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ARIZONA GEOPHYSICAL DATA BASE

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ABSTRACT

A series of digital data sets were compiled for input into a geophysical data base for a one degree quadrangle in Arizona. Using a Landsat digital mosaic as a base, information on topography, geology, gravity as well as Seasat radar imagery were registered. Example overlays and tabulations are performed.

The role of remote sensing in environmental inventory has evolved into an important supplement to field work and ground survey. The cost and time required to conduct a project can be reduced when remotely sensed imagery is used to identify and pinpoint areas of critical environmental concern. The initial stratification allows researchers to concentrate efforts in these areas and conduct the slow and tedious ground data collection process only where absolutely necessary. In this respect, environmental analysis benefits from the synoptic coverage of remote sensor data where a complete eco-zone or geomorphic province can be viewed in context.

Remote sensor data can easily provide information about the landscape that would not otherwise be obtained except by long and difficult ground data collection efforts.

Often, environmental analysis is hampered by a host of problems. Lack of data is a major concern to planners because of the obvious difficulty on what to base land management and resource allocation decisions. Quality of data is also a problem especially when the information is gathered from a number of sources. The very fact that much of the information obtained is from several sources leads to data type incompatibility which is not a trivial problem. To illustrate how these problems can be understood and overcome, a good example is the California Desert Project.[1]

The goal in the California Desert Project was to provide basic information on soils, land forms and vegetation throughout the 25 million acres of the California Desert Conservation Area (CDCA) to be used as input to the CDCA Master Plan and Environmental Impact Statement. In the soils and landform inventory process, U-2 color IR imagery was flown for the desert and manually interpreted into basic class types. This process was assisted with digital data from Landsat to isolate problem or anomalous areas to help improve the classification. The classification yielded 15 basic soil classes. The vegetation inventory sequence consisted of two specific objectives. First, a complete vegetation type map of the CDCA was needed. This meant not only a map depicting the spatial distribution of vegetation types, but also summary tabulations of acres of vegetation types. Secondly, the amount of vegetation present had to be known in terms of kilograms of forage intended for grazing animals. This information was obtained with the integration of data from several sources; Landsat, aerial photography (both large and small scale), ground gathered data, conventional maps, and historical records.

It is with the integration of several data types that makes such a project possible and successful for a relatively small amount of money. "For the purposes of consistency and simplicity, the values obtained from the recent multi-stage sampling and remote sensing survey are presented ... as the most current estimate of range carrying capacity. The reliability of these estimates is considered satisfactory when reviewed in comparison with earlier survey results from common areas."[2,p.52] It is the very fact that these conventional data types and derived information were used in a Federal plan and program that lends credibility to its use and development.

While the techniques worked well for soils and vegetation studies, they are also applicable to other types of applications such as water quality monitoring[3], forest type mapping[4] and urban applications.[5] One particularly interesting application is the development of a geophysical data base. While the CDCA project dealt chiefly with renewable resources, a geophysical data base such as the one compiled here for a one degree quadrangle in Arizona deals with non-renewable resources. Since most of our energy sources are non-renewable, the application of image processing to this topic can be valuable.

I. ARIZONA DATA BASE DEVELOPMENT

As with the data base developed for the California Desert, the Arizona geophysical data base described here was compiled using the same methods and techniques but with differing data types. Data variables included are: 1. Landsat multispectral data, 2. Digital terrain information, 3. Seasat radar data, 4. Conventional geologic map information, and 5. Geophysical data.

LANDSAT MULTISPECTRAL DATA

More often than not, study areas of interest do not conform to the Landsat framing convention, posing difficult data organization problems, especially from the viewpoint of the analyst. Geographic and radiometric control is difficult when more than one scene is involved. This led to the development of large scale full resolution digital Landsat mosaics first undertaken for the CDCA project in 1977 at the Jet Propulsion Laboratory.(JPL) Subsequent tasks such as the California State Mosaic and Arizona State Mosaic[6] refined and advanced the technology to permit better geometric/radiometric control and overall accuracy. Recently, incorporated into the mosaicking process is the Master Data Processor Ground Control Point file developed at Goddard Space Flight Center.[7] Use of this information provides satisfactory control while reducing the time the analysit has to spend in compiling the ground control file.

While the Arizona Mosaic used manually selected control points, the overall accuracy is quite good. The mosaic consists of 21 full frame Landsat digital images corrected to a Lambert Conformal conic projection with two standard parallels. The pixel size selected was 80 meters square. Resampling was also done in the "Z" domain (brightness) to provide a smooth surface for classification. The resultant data set as shown in Figure 1 is 10,300 by 9,000 pixels for one band (IR1). All four bands were corrected.

Figure 1: Arizona State Mosaic. This image is 10,300 lines by 9,000 samples and is composed of 21 Landsat scenes imaged on five consecutive days in June of 1977. The data are corrected to a Landsat Conformed Conic projection with 80 meter pixels. The sharp brightness difference line is the result of clouds on one of the days. Band 6 (IR1) is shown.

Landsat imagery is well suited for a base upon which ancillary data can be added. It is a familiar data type and is quite similar to an aerial photograph as opposed to digital terrain data, for example. It is the "familiarity factor" that allows tiepoints for registration of other data to be chosen with relative ease.

Large data sets can be difficult to handle efficiently. Because of this, an area was selected from the large mosaic data set that corresponded to a one degree of latitude by one degree of longitude area. For demonstration purposes here, the Phoenix West quadrangle NI 12-7/W was extracted from the mosaic and used as the base image, as shown in Figure 2. The pixel size is 80 meters square. The one degree quad format corresponds to most mapping conventions as well as the digital terrain information format.

II. DIGITAL TERRAIN INFORMATION

Files for terrain information were obtained from the National Carographic Information Center and converted into image format. Figure 3 is an example of an elevation brightness image detailing relief in a somewhat continuous fashion. In addition to elevation, measures of slope gradient, and slope aspect were derived. This information can be useful as a stratifier or identifier of geomorphic and lithologic features.

These data were resampled to 80 meter pixels and rotated approximately 11° to conform to the satellite track. The registration process is fairly elementary in that the latitude and longitude of each pixel in the terrain data is known as is the latitude and longitude of each pixel in the Landsat quadrangle. All that remains is to run the correction algorithm on the terrain data set.

III. SEASAT RADAR DATA

Radar imagery has proven valuable in the identification of lineaments, primarily becuase of low imaging angles. It was thought such information should be included in the data base.

The Seasat radar image was resampled to conform to the resolution of the Landsat quad and digital terrain information. A series of tiepoints were manually selected that corresponded to common points in each data set. A total of approximately 80 points were used as input to the correction algorithm. Registration appears fairly good overall but significant lay over problems are apparent in areas of high local relief. Modeling efforts which use digital terrain information to correct for this condition are needed. This data set is shown in Figure 4. The radar brightness data was increased 75 grey values for display purposes.

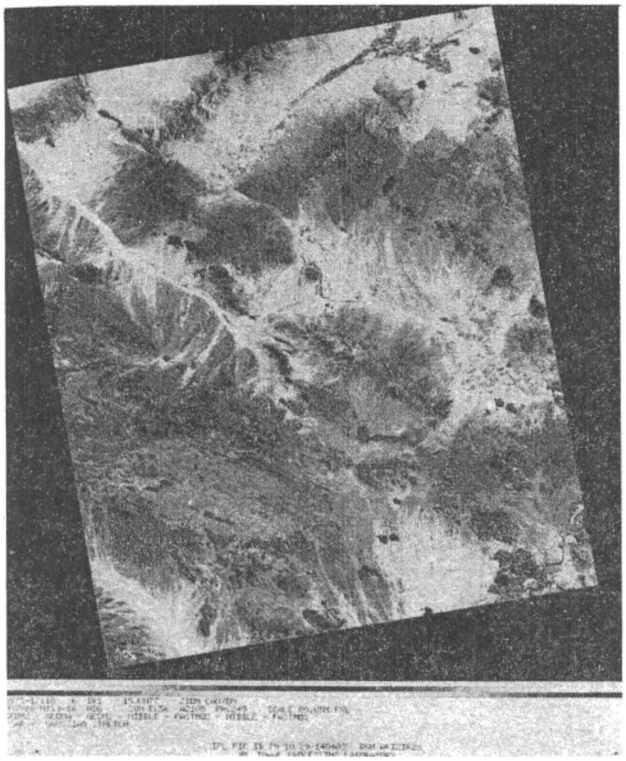

Figure 2: Phoenix West Quadrangle. A $1^{o} \times 1^{o}$ quadrangular segment was extracted from the digital mosaic data base. This image corresponds to the AMS map series (1: 250,000) NI 12-7/W just west of Phoenix. Segmenting the image into smaller conventional portions permits efficient computing as well as easing organizing problems related to data handling. This image, the IR1 band, is 1,600 lines by 1,450 samples.

IV. CONVENTIONAL MAP DATA

A geologic map for the state of Arizona was obtained and the Phoenix West quad portion was digitized. Geologic unit boundaries were digitized on a coordinate digitizer and converted into image format where the areas defined by the boundaries were uniquely encoded with a digital number. An affine transformation was performed to fit the digital geology map to the Landsat quad which proved surprizingly good. The geologic map base was in the same map projection as the Landsat base quad posing minimal registration problems.

V. GEOPHYSICAL DATA

Land gravity data was obtained from the United States Department of Commerce, NOAA Environmental Data and Information Service in Boulder, Colorado. The data is stored in point format for observed gravity, Free-air anomaly, Bouguer anomaly and elevation. Each point is tagged with a latitude position and with this information the data are converted into a Lambert conform conic projection and registered to the Landsat quad.

Figure 3: Phoenix West Elevation Image. Digital terrain information for the Phoenix West quad is shown here as a brightness image i.e., the brighter the image, the higher the elevation. This data has been corrected to register with the Landsat quad with an accompanying pixel change to 80 meters.

One difficult aspect of the data is that it is represented solely as a set of points and not as a continuous image. The challenge lies in transforming random points into a "continuous" image.

An algorithm designed to "grow" each point until it collides with its neighbor was implemented for this task. It is fairly expensive computer-wise and will accept up to 8,000 points per try. The result is an image of facets depicting gravity, for example, whereby the grey tones reflect the intensity of gravity (Figure 5). A boxfilter is applied to the data set to smooth the surface and provide more continuous data (Figure 6). This process essentially interpolates between points to make up for the missing data. There were only 800 observations in this particular quadrangle so the window size on the filter was quite large (101 x 101). Obviously, the more data points contained in the file, the more accurate the representation of a surface displayed. However, data sources such as these direct researchers and field workers to areas where anomalies may reside.

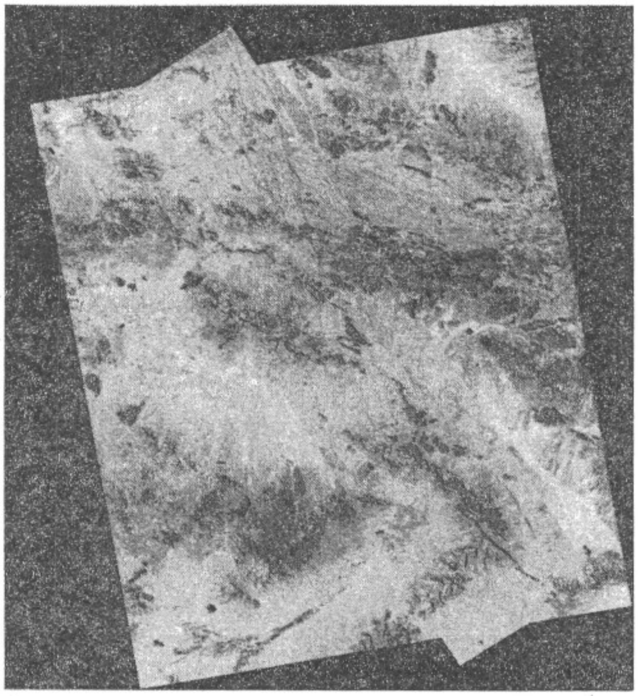

Figure 4: Phoenix West Landsat Quad with Registered Seasat Radar Imagery. This Seasat data was acquired on July 30, 1978, is like polarized and was imaged as the spacecraft passed over from south to north. The data were resampled to the Landsat pixel size of 80 meters.

The cost of this data, as with the other types described is nominal, and especially so when viewed in the light if it has to be collected by the independent researcher. However, the real advantage that this collection of data has is its ease of manipulation and access within the computer. The combinations that could be generated by the intersection of these data planes are quite numerous and perhaps too numerous to make much sense of. Data reduction techniques such as multispectral classification, aggregation and stratification can effectively present the information at hand in a usable form and format without confusing the analyst. An example of a usable format is shown in Figure 7.

The tabulation in Figure 7 is a typical example of the sort of information that may be extracted from a series of image data sets. Images don't lend themselves well to quantification, but with computer assistance numbers can be generated in the form as shown.

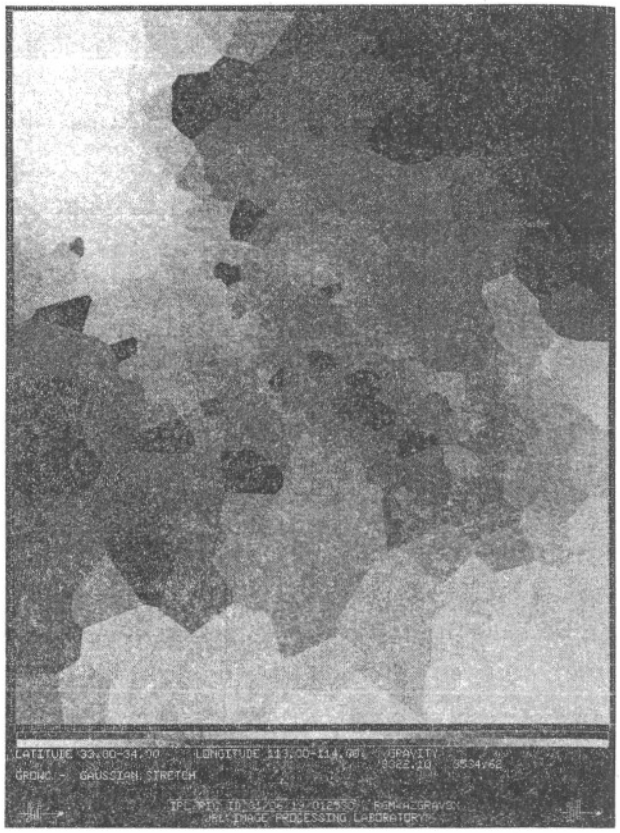

Figure 5: Interpolated Gravity Image. This image, for the Phoenix West Quad shows the faceted gravity data. The data were a set of points distributed somewhat randomly throughout the quad and were "grown" until all converged. The brightness of each grey tone corresponds to the intensity of gravity. These data were rotated and scaled to register with the Landsat quad.

VI. SUMMARY

Although this paper has no set experimental design or set conclusions, it does serve to illustrate the types of data analyses that can be performed. All the processing was done at the Caltech/Jet Propulsion Laboratory's Image Processing Laboratory, using the VICAR/IBIS software (Video Image Communication And Retrieval System/ Image Based Information System).

With the aid of these software packages, data can be reduced in a fraction of the time it would take if it was done via conventional methods. Information systems which use Landsat digital data as a base are best suited towards regional applications and the Arizona geophysical data base is a good example. Difficulties do exist however with layover problems in side looking radar, availability of cloud free images, and local misregistration problems due to sensor anomalies and map inaccuracy. But all in all, such a data base is quite helpful in establishing baseline inventories and obtaining a better understanding of the spatial distribution of geophysical phenomena.

Figure 7: Terrain Tabulation. This tabulation displays terrain variables derived from the digital terrain information by geologic formation as defined by the digitized geologic map of the Phoenix West Quad. Also displayed are Landsat signatures by geologic unit. The area in acres, percent of total area, as well as the mean (AVE.) and standard deviations (S.D.) of each variable. The "geol. form" symbols are the standard USGS abbreviations for rock types.

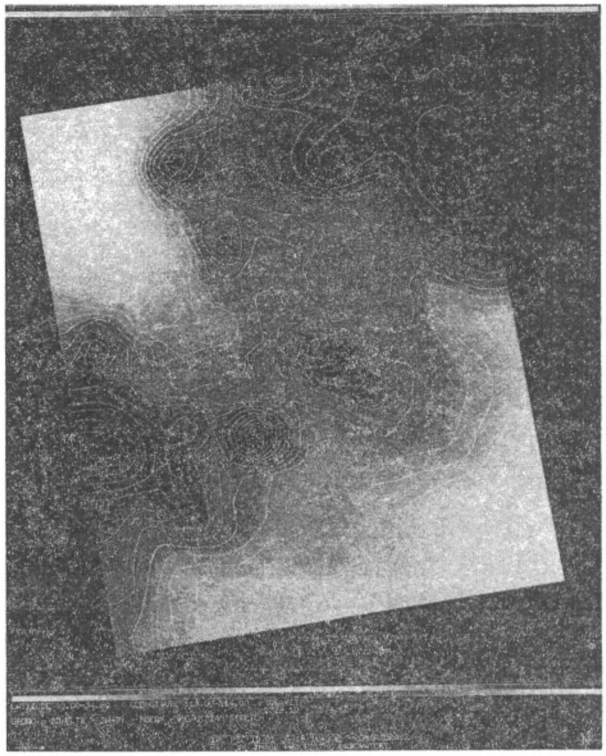

Figure 6: Filtered Gravity Data. A 101 x 101 window filter was passed over the data to produce a smoother image. The data were contoured for easy visualization.

PHOENIX WEST PHYSIOGRAPHIC ANALYSIS

BASED ON GEOLOGIC FORMATIONS

USING DMA SLOPE,SLOPE ASPECT AND ELEVATION DATA
WITH LANDSAT II MULTISPECRAL SCANNER IMAGES

GEOL. FORM.	AREA IN ACRES	PERC. TOTAL AREA	AVE. SLOPE DEG.	S.D. SLOPE DEG.	AVE. ELEV. FEET	S.D. ELEV. FEET	AVE. ASP. AZIM.	S.D. ASP. AZIM.	AVE. MSS/4 DN	S.D. MSS/4 DN	AVE. MSS/5 DN	S.D. MSS/5 DN	AVE. MSS/6 DN	S.D. MSS/6 DN	AVE. MSS/7 DN	S.D. MSS/7 DN
QS	1608759	67.0	1.5	4.5	1167.6	395.1	85.5	46.2	150.7	22.5	92.2	12.3	141.8	21.6	121.1.	19.4
QB	196074	8.2	2.3	1.8	1294.8	442.2	87.7	47.0	110.3	25.1	71.7	12.9	104.0	23.7	87.6	21.2
QTB	6606	0.3	2.7	1.7	1580.4	316.7	109.3	46.9	110.8	26.9	72.7	14.2	105.7	25.9	88.4	22.1
QTI	480	0.0	3.0	2.2	1359.0	131.0	74.6	45.2	127.5	23.2	81.0	11.3	119.7	20.7	102.5	20.3
QTS	11724	0.5	3.9	6.5	858.7	86.8	120.4	31.7	156.6	27.4	100.6	15.5	151.0	26.2	123.6	22.7
TKG	23553	1.0	3.5	4.1	2345.9	782.5	89.4	55.9	122.8	22.7	81.7	13.8	113.9	22.8	100.2	20.1
TKI	11278	0.5	3.0	2.0	1696.8	356.4	83.6	56.2	126.2	21.9	78.3	11.7	117.4	20.5	101.3	18.6
TKS	2778	0.1	1.5	0.9	982.5	77.7	89.8	39.4	127.1	15.2	77.2	7.3	119.3	13.9	103.6	13.1
KA	175768	7.3	2.4	3.8	1565.6	537.7	84.7	47.7	120.0	19.7	75.6	10.1	112.5	18.6	95.5	17.6
KR	4317	0.2	2.6	1.5	1758.6	157.4	90.8	42.9	109.9	18.7	70.9	8.9	101.9	17.0	85.6	16.7
KV	85866	3.6	2.2	1.7	1633.5	433.3	78.6	47.6	124.8	19.7	75.9	10.3	115.3	16.7	98.5	17.1
PZS	3714	0.2	2.7	1.5	1622.5	178.9	89.5	44.2	119.1	16.1	76.4	8.5	112.0	15.5	95.7	14.3
PZSC	22687	0.9	2.2	1.4	1903.0	520.5	97.0	41.9	112.3	13.9	74.1	10.1	105.6	18.4	90.1	16.3
MZGR	38407	1.6	1.9	2.5	1441.9	337.9	96.8	46.9	118.5	17.5	82.2	10.8	114.9	17.3	91.2	14.8
MZGN	11095	0.5	1.1	0.6	1216.2	89.1	95.0	37.2	127.1	18.4	85.3	10.5	123.9	17.6	98.5	16.0
MZS	32290	1.3	2.1	2.3	1596.0	292.5	95.4	41.9	104.6	15.3	72.6	8.5	99.8	14.3	79.1	12.9
MZSC	15009	0.6	1.7	1.2	1242.1	479.8	82.6	45.6	112.2	17.2	76.2	8.7	108.4	16.0	86.8	15.1
MZPZS	8296	0.3	3.1	1.7	2070.6	452.0	82.4	36.4	115.8	23.3	77.0	12.2	108.2	22.4	93.7	20.3
PCGR	129411	5.4	2.8	3.8	1976.4	686.6	95.0	49.9	119.2	17.7	80.0	10.1	112.7	17.4	95.7	15.3
PCGN	12069	0.5	2.6	6.8	1404.4	282.8	94.7	53.3	136.1	17.4	88.6	11.2	130.4	16.8	109.2	15.2
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BIOGRAPHY

Ronald G. McLeod is currently on the staff at Caltech's Jet Propulsion Laboratory engaged in research on Landsat digital mosaics. He holds degrees from San Diego State University in Geography. Other research interests include land resources inventory techniques, and land capability/suitability modeling in the range land environment