Parks and Recreation, Los Angeles
(c) Riverside City Planning Department

2. County

(a) Los Angeles County Planning Department
(b) Los Angeles County Parks and Recreation
(c) Riverside County Planning Department
(d) San Bernadino County Planning Department
(e) Orange County Planning Department
(f) San Diego County Planning Department

3. State

(a) Department of Water Resources
(b) Department of Highways
(c) Department of Parks and Recreation

4. Federal

(a) Bureau of Land Management
(b) NASA (Goddard)
(c) Bureau of Reclamation
(d) U.S. Department of Agriculture

(e) NSF Institute

(f) U.S. Department of State

C. Private

1. Southern California Testing Labs, San Diego
2. Davidson Engineering, Riverside
3. Doubleday and Company, La Habra
4. Los Angeles Times

II. Types of Assistance

A. Philosophy and Uses

B. Introduction to Remote Sensing Technology

C. Sensors and Processing

D. Techniques and Methods

E. Automated Interpretation and Mapping

F. Classroom and Instructional Aids

G. Bibliographic Aid

III. Subjects Analyzed

A. Land Use

B. Natural Vegetation and Wildlife Habitats

C. Geomorphology

D. Urban Growth

E. Environmental Impact Studies

F. Real Estate Development

G. Recreation

H. Statistics on Newcastle Disease

I. Regional Planning

J. Environmental Hazards

K. Environmental Perception

IV. Coordination on Projects