Hydrogeochemical and Stream Sediment
Reconnaissance of the National
Uranium Resource Evaluation Program

Semiannual Progress Report
April—September 1979

Primarily for the Rocky Mountain States of New Mexico,
Colorado, Wyoming, and Montana
and the State of Alaska
Hydrogeochemical and Stream Sediment Reconnaissance of the National Uranium Resource Evaluation Program

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Wayne A. Morris
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HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE OF THE
NATIONAL URANIUM RESOURCE EVALUATION PROGRAM
SEMIANNUAL PROGRESS REPORT
APRIL-SEPTEMBER 1979
PRIMARILY FOR THE ROCKY MOUNTAIN STATES OF NEW MEXICO, COLORADO,
WYOMING, AND MONTANA AND THE STATE OF ALASKA

by
Wayne A. Morris, Merle E. Bunker,
Glenn R. Waterbury, and Ray A. Waller

ABSTRACT

During this six-month period, reconnaissance sampling was done in five partially completed quadrangles, the North Slope of Alaska, and the Panhandle of Alaska. Detailed geochemical survey sampling was done in nine follow-up study areas. About 23 000 waters and 25 000 sediments were collected, bringing the LASL totals to 165 000 waters and 185 000 sediments from 220 000 locations. Almost all of the Rocky Mountain region and 85% of Alaska have been sampled. About 9000 water and 22 000 sediment samples were analyzed for the standard LASL multielement suite (uranium plus 43 additional elements). Work continued on improving and automating all analytical techniques and building a "state-of-the-art" emission spectrograph for waters and sediments. The second neutron activation line became operational in July, bringing the sediment throughput to the designed 400 samples per day. Seven multielement reconnaissance reports, one detailed geochemical survey report, one semiannual progress report, and one topical report were open filed.
I. INTRODUCTION

This semiannual report highlights the activities and progress of the Los Alamos Scientific Laboratory (LASL) from April through September 1979 in the Hydrogeochemical and Stream Sediment Reconnaissance (HSSR). The HSSR is sponsored by the Department of Energy (DOE) and managed through the DOE, Grand Junction Office, Colorado, as part of the National Uranium Resource Evaluation (NURE). The NURE is designed to provide information for estimating the nuclear fuel resources of the United States and to make available to industry information for developing and producing these resources. The LASL is responsible for conducting the HSSR primarily in the Rocky Mountain states of New Mexico, Colorado, Wyoming, and Montana and in Alaska.

II. ACTIVITIES

Sample Collection

Commercial contractors completed the reconnaissance sampling that had been partially done in previous years in the Thermopolis, St. Johns, Dubois, Elk City, and Hamilton quadrangles. Sampling in nine other partially sampled quadrangles is planned for FY 80 (Fig. 1). The sampling of the North Slope of Alaska, north of 66°N latitude (Fig. 2), was also completed. Although preparations had been made in 1978 to do this work in Alaska, the bidding process was not undertaken until April 1979 when supplemental funds were made available.

The southeastern Alaska sampling project (essentially the complete Panhandle) took advantage of end-of-the-year money that became available from the Grand Junction Office on August 24. At that point, the entire project for collecting samples from 4000 locations by the end of September was planned. One Bendix employee and 14 LASL people were involved in completing the field work.

Additionally, samples were collected for the following detailed geochemical surveys requested by the DOE Grand Junction Office:

- Pie Town area, west-central New Mexico: follow-up ground water study of anomalous uranium values obtained from HSSR of the area, particularly from the Baca and Mesa Verde formations.

- Bozeman quadrangle, Montana: follow-up on HSSR data that indicated possible uranium mineralization in volcanogenic sediments, Precambrian gneisses and schists, and quartz pebble conglomerates.

- Grants Mineral Belt, west-central New Mexico: study to provide a picture of HSSR data for sandstone-type uranium deposits and a geologically similar but nonmineralized region.

- Oscura Mountains-San Andres Mountains, southern New Mexico: follow-up study to investigate above-background HSSR uranium values in sediments from an area of fault zones in Precambrian granites.
Fig. 1. Status of LASL HSSR sampling in the conterminous Rocky Mountain states as of September 30, 1979.
Fig. 2. Status of LASL HSSR sampling in Alaska as of September 30, 1979.
Vallecito Creek-Needle Mountains, southwest Colorado: a complement to DOE study of Precambrian quartz pebble conglomerates and follow-up on HSSR data that indicate possible uranium deposits.

Sawatch Range, central Colorado: detailed investigation of vein deposits along or near fault contacts between Precambrian granites and Paleozoic or Mesozoic sedimentary rocks.

Red Creek Quartzite, northeast Utah: complement to DOE geologic study of Red Creek quartzite in Uinta Mountains as part of uranium potential investigation of Precambrian quartz pebble conglomerates.

Spring Creek, northwest Colorado: follow-up on HSSR data to improve uranium resource estimates of the Browns Park and North Park formations, complementary to other DOE studies of these formations.

Southern Powder River Basin, northeast Wyoming: investigation of ground waters from the Fort Union and Wasatch formations along the axis of the major mining districts to improve resource estimates for areas outside known uranium deposits.

The Vallecito Creek detailed survey was designed to complement the world-class uranium potential study of that area by the Colorado State University. Because of the extremely rugged terrain of the Weminuche Wilderness and because all sample locations needed to be referenced specifically to the local geology, the LASL undertook the field work. It took four man-months to complete; one Bendix geologist and 13 LASL employees collected samples from the 526 locations using two outfitters.

During the past six months, about 23,000 water and 25,000 sediment samples were collected, bringing the LASL program totals to 165,000 waters and 185,000 sediments. Almost all of the Rocky Mountain region and 85% of Alaska have been sampled. The status of the LASL sampling as of September 30, 1979, is shown in Figs. 1 and 2.

Sample Analysis

Fluorometry. Some 7700 water samples from nine quadrangles were analyzed for uranium, and the results were transmitted to the data base management group.

A modification in the fluorometric determination of uranium in water is being tested in an effort to improve sample analysis rates and reliabilities. The modification uses a GEOCO Rotating Fusion apparatus which has an automatic temperature programming system. After the 0.20-mL aliquot of sample water has been dried in the platinum dish, a LiF-NaF pellet is added, and the dish is transferred to the GEOCO apparatus for the programmed temperature cycle to dry and fuse the sample plus pellet. The main problem encountered was the efficient removal of heat. The eight large propane burners generate sufficient
heat to break the hood windows and melt plastic connections. Remodeling the hood exhaust system to improve heat removal and installation of heat shields and metal connectors were completed in one fume hood. A comparison of fusions using the GEOCO and the existing modified Fletcher burners has been started. If the GEOCO proves to be superior, as anticipated, two additional GEOCO burners will be installed.

Interference studies with manganese, iron, magnesium, and calcium at different parts per billion (ppb) levels of uranium are continuing. The studies with manganese and iron have been completed; those with magnesium are approximately 60% complete.

Plasma-Source Emission Spectrography. Using an inductively coupled plasma source and a 3.4-m direct-reading spectrograph, 8700 water samples were analyzed for calcium, cobalt, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, lead, titanium, and zinc, all in ppb.

Emphasis on quality control is being increased, and features were added to the SAMPLE program which warn the operator of possible nebulizer clogging or detect apparent shifts in background continuum radiation levels. These calls for tests to determine if corrective action is necessary. These improvements will allow more reliable detection of results that may be erroneous due to nebulizer clogging. They also will increase the accuracy of the results at concentration levels near the detection limits of the elements where the apparent signal is greatly influenced by changes in background radiation.

An automatic sample changer has been mechanically perfected so that it can be operated in a reliable manner. A program has been developed for rapidly assigning the proper sample numbers to changer-processed samples. The computer program for analyses using the changer has been tested and is fully synchronized to changer operation. In short, all aspects of the sample changer system function as planned.

In addition, a special analysis program was started to determine the reproducibility of results for actual samples over an extended time period and to pinpoint factors that adversely affect the system. This program consists of twice-daily analyses of two natural water samples, selected because they have a high salt content, especially calcium, magnesium, and sodium salts, which are known to cause analytical difficulties. Classical spectrochemical analyses of these two samples also showed high contents of potassium, strontium, lithium, and boron. Examination of photographic spectra characterizing the plasma has shown that high strontium impurity levels can cause problems with the system. Scattered light from potassium and lithium is a well recognized ICP problem. Space limitations on the Ebert spectrograph used in the system prevent monitoring all of these lines but LASL chemists will be able to do so on the new direct reading spectrograph being built for HSSR analyses.

Arc-Source Emission Spectrography. Altogether, 23 300 sediment samples were analyzed for beryllium and lithium in the part per million (ppm) range by arc-source emission spectrography during this report period. Some problems occurred with samples having high calcium concentrations, which interfere with the lithium line (610 nm) used to determine that high lithium is present in the sample. This line was used when the lithium concentrations were above 10 ppm and the lithium line at 671 nm was used for lower concentrations. Two changes were made: the change-over level was increased to 50 ppm, and the values from both lithium lines were printed out for the operator whenever there was a large difference in values from the two lines. The increase in the
change-over level eliminated most of the problems; the others are detected and solved from the values from the two lines.

Advanced Multisource Direct-Reading Emission Spectrograph. Construction of the multisource direct-reading spectrograph for analyses of liquids and solids is continuing. This spectrograph will determine all metallic elements and possibly some nonmetallic ones with most detection limits in the ppb range. It consists of a plasma source for liquids, with an associated optical system designed to take the light from the top of the plasma, and either an arc source or laser-induced plasma source for solids.

For the multielement analysis of water samples the list of elements being evaluated has been expanded to the following 25 elements:

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<thead>
<tr>
<th>Element</th>
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<tbody>
<tr>
<td>calcium</td>
<td>magnesium</td>
<td>titanium</td>
<td>barium</td>
<td>cadmium</td>
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<tr>
<td>cobalt</td>
<td>manganese</td>
<td>zinc</td>
<td>strontium</td>
<td>arsenic</td>
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<tr>
<td>chromium</td>
<td>molybdenum</td>
<td>sodium</td>
<td>aluminum</td>
<td>selenium</td>
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<td>copper</td>
<td>nickel</td>
<td>potassium</td>
<td>vanadium</td>
<td>mercury</td>
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<tr>
<td>iron</td>
<td>lead</td>
<td>silicon</td>
<td>boron</td>
<td>lithium</td>
</tr>
</tbody>
</table>

Preliminary setting of the exit slits for these elements was completed except for arsenic, selenium, and potassium. The best lines for arsenic and selenium are in the low ultraviolet region where the light throughput for these wavelengths may fall off because of the long optical path length and the large number of reflecting surfaces external to the spectrograph. The LASL has had a large degree of success in using a fiber optic ribbon to conduct light from the line position by the entrance slit to a photo detector mounted some distance away. This also has the advantage of eliminating second order ultraviolet light.

For monitoring the effects of background, the argon 415.859-nm line and the OH bandhead at 306.36 nm have been set. Slits have, additionally, been set on germanium and indium for internal standard use.

Instrumentation has been designed and built into the system to permit the rapid setting of slits and the alignment of the external mirror optics. Electronic gas-flow controllers now regulate both the nebulizer argon flow and the coolant argon flow. The box containing the flow controllers also controls the solenoids for the argon and water supply lines and has been designed to permit both manual and computer control of all functions.

Analysts are in the process of obtaining detection limits for the elements that have lines set on the new spectrograph and on the existing system. As soon as reasonable results are obtained for these, they will begin to establish detection limits for the additional elements.

A continuing program is underway for the preparation of individual elemental water standards from high purity spectrographic materials. Also, two multielement solutions have been obtained from Spex Industries; these solutions encompass both the present elements and the newly specified elements for this project.

To take advantage of the higher speed of the multiplexer on the new direct-reading spectrograph (3000 readings per second compared to 200 on the previous system), FORTRAN was selected as the programming language instead of BASIC. The standard program is running satisfactorily and should require modification only after interelement effects are determined and the correct analytical procedure is established.
X-Ray Fluorescence. About 25 000 sediment samples were analyzed for nine elements by x-ray fluorescence. A 40-position sample changer was investigated to determine if it could replace the 20-position changers now in routine use. The 40-position changer could increase sample throughput by 40 per day if it proved satisfactory. New 12.5-mm cells were made to fit the new changer, and it was installed in one of the two x-ray fluorescence analyzers. The new changer functioned well mechanically, but the limits of detection were not satisfactory for six of the nine elements determined. This is attributed to the nearly eight-fold reduction in sample surface area exposed to the x-ray beam in the new 12.5-mm cells as compared to the 31.8-mm cells for the 20-position changer. As this new changer will not accommodate the larger cells, the investigation is being deferred until techniques for lowering the detection limits can be found or developed.

Delayed-Neutron Counting. During this six-month period, 169 water samples, found by fluorometry to have greater than 40 ppb uranium or to exhibit interference problems, and 22 000 sediment samples were analyzed for uranium by delayed-neutron counting (DNC). Two of the water samples contained more than 1300 ppb uranium.

Neutron Activation Analysis. Some 22 000 sediment samples were assayed for 31 elements (including uranium) with the two automated analysis systems. Each system combines DNC and neutron activation analysis (NAA) assaying, including one delayed-neutron counter and four Ge(Li) γ-ray detectors. Through the installation of two large magnetic disk storage units and other peripherals, it is now possible to operate the two analysis systems independently, using a single PDP-11/34 computer. The final processing of the analytical data is done with a PDP-11/60 computer system.

The second analytical line was first operated at its designed throughput of 200 samples per day on July 18. This system has continued to operate satisfactorily, with only occasional mechanical failures. To date, only a small fraction of the data acquired with the second line has been analyzed because of the many weeks required to accurately calibrate the system, i.e., to establish the efficiencies of the four γ-ray detectors and to adjust the "effective" neutron cross-sections in the analysis code until the element assays of well-characterized reference materials match the standard values.

Data Management
Fifteen new data bases were loaded from 14 462 field data sheets, bringing the total to 150 data bases with 195 819 locations, representing 2 459 268 pieces of data. All data bases have been moved from NOS disk to MASS for storage, each on two separate nodes. All analytical files are also stored on MASS. Programming efforts have produced codes to check the input data for errors and to check the internal consistency of information in the data bases. A limited contour plot capability was developed; plots can be made of any elemental concentration against any other. The new Versatek plotter makes clearer plots and is faster than the old Calcomp. Many special statistical analyses were made to study particular areas of interest in multielement correlations.

Reporting
Ten LASL reports were open filed by the DOE during the six-month period; each is summarized in the appendix. These reports cover quadrangles in the Rocky Mountain states (Fig. 3) and in Alaska (Fig. 4) and provide uranium and
Fig. 3. Status of LASL HSSR reports for the conterminous Rocky Mountain states as of September 30, 1979.
Fig. 4. Status of LASI HSSR reports for Alaska as of September 30, 1979.
multielement analyses of water and sediment samples along with the field data recorded at each sample location. Several other reports are in various stages of completion and, as indicated in Figs. 3 and 4, will be open filed in the near future.

The field and elemental data for each of the open-filed reports are available on magnetic tape from: GJOIS Project, UCC-ND, Computer Applications Department, 4500 North Building, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tennessee 37830.
APPENDIX

ANNOTATED BIBLIOGRAPHY OF LASL HSSR REPORTS OPEN FILED BY THE US DEPARTMENT OF ENERGY, GRAND JUNCTION OFFICE, COLORADO, BETWEEN APRIL 1 AND SEPTEMBER 30, 1979


During this six-month period, reconnaissance samples were collected by the Los Alamos Scientific Laboratory from approximately 60,000 locations in the Rocky Mountain states and Alaska. To date, all of the Rocky Mountain region and 65% of Alaska have been sampled. Water samples from 13,771 locations were analyzed for uranium by fluorometry or delayed-neutron counting. Water samples from 12,993 locations were analyzed for 12 other elements by emission spectroscopy. Sediment samples from 8,820 locations were analyzed for uranium and 31 other elements by combined delayed-neutron counting and neutron activation analysis. Sediment samples from 22,596 locations were analyzed for two additional elements by x-ray fluorescence. Fourteen reconnaissance reports, one pilot study data release, one quarterly progress report, and a manual of field procedures were open filed.


During the summer of 1977, 1268 water and 1206 sediment samples were collected from 1292 lakes and streams throughout the McGrath and Talkeetna quadrangles in south-central Alaska. The water samples were analyzed for uranium and 12 other elements, and the sediment for uranium, thorium, and 41 other elements. Only the uranium and thorium data are discussed. Uranium concentrations in water samples range from below the 0.02-ppb detection limit to 19.64 ppb. In general, lake waters contain somewhat less uranium than stream waters, and the highest concentrations in both sample types were found in or near the Alaska Range. Uranium concentrations in sediment samples range from 0.10 ppm to 172.40 ppm. The highest concentrations are in samples collected in the Alaska Range near areas of felsic igneous rocks. On the basis of the combined water and sediment data, six areas were delineated to be most favorable for significant uranium mineralization.


Totals of 1234 water and 1732 sediment samples were collected from 1743 locations in the Craig quadrangle. All water samples were analyzed for uranium and 12 other elements. Sediment samples were analyzed for uranium, thorium, and 41 additional elements. Only uranium and thorium are discussed.
The uranium concentrations in water samples range from below the detection limit of 0.02 ppb to 856.44 ppb. Waters with anomalous uranium concentrations were found southwest of Craig, in Middle Park, and in the southeast corner of the quadrangle. Sediment samples have uranium concentrations that range from 1.53 ppm to 385.60 ppm. Eight areas with anomalous uranium concentrations are delineated. The two areas containing the highest uranium concentrations are in the Sand Wash basin and in the Park Range northeast of Steamboat Springs.


Totals of 1148 water and 1721 sediment samples were collected from 1796 locations in the Dillon quadrangle. All water samples were analyzed for uranium and 12 other elements. Sediment samples were analyzed for uranium, thorium, and 41 additional elements. The uranium contents of water samples range from below the detection limit of 0.02 ppb to 79.31 ppb. Most water samples having anomalously high uranium contents were collected in areas underlain by felsic rocks of the Boulder, Pioneer, and Idaho batholiths. The uranium contents of sediment samples range between 0.95 and 130.50 ppm. Anomalous uranium values in sediment are associated with felsic rocks of Cretaceous batholiths and Belt quartzites near the Montana/Idaho border. Samples having uranium contents significantly above local background levels also occur in Tertiary strata adjacent to the anomalous areas in the crystalline terranes.

Kosiewicz, S. T., 1979, Automated data handling of uranium analyses for the NURE program, GJBX-79(79), 12 p.

Data acquisition and processing for uranium analyses by the pellet fluorometric method are automated. Upon command from a dedicated minicomputer, voltage signals are processed. Then, concentration data are printed on paper and also placed directly on a magnetic tape cassette. Comparisons of more than 500 calculations done with a desk-top calculator and those done by the automated system show excellent agreement. Benefits of the automated system include decreased errors and savings in time and labor.


During the summer of 1977, totals of 1351 water and 656 sediment samples were collected from 1832 locations in the La Junta quadrangle. For both water and sediment populations, clusters of samples containing approximately the highest 5% of the reported uranium values were chosen for discussion. These values were >20 ppb for waters and >8 ppm for sediments. The uranium concentrations in waters range from below the detection limit of 0.02 ppb to 748.40 ppb, with a mean of 7.22 ppb. Five clusters of samples containing relatively high uranium values are defined. The cluster associated predominantly with the Morrison formation has the most favorable lithologic and structural
setting for possible uranium mineralization. Sediments have uranium concentrations that range between 1.60 ppm and 52.20 ppm, with a mean of 4.54 ppm. The majority of sediment samples with relatively high uranium concentrations were collected in four areas. The cluster of samples containing the highest uranium values for sediments and the cluster containing the highest uranium values for waters are coincident.

Shannon, S.S., Jr., 1979, Uranium hydrogeochemical and stream sediment reconnaissance of the Lamar NTMS quadrangle, Colorado, including concentrations of forty-three additional elements, GJBX-64(79), 149 p.

Totals of 1043 water and 734 sediment samples were collected from 1589 locations in the Lamar quadrangle. Water samples were collected from wells, streams, ponds, and springs; sediment samples were collected from streams, ponds, and springs. Water samples were analyzed for uranium and 12 additional elements. The mean uranium content of all water samples is 17.63 ppb. Waters from 21 wells contain more than 100 ppb uranium. Clusters of anomalous water samples, containing more than 50 ppb uranium, are delineated. Sediment samples were analyzed for uranium, thorium, and 41 other elements. The mean uranium content of all sediment samples is 7.2 ppm. Major clusters of sediment samples containing more than 21 ppm uranium are limited to areas underlain by the Pierre shale. In-situ leaching of uranium might be feasible in areas in the southern half of the quadrangle where well waters have a high uranium content.

Shannon, S.S., Jr., 1979, Detailed uranium hydrogeochemical and stream sediment reconnaissance of the Tallahassee Creek, Badger Creek, Castle Rock Gulch, and Buffalo Gulch areas in the northwestern part of the Pueblo NTMS quadrangle, Colorado, GJBX-42(79), 109 p.

In the fall of 1978, the Los Alamos Scientific Laboratory conducted a detailed geochemical survey for uranium in the northwestern part of the Pueblo quadrangle as a follow-up to the uranium reconnaissance. Totals of 62 water and 620 sediment samples were collected from 626 locations within four areas covering 400 km². All water samples were analyzed for uranium and 12 additional elements; all sediment samples were analyzed for uranium, thorium, and 41 other elements. Relatively high uranium concentrations in water and sediment and high uranium-to-thorium ratios in sediment indicate the Tallahassee Creek and Castle Rock Gulch areas to be favorable places to search for uranium ore bodies.

Sharp, R.R., Jr., et al, 1979, Results of elemental analyses of water and waterborne sediment samples from the Fairbanks NTMS quadrangle, Alaska, GJBX-74(79), 218 p.

During the late spring and then again in late summer 1977, lake and stream water and bottom sediment samples were collected by the University of Alaska. Their study will attempt to identify variance on total uranium contents related to natural factors such as seasonal changes, source types, and geologic/geographic environments. The Alaskan investigators will complete
a detailed analysis of variance study of these data in the near future and a second open-file report will be forthcoming upon its completion.


During the summers of 1976, 1977, and 1978, 598 water and 1657 sediment samples were collected from 1775 locations within the Cortez quadrangle. Each water sample was analyzed for 13 elements, including uranium, and each sediment sample was analyzed for 43 elements, including uranium, thorium, and vanadium. Uranium concentrations in water samples range from below the detection limit of 0.01 to 241.47 ppb and have a median of 0.87 ppb and a mean of 3.80 ppb. Background uranium concentrations are 2-5 ppb in several non-mountainous regions but are much lower in mountainous areas. Water samples containing high uranium concentrations (>20 ppb) generally are associated with high conductivities, high concentrations of other metallic elements, and geologic units that are unfavorable for uranium mineralization. Uranium concentrations in sediment samples range from 0.51 to 76.41 ppm and have a median of 2.76 ppm and a mean of 3.08 ppm. Background uranium and metallic element concentrations decrease to the southwest from the highest values in the northeastern portion of the quadrangle.