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SAMPLE COLLECTION - AN OVERVIEW

OF THE

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by

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ABSTRACT

A Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) for uranium is currently being conducted throughout the conterminous United States and Alaska. The HSSR is part of the National Uranium Resource Evaluation sponsored by the US Department of Energy.

This ambitious geochemical reconnaissance program is conducted by four national laboratories: Los Alamos Scientific Laboratory, Lawrence Livermore Laboratory, Oak Ridge Gaseous Diffusion Plant, and Savannah River Laboratory. The program is based on an extensive review of world literature, reconnaissance work done in other countries, and pilot studies conducted by each laboratory. Sample-collection methods and sample density are determined to optimize the probability of detecting potential uranium mineralization. To achieve this aim, each laboratory has developed independent standardized field collection procedures that are designed for its section of the country. Field parameters such as pH, conductivity, climate, geography, and geology are recorded at each site. Most samples are collected at densities of one sample site per 10 to 23 km^2.

The HSSR program has helped to improve existing hydrogeochemical reconnaissance exploration techniques. In addition to providing industry with data that may help to identify potential uranium districts and to extend known uranium provinces, the HSSR also provides multi-element analytical data, which can be used in water quality, soil, sediment, environmental, and base-metal exploration studies.

INTRODUCTION

In 1973, the Atomic Energy Commission initiated a National Uranium Resource Evaluation (NURE). The major objective of this program is the assessment of the nuclear fuel resources in the US and Alaska (US Department of Energy, 1979). The NURE program is now administered by the Department of Energy (DOE) and consists of hydrogeochemical and stream-sediment reconnaissance, aerial gamma-ray radiometric surveys, topical geologic studies, world-class studies, subsurface geologic investigations, technology applications, and resource-estimation methodology.

This report is concerned with the Hydrogeochemical and Stream Sediment Reconnaissance (HSSR). Four DOE laboratories, Lawrence Livermore Laboratory (LLL), Los Alamos Scientific Laboratory (LASL), Oak Ridge Gaseous Diffusion Plant (ORGDP), and the Savannah River Laboratory (SRL), have conducted the hydrogeochemical program. Areas of responsibility are shown for each laboratory in Fig. 1. Each laboratory developed its own geochemical reconnaissance program for uranium based on time and funding constraints and emphasized the determination of uranium concentrations in both natural waters and waterborne sediments. This report summarizes the programs developed by the LASL, ORGDP, and SRL. The LLL program is not discussed because of the very small aerial coverage by this laboratory.

RECONNAISSANCE GEOCHEMICAL EXPLORATION

In the HSSR program, reconnaissance geochemical exploration can be readily defined as any method which employs a systematic search for uranium deposits by detecting one or more elements in sampling media. The analytical precision (reproducibility) required generally needs only to be quantitatively accurate enough to distinguish above and below background (Lovering et al, 1956). However, because relatively low concentrations of uranium can be commercially exploited, it is necessary to be able to analyze accurately concentrations of uranium as low as 0.01 parts per billion (ppb).

All of the laboratories use delayed neutron counting to analyze at least part of their samples. This method has proved to be precise, as well as rapid and inexpensive, for very low levels of uranium. Other major methods of analyses include neutron activation analysis (LASL, ORGDP), plasma-source emission spectrography (LASL, ORGDP), fluorometry (LASL, ORGDP), x-ray fluorescence (LASL), and atomic absorption spectrophotometry (ORGDP).

The media most commonly used in geochemical exploration are listed in Table I. Unfortunately no single medium is a panacea for the geologist, and the one selected depends on several variables, including the type of material available to sample, geology, climate, topography, and the geochemistry of the element(s) sought.

Geochemical sampling can identify the presence and aerial extent of new uranium districts and can extend old uranium provinces, but it cannot supply the third dimension--the depth of the body (Brown, 1971). Reconnaissance geochemical exploration is only one means of localizing areas of interest; for maximum success it is imperative to integrate all available methods of exploration and to utilize all geological, geochemical, and geophysical information available. In the HSSR, areas identified as favorable in the reconnaissance phase can then be used to guide detailed follow-up surveys.

THE SEARCH FOR URANIUM

During the complex decay of uranium to its various daughter products, several radioactive elements are formed that can be detected easily by direct radiometric methods. Simple, rapid methods using a gamma-radiation detector such as a Geiger-Muller or scintillation counter are ineffective where a relatively thin inactive overburden covers an ore body (Bowie et al, 1971). Because uranium is soluble and because of the recent use of highly sensitive analytical technology such as neutron activation analysis, which permits fast and relatively cheap automation-type programs, the use of geochemical methods of exploration has yielded favorable results.

Uranium in most rocks occurs as an oxide in the +4 valence. In weathering zones of surficial environments, the uranyl ion is oxidized to the +6 valence, which is easily leached from surface rocks and carried into solution in most natural waters. This hexavalent ion generally stays in solution until it is absorbed or encounters a reducing environment where it is precipitated as an hydroxide. Organic matter in streams and lakes provides favorable surfaces for the precipitation of uranium. However, uranium also will precipitate with ferric and manganic hydroxides, particularly where pH and carbonate ion concentrations are low (Dyck et al, 1971).

Uranium is extremely well suited for hydrogeochemical surveys because of its high solubility compared to most other metals (Bowie et al, 1971). General reviews of the use of hydrogeochemical prospecting are found in Hawkes and Webb (1962), Bradshaw et al (1973), and Levinson (1974) among others. However, the mobility of uranium depends on several factors, including the time of year, weathering and erosion, pH, Eh, absorption, the permeability of the geologic material in which water is in contact, and the content of clay minerals and colloids. In the HSSR program, time and funding constraints require that any field measurements taken are a maximum aid in evaluation of the data, yet require minimum time in the field to conduct. The field measurements taken by each laboratory, respectively, are listed in Table II.

Media used in the HSSR Program

In the HSSR program, stream water, ground water, and stream sediments are the major media used. However, organics were used by ORGDP in pilot studies and helium samples are collected by SRL in pilot and reconnaissance studies. Because much of Alaska is extensively covered by lakes, LASL collects lake waters and lake sediments. The types of samples collected in any area depend on the results of extensive literature research of studies in similar terrain having comparable geology and geography (Table II).

Stream waters may be most useful in the broad-scale detection of anomalous areas in both reconnaissance and detailed exploration programs (Saukoff, 1956; Grimbert and Loriod, 1968; Boberg and Runnells, 1971). This media is an invaluable tool in heavily forested and mountainous terrain in which access is difficult. Furthermore, according to Fix (1956), uranium can be considered to be a rough index of nearby geologic formations in most natural waters. However, natural waters must come into contact with mineral deposits and remain in contact with them long enough for some of the ore and/or indicator elements to be dissolved and for dispersion patterns to form. In addition, hydrosystems are generally very complex, and a knowledge of how these work is essential in the detailed interpretation of geochemical data.

Ground waters, because of their long residence time with subsurface rocks and potential to contain more dissolved minerals than surface streams, can provide invaluable subsurface data. Samples of well water and spring water may be particularly valuable for exploration in arid regions where ground waters not only penetrate deeply, but may be the only medium available to sample (Boyle et al, 1971). This medium is also useful in humid areas, where surface streams contain low uranium concentrations because of continual exposure of outcrops to rain and consequent leaching and removal of soluble uranium (Little and Durham, 1971). For optimum use, ground water samples should be taken from aquifers at known depths (Denson et al, 1956).

Stream sediments (wet or dry) also are valuable indicators in outlining geochemical provinces. In the last 12 years, stream sediment surveys have been the chief method for geochemical reconnaissance exploration (Rose, 1977). Information from sediment samples can be related directly to the catchment basin of each stream. This type of medium is not affected directly by climatic changes as readily as surface waters are. Consequently, uranium values in sediment samples are generally more consistent and yield more easily recognizable anomalies than do uranium values in surface waters that fluctuate between wet and dry periods. In areas of high relief or in desert areas, stream sediment samples may be the only available sample medium. In Sweden, stream sediments have been used extensively (Brundin and Nairis, 1972) and as a geochemical prospecting medium are clearly desired over water samples by some authors (Morse, 1971). Investigators differ as to what type of sediment sample to collect; Morse (1971) favors samples composed of clastics, Dyck et al (1971) favor organic-rich samples.

In some regions of Alaska that are extensively covered by lakes and also underlain by permafrost, the low relief results in complex and disrupted drainage systems with poor circulation and with sediments that are irregularly deposited. Therefore, lake waters and lake sediments may give the best results in these areas. These type water samples have very low uranium concentrations and a laboratory with sufficient analytical capability is needed. Dyck et al (1971) have showed that lake sampling in parts of the Canadian Shield is effective in delineating areas favorable for future exploration and is faster than stream sampling; however, they emphasized that lakes should be sampled near inlets and outlets to obtain best results. Other surveys utilizing lake samples include MacDonald (1969), Meyer (1969), Boyle et al (1971), and Dyck (1974).

Various combinations of media may provide the optimum exploration method. For example, in a rain-forest terrain, a stream water (and possibly stream sediment) sample coupled with a vegetation samples might be optimum. Each particular physiographic province should be studied separately, and all sampling media should be thoroughly tested in the orientation studies (Bradshaw et al, 1973; Levinson, 1974), particularly if vegetal or biogeochemical type media are used. Biogeochemical studies have been used with some success especially in arid areas (Bowie et al, 1971). For example, in the Colorado Plateau, a deep-rooted vetch, Astragalus pattersoni, requires considerable selenium to grow. Because selenium is associated with uranium deposits in this area, this species can be used as an ore guide (Massingill, 1979). However, biogeochemical studies involve complex interrelationships between geology, soil science, botany, and ecology and should be used with extreme caution (Levinson, 1974).

Ancillary Elements

In searching for uranium deposits, the major element of interest is obviously uranium. But certain other elements may form a much wider dispersion halo resulting from their chemical behavior and weathering characteristics and may act as supplemental indicators of uranium. The indicators or pathfinder elements most commonly used in uranium exploration are molybdenum, sulphur, lead, arsenic, vanadium, zinc, copper, nickel, and cobalt (Hawkes and Webb, 1962). Other elements, such as gold, tin, and tungsten can be analyzed for their own worth. Rare earth elements provide a basis for in-depth geochemical studies, particularly with respect to uranium mobilization and ore genesis. In general, the more elements sought, the more potential value the analytical data have. The particular elements selected for analysis by the respective laboratory depend on pilot surveys, analytical facilities, and funding constraints (Table II).

SETTING UP AN HSSR PROGRAM

From the principles first applied by Russian scientists in the early 1930s, geochemical exploration has evolved tremendously. Reviews of geochemical exploration for uranium have been compiled by Boyle et al (1971), Bowie et al (1971), Grimbert (1972), Dall'Aglio (1972), and Rose (1977) among others. In addition, large-scale geochemical surveys have been conducted in Canada, Finland, France, Norway, United Kingdom, and the USSR, as well as the NURE in the US. Most procedures and ideas reviewed in this paper are a direct consequence of similar HSSR programs developed in other countries and of standard geochemical sampling practices summarized by Hawkes and Webb (1962) and Levinson (1974), conformed to meet with individual laboratory philosophy with respect to the area of responsibility.

In a program of the magnitude of the HSSR, certain problems are inherent. More than one million samples will be collected from more than 650 000 locations. These samples then are transported to the laboratory and analyzed. The raw data must be edited so that it is analytically correct and site locations are accurate, before it is reported to the public. Lastly, the samples need to be archived for future reference. Because the different regions of responsibility contain extensive mountainous areas, basins, piedmonts, and desert terrain, each laboratory developed its own efficient program. To accomplish this goal, the five basic steps cited in Table III were followed.

In the HSSR, the goal is to sample the entire US and Alaska so that areas favorable for uranium exploration are delineated on a regional scale. In all likelihood, data from the HSSR program will not identify ore bodies, but rather, it will help outline geochemical provinces that can be used to delineate areas favorable for detailed follow-up studies.

After management was selected, a thorough literature research was conducted. The geochemistry of uranium as well as regional information on type of geology, climate, structure, known types of ore deposits in the area, proven methods of exploration, and various types of equipment available for field sampling and field measurements were all examined. Based on this research, an initial program was set up.

As uranium deposits seldom occur under simple geochemical conditions, one important aspect in developing a successful HSSR program is the ability to test all methodologies and sampling philosophies. Most geochemical anomalies result from the movements of natural waters and soils; therefore, it is also necessary to understand the geometry, size, and type of dispersion patterns that may exist and how they are influenced by geology, climate, and topography (Lovering et al, 1956). This is done by means of pilot or orientation studies. The ideal place to conduct pilot studies is in the vicinity of known uranium deposits characteristic of the region being studied, where the extent of dispersion halos for anomalies related directly to ore bodies can be determined. Ideally, the areas should not be contaminated by human activity so that natural geochemical patterns can be observed and compared to background levels in unmineralized terrain (Hawkes and Webb, 1962). However, such areas may not be available or may be limited to small deposits. Studies should cover the full range of environmental and climate conditions typical of the study area. In addition, technical parameters and limits of the program are tested, modified, and improved until a methodology is developed that satisfies the goals of the overall program. Some parameters that need to be considered in designing and undertaking an HSSR program are listed in Table IV; the pilot studies completed by the laboratories are shown in Fig. 1.

Each laboratory has developed for its own area of responsiblity a field procedures manual that explains the purpose of the program; the care, calibration, and use of field equipment; and general procedures to be followed for all aspects of the program. Because varying methods of collection and sample preparation affect the effectiveness of geochemical surveys, field procedures and equipment are continuously being updated, and pilot studies are conducted for each new region so that the manuals are revised annually.

The last and possibly the most difficult step in Table III is to complete the program. To accomplish this, the DOE laboratories subcontract the majority of their sample collection responsibilities. The samples are collected according to systematic and standardized sampling procedures that are outlined in sample collection manuals. All field equipment necessary to collect samples and to take and record the required measurements, including sample vials and data forms, are provided by the laboratories. At least two sets of maps which contain either a grid outline or preselected sample locations are also provided. Field personnel are required to attend a short training course where the objectives of the program, sampling methodology, and care and calibration of field equipment are taught. Samplers are required to be able to read a map and recognize geologic regimes. The DOE provides identification cards which are issued by laboratory personnel after a prospective sampler attends the training course. In addition, each laboratory provides a public relations brochure, written for the layman, explaining the HSSR. In every case the property owners' rights are obeyed and respected. Laboratory personnel are present in a supervisory capacity during all aspects of the sampling and provide help with equipment malfunctions and access as well as with monitoring the program. Subcontractors are required to contact the respective laboratory personnel at least weekly. In addition, LASL and SRL require field crews to keep a composite 1° x 2° NTMS quadrangle showing the process of the contract.

Contract areas generally cover one or more NTMS quadrangle. Access is provided by the subcontractor and usually involves private vehicles. However, sample collection in some mountainous terrain requires four-wheel drive vehicles, horses, or backpacking. Most areas in Alaska are sampled by use of helicopters.

FIELD MEASUREMENTS

There are several chemical factors that control the solubility of uranium in water, several of which are listed in Table V. A review of the literature shows disagreement as to which measurements are most important. Uranium itself is still the best indicator of uranium. Of the measurements listed in Table V, the following are relatively easy to measure in the field.

pH - In general, as pH decreases, uranium content increases. However, because uranium is soluble over such a wide range of pH (Grimbert and Loriod, 1968), pH is important to interpretation only when extreme values are encountered (Ostle and Ball, 1973).

conductivity - Uranium concentrations in waters of a given region generally correlate with concentrations of major components (approximated by conductivity), i.e., an increase in conductivity will usually correspond to an increase in uranium content in natural waters (MacDonald, 1969; Dall'Aglio, 1971; Dyck, 1975).

<u>temperature</u> - The temperature of water affects the rate of chemical and biological reactions which may influence the concentration of uranium (Fix, 1956; Ostle and Ball, 1973).

<u>equivalent uranium</u> - Scintillometer measurements of "shield in" and "shield out" readings allow an equivalent uranium value to be calculated, which then can be used as a ground truth tie for airborne radiometric data. A high equivalent value may be an indication of mineralization of uranium and thorium daughter products (Whitehead and Brooks, 1969).

In general, field measurements are taken by use of small, lightweight, battery-operated portable field instruments (Figs. 2A and 2B). Typical pH meters weigh about 0.5 kg, can be easily calibrated in the field, are temperature compensated, and have a ±0.1 pH precision. Spare probes can readily be exchanged. Conductivity meters, similar in size and weight to the pH meters, can measure up to 50 000 µmho/cm (±1%) and are easily calibrated by use of a standardized KCl solution.

All temperatures are measured with precalibrated thermometers. The air temperature in the shade is recorded to the nearest centigrade degree. The water temperature is usually recorded to the nearest 0.5°C.

Several types of instruments that combine pH, conductivity, temperature, and dissolved oxygen measurements are also available. One type, a Model U-7 Horiba water quality checker, is a lightweight instrument having the versatility of making these measurements with only one piece of equipment. It is ideal for use in areas of difficult access (Fig. 2C). Temperature (0 to 40°C, ±0.5°C), conductivity (0-2000 µmho/cm, ±5 µmho/cm), pH (0 to 14, ±0.1 pH), and dissolved oxygen (0 to 20 parts per million (ppm), ±1.0 ppm) can be measured. This instrument is battery operated and can be recharged.

Alkalinity measurements are usually performed with field titration kits. Ground radioactivity is measured with portable scintillometers.

Some water samples may contain abundant suspended material. This material may require filtration, as the suspended matter may contain additional uranium that is not in solution. All laboratories filter their water samples. Depending on the weight and size limitations of sample gear, several different filter models are used. One lightweight type used by LASL is shown in Fig. 3A. A slightly different and heavier model is used by SRL and runs off a fluorocarbon gas canister that can apply pressure up to 40 psi (Fig. 3B).

In any program of this magnitude, thousands of sediment samples are handled during peak periods. Because samples are analyzed for both uranium and multielements, of particular concern is what material comes in contact with the sample which could drastically affect the trace element data. Consequently, a method to collect the sample (usually some sort of plastic scoop), transport the sample (either a plastic or paper bag), and the particular size fraction required for analysis had to be determined. All laboratories analyze the fine-sized fraction that passes through a 100 mesh screen.

SAMPLE COLLECTION

LASL

The LASL collection procedures are written for samples collected either in the Rocky Mountain states or in Alaska (Sharp and Aamodt, 1978).

Water samples. In the Rocky Mountain states, about 50 ml of water are collected in two 25-ml vials that have been prewashed with dilute nitric acid. Ground-water samples from both wells and springs are collected as near the emergence source as possible. Holding tanks are not sampled. Stream waters are collected from the flowing current away from the bank. All waters are filtered through a 0.45-µ membrane and acidified to pH ≤1.0 with 8 M reagent-grade nitric acid. All water measurements are made with instruments previously discussed (Fig. 2).

In Alaska, 50 ml of water are collected, but due to the high costs per sample location, the time-consuming operation of filtration is omitted. Measurements are usually taken with a Martex digital water quality analyzer or a Horiba water quality checker (Fig. 2C). In addition to LASL standard field measurements (Table II), dissolved oxygen is taken for all Alaska water samples.

Sediment Samples. Up to 1 kg of sediment is collected from at least three adjacent spots at each location. The sample is usually collected with a polyethylene scoop. The sediment must be water transported and taken below water level (if water is present) and must contain enough organic-rich fine-grained particles to fill a 25 ml polyethylene vial. In lake areas in Alaska, the sediment is collected with a specially designed 11-kg, suction-operated bottom sampler that can be dropped from the side of a helicopter (Fig. 4). After collection, sediments are put into a rip-top polyethylene bag and double labeled. The subcontractor then dries the samples at less than 100°C and sieves the samples, retaining only the fraction that passes through a 100 mesh screen. Ground radioactivity measurements are taken at all sites.

ORGDP

The ORGDP collects samples according to a ground-water (Oak Ridge Gaseous Diffusion Plant, 1978a) or a stream-water (Oak Ridge Gaseous Diffusion Plant, 1978b) format.

Ground Water. Only well waters are collected. After flushing the pipe system and rinsing the water containers, two 250-mℓ polyethylene bottles are filled. The samples are taken as close to the wellhead as possible, but all treated water and holding tanks are avoided. The samples are then sent to ORGDP for filtering through a 0.45-μm cellulose acetate paper and analysis. All field measurements (Table II) are made with a Horiba water quality checker (Fig. 2C) which has been in operation for at least two minutes. This instrument is calibrated daily. In addition, total alkalinity, phenolphthalein alkalinity, and mixed-indicator alkalinity are determined with a LaMotte alkalinity test kit.

Stream Samples. A stream water and stream sediment sample are collected, when possible, from all basin locations. Stream waters are collected at the point of maximum flow. After a water sample is collected, the same field measurements are made as for a ground water sample.

Sediment samples are gathered with a scoop and collected parallel to the longitudinal axis of the stream. The sample consists of a composite of several samples taken 2 to 3 m apart. The sediment is collected from the active portion of the stream and all organic, windblown, and floodplain materials are avoided. At least 25 g of the -100 mesh fraction are required. After collection, the sample is placed in a paper envelope, sealed with vinyl tape and sent to ORGDP. It is then dried at 85°C and sieved to -100 mesh.

SRL

The SRL samples are collected according to procedures outlined by Price and Jones (1979). Sample procedures vary according to sample type and climate and are grouped according to ground water, surface stream taken in humid areas, or surface stream taken in arid areas.

Ground Waters. Spring and well-water samples are collected as near the source as possible. Well systems are thoroughly flushed before sampling. All treated waters (e.g., chlorinated) and samples from holding tanks are avoided. After sample containers are prerinsed, about 2ℓ of water are collected. Samples are filtered through a 0.8-μm Nuclepore membrane in the field by use of a pressure filter apparatus (Fig. 3). Temperature, pH, and conductivity measurements are taken on the unfiltered water samples by instruments similar to those shown in Figs. 2A and 2B. About 50 mℓ of filtered water is used for alkalinity measurements that are made with a field titration kit.

Because of the low uranium concentrations in water samples in the eastern US and because of sample preservation problems, SRL developed a field ion-exchange procedure. About 1 ℓ of water with a conductivity of 500 μmho/cm or less is mixed with 59 ml (2 oz) of 100- to 200-mesh high purity cation-anion exchange resin. For samples containing conductivity values greater than 500 μmho/cm, a smaller volume of water is used. The ion exchange resin is mixed for about 10 minutes using a battery-operated stirrer. The resin is then allowed to settle into the original 59-ml bottle, which is sent to SRL for analysis of its contents.

Dissolved helium is measured for all ground water samples. The collection technique is modified from Dyck et al (1976). Generally, a clean, 296 ml (10-oz) soft drink bottle is filled, a specific volume of water withdrawn; the bottle is capped, inverted, and then sent to SRL for analysis.

Surface Streams Taken in Humid Areas. Sample procedures and measurements for stream water samples are identical to those for ground water samples. In addition, 60 μℓ of filtered water is collected in a 59-ml bottle containing ultrapure nitric acid.

A sediment sample is collected either by use of a spring-loaded jaw scoop (for silt to rocky bottoms) or by a bag sampler which consists of a stainless tube with an attached bail and bag (for silt to sand fractions). At least five sediment samples within a 20 m radius are composited. A stainless steel sieve is used to field screen the sediments and the -100 mesh fraction is retained. About 0.5 kg of the -100 mesh fraction is then placed into a Kraft paper bag and labeled with a flowmaster pen. Samples are dried at 90 to 100°C before sending them to SRL.

Surface Streams in Arid Areas. Pilot surveys have determined that soil samples from arid areas generally are as effective as stream samples, although dry wash areas are avoided when stream beds coexist in the same grid square. The sample procedure for dry sediments is the same as for wet sediments; however, the sample is usually collected with a shovel or trowel. If significant amounts of windblown sand are present, a composite of at least 15 separate areas is used and the sample is then sieved to a -18 to +40 and -40 fractions. Both size fractions are then sent to SRL.

FIELD OBSERVATIONS

In a reconnaissance program, chances are high that any particular sample location will not be revisited. Therefore, it is essential to record all field measurements and observations at the site so that the information later can be used in evaluation of the data.

To do this, each laboratory has developed data forms on which the sampler can record the sample type, location, weather, possible contaminants, field measurements, and geologic observations. Because some field observations require subjective judgment by the sampler, observations are number coded to require very little training or background and can be recorded in minimal time. Each form has additional space for comments or clarification of information. Figure 5 is an example of the form used by the LASL and can be adapted for any type of sample normally collected. The SRL has separate data forms for ground water samples, surface samples from humid areas, and surface samples from arid areas. The ORGDP uses two types of data forms, one for ground water samples and one for stream samples. However, the context of all data forms for all laboratories is similar.

In addition, each laboratory has systematic coded numbering systems. The LASL used prenumbered adhesive stickers whereas the SRL and ORGDP employ a system that requires writing the sample number on the sample containers. Each system is coded so that the state and quadrangle from which the sample was taken can be identified easily.

The following observations are generally recorded at each location site for each laboratory.

location - All laboratories supply subcontractors with at least two copies of field maps. These maps are generally 7.5 minute (1:24 000), 15 minute (1:62 500), or county road maps. Each map contains a sample grid and/or premarked sample location. After sample collection, locations are transferred from the field map to an unrolled copy that can then be digitized at the respective laboratory for latitude and longitude. Two laboratories, ORGDP and SRL, also require a photograph of the site. In addition, SRL requires directions for reaching the site.

weather - Seasonal climatic conditions may drastically affect uranium concentrations in surface waters and, to a much lesser extent, in sediments (Fix, 1956; Germanov et al, 1958; Doi et al, 1975; Rose et al, 1976). Consequently, hydrogeochemical surveys should be completed as rapidly as possible. During periods of high runoff, normal uranium concentrations may be diluted whereas after a prolonged drought, uranium concentrations in runoff may be increased for a short period (Peacock, 1961; Lopatkina, 1964).

relief - Several elements, including uranium, in both surface waters and sediments tend to have relatively short dispersion patterns in areas of high relief (Chamberlain, 1964). Furthermore, access to water may be difficult and sediment may be absent locally. Therefore, sample densities may have to be increased so that adequate coverage can be obtained.

geology - Uranium content in both water and sediment generally reflects the local geology. For example, because of complexing of uranium with carbonate ions, a stream flowing over carbonate terrain would be expected to have higher uranium content than a similar stream flowing over siliceous terrain (Levinson, 1974). Sediments from acidic igneous rocks generally have greater uranium concentration than sediments from other rock types (Rogers and Adams, 1970). Also, ground waters that circulate along fractures and faults may contribute significant amounts of uranium as well as other trace metals (Doi et al, 1975; Dyck, 1975). Consequently, the local geology may be one of the most important observations that will help in interpretation of the data.

contamination - All sources of contamination, such as mine waters, tailings, trash, and man-made structures (such as bridges, culverts, and well casings) are avoided where possible. However, any potential contaminant, such as uranium-rich phosphate fertilizers (Boberg and Runnels, 1971), is noted on the data form.

vegetation - In terrain containing abundant vegetation, relatively short dispersion trains in surface water can result. This generally results from organic matter absorbing uranium from the water and consequently increasing the uranium concentration in sediments (Dall'Aglio, 1971; Dyck et al, 1971).

SAMPLING DENSITIES

In reconnaissance exploration sampling, densities may range from one sample per 1.6 km^2 to one sample per 160 km^2 or even greater (Levinson, 1974). Dispersion haloes even for small deposits can ordinarily be detected as far as several hundred meters in ground water and at least 20 km in streams. Large deposits in the western US can be detected many kilometers downstream (Fix, 1956). According to Hawkes and Webb (1962), for a catchment area of 8 to 32 km^2, the surface drainage and/or sediment dispersion pattern for a significant ore body may vary from 300 to 3200 m. Ostle (1954) was able to detect anomalies in surface waters over 10 km downstream from waste dumps. Results of Canadian surveys for areas extensively covered by lakes suggest similar information can be obtained on a grid of one sample location per 8 km^2 compared to one sample location per 16 km^2 except for areas where deposits are very localized (Garrett, 1977). Clearly, the selected density depends on geology, hydrology, and climate. Complete coverage is not always possible for areas having poor access or where the geology is not particularly favorable for uranium deposits. One should choose a spacing so that at least two or more samples fall within the anticipated zone of an anomaly (Lovering et al, 1956). Based on an extensive research of similar studies in similar terrains, the laboratories have selected the nominal sample densities shown in Table II. However, laboratory personnel are flexible in selection of sample locations, and densities vary from map to map.

The following sections briefly describe the type of media sampled for respective physiographic provinces. An extensive review of the geology and known and potential uranium hosts can be found in US Department of Energy Interim Report (1979).

LASL

LASL's total land area of responsibility in the program amounts to about 35% of the US. Some 250 000 sample locations will be taken from 2.7 million km^2 of land. The area includes most of the Rocky Mountain states and all of Alaska (Fig. 6). Much of the northern and southern Rockies consist of rugged mountain ranges separated by intermontane basins. In these mountains and on their flanks, fast-flowing streams and their sediments are the major sample media. Well-water samples are the major sample media in the intermontane basins.

Part of the Colorado Plateau is also in the LASL region, and this area contains several uranium districts including the Grants mineral belt in New Mexico, which is the largest uranium-producing area in the US. The climate in the Plateau region and in the southern part of the LASL area of responsibility is semi-arid. Well water samples are collected when possible, although in sparsely populated areas dry stream beds, which usually contain abundant windblown debris, may be the only available sampling media.

Alaska contains a diversity of physiographic provinces. The northern and much of the interior of the state is underlain by regions of permafrost. These areas are also extensively covered by lakes and, consequently, primarily lake water and sediments are sampled. Two mountain ranges cross the state, the Brooks Range in the north and the Alaska Range in the south, and in these areas fast-flowing streams and stream sediments are predominantly collected.

The southeast part of the state is not only rugged but also heavily vegetated. Therefore, primarily streams and stream sediments are collected from this region.

The LASL area of responsibility contains extensive mountainous terrain with difficult access; consequently, LASL selected a sample density of one location per 10 km^2 for the Rocky Mountain states. All sample locations are preselected by LASL personnel. Surface streams are selected to represent drainage areas of about 10 km^2. Sites which cannot be reached in the field are reselected to approximate the original drainage area as closely as possible. For sampling in Alaska, a pattern containing 23-km^2 grids (1 per 9 mi^2) is put onto field maps and, because of access and safety considerations, helicopter pilots select all sample locations as near as possible to the center of each grid square. Streams are sampled at twice this density or two sample locations per 23 km^2.

ORGDP

The total area of responsibility for ORGDP is about 2 600 000 km^2 (Fig. 6). Samples in the northern regions are collected mostly from streams in marshlands. Much of the ORGDP area is within the Great Plains and Central Lowlands, which is comprised of generally low-lying topography. Much of this area is farmed and, while abundant, surface streams do not offer optimum samples. However, these lowlands are underlain by extensive ground-water aquifers and, consequently, ground-water samples predominate.

The southern area of responsibility with its semi-arid climate contrasts sharply to the mid-continental US and also contains some known sandstone-type deposits in the Coastal Plain of Texas. Ground-water media provide the best sample media here, as streams generally are dry and may contain windblown material.

The sample density for ORGDP of one location per 26 km^2 predominantly reflects collection of ground-water media. All ground-water locations are selected according to a grid system. A well location is selected in a grid for which well log information exists. If a site cannot be reached, an alternate is chosen by the sampler, but it is the sampler's responsibility to select a site near to and representative of the original and to collect the necessary well-log information, which includes such parameters as producing horizons, depth, and pump type.

Stream-sample sites are selected according to considerations of drainage basins and drainage patterns. Sites are selected by ORGDP personnel for basins that drain from 3 to 30-km^2 areas and average about 26 km^2. Any site locations that samplers are unable to reach are reselected to simulate the original site as nearly as possible.

SRL

The SRL area of responsibility includes all or parts of 37 states in the eastern US and western US, although the procedures described in this report generally refer to SRL's operation in the eastern US as they have only recently begun sampling in the western US (Fig. 6). Regions in the eastern US consist predominantly of rolling hills and piedmont-type topography. The climate in these areas is generally humid with significant rainfall and abundant vegetation. Both streams and ground-water sample media are available, but access onto private property may be locally difficult.

The SRL region of responsibility in the western US includes part of the Basin and Range physiographic province. Much of this region is semi-arid and sparsely populated. Consequently, availability of the ground-water medium may be at a minimum and stream beds may be dry and filled with windblown debris. In addition, much of the area has interior drainage, and evaporites and playas are common.

The far western area, the Pacific Coast and Sierra Nevadas, consists predominantly of north-trending mountain ranges separated by valley systems. Fast-flowing streams and sediment are abundant, but access is a major problem.

The SRL locations are selected based on a random grid. A sample location, regardless of the sample type, is selected by the subcontractor for 10 to 50 km^2 areas; average spacing is one site for every 13 km^2. Rules of thumb are that no two adjacent grid squares can be left vacant and no two sample points can be closer than 1.5 km. Streams can drain no more than three times the area of the grid; the largest stream which heads in a grid is usually sampled.

SUMMARY

The NURE HSSR program is one of the largest reconnaissance geochemical exploration programs ever attempted. By the completion of the program, more than one million samples will be collected from more than 650 000 sample locations. All data are reported by 1° x 2° National Topographic Map Series quadrangle boundaries (Fig. 1). Each quadrangle contains from 1000 and 2000 sample locations; each sample location consists of one water and/or one sediment sample. Uranium and as many as 43 additional elements are reported for each location, depending on sample type and laboratory capability (Table II). All information is considered confidential and not for private use until it is open filed. These data are then made available to the public. The magnetic tapes can be obtained from:

GJOIS Project
UCC-ND Computer Applications Dept.
4500 North Building
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, Tennessee 37830
Phone: (615) 574-5463

The reports are available from:

Bendix Field Engineering Corporation
Technical Library
Grand Junction Office
P. O. Box 1569
Grand Junction, Colorado 81501
Phone (303) 242-8621, Ext. 278

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TABLE I

TYPICAL MEDIA USED IN RECONNAISSANCE GEOCHEMICAL SAMPLING

Media	Use
rocks	Helps to determine potential host rocks; used mainly in detailed surveys.
soils	Extremely useful in areas of low relief, thick overburden, and arid climate; used predominantly in detailed surveys.
organic matter	Some biogeochemical processes concentrate certain elements in plant tissues; extremely useful in semi-desert areas and in detailed surveys.
gases	Due to radioactive decay, some daughter products may be detected depending on atmosphere and soil conditions.
ground waters	Extremely useful in arid areas and give information on subsurface environment; commonly used in reconnaissance.
stream waters	Waters circulate over large areas and are extremely useful in searching for soluble elements; most used in reconnaissance.
stream sediments	Useful in areas of high relief and give rough index of geology of catchment basin; commonly sampled in reconnaissance programs.

TABLE II

FIELD MEASUREMENTS, NOMINAL SAMPLING DENSITIES, AND CHEMICAL ANALYSES FOR THE HSSR PROGRAM

	LASL		ORGDP	SRL
	Rocky Mountains	Alaska		
Field Measurements				
	pH	pH	pH	pH
	temperature	temperature	temperature	temperature
	conductivity	conductivity	conductivity	conductivity
	ground radioactivity	ground radioactivity		ground radioactivity
		dissolved oxygen	total alkalinity phenolphthalein mixed-indicator	total alkalinity
			dissolved oxygen	
Media and Sampling Densities				
Stream waters	10 km^2	11.5 km^2	26 km^2	13 km^2
Stream sediments	10 km^2	11.5 km^2	26 km^2	13 km^2
Ground waters	10 km^2 (springs and wells)	--	26 km^2 (wells only)	13 km^2 (springs and wells)
Lake waters	--	23 km^2	--	--
Lake sediments	--	23 km^2	--	--
Organic matter	--	--	pilot only	--
Helium	--	--	--	with ground water only
Chemical Analyses				
Sediment	Ag, Al, Au, Ba, Be, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Eu, Fe, Hf, K, Li, La, Lu, Mg, Mn, Na, Ni, Nb, Pb, Rb, Sb, Sc, Sm, Sn, Sr, Ta, Tb, Th, Ti, U, V, W, Yb, Zn		Ag, Al, As, B, Ba, Be, Ca, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Sc, Se, Th, Ti, U, V, Y, Zn, Zr	Ag, Al, Ba, Be, Ce, Co, Cr, Cu, Dy, Eu, Hf, K, La, Li, Lu, Mg, Mn, Mo, Nb, Ni, P, Pb, Se, Sm, Sn, Sr, Th, Ti, U, V, W, Y, Yb, Zn
Water	Ca, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pb, Ti, U, Zn		Ag, As, Au, B, Ba, Be, Ca, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Na, P, Sc, Se, Ti, U, V, Y, Zn, Zr, SO_4	Al, Br, Cl, Dy, F, Mg, Mn, Na, U, V

TABLE III

STEPS IN SETTING UP AN HSSR PROGRAM

1. Goals Outlined.

2. Leadership and Experience.
   Experienced management helps to minimize program costs.

3. Literature Research of Selected Area.
   This research includes examination of all available information pertaining to the area of study. Topics should include physiography, geology, structure, hydrology, climate, known types of mineralization, geochemistry of element(s) sought, and case histories.

4. Pilot (Orientation) Studies.
   All variables--how to collect the sample, which samples to collect, and how to transport the sample--should be fully examined. At the conclusion of the pilot study, a manual of systematic procedures is prepared and followed during later collection of the samples from comparable terrains.

5. Completion of Program.

TABLE IV

PARAMETERS TO CONSIDER IN DESIGNING AND UNDERTAKING AN HSSR PROGRAM

A. Geology
  - a) lithologic regimes
  - b) structural controls
  - c) geomorphology
  - d) weathering profiles
  - e) ore occurrences (mineralized areas)
  - f) uranium concentrations, background vs anomalous
  - g) uranium and indicator element geochemistry
  - h) dispersion patterns
  - i) area to which pilot applies

B. Hydrology
  - a) climatic regimes
  - b) seasonal variations
  - c) precipitation
  - d) surface waters (drainage area, flow rates)
  - e) ground waters (aquifers, recharge rates)

C. Sample Types
  - a) surface waters (streams, lakes)
  - b) ground waters (springs, wells)
  - c) sediment (wet--dry)
  - d) others (organic matter, gases)
  - e) amount of sample to collect
  - f) relation among different media
  - g) influence of topography

D. Sample Spacing (Reconnaissance Scale)
  - a) minimum
  - b) maximum
  - c) optimum for each sample type
  - d) adequacy of analytical facilities

E. Sample Location
  - a) where to take samples
  - b) potential contaminants

F. Sample Preparation
  - a) water--no treatment, acidification, filtration, ion-exchange concentrations
  - b) sediment--sieving, type of sieve material, drying considerations, crushing, acid leach
  - c) storage problems

G. Sample Containers
  - a) water--glass bottles, polyethylene, teflon
  - b) sediment--polyethylene, paper, or cloth bags
  - c) storage problems

TABLE V

SOME PARAMETERS TO BE CONSIDERED IN FIELD MEASUREMENTS

pH
conductivity
temperature
ground radioactivity
alkalinity
dissolved oxygen
Eh
bicarbonate
chloride
sulfate

LIST OF FIGURES

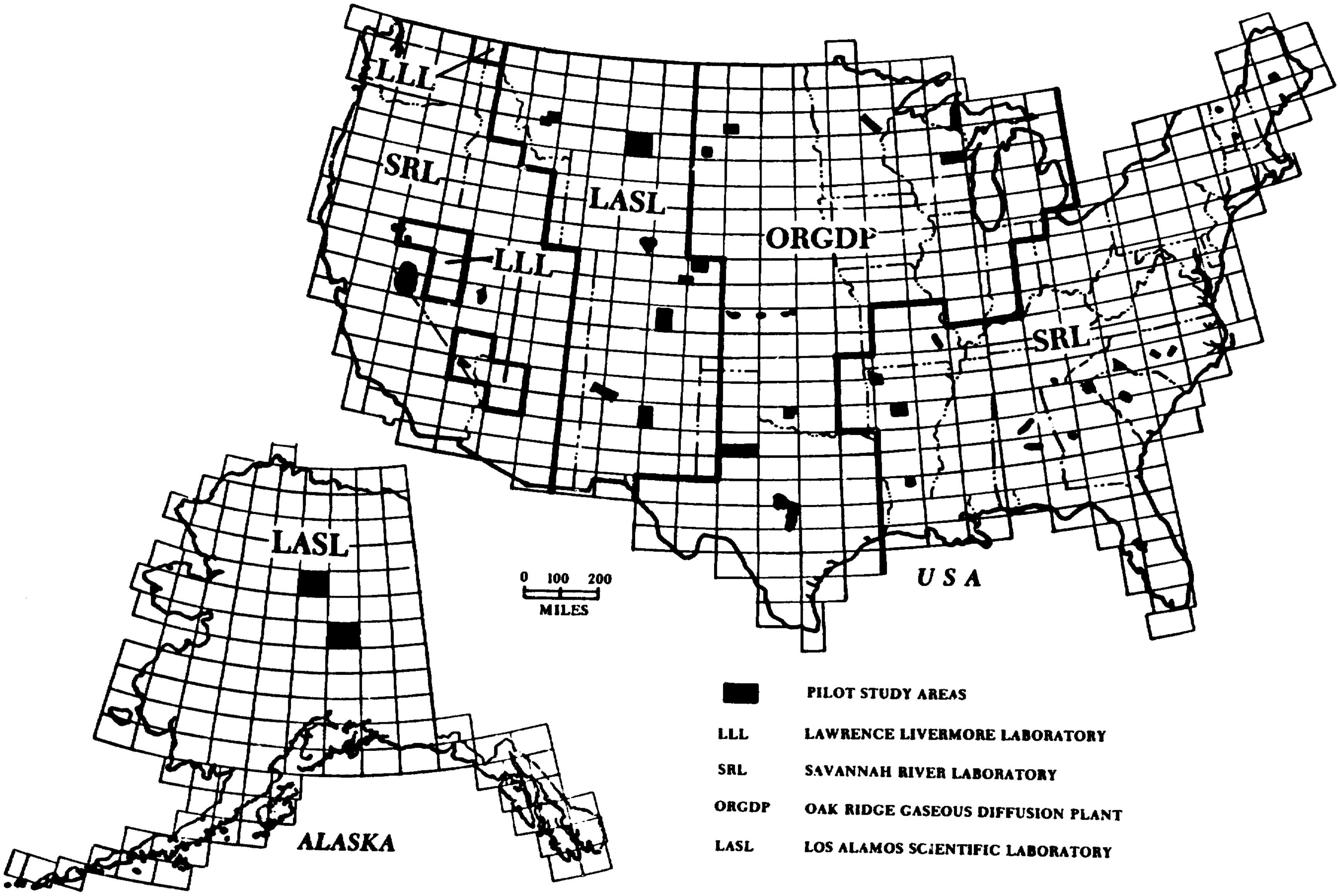
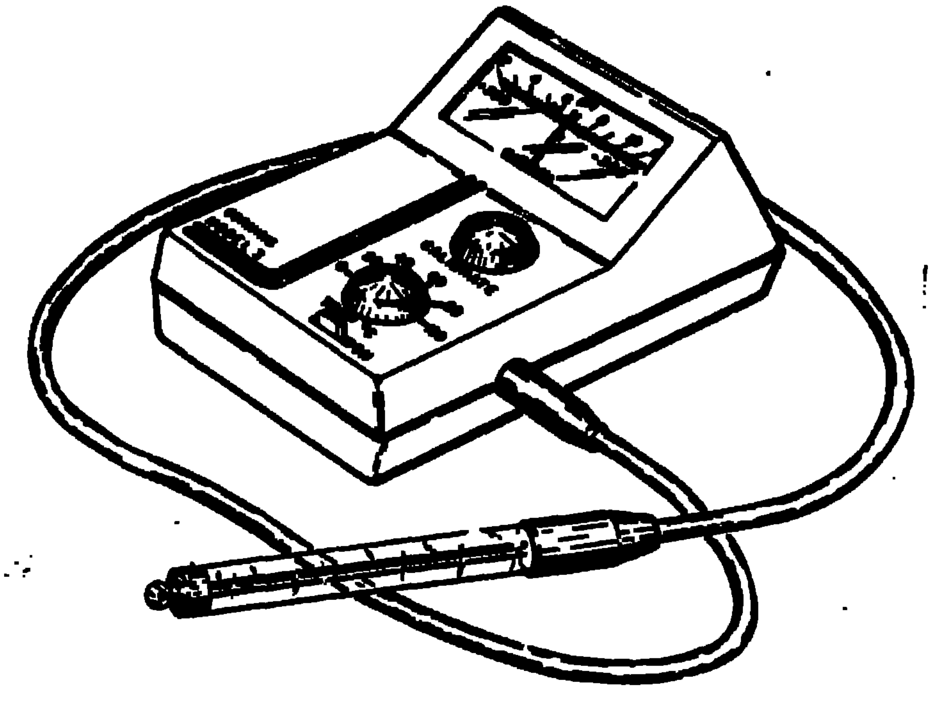
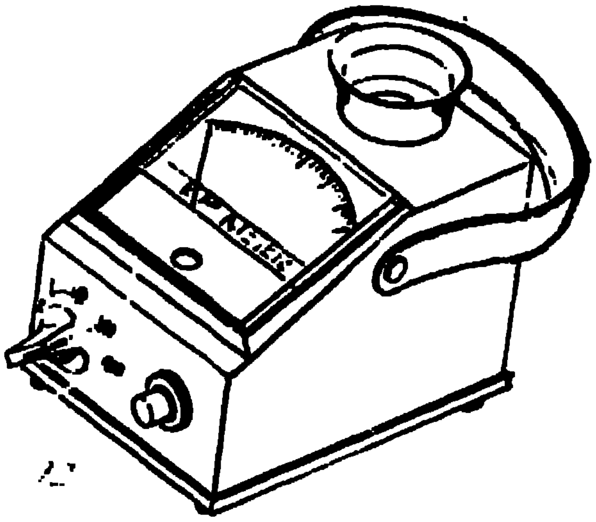

LLL
SRL
LASL
LLL
ORGDP
SRL
USA
LASL
ALASKA
0 100 200
MILES
■ PILOT STUDY AREAS
LLL LAWRENCE LIVERMORE LABORATORY
SRL SAVANNAH RIVER LABORATORY
ORGDP OAK RIDGE GASEOUS DIFFUSION PLANT
LASL LOS ALAMOS SCIENTIFIC LABORATORY

Fig. 1

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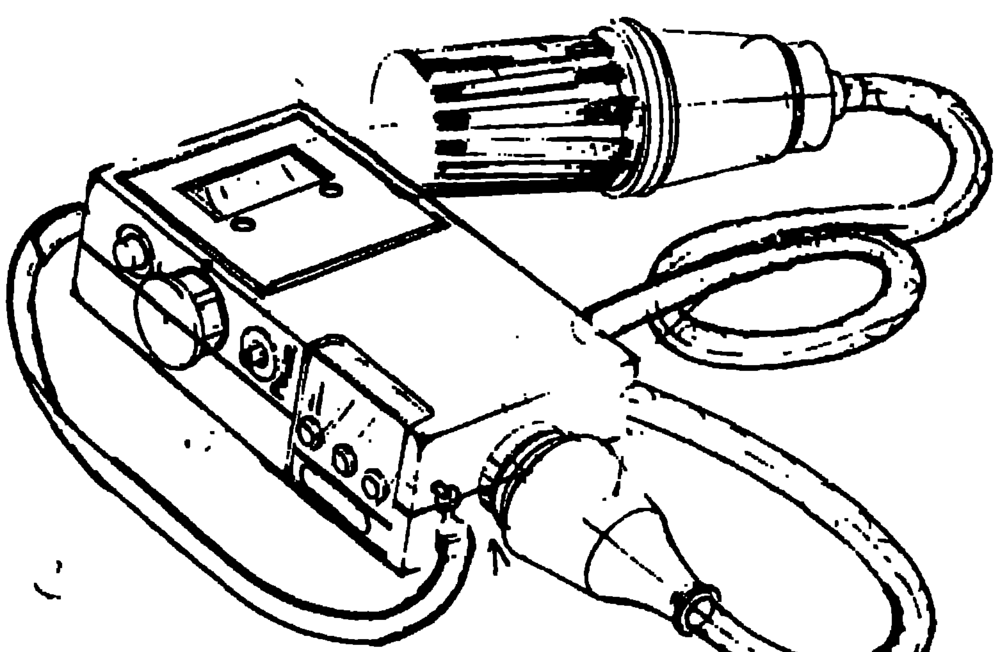

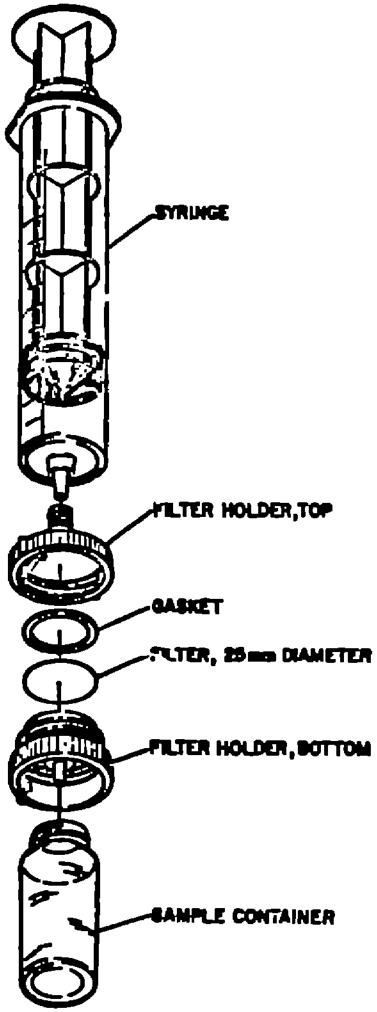
SYRINGE
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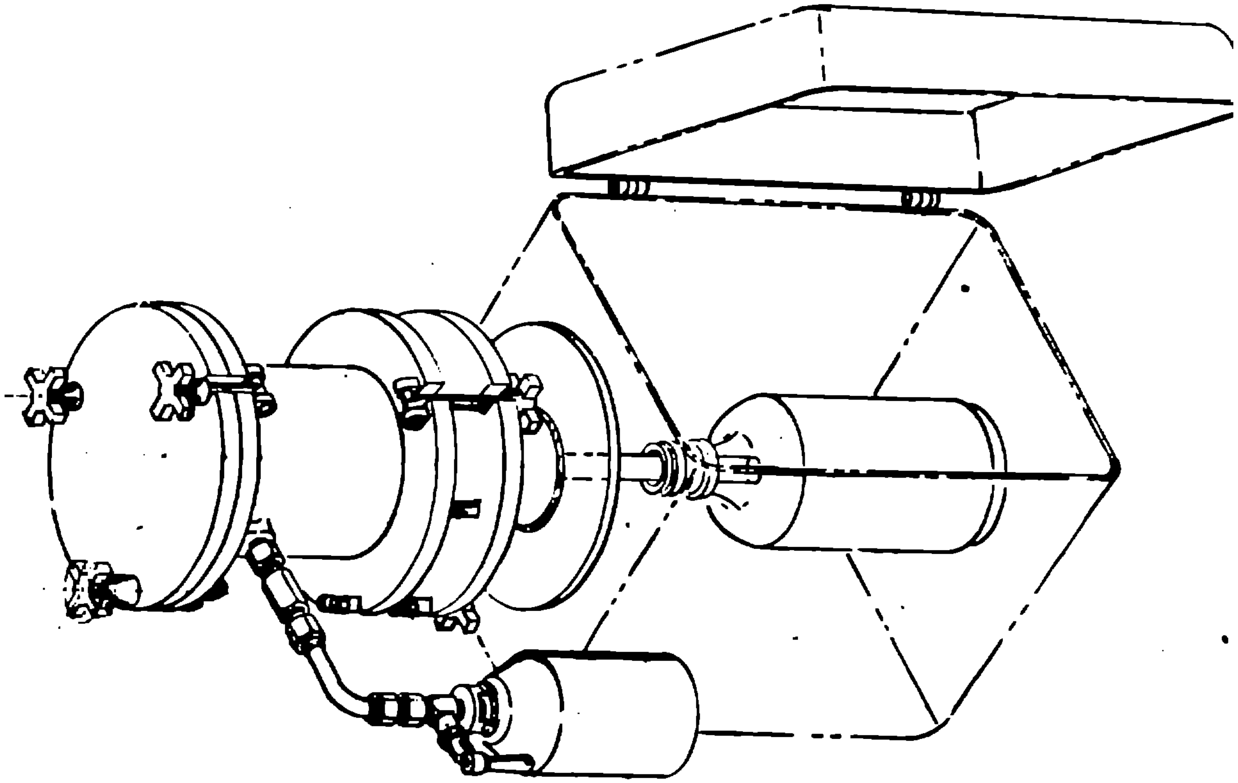
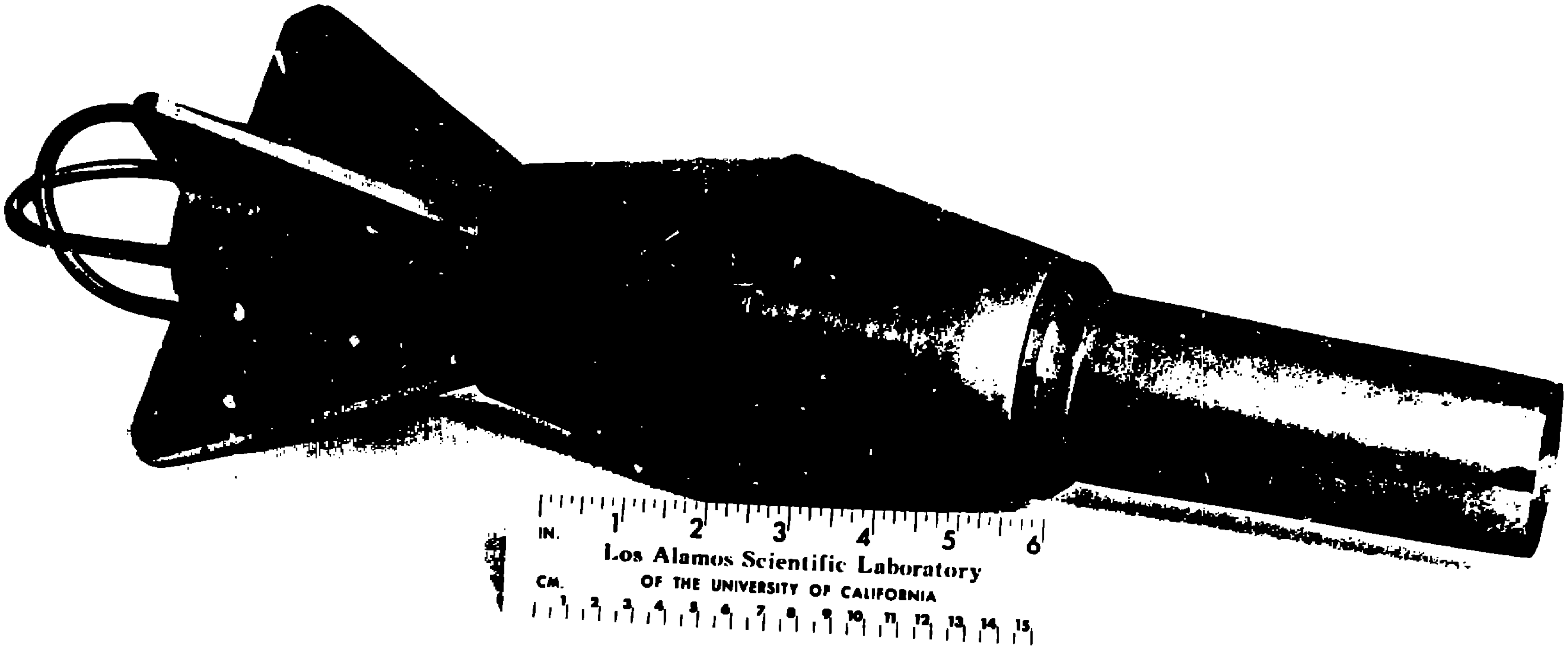
GASKET
FILTER, 25mm DIAMETER
FILTER HOLDER, BOTTOM
SAMPLE CONTAINER

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Los Alamos Scientific Laboratory
OF THE UNIVERSITY OF CALIFORNIA
CM.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

LASL HYDROGEOCHEMICAL AND STREAM/LAKE SEDIMENT FIELD DATA

	ATTACH IDENTICAL SAMPLE NUMBER HERE						REPLICATE	SAMPLE TYPE(S) WATER	TREATMENT	SEDIMENT	TREATMENT	LOCATION LATITUDE DEG		MIN		SEC		LONGITUDE DEG			MIN		SEC		DATE DAY		MO		YR		HR		AIR TEMP °C + or −			WATER TEMP °C			COMMENTS	SPEC. MEAS.
	1	2	3	4	5	6	~~⑦~~	⑧	⑨	⑩	⑪	12	13	14	15	16	17	18	19	20	21	22	23	24	~~25~~	26	~~27~~	28	29	30	~~31~~	32	33	34	35	~~36~~	37	38	㊴	~~㊵~~
S/N	3	0	4	9	2	7		2	2	2	4	4	5	1	5	0	7	1	1	4	3	8	2	7		5		6	7	7		9	+	1	2		7.	5	C	

	6.	8			1	2	0	B			8	5			9	8	1	6	4	6	2	2	1	1	3	2	3	1	1	2									
~~41~~	42	43	~~44~~	~~45~~	46	47	48	49	~~50~~	~~51~~	52	53	~~54~~	~~55~~	56	57	(58)	(59)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(67)	(68)	(69)	(70)	(71)	~~(72)~~	~~73~~	~~74~~	~~75~~	~~76~~	~~77~~	~~78~~	~~79~~	~~80~~
pH			SPECIFIC CONDUCTANCE µmhos/cm					LETTER I.D.	SCINTILLOMETER SHIELD IN CPS				SHIELD OUT CPS				GENERAL SITE DATA ROCK TYPE	COLOR	SED. TYPE	COLOR	WATER FLOW	LEVEL	COLOR	STREAM CHANNEL	VEG. TYPE	DENSITY	RELIEF	WEATHER	OWNERSHIP	CONTAMINANTS	WELL DATA TYPE	WELL DIAM. IN.		WELL DEPTH (SURFACE) FT			WATER DEPTH (SURFACE) FT		

IN THE CASE OF EACH CIRCLED ENTRY SPACE, ENTER MOST APPROPRIATE DESIGNATORS LISTED BELOW:

⑦ USE WITH REPLICATE SAMPLES ONLY (CHRONOLOGICALLY A,B,C,etc.)

⑧ 1 NONE
2 STREAM<1.5m WIDE
3 STREAM>1.5m WIDE
4 SEEP
5 SPRING
6 WELL
7 NATURAL POND
8 ARTIFICIAL POND
9 OTHER

⑨ 1 NONE
2 FILTERED AND ACIDIFIED
3 FILTERED ONLY
4 ACIDIFIED ONLY
5 OTHER

⑩ 1 NONE
2 WET STREAM
3 WET SEEP
4 WET SPRING
5 WET POND
6 DRY STREAM
7 DRY NATURAL POND
8 DRY ARTIFICIAL POND
9 OTHER

⑪ 1 SIEVED +40 MESH
2 SIEVED −40 MESH
3 SIEVED −80 MESH
4 SIEVED −100 MESH
5 SIEVED −170 MESH
6 SIEVED −230 MESH
7 OTHER

㊴ ENTER "C" WHEN COMMENTS ARE MADE

㊵ ENTER "S" WHEN SPECIAL MEASUREMENTS ARE MADE

(58) 1 SEDIMENTARY
2 METAMORPHIC
3 IGNEOUS
4 UNKNOWN

(59) & (61) 1 WHITE/BUFF
2 YELLOW
3 ORANGE
4 PINK/RED
5 GREEN
6 BROWN
7 GRAY
8 BLACK
9 OTHER

(60) 1 BOULDERS
2 COBBLES
3 GRAVEL
4 SAND
5 MUD
6 MUCK
7 OTHER

(62) 1 STAGNANT
2 SLOW
3 MODERATE
4 FAST
5 TORRENT

(63) 1 DRY
2 LOW
3 NORMAL
4 HIGH
5 FLOOD

(64) 1 CLEAR
2 MURKY
3 CLOUDY
4 MUDDY
5 ALGAL
6 OTHER

(65) 1 DEPOSITING
2 ERODING
3 UNKNOWN

(66) 1 CONIFER
2 DECIDUOUS
3 BRUSH
4 GRASS
5 MOSS
6 MARSH
7 OTHER

(67) 1 BARREN
2 SPARSE
3 MODERATE
4 DENSE
5 VERY DENSE

(68) 1 FLAT
2 LOW<15m
3 GENTLE 15-60m
4 MODERATE 60-300m
5 HIGH>300m
6 OTHER

(69) 1 CLEAR
2 PARTLY CLOUDY
3 OVERCAST
4 RAINY
5 SNOWY
6 OTHER

(70) 1 FEDERAL
2 STATE
3 PRIVATE
4 INDIAN
5 OTHER

(71) 1 NONE
2 MINING
3 AGRICULTURE
4 INDUSTRY
5 SEWAGE
6 POWER GENERATION
7 URBAN
8 RECREATION
9 OTHER

(72) 1 WINDMILL-STOCK
2 WINDMILL-DOMESTIC
3 SUBMERSIBLE PUMP
4 SUCTION PUMP
5 JET PUMP
6 LARGE TURBINE
7 HAND BAIL
8 UNKNOWN
9 OTHER

MAP NAME(s) Mt. Sample Montana MAP NUMBER(s) N4515.0-W11437.5 MAP SCALE 1:24000

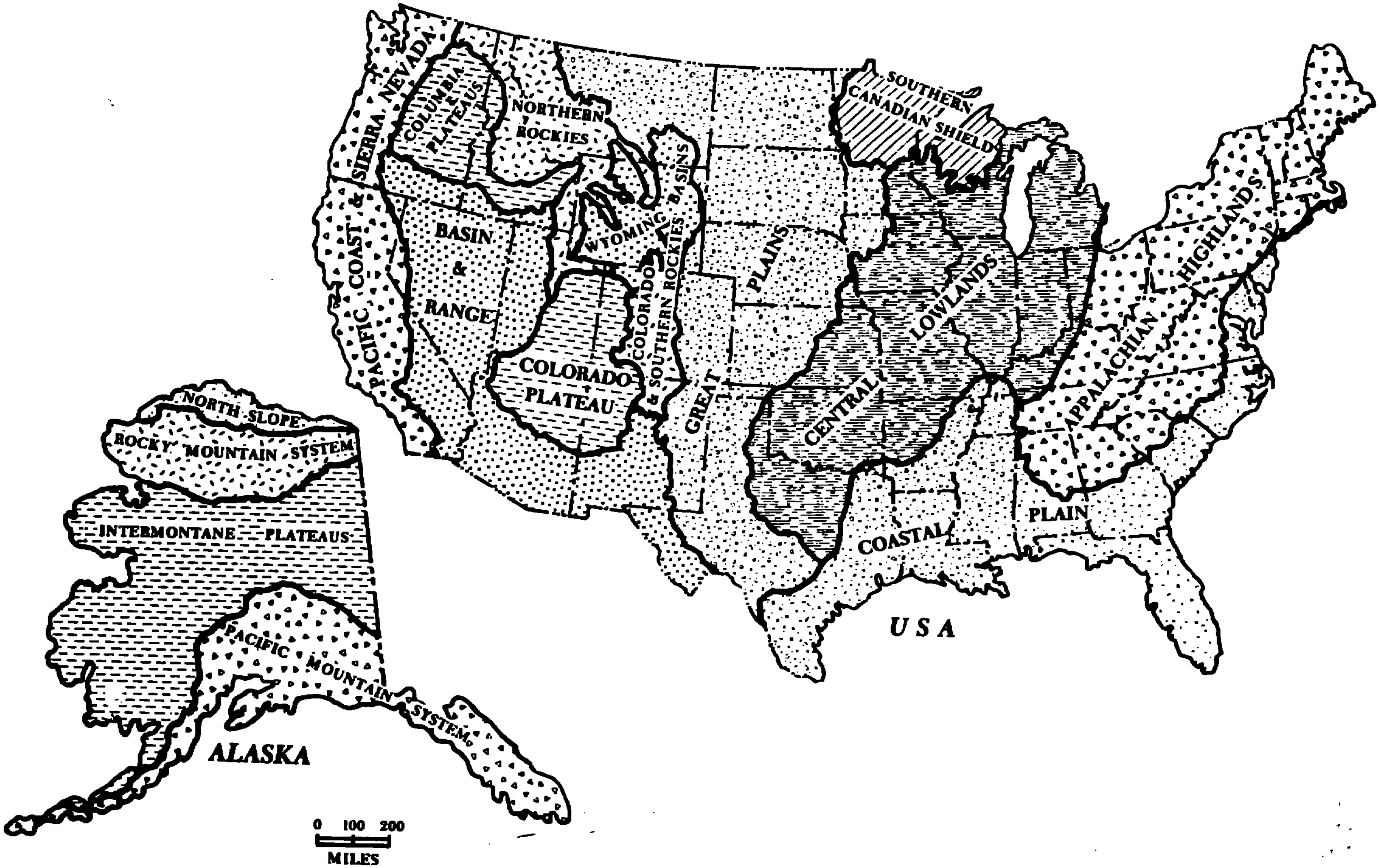
COMMENTS: EXPLAIN ALL "OTHER" DESIGNATORS USED ABOVE, PLUS DESCRIBE ALL UNUSUAL OR SIGNIFICANT CONDITIONS SUCH AS SPECIAL RESTRICTIONS, TYPE(s) AND PROXIMITY OF CONTAMINANTS, QUANTITY OF ORGANIC DEBRIS, WELL CASING DESCRIPTION (AGE, RUST, AMOUNT OF USE, etc.), AQUIFER DESCRIPTION (NAME, DEPTH, etc.), STREAM CHANNEL DESCRIPTION, AND GENERAL ROCK NAME WHEN KNOWN. NOTE EVIDENCE OF RECENT PRECIPITATION.

Abandoned lead/zinc mine approx. 1 mile upstream

SPECIAL FIELD MEASUREMENTS AS PER CONTRACT SPECS

I CERTIFY THAT THE ABOVE SAMPLE HAS BEEN TAKEN AND TREATED AS SPECIFIED BY LASL AND INDICATED ABOVE John Smith
SIGNATURE

LASL HSSR MAR 76


SIERRA NEVADA
COLUMBIA PLATEAUS
NORTHERN ROCKIES
PACIFIC COAST &
BASIN & RANGE
WYOMING
BASINS
COLORADO & SOUTHERN ROCKIES
COLORADO PLATEAU
GREAT PLAINS
SOUTHERN CANADIAN SHIELD
CENTRAL LOWLANDS
APPALACHIAN HIGHLANDS
COASTAL PLAIN
USA
NORTH SLOPE
ROCKY MOUNTAIN SYSTEM
INTERMONTANE PLATEAUS
PACIFIC MOUNTAIN SYSTEM
ALASKA
0 100 200
MILES