APPLICATION OF REMOTE SENSOR DATA TO GEOLOGIC ANALYSIS OF THE BONANZA TEST SITE COLORADO

SEMIANNUAL PROGRESS REPORT

1 October 1973 - 31 March 1974

Remote Sensing Report 74-1

NASA Grant NGL 06-001-015
National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C. 20546

May 1974

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INTRODUCTION

This report summarizes the research activities of the Colorado School of Mines faculty and students for the period 1 October 1973 to 31 March 1974. During this period, Professors Keenan Lee and D.H. Knepper, and graduate students R.W. Butler, J.C. Fisher, and D. Huntley carried out research under the project.

During the reporting period, considerable time was spent in the preparation of a paper titled "New Uses of Shadow Enhancement" by D.L. Sawatzky and Keenan Lee. The paper was presented at the 3rd Annual Remote Sensing of Earth Resources conference, University of Tennessee Space Institute, and will be published in the conference proceedings. The paper was also published as Colorado School of Mines remote sensing report 74-5.

ACQUISITION OF REMOTE SENSOR DATA

Two flight requests for additional remote sensor data of the Bonanza test site were submitted to NASA Headquarters. One request was disapproved, and the second stands little chance of approval, although final action has not been taken.

No remote sensor data was acquired over the Bonanza test site during the report period.

PROGRESS REPORT ON GEOLOGIC REMOTE SENSING APPLICATIONS

Regional Geologic Mapping

Bonanza Test Site Geologic Compilation Map

Using published large-scale geologic maps from various sources, the geology of the Bonanza test site has been compiled at a scale of 1:250,000. After proofing, this compilation map will be used to evaluate ERTS, Skylab and remote sensing underflight data and to identify those areas within the test site for which detailed geologic interpretations need to be made, both by field studies and by interpretation of remote sensor data.

Regional Geology Test Site

A geologic map (1:62,500) and report on the RGTS was completed during the report period. The results of the remote sensing research conducted during geologic analysis of the RGTS will be published during the next reporting period.

Mineral Deposits (Uranium) Exploration

Introduction

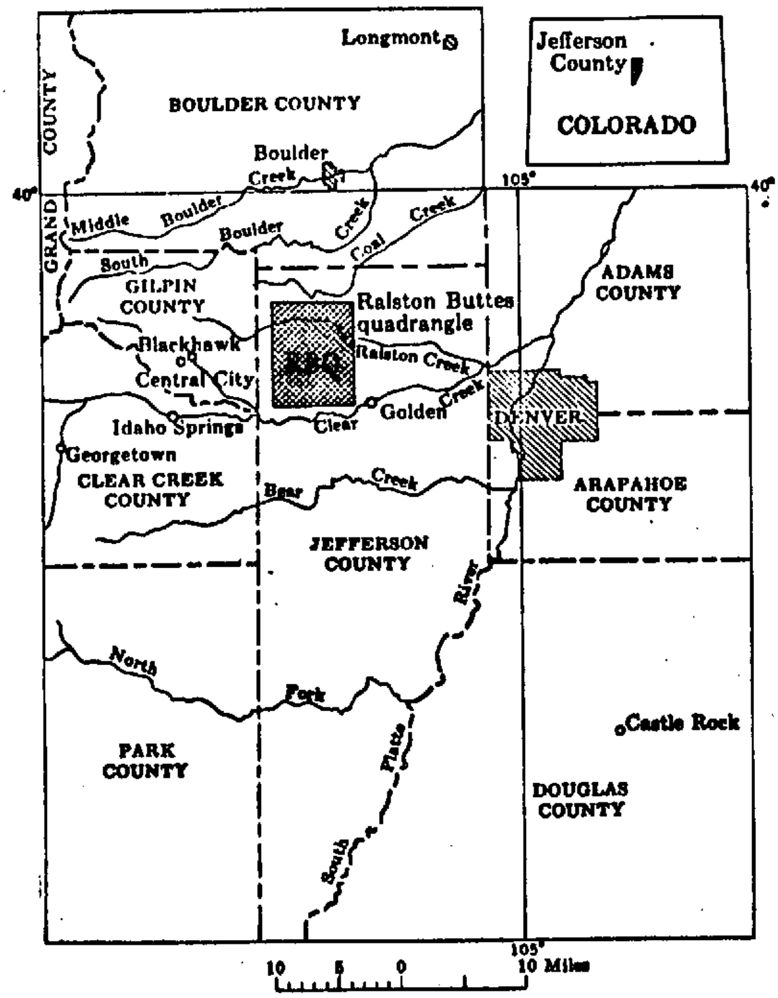
The application of remote sensing data to uranium exploration has proven successful in an area of Precambrian vein-type uranium deposits. A program of photo interpretation was undertaken to geologically map an area of known uranium deposits and then choose a few small areas as ground reconnaissance targets for further study and confirmation of the uranium mineralization potential.

The area chosen was the Ralston Buttes quadrangle, an area of metamorphic rocks in the Front Range of Colorado located marginal to the Colorado Mineral Belt (Fig. 1).

The high order of coincidence of the target areas, chosen after construction of a compiled remote sensing geologic map, with areas of known uranium occurrences and mines, indicates that the application of remote sensing data to uranium exploration may be successful. This, hopefully, will promote world-wide use of remote sensing in the exploration for vein-type uranium deposits.

Sensor Interpretation and Evaluation

An evaluation of the application of various types of remote sensing data to the exploration for uranium has recently concluded with significant successful results.



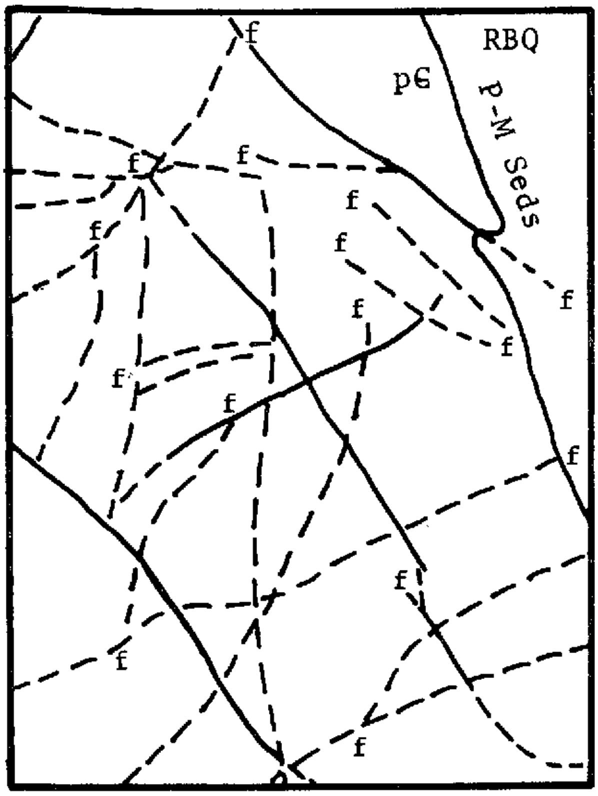
INDEX MAP SHOWING LOCATION OF RALSTON BUTTES QUADRANGLE, JEFFERSON COUNTY, COLORADO

Figure 1

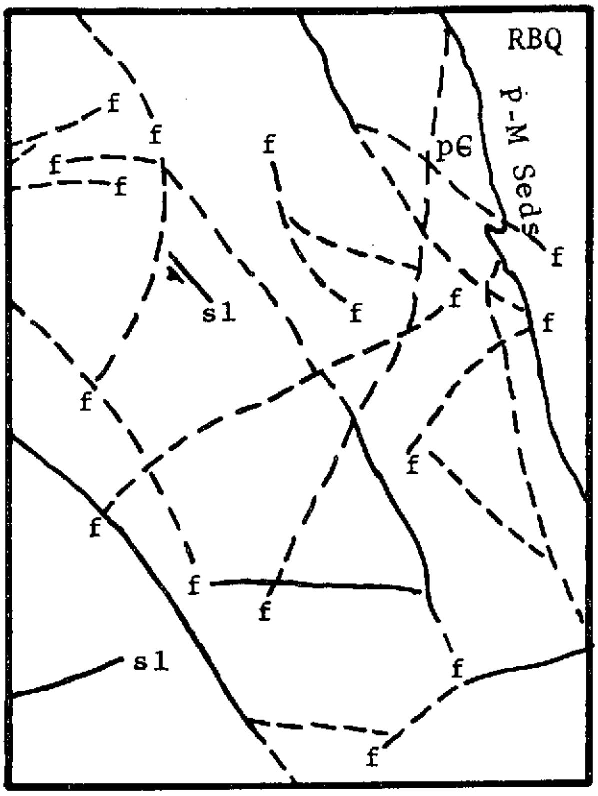
The first step in this evaluation was photo interpretations of all available remote sensor data. These data include; E.R.T.S. imagery (1:1,000,000), U-2 black and white photography (1:120,000), medium-altitude black and white photography (1:62,260), low-altitude black and white photography (1:22,000), high-altitude color photography (1:106,000), high-altitude color infrared photography (1:106,000), medium-altitude color infrared photography (1:53,000) low-altitude color photography (1:12,000), low-altitude color infrared photography (1:12,000), thermal infrared imagery (1:12,000), L.S.A.P. photography (1:40,000), and I^2S multiband photography (1:12,000).

During photo interpretations, a record was kept as to the relative utility of these various data types. This phase of the study was reported on previously (RSR 73-4, 30 September 1973). A graphic presentation of the information gained from the twelve various sensors is included in Figure 2 (pages 7 to 9). The differences in information content will be obvious to the reader by an examination of these geologic maps and, therefore, no explanatory text will be included on this subject.

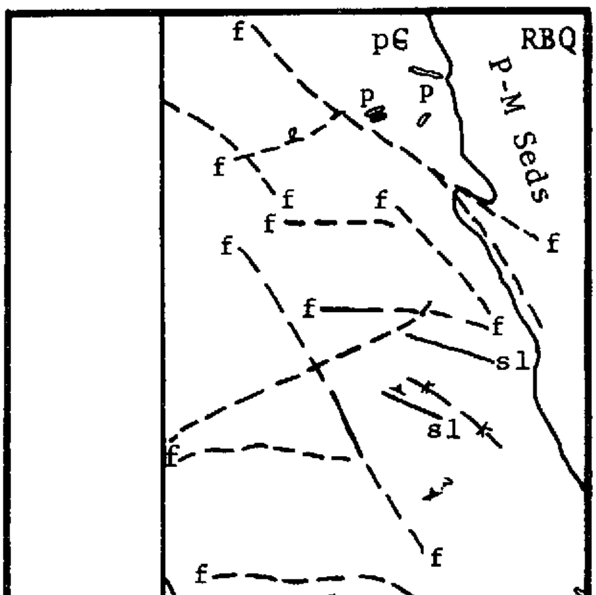
The photo interpretations involved no prior knowledge of the geology of the Ralston Buttes quadrangle. A series of rock samples was collected in an area outside the test site to help provide a basis for lithologic mapping, but no knowledge of the spatial relationships between rock types was gained.



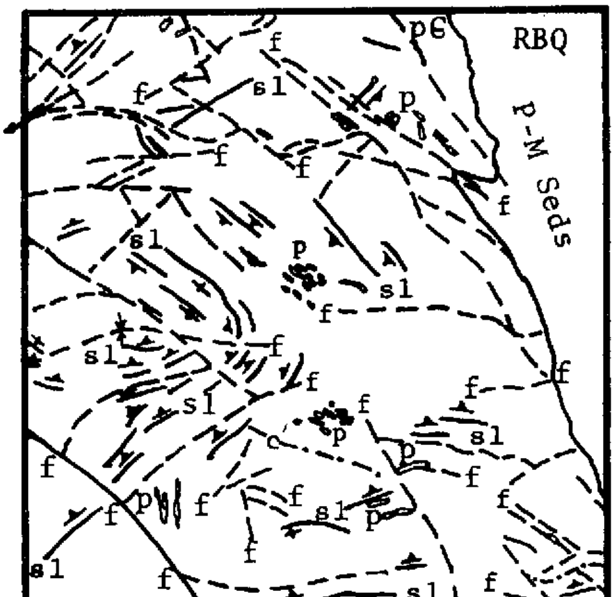
E.R.T.S.
1:1,000,000



U-2
1:120,000

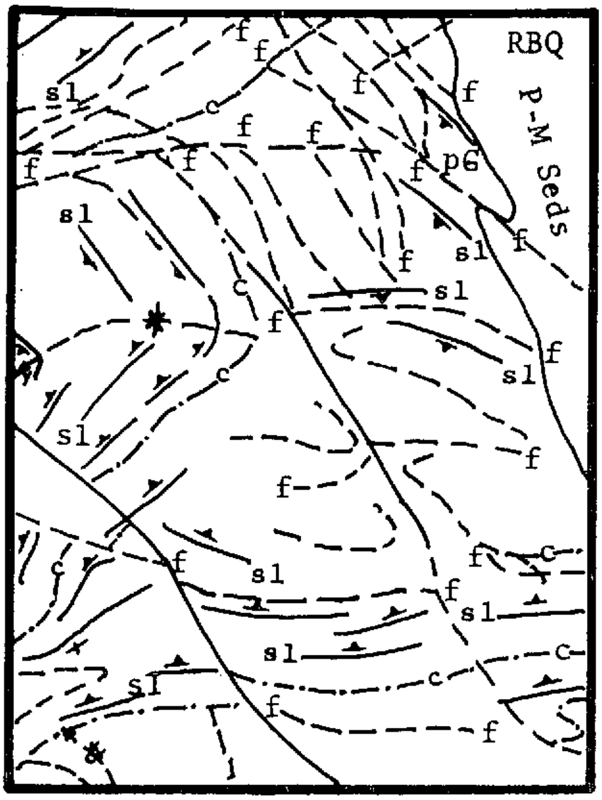


Med. Alt. B&W
1:62,260



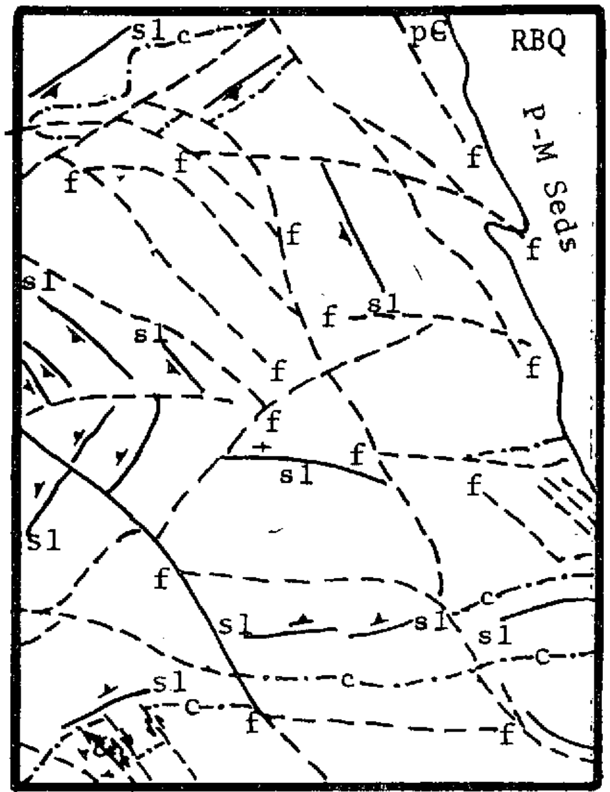
Low Alt. B&W
1:22,000

FIGURE 2A



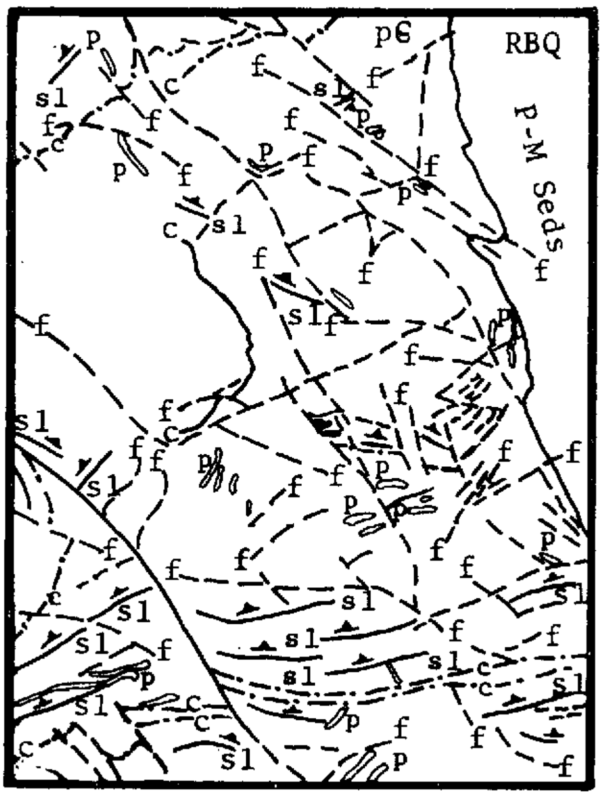
High Alt. Color

1:106,000



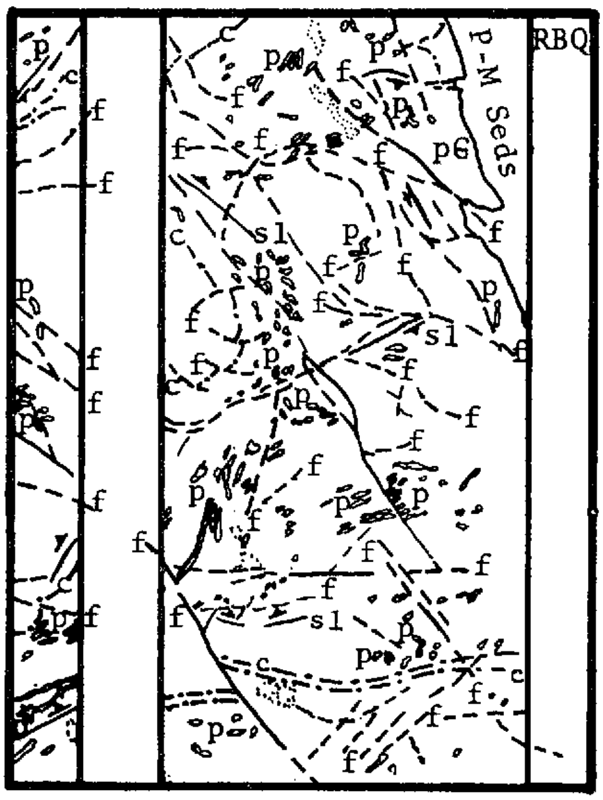
High Alt. CIR

1:106,000



Med. Alt. CIR

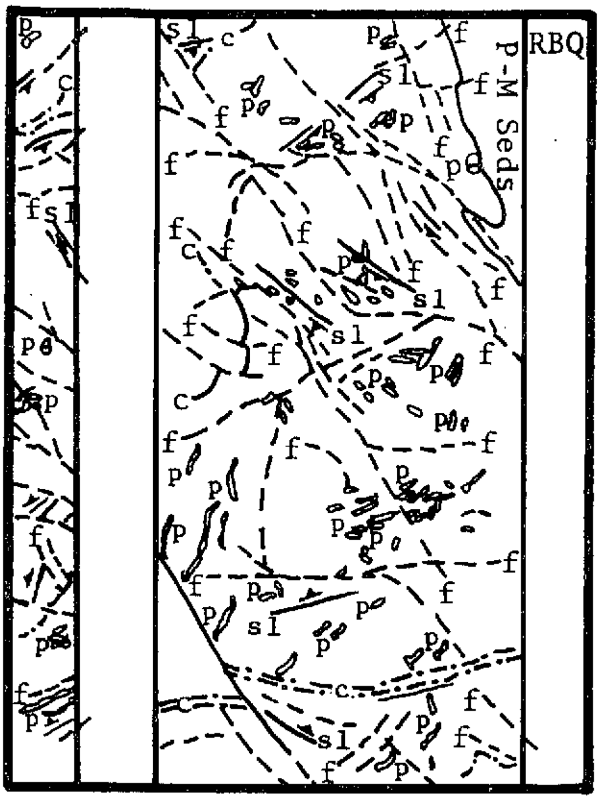
1:53,000



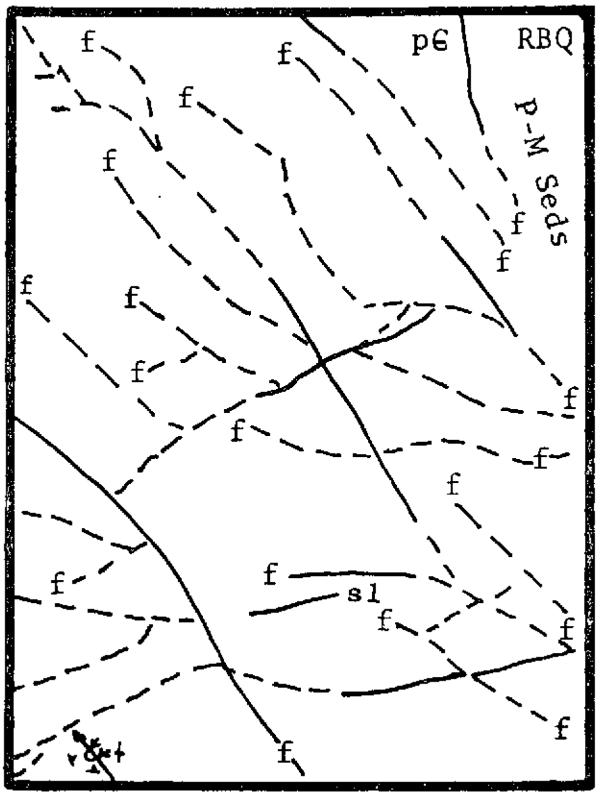
Low Alt. Color

1:12,000

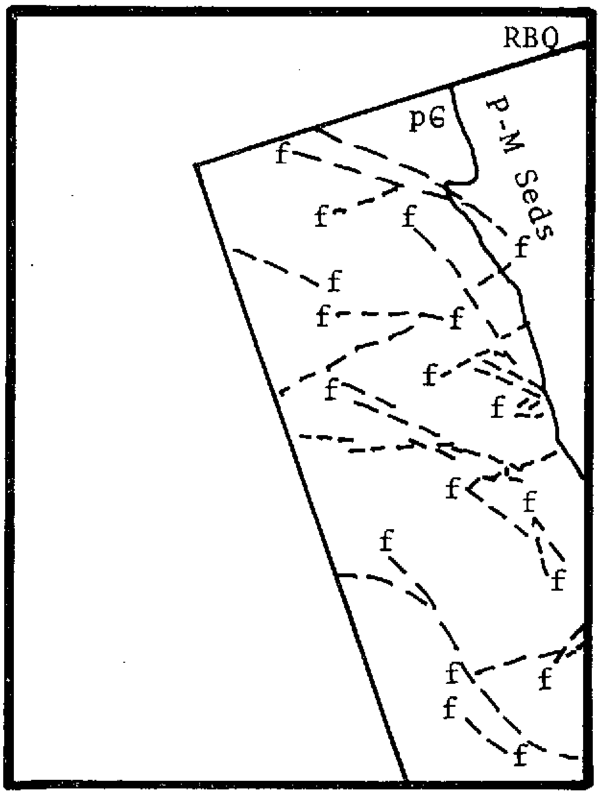
FIGURE 2B



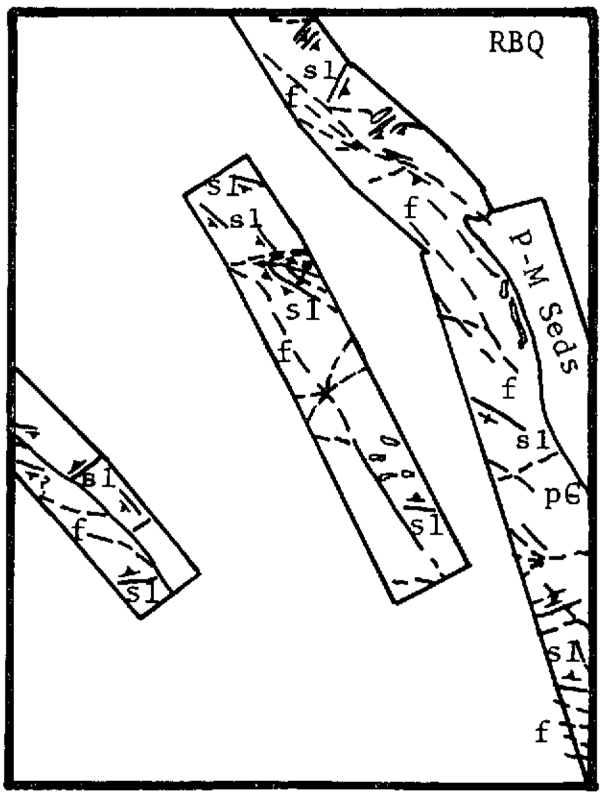
Low Alt. CIR
1:12,000



Thermal Infrared
1:12,000



LSAP
1:40,000



I²S Multiband Imagery
1:12,000

FIGURE 2C

Compilation Map

A remote sensing geologic map was compiled from the separate sensor data (Fig. 3). This somewhat simplified geologic map presents only the main fault and fracture systems mapped. Also presented are the most obvious foliations and lithologic contacts. In most cases the data compiled onto this final map should have a high order of correctness; in many instances the data compiled was seen on at least three types of sensor data examined.

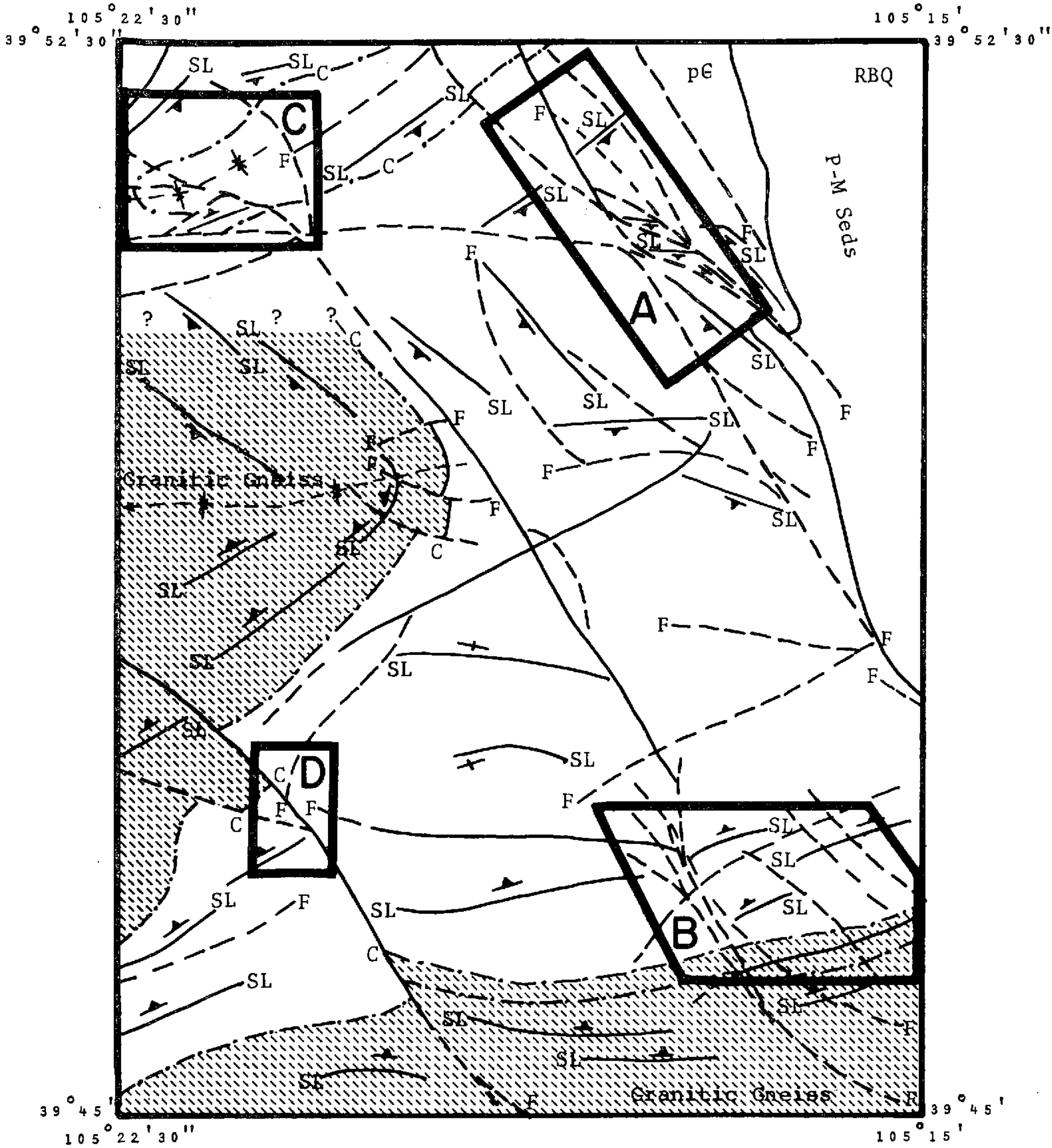
Target Areas

After preparation of the compiled geologic map, four target areas of potential uranium mineralization were chosen. This reduced the total area of interest from 42 square miles to six square miles, a reduction to 14.5% of the original area.

The choice of target areas in the Ralston Buttes test site was governed by the occurrence of two of the five main features that seem to control the uranium mineralization:

1. The existance of major NNW-trending fault zones within the metasedimentary rocks. Areas of intense fault bifurcation are especially prospective as exploration targets.

2. Faulting at an angle to metamorphic foliation (s1), rather than along it, as the former causes fault dilation and greater associated brecciation. This brecciation provides excellent loci for mineralization.



COMPILED REMOTE SENSING GEOLOGIC MAP

FIGURE 3

0 1 2 Miles
Scale

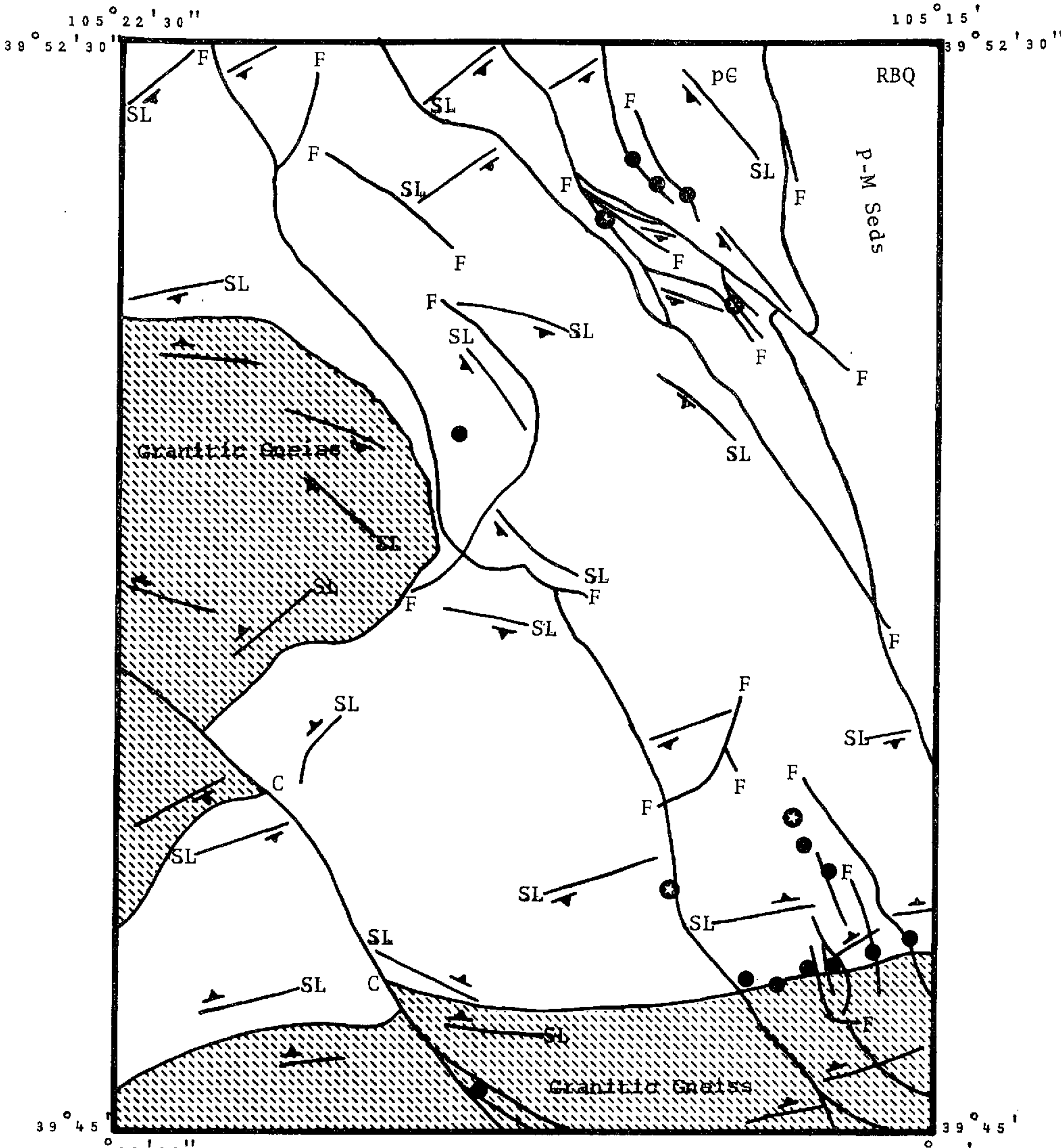
Target Areas

On the basis of these two parameters, four target areas were chosen in decending priority from A to D. In all cases extreme fault bifurcation is present and faulting is oblique to metamorphic foliation. The priority assignment was given on the basis of the relative intensity of fault bifurcation and fault obliqueness to foliation .

Comparison

A simplified geologic map was prepared for comparison to the compiled remote sensing geologic map (Fig. 4). This map was based on the one prepared by Sheridan, D.M., Maxwell, C.H., and Albee, A.L. in Geology and Uranium Deposits of the Ralston Buttes District Jefferson County, Colorado; U.S.G.S. Prof. Paper 520, 1967. Such features that were seen and compiled from remote sensing data were copied. Faults, obvious contacts (granitic gneiss-amphibolite/biotite gneiss) and foliations were transposed for comparative purposes.

In most cases major fault systems, general foliation orientation and the major contacts match very closely. Uranium mineral occurrences and mines also were plotted to compare with the four major target areas. The two highest priority target areas (A and B) encompass 11 out of 13 of the known uranium occurrences and 4 out of 4 of the uranium mines.



PUBLISHED GEOLOGIC MAP

0 1 2 Miles

Scale

Uranium Occurences ●

Uranium Mines ✪

FIGURE 4.

Conclusions

The accurate mapping of the geology and successful targeting of most of the uranium occurrences indicates that remote sensing applied to uranium exploration in areas of Precambrian vein-type deposits can be a very effective exploratory tool.

Future Plans

This summer the four target areas outlined will be investigated to determine the extent and appearance of uranium mineralization. Ground reconnaissance exploratory techniques will be evaluated as to their applicability to uranium exploration as well as their applicability to ground support of basic remote sensing data utilized in mineral (uranium) exploration.

Field activities will include:

1. Checking geologic interpretations (minor)
2. Ground scintillometry surveying
3. Soil radon surveying
4. Sulfur gas sampling
5. Biogeochemical and geobotonical sampling
6. Soil and stream sediment geochemistry

Hydrogeology-Mosquito Range

Introduction

The purpose of this project is to study the hydrogeology of the upper drainage, Middle Fork, South Platte River north of Fairplay, Colorado, and to evaluate selected remote sensors for hydrogeologic applications. Work to date has included field studies in the summer of 1973, preliminary observations as a result of the field work (CSM Remote Sensing Report 73-4, p. 14-24), and laboratory work to be discussed in this report.

Test Site

The test site has been described in the previous Remote Sensing Report (73-4), and will only be briefly discussed. The test site is a 50 square mile area on the east slope of the Mosquito Range and is the drainage basin of the upper drainage, Middle Fork, South Platte River. The area is part of the east flank of the Sawatch arch with eastward-dipping Paleozoic sedimentary rocks forming a homoclinal sequence. Quaternary glacial deposits of varying thickness are found in the intermontane valleys.

Five hydrogeologic units were delineated based on their similarity of ground water properties: 1) Precambrian granites, gneisses, and schists, 2) Pre-Pennsylvanian sedimentary formations, 3) Pennsylvanian Belden Formation, 4) Upper Cretaceous and Tertiary intrusive rocks and 5) Quaternary glacial deposits. Domestic wells are currently withdrawing water from the glacial deposits and the Belden Formation.

Study During This Reporting Period

Work during this research period has mostly been laboratory studies of field data and field samples. Because the majority of this work is in progress and/or near completion, only a brief outline will be discussed. A final report on this research will be given at the end of the next reporting period.

Laboratory work includes:

1) Preparation of a geologic map (scale 1:24,000) to correlate with the photographic evaluations.
2) Preparation of a surficial geologic map (scale 1:24,000) from field work, and Mx184/Mx235 color photography.
3) Analysis of well log data for depth to ground water, thickness of surficial materials, and type of bedrock.
4) Water chemistry analysis of samples plus correlation with other existing water chemistry data.
5) Permeability determinations of glacial deposits from grain-size distribution analysis plus correlation with field infiltration tests.
6) Literature investigation of the major vegetation associations and of individual plant species to decide whether the plant phenology can be used to determine environmental factors of the area.
7) Petrographic studies of the Belden Formation with particular reference to the type and amount of cement.
8) Evaluation of aircraft photography for hydrogeologic studies.

Hydrogeology - San Luis Valley

Introduction

Research on the evaluation of the applicability of remote sensing techniques to regional hydrogeologic investigations has proceeded to the second stage of study. The first stage was a detailed study of a small area to determine the hydrogeologic properties of the various rock units and the general hydrologic conditions that exist in the San Luis Valley. The second stage involves extrapolation of information gained in the preliminary stage to a regional study with extensive use of remote sensing techniques.

First Stage Study

The area chosen for the initial study encompasses approximately 90 square miles of the San Luis Valley and Sangre de Cristo Mountains near Crestone, Colorado. Detailed hydrogeologic rock descriptions are included in the previous Semiannual Progress Report (73-4, p. 25-35), but in general the area includes fractured Precambrian igneous and metamorphic rocks and Paleozoic sedimentary rocks of the Sangre de Cristo Mountains, as well as extensive Quaternary alluvial deposits lying on a thick section of Tertiary sediments in the San Luis Valley.

Important general conclusions from this initial study are:

1) Essentially all permeability in the Precambrian and Paleozoic rocks of the Sangre de Cristo Mountains is fracture permeability. Air permeabilities measured by Core Laboratories of Denver on samples of Paleozoic sedimentary rocks range from less than 0.01 millidarcies to 0.09 millidarcies. At these low values, air permeability is roughly 2-3 times water permeability (Core Laboratories, personal communication, 1973). Regional permeability due to fracturing is estimated to be on the order of 0.1 to 0.5 darcys, four orders of magnitude greater than intergranular permeability. Fractures in the Sangre de Cristo Formation are more water-bearing than comparable fractures in pre-Sangre de Cristo Formation rocks.

2) An important hydrogeologic boundary in the San Luis Valley exists at the highest continuous blue clay layer, and separates a lower confined aquifer system from an upper semi-confined aquifer system. The confined aquifer is recharged primarily from the volcanic terrain west of San Luis Valley. The upper system has identifiable zones of recharge, lateral flow, and discharge.

3) Quaternary alluvial units can be subdivided into distinct, mappable, hydrogeologically-significant units.

4) Recharge to the upper, semi-confined aquifer occurs primarily from seepage of surface water into the alluvial

fans, though some hidden recharge from the fractured Precambrian and Paleozoic terrain also occurs. Most of the seepage into the alluvial fans occurs within the first 2 miles of flow over the fans.

5) Quaternary faulting affects ground water movement in the zone of recharge into the San Luis Valley. Ground water seeps and springs occur on the scarp-slope of several of the eroded fault-line scarps. This may be attributed to either ground water ponding behind an impermeable fault zone or to seepage because of an abrupt change in topography, or both. Ground water levels are believed to be more shallow east of the faults, because of the relatively shallow basement east of the fault-line scarps.

6) Pump tests, grain-size analysis, seepage studies, water chemistry studies and phreatophytes are important tools in the study of the hydrogeology of the San Luis Valley.

7) Remote sensing is a valuable tool in hydrogeologic studies. In general, the geologic factors affecting ground water movement can be better mapped on photography and imagery than in the field, with considerable addition of accuracy and savings in time. Most valuable of all the data appears to be low-altitude (1:20,000) color IR photography. The most desirable package of data appears to be high-altitude (1:100,000) color IR photography, low-altitude (1:20,000) color and color IR photography, and thermal infrared imagery.

Second Stage Study

The second stage of research involves extrapolation and expansion of research summarized above. The study area has been expanded from 90 square miles to approximately 4,000 square miles (Fig. 5) and is defined by the extent of rocks affecting recharge into the aquifers of the San Luis Valley, either by "hidden" recharge or by affecting streams that recharge the aquifers of San Luis Valley. The maximum extent of the area of study will be bordered on the east by the surface-water divide of the Sangre de Cristo Mountains, on the north by Poncha Pass, on the west by the continental divide, and on the south by the Rio Grande River and the ground water divide that defines the northern closed basin of the San Luis Valley. The area includes the same rock types as in the intital study area, plus extensive Tertiary volcanic rocks of the La Garita Hills (Fig. 6).

The specific objectives of the expanded research are:

1) To map hydrogeologically-significant rock units and structures in the Precambrian and Paleozoic rocks of the Sangre de Cristo Mountains and Tertiary volcanic rocks of the La Garita Mountains, and determine their influence on recharge into aquifers of the San Luis Valley.

2) To map the different phases of Quaternary alluvial development and determine the influence of these features on infiltration into the semi-confined aquifer and recharge into the confined aquifer of the San Luis Valley.

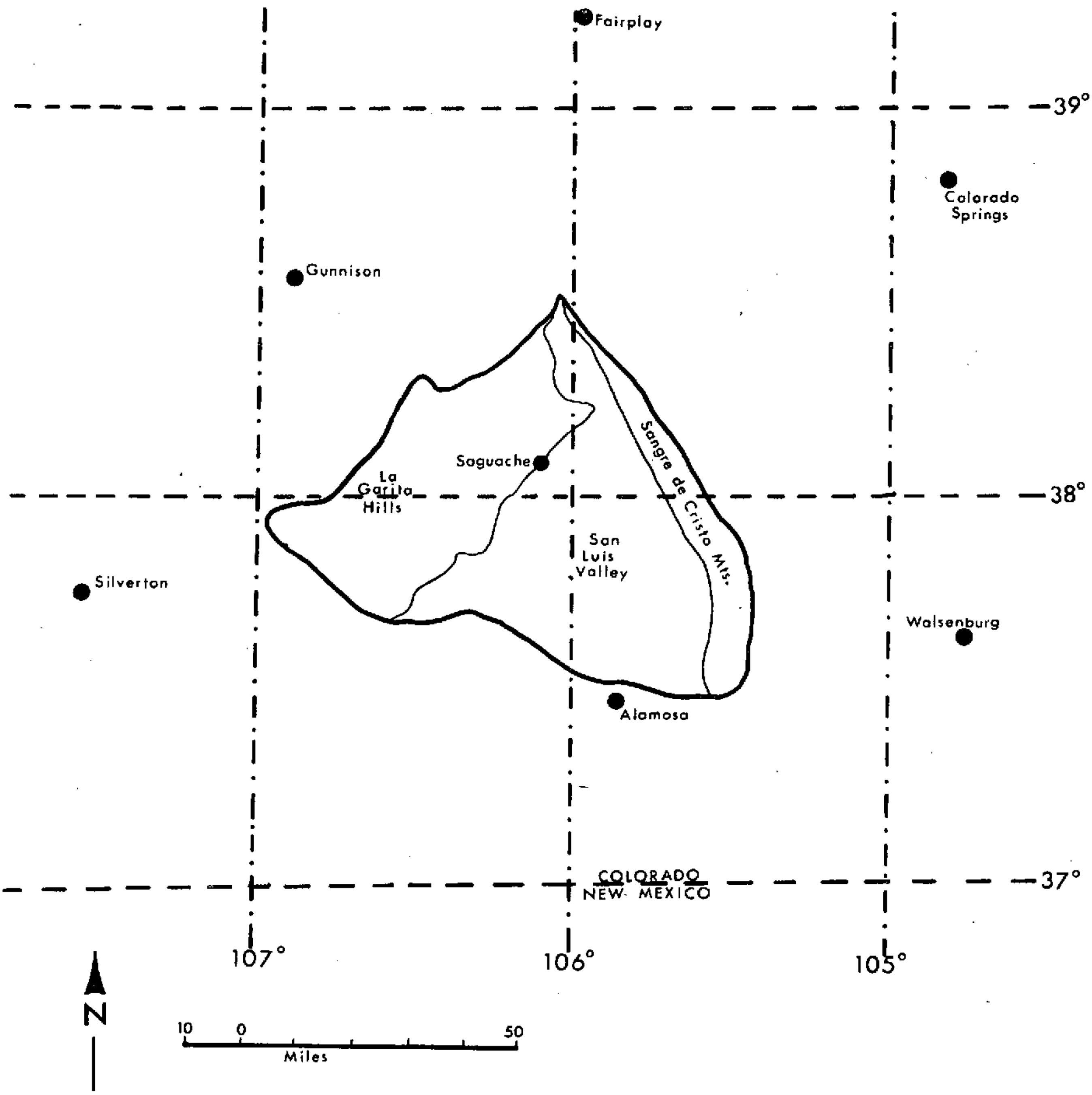


FIGURE 5. Location of San Luis Valley Hydrogeology test site.

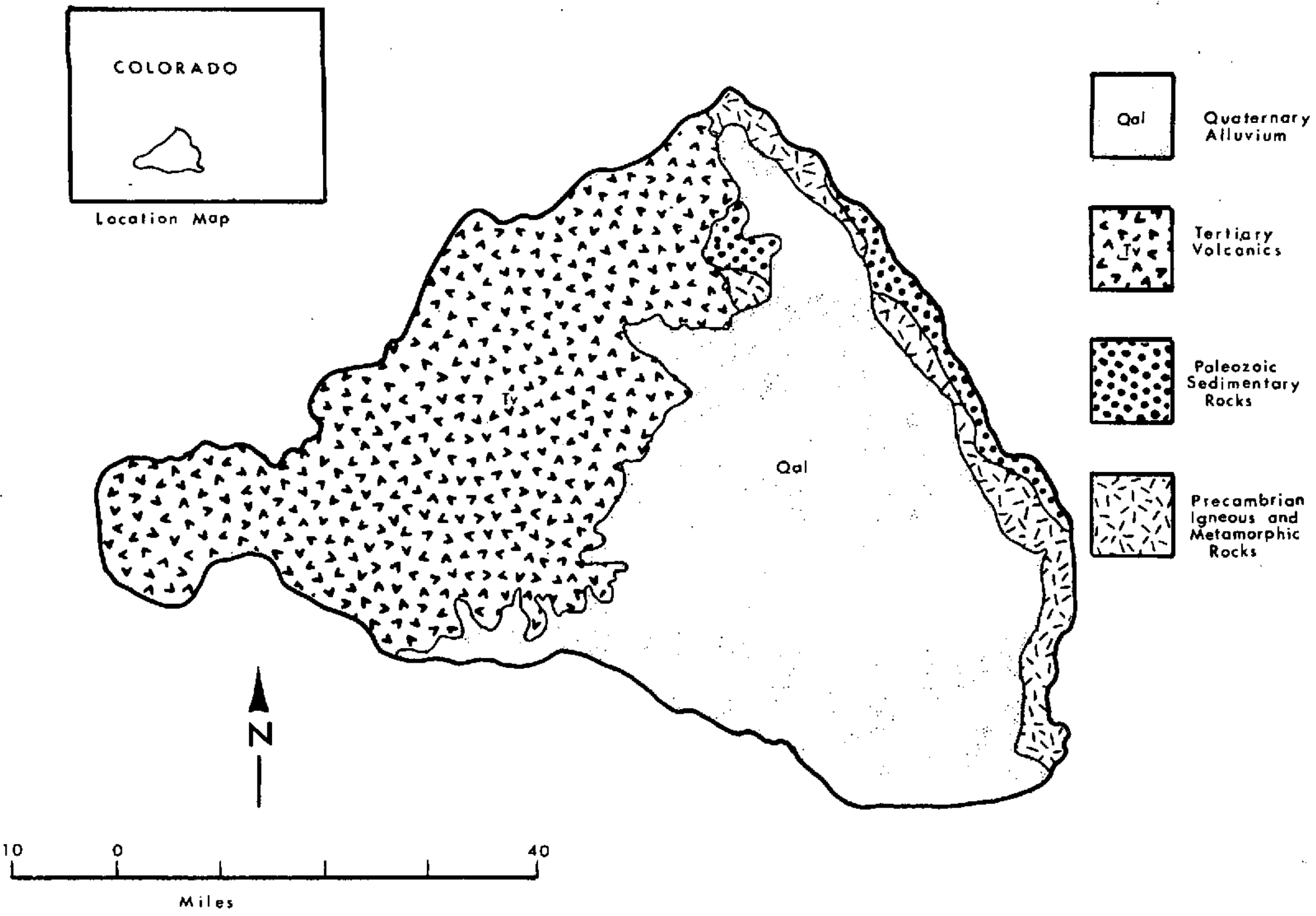


FIGURE 6. Generalized geologic map of San Luis Valley test site.

3) To define the water table of the semi-confined aquifer in the area of recharge as well as the direction and magnitude of ground water flow within that area.

4) To determine the chemical quality of recharging waters and ground water near the zone of recharge.

5) To further evaluate the applicability of remote sensing as a tool in hydrogeologic studies.

Remote Sensing Evaluation

Photo interpretation of the section of the Sangre de Cristo Mountains that falls within the study area, as well as the alluvial units on the east side of the study area, has been completed using conclusions drawn from the initial study as a basis for subdividing units. No attempt has yet been made to photo interpret the Tertiary volcanic units of the La Garita Hills or the alluvial units on the west side of the study area.

Rock Discrimination: In the Precambrian-Paleozoic rock complex of the Sangre de Cristo Mountains, rock discrimination is minimal. Throughout much of the study area the Precambrian rocks are strongly foliated, with the attitude of foliation often parallel to the bedding attitude of the Paleozoic sedimentary rocks. This, together with a general lack of color or vegetative differences between units allows discrimination only in places. Similarly, hydrologic properties vary only slightly between the units, with maximum variety of properties found in areas where rock discrimination is possible on photography, due to variations in outcrop resistance, surface texture, or drainage patterns. It is intuitively obvious that many factors that relate to ground water flow will be reflected in a units appearance on photography. Variations in porosity, cementation, permeability are likely to be shown as variations in outcrop resistance, surface drainage characteristics and associated vegetation. In the case of the Sangre de Cristo Mts., a similarity of hydrologic properties is associated with a similarity in appearance on photography. Several corollary conclusions follow from this analysis.

1) Large-scale, high resolution photography is best for viewing rock properties related to ground water flow.

2) Except where rock color differences or vegetation differences relate to hydrogeologically-significant rock units, high resolution black and white photography is as good as color or color IR photography for rock discrimination.

3) Stereo viewing is essential for rock discrimination.

In the San Luis Valley alluvial units, both scale and type of photography are important. Discrimination between alluvial units is minimal on high-altitude (1:100,000) color and color-IR photography. Low-altitude (1:20,000) color and color IR photography show excellent discrimination capabilities within the alluvial sequence based on geomorphic relation of units, surface texture and drainage patterns, color and vegetative differences. Color IR photography is more suited to this task because it separates relatively subtle vegetation variations. Again, stereo viewing is essential for maximum information extraction.

Structure: The most useful application of high-altitude (1:100,000) color and color IR photography appears to be in the identification of major fractures and fracture systems in the study area. The synoptic view afforded by the small-scale photography gives the interpreter a continuous view of a large area that is relatively uncomplicated by details of structure. Many major fractures are thus observed that are much less visible on larger scale photography. Color IR is preferable over color photography, again because of the separation of subtle vegetation variations that are often associated with soil moisture differences related to fracturing, both in the mountain complex and in the alluvium of San Luis Valley.

Low altitude (1:20,000) photography is essential for detailed mapping of fractures, both in the Sangre de Cristo Mts. and in the San Luis Valley. While the high-altitude photography reveals major fractures and fracture systems, the low-altitude photography gives information related to small-scale fractures, such as joints, that provides most of the shallow-depth permeability in the mountain complex.

The low-altitude photography also reveals the complexity of faulting in the Quaternary sediments in the study area. Color IR photography often gives information on the occurrence of springs or ground water ponding associated with faulting that is not as readily available on color photography.

Plans

Plans for the next reporting period include:

1) Field checking of photo interpretation work in the Sangre de Cristo Mts. and eastern alluvial areas.

2) Detailed field mapping of a small area in the volcanic complex of the La Garita Hills in preparation for photo interpretation of the western part of the study area.

3) Stream seepage studies.

4) Sampling of representative well and spring water.

5) Extensive measurement of soil temperature profiles, from the surface to 90 cm depth, to determine the affect of depth-to-ground water and direction of ground water motion on surface soil temperatures. This will be used to evaluate the physical phenomena related to thermal anomalies seen on thermal infrared imagery.