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FINAL REPORT

(E75-10221) [ANALYSIS OF AERIAL PHOTOGRAPHY AND MULTISPECTRAL DATA FOR CARTOGRAPHY AND GEOMORPHOLOGY OF NEVADA] Final Report (Nevada Univ.) 15 p HC $3.25 CSCL 08B

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I. INTRODUCTION

This report is the Final Report specified by the terms of Contract NAS5-21864 dated September 14, 1972 between the National Aeronautics and Space Commission and the University of Nevada, Reno. The work was performed at the Mackay School of Mines under the direction of Dr. Joseph Lintz, Jr., the principal investigator.

OBJECTIVES

The proposal to the ERTS program on which the contract was based contained two main objectives: (1) A cartographic aspect utilizing film base material, and (2) geologic interpretation of ERTS data covering the State of Nevada.

The cartographic objective was to produce a new basemap of Nevada with color separation. It was to be based upon the use of positive transparencies which would then be mosaiced. This would save the usual intermediate step of mosaicing prints which require two intermediate laboratory procedures: (a) making the prints from the negatives, and (b) rephotographing the mosaic. With each laboratory step, it is usual to suffer a degradation of about 10% of the available detail. The proposal was aimed at retaining this 10% data. The proposal also stated that a set of mosaics would be performed for data acquired by the ERTS satellite once when the vegetation was extensive, and once when the vegetation was minimal and prior to snow cover.

The geologic objective concentrated on lineations, especially those comprising (a) "Walker Lane", (b) the Battle Mountain arc, (c) The Secret Canyon arc, and (d) The decollment zone of the Sevier Thrust Zone in eastern White Pine County. Once the data came to hand, additional tasks came to light and were undertaken. These included (a) an examination of the zone of caldera extending east-west across the southern sector of the state, (b) the confirmation of a possible E-W zone of mineralization in west central Nevada as interpreted by E. C. Bingler of the Nevada Bureau of Mines and Geology (c) and attempt to ascertain the fossil remanents of the ancient, pre Basin and Range faulting land surfaces.

The report is organized into two main sectors covering the cartographic work and the geologic investigations.

SUMMARY OF RESULTS

A) The cartographic sector of this investigation was plagued from the beginning with a variety of problems which consumed unforeseen amounts of time and put the budget out of balance. The result was that time did not permit the creation of the two mosaics specified in the proposal. One mosaic was constructed for each of the ERTS-1 images and from this set, it is possible to create a color photo map of the State. Examination of the data of the vegetated vs the non-vegetated dates showed that geologically in semi-arid climate vegetation changes were insignificant between the growning and non-growing season. Areas of geologic interest in Nevada when covered by vegetation usually have a conifercus assemblage (pinyon pine and juniper) which does not change significantly. Once this data was established from the ERTS-1 data, it was decided to forego the second set of mosaics and concentrate upon improving the quality of the first set.

B) The geologic investigations performed with the aid of ERTS-1 imagery turned out to be surprisingly disappointing. Basically, little new knowledge was added concerning Nevada geology, no new insights were derived, and confirmation of current hypotheses based upon ground studies was not possible. We feel that we were partially limited in our analytical techniques, but that principally the ERTS-1 resolution prevented us from obtaining detail significant to the decision making process. We were able to see on ERTS-1 imagery most of the major features we already knew of, including Walker Lane, the Battle Mountain and Secret Canyon arc. The zone of caldera are readily visible and the zone of decollment in the Snake Range can be derived. But the hoped for incremental knowledge eluded us, despite rather rigorous analytical techniques. We undertook multiple trips to NASA/Ames to avail ourselves of analytical instrumentation there. Generally it was found to be disappointing. We also experimented with the so-called "sandwich technique" utilizing the varicolored transparencies developed from the positive negatives supplied us. We did not have access to the instrumentation necessary for density slicing and we find ourselves wanting to try this approach to data analysis and interpretation. Details of our accomplishments and activities in the geologic interpretation of ERTS-1 data are spelled out in section III.

II. CARTOGRAPHY

Photographic techniques generally result in a degradation of the photographic image on the order of 10-15% with each generation of reproduction. The proposal to create a set of mosaics utilizing negatives rather than paper prints and a rephotography step was designed to eliminate the 10% degradation. Nearly all aerial photography mosaics are compiled from prints, and it was hoped that the use of negatives would make available a new technique that might save time, reduce costs, and result in a generally improved product. This has not been the case.

Our principal problems have generally been with technique. The mosaicing of negatives has a couple of serious drawbacks. One is the requirement of a substrate on which to mount the negatives and the second is the loss of flexibility gained by using photographic prints in mosaics. By the use of prints it becomes possible to reprint individual negatives with variable exposures and paper contrasts so that a very uniform level of grain density (gamma) is obtained and thus results in a more attractive end product. Additionally compiling a mosaic with paper prints has the advantage of allowing a variety of techniques in forming the junctures between prints; i.e. some boundaries are cut sharply with scissors where a "hard" line exists, and others are torn or "feathered" where a "soft" boundary exists. This technique is totally denied the compiler of mosaics from negatives, who in every instance must come up with a hard, cut boundary between adjacent edges of the negatives.

We spent nearly four months attempting to select the best substrate for the negative mosaic. We tried various transparent plastic sheets and attempted to use glass panes. The trick was to get the adhesive (which is going to be photographed for the creation of the engravers plate) uniformly distributed between the negative and the substrate. Heating and the addition of thinners or small amounts of dispersing agents still left the distribution of the adhesive areally spotty and of varying thickness. The most successful technique involved the use of pre-coated plastics which had a press-type adhesive factory applied with superior density and evenness. The technicians found that this material worked very well where they could get the negatives down flat, but that care must be exercised to expell small pockets of air which might create local bubbles which would degrade the final product.

Another problem was that of getting the adjacent negatives to fit properly. Even though the technicians worked diligently to cut the negatives on the appropriate side of a line of density change on the negative, all too often in the final assembly it proved impossible to get a precise fit for adjacent negatives and a thin void, frequently about the thickness of a razor's edge remained. Efforts to eliminate this defect were seldom successful and, unfortunately, it is noticeable on the final product. This is perhaps the greatest deterrent to creating mosaics from negatives. With negatives there can be no overlap of any sort between the negatives, while with mosaics made with paper prints they are usually cemented one on top of the other without reference to any substrate and a better product is obtained.

A third problem has evaded our understanding. In the final mosaic we have made extensive use of data acquired in the orbits of early October 1972. These orbits were, for the most part, taken on clear Indian summer days that provided great clarity. Our problem concerned the line covering the area along Contact, Ruby Mountains, Railroad Valley, and Lathrop Wells, Nevada. The original data taken in the same sequence as the other data used possessed two defects. (1) it was of a different scale, and (2) there was insufficient overlap to permit mosaic via negatives. Our early recognition of this problem which we thought was due to some orbital irregularity, did not worry us, as we knew we would obtain subsequent data every eighteen days and our assumption was that barring potential problems due to cloud cover, we would receive an adequate strip of photos for the negative mosaic. However, this proved to be much more difficult than we conceived. First of all we received relatively few reprints of data from overflights along this particular orbit. We have received only 5 flights along this line, compared to 12 along the Pyramid-Tahoe line. We assume this difference is due to the presence of clouds in the area a greater percentage of the time, but we confess to no true understanding of the problem. Eventually we solved this problem through the courtesy of Dr. Paul Tueller, Principal Investigator of Contract # NAS5-21870, who received much more voluminous data on his contract than we requested and who gave us one set of duplicate negatives from his file which enabled us to obtain a superior fit, although the negative density was not a good match.

The inherent difficulties of fabricating a mosaic of negatives, outlined above, especially the time required to arrive at the technique used and the problem with getting a good fit on one orbital line, caused us to scrutinize carefully the commitment to develop a second set of photo mosaics. As the November 72 and April 73 data arrived, it was closely scanned and compared with the data of October 1972 to determine the extent to which vegetation obscured data of geologic interest. We found the answer to be: at the ERTS-1 resolution, not at all. The more heavily vegetated regions of Nevada are two fold: (1) a pine-spruce assemblage on the upper slopes of many of the ranges, and (2) irrigated regions of agricultural interest. The remainder of the state had insufficient vegetation to interfere with a geologically oriented interpretation. The irrigated regions, generally occurring out in the open regions of some of the basins also had minimal effect upon geological interpretations. The Pine-spruce assemblage being conniferous retained its needles in the winter months and showed miniscule or no change from the "leaf-on" to the "leaf-off" season. This data, together with the disappointing quality of the first set of mosaics brought about the abandonment of the second set of maps on the basis that they would depict no new information of value. The sorts of things they might expect to show, such as the change due to loss of leaves of aspen, poplar, and cottonwood trees along rivers and/or canyons, at the mouths of canyons flowing out onto alluvial plains and about various springs and seeps, in nearly every case possess too limited an areal extent to be visible with ERTS-1 imagery.

The final product of this segment of the contract, then, consists of a set of negative maps, one for each of the four spectral bands of data collected by the ERTS-1 satellite. From the mosaics it is possible to project directly onto photoengravings to produce plates for a three or four colored map. Eliminated are the intermediate steps of paper prints with the consequent 10-15% degradation upon rephotographing, and also this technique preserves the original color separation technique of the multispectral camera array of the satellite package and recombines the multispectral data back together at the last possible processing step in the printing of a colored map.

III. GEOLOGICAL INTERPRETATION

A. Techniques

Analysis of multispectral data offers many challenges and should have exciting potentials. We met the challenges and failed to find exciting potentials.

The first and easiest type of data analysis was performed on single band data - merely the photointerpreter's look at 10,000 - 12,000 mi^2 in synoptic view. Here is a first order interpretation of what is available on each frame and a classification of the data into the gross geomorphologic forms present. The discernment of textural and color patterns, of lineations, and of areal shapes forms the basis of the analysis. It is backed with a background study and familiarity of the territory covered. The final result is melding of the visual data with the background data to arrive at a decision which represents the interpretation. While this step need not be performed for each of the four bands of data, it is usually wise to use the number seven channel which does depict data not seen on the others because of the capability of recording out to 0.9 micrometers and one other band in the visible sector.

The cross correlation between the bands requires some sort of instrumentation or a superior mind. Instrumentation developed in the past few years has become generally available and was used in this study. We performed multispectral analysis by means of two techniques. One was the use of a multispectral data analyzer "Addicol" manufactured by International Imagining Systems, Inc. (I^2S) of Mountain View, Ca. For this purpose we were afforded access to the I^2S analyzer owned by NASA at the Ames Research Laboratories. The results of our visits to Ames for the purpose of using this instrumentation were discouraging. We had hoped strongly to be able to make various geologic features "pop out" in conspicuous clarity through this technique of color enhancement. There was no difficulty in enhancing various features through the false color techniques - contrast was magnified definitely, but we failed to elicit additional informacolor change on the black and white positives, but we were unable to bring out any significant change by either analytical procedure.

The technique of density slicing is available in the literature, and offers hope that it might be a superior technique to that of the Addicol System or Sandwich technique. We did not have the opportunity to use this device for two reasons: cost and time. We simply ran out of time insofar as this project is concerned and within the time frame allowed by NASA. As we were also on our own, internal budget, we were not able to fund rental on commercial density slicing instrumentation. This is definitely a technique that we are interested in following. When and if NASA/Ames acquires such an instrument, we will have access to it through the University of Nevada's membership in the NASA/Ames University Consortium, and analytical work on the 70mm ERTS-1 data could be done on a very reasonable basis. Probably less than $1000 budget would be sufficient.

B. Results of Interpretations

Results of interpretations are listed below, starting with items specifically mentioned in the proposal and followed by additional items undertaken during the course of the investigation as time permitted, as ideas and data suggested.

1. LINEATIONS

A. Walker Lane. Walker Lane was first named in 1940 by Billingsly and Locke for a juncture or suture trending SE from Pyramid Lake Nevada across the State. It appears to tie in very nicely with lineations seen on Gemini Photography crossing the State of Arizona and extending into Sonora to the vicinity of the Cananea Mining District, a total distance of about 1550-1600km. The term Walker Lane is generally restricted to Nevada and defined as the boundary between the structural elements (mountain ranges) trending N 10° typical E of the Basin and Range Province and those trending N 45° W of the Sierran complex. Walker Lane generally occupies a fairly broad low topography which is covered nearly everywhere by quaternary alluvium. Some right lateral movement along Walker Lane has been reported by Nielson in the vicinity of Mineral County in the Mina-Luning region and by Bonham in the Virginia Range near Pyramid Lake, and by Oldham in an unpublished MS thesis on the east side of the Virginia Range.

The ERTS-1 imagery is the first synoptic view of Walker Lane and it yielded no new information concerning this feature. Multispectral analysis of the alluviated areas showed them to be no different than any other alluviated area. Nor were attempts to establish possible lateral movement along the Walker Lane successful. Thus the full significance of Walker Lane remains a problem for future workers. How much information will be derived from the better quality data expected from Skylab remains to be seen, but hopefully the details of resolution on Skylab data may well allow for the discernment of new evidence for this large scale enigmatic feature.

B. The Battle Mountain Arc. The Battle Mountain Arc is a curving lineament which has been little described in the geologic literature although it is well known to the geologists of Nevada. It is seen emerging from the lava field of the Owyhee Desert north of Battle Mountain. Near Battle Mountain it truncates the southern edge of the Tertiary lavas north of the Humboldt River. It continues south through Paleozoic rocks via Mill Creek Cortez, the S.W. margin of the Roberts Creek Mountains, the S.W. margin of Lone Mountain, the South end of the Fish Creek Range, crosses the Pancake Range and dies out somewhat south of the major playa in Railroad Valley. On the ERTS-1 imagery, this lineation is seen very clearly and in sharp focus, especially in its northern two-thirds. However, attempts to gain additional information through multispectral analysis met with no success. In this case, we are not dealing with a broad older zone as we were with Walker Lane, but rather with a thin narrow hairline and it is unlikely that detail within this hairline would be preserved given the spatial resolution of the ERTS-1 system. Apparently, this too, must await the higher quality data of Skylab before our knowledge can be increased or a better understanding of the cause of this feature can be derived.

C. The Secret Pass Arc. This arc is seen only very weakly. It originates in the country north of the Humboldt River, probably west of Mary's River, cuts through Secret Pass separating the East Humboldt Range from the Ruby Mountains, truncates the south end of Spruce Mountain and then becomes less well formulated near the north end of the Schell Creek Range. ERTS-1 imagery did not accentuate this probable feature, and certainly one would hope to acquire new information on the Battle Mountain arc prior to tackling this one.

D. West Central Nevada Mineralized Zone. E. C. Bingler of the Nevada Bureau of Mines and Geology has suggested the possibility of an E-W zone of mineralization occurring at the latitude of the north end of the Wussak Range in Mineral County. His data suggests geochemical anomalies which may extend some 60-75 miles east. Analysis of this type of working hypothesis by ERTS-1 data seemed to be a natural investigation falling within the limits of ERTS capability. We are, however, unable to detect any activity of an anomalous nature in Bingler's region based either upon lineations or upon rock composition utilizing multispectral analysis. Confirmation of this hypothesis would have been a significant contribution. Failure of this analysis by ERTS-1 technique does not necessarily invalidate Bingler's hypothesis. Additional study utilizing ERTS-1 imagery and the density slicing technique is warranted, and, of course, a look at this technique with Skylab data will follow when Skylab data becomes available.

E. A belt of ancient caldera cross southern Nevada between Rhyolite on the west and terminating in Lincoln County to the east has been reported by various members of the U.S. Geological Survey in a series of reports concerned principally with the geology of the Nevada Proving Grounds of the U.S. Atomic Energy Commission. Many of these caldera are visible in the ERTS-1 images. Multispectral analysis causes them to stand out in greater contrast, but fails to provide any significant new information, nor additional caldera to those reported in evidence.

2. DECOLLMENT ZONE

More than a decade ago, Misch and Hazzard, in partially published studies of the Snake Range in extreme eastern Nevada, reported a decollment zone probably associated with the Sevier Event of 65-70 million years of age. ERTS-1 data is the first to allow a synoptic view of this region and a study was undertaken of this metamorphosed region. The zone is recognizable by the lighter color of the rocks it contains, differentiation from the surrounding limestone terrains is enhanced by multispectral analysis, but fails to yield additional information assisting in the understanding of the geology of the feature. It is interesting to note that the enhancement yielded results similar to that of the granitic terrain in the Ruby Mountains, which would be expected geologically, although the features have differing origins. That is, the chemical composition of the rocks of the decollment zone and the granite begin to approach one another and offer a distinct contrast from other rocks surrounding them.

3. ORE DEPOSITS

We have looked in detail on the ERTS imagery at some of the larger orebodies in Nevada, especially the two large copper districts of Kimberly Mining District at Ruth, Nv. and the Yerington District. These rather large scale open pit deposits are not visible on ERTS-imagery. An analysis of the surrounding terrain by multispectral means also yields no clues to the presence of the ores being worked. Once this information was determined a decision to seek information concerning relatively localized gold and silver deposits was abandoned.

Instead we decided to take advantage of a major scale feature which would be of geologic interest, if only potential economic value. As a part of the Antler Event at the close of the Devonian period there was a gravity slide to the east of an order of magnitude of 50-75 miles. This allothonous material, the so-called western assemblage or eugeosynclinal facies moved eastward over an eastern assemblage of predominately carbonate miogeosynclinal facies material. Subsequent geologic events, especially erosion and basin-and-range faulting have broken the allothonous material into a checkerboard pattern complicated by Tertiary faulting and Quarternary alluvium. Here the individual pieces of the terrain should be (1) sufficiently large to be resolved in ERTS-1 resolution limitations, and (2) sufficiently differentiated compositionally to be enhanceable by the multispectral analytical technique. They ~~There~~ are. However, ERTS appears to be a bit too late, for the discrimination of the various bits and pieces of this magnificent geologic puzzle have been previously accomplished by members of the U.S. Geological Survey.

ACKNOWLEDGEMENTS

This report covers work performed by numerous people and it is appropriate here to recognize these individuals for their contributions. To the Co-principal Investigator, Arthur Baker III, go thanks for the internal funding which supported this project. Certainly the work covered in this report is not the final work to be performed with the NASA ERTS-1 data, and additional work will continue in the years ahead.

Mss Margaret Perry and Linda Kapler struggled with the mosaics and brought them to their present form. It is a pleasure to thank Martin Knutson and Tom Pochari of NASA/Ames for their hospitality and help in using instrumentation under their jurisdiction at NASA Ames. I thank Bob Fairer and his staff at the audio-visual center for the care with which they have taken on the photographic reproductions used in this research, for their patience, and for their ability to meet deadlines asked of them.

Lastly, my appreciation to the data distribution personnel at NASA/Goddard for their efficient distribution of the ERTS-1 data received under the terms of the grant. Their record stands at virtually 100% correct and the possible errors are exceeding minor, and of no consequence to the research performed. And my appreciation to Dr. Arthur Anderson, technical monitor of this contract, for his sympathetic assistance and response to my questions from time to time.