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A Critical Component of Energy Research

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by

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ABSTRACT

This document represents the consensus of members of the *ad hoc* Committee on Isotope Geochemistry in the US Department of Energy; the committee is composed of researchers in isotope geochemistry from seven of the national laboratories. Information included in this document was presented at workshops at Lawrence Berkeley Laboratory (April 1989) and at Los Alamos National Laboratory (August 1989). Delegates to the Committee in 1989 were Dr. David R. Cole (Oak Ridge National Laboratory). Dr. David B. Curtis (Los Alamos National Laboratory), Dr. Donald J. DePaolo (University of California, Berkeley), Dr. Terry M. Gerlach (Sandia National Laboratories), Dr. J. C. Laul (Pacific Northwest Laboratory), Dr. Henry Shaw (Lawrence Livermore National Laboratory). Dr. Brian M. Smith (Lawrence Berkeley Laboratory), and Dr. Neil C. Sturchio (Argonne National Laboratory).

I. Introduction

In his remarks of June 27. 1989. Secretary of Energy James D. Watkins redefined the priorities of the Department of Energy to "reflect environment. safety, and health as more heavily weighted than production." He further remarked, "I have...been surprised to learn that the Department relies on insufficient scientific information in making its decisions and in developing public policy. In this regard, we are instituting measures that will greatly increase the roles of state agencies. the Environmental Protection Agency. the National Academy of Sciences, and our own national laboratories play in DOE decision-making. Our goal is to provide a greater influence on the quality of the scientific data we employ in making decisions which affect public health. safety, and the environment."

Many of the emerging environmental concerns that require oversight and regulation by the Department of Energy (DOE) have no precedent. The lack of scientific information to address these concerns reflects (1) a history of inadequate support for DOE laboratory facilities ... (2) an absence of focus on those issues that are most important to the DOE. This report provides arguments in support of these two points; it also recommends that the DOE provide the resources to support research and development in isotope geochemistry for the specific purpose of gathering information applicable to the needs of the Department and the concerns of the global community. Many of these informational needs require a broader understanding of natural processes and the effects of these processes on anthropogenic materials. Our current lack of such understanding is evident in the contamination of DOE facilities. Another concern is our increasing reliance on theoretical models in decision making. Widely publicized examples include the long-term stability of nuclear waste in geologic repositories, the climatic consequences of variations in atmospheric trace gas abundances, and the search for increasingly scarce natural resources. Many of our theoretical models are based upon assumptions that have not been validated. At best, the consequences of decisions based upon invalid models are wasted resources.

In general terms, the natural processes that are relevant to energy-related issues can be described as (1) the movement of mass in the hydrosphere or atmosphere and (2) the chemical and physical interactions between coexisting phases—or energy sources and sinks. For example, much of our understanding of how water moves in the lithosphere stems from an interest in water as a resource for drinking and agriculture. However, we now urgently need to understand how water functions as a medium for transporting contaminants of human origin. The types of information required for these two purposes are disparate, as illustrated by several examples.

- In studies of groundwater flow, water-bearing rocks are characterized as homogeneous media, and flow through the rocks is described in terms of averaged parameters. The validity of such assumptions can be verified by hydraulic tests. In contrast, to understand how water functions as a transport medium requires that we understand how fluid flows in heterogeneous, fractured, or unsaturated rocks—processes that cannot be characterized by average hydraulic parameters. It is the extremes of the flow properties that concern us: When and where will a contaminant first be introduced into the human environment? How long will it persist at a particular location? What are the uncertainties of these predictions? Reliable answers to these questions can only come from an understanding of the spatial and temporal variability of the hydraulic properties through the rock mass. Traditional models of fluid flow and tests of their validity are not appropriate to our current needs. New models are being developed, and the subsequent development of methods to test their validity is a critical component of modern hydrologic research.

- In the past, research on water/rock interaction was principally motivated by water quality issues. Typically, the basis for our studies was reversible thermodynamics and equilibrium between the aqueous phase and the minerals that compose the host rock. Current interest in water/rock interactions revolves around water pollution and water as a transport medium for dissolved and entrained contaminants. Our new information requirements are quite different from those of the past, and the nature and variety of migrating materials complicate the problem. We have recently become concerned with organics, multivalent elements, trace solutes, colloids, and a variety of constituents that were of little interest in the recent past. Our current knowledge of the parameters controlling concentrations of such groundwater contaminants is based largely upon laboratory experiments. The validity of extrapolations from the laboratory to natural systems depends upon our ability to demonstrate a consistency between results from these two.

An example of emerging environmental problems is the increased concentration of trace gases in the atmosphere and the implications of these changes in the terrestrial climate. To assess the human roles in global climate change, we must first determine the magnitudes and rates of *natural* changes in the past. An understanding of the natural global cycles of the trace gases is a fundamental component in our effort to identify and control anthropogenic sources.

Research in the geosciences provides a precedent for developing information critical to the DOE's environmental and resource concerns. The four basic components are:

(1) laboratory studies of the properties of earth materials,

(2) field observations of earth systems in real time,

(3) field studies of ancient earth systems as represented in the rock record, and

(4) development of predictive models that satisfy both the physical and chemical laws and the observational record.

There are large gaps in our knowledge of the fundamental material properties and the behavior of natural materials under the vast range of conditions present in the earth. Earth processes are too complicated to be approached solely from first principles and theoretical calculations, and thus observation has typically been our vehicle for better understanding.

Isotopic measurements are among the most powerful observational techniques available. They provide absolute time scales and specific tracers for most earth processes. The tracers can be either man-made or natural; they are sufficient in number to allow study of a wide range of processes with time scales that vary from seconds to billions of years. Many isotopic studies are legendary; for example, the use of lead isotopes to determine the age of the earth and the use of ^{14}C to study the history of man.

The national laboratories contain a broad science and technology base and have the potential to be a powerful force in multidisciplinary earth science research. The DOE laboratories currently support personnel and facilities that, properly focused and organized, can constitute the most powerful and diverse isotope geochemistry capability in the world. Many of these resources are unmatched in instrumentation and support infrastructure by anything available in academia, private institutions, or other government agencies. Brief descriptions of some of these facilities are presented in Sec. III of this document. These capabilities are generally supported by resources from the traditional DOE missions—nuclear weapons, nuclear energy production, and nuclear research. The DOE can capitalize on these unique and expert capabilities by redirecting the efforts of existing facilities and manpower, hiring additional staff, supporting collaboration with non-DOE scientists, encouraging a creative working environment, and focusing research on the most compelling problems. The result will be scientific information to assist the DOE in making decisions, establishing policy, and determining priorities in earth science based issues.

The DOE resource in isotope geochemistry should be used to conduct comprehensive multi-isotopic studies of natural processes and to develop observational models of these processes. Such studies would provide the DOE with an information base to support practical decisions and sound policy judgements on technical issues. New techniques for improving the precision and sensitivity of isotopic measurements should be developed to fulfill the emerging needs of the DOE. Such activities are typically too expensive for academic institutions and are not profitable for private industry. The National Laboratories are the logical place for such new technologies to be developed. It is unlikely that federal funding agencies can support the development of expensive new isotope measurement facilities or continue to establish appropriate laboratories for individual investigators at universities. However, existing DOE isotope geochemistry laboratories could serve as national resources for research and education through the creation of a few well-equipped and well-staffed National Centers for Isotope Geochemistry that would serve both academic and national laboratory communities.

II. Summary of Isotope Facilities in the National Laboratories and 10-yr Projections of Their Needs

The table below shows a 10-yr projection for capital and staffing needs of the National Laboratories' isotope programs: this summary is based on information from the individual laboratory plans that follow in Sec. III. Capital requirements for instrumentation and sample preparation facilities include funds for new equipment as well as replacement costs for existing instruments—calculated at a rate of 10% per year. Capital needs are shown as totals for the next 10 yr (Column 1) and as average yearly needs (Column 2). Staffing totals are given for FY1990 (Column 3) and for fully staffed laboratories in FY2000 (Column 4).

To redirect efforts of the existing isotope facilities at the seven National Laboratories to the most critical DOE missions, it will be necessary to increase existing DOE funding for staffing by nearly a factor of 2 to a level near 13 $M/yr in the year 2000. Additional capital funding of 3.27 $M/yr will be required for new instrumentation and replacement of existing hardware.

Capital and Staffing Costs Summary

National Laboratory	Capital ($M)		Staffing Costs ($M/yr)	
	10 yr	1 yr	1990	2000
Argonne National Laboratory	2.8	0.28	0.80	2.05
Lawrence Berkeley Laboratory-UCB	4.0	0.40	0.55	2.05
Lawrence Livermore Laboratory[a]	5.4	0.54	2.00	2.25
Los Alamos National Laboratory[a]	10.0	1.00	3.00	3.00
Oak Ridge National Laboratory	6.5	0.65	0.40	2.00
Pacific Northwest Laboratories	3.5	0.35	0.40	1.00
Sandia National Laboratories	0.5	0.05	0.20	0.60
Totals	**32.7**	**3.27**	**7.35**	**12.95**

[a] Los Alamos and Livermore costs reflect projections of little or no growth in the next decade. Projections for these two laboratories emphasize shifts of support within the DOE as the facilities shift from the missions of one DOE office to another.

III. Current and Projected Staffing, Programs, and Instrumentation for Isotope Facilities of the National Laboratories

The following pages contain descriptions of current scientific programs and staffing levels at participating isotope facilities of the National Laboratories, current instrumentation at these facilities, and 10-yr projections of the manpower and capital needs for the seven laboratories. The largest isotope programs, at Lawrence Livermore and Los Alamos National Laboratories, derive the majority of their current funding from the US DOE Office of Defense Programs. Without a shift of support within the DOE, the unique capabilities at these laboratories are threatened by cuts in defense spending. The other Laboratories are currently supported mostly from the US DOE Office of Basic Energy Sciences. Redirection and growth of the scientific efforts in these groups will depend on new funding from the DOE.

A. Argonne National Laboratory

Principal areas of investigation

- **Atmospheric methane** — isotopic composition of atmospheric methane. major natural and anthropogenic sources, global variation with time
- **Active geothermal systems** — sources of hydrothermal fluids and dissolved components. rates and mechanisms of hydrothermal reactions and solute transport. longevity of active geothermal systems. relations to large-scale tectonomagmatic and climatic processes
- **Hydrocarbon metamorphism** — isotopic structure of kerogens. thermal and chemical effects of magmas on hydrocarbons in sedimentary basins
- **Environmental actinide chemistry** — speciation and behavior of natural and anthropogenic actinides in surface waters and shallow groundwaters. role of colloids

Current staffing — Argonne National Laboratory employs 4 FTEs performing basic research in isotope geochemistry: they are all currently supported from DOE funding sources.

Anticipated FTE requirements — Program growth over the next decade will require 5 additional FTEs ($200K/yr/FTE) and 5 postdocs ($50K/yr/postdoc). Total funding requirement for full staffing (9 FTEs, 5 postdocs) will be $2.05M/yr in FY1990 dollars.

Staffing for Argonne National Laboratory

	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	4	5	9	200	1800K$
Postdocs		5	5	50	250K$
Total					**2.05M$**

Argonne National Laboratory Equipment

Current	Principal Uses
Thermal ionization mass spectrometers (2)	Nuclear fuel related work. geoscience programs
Gas source mass spectrometers (2)	Isotope ratio measurements on CO_2 produced from atmospheric methane and geologic samples
Alpha-beta-gamma spectrometers	Geoscience (uranium-series studies). environmental studies. radiobiology
Accelerator mass spectrometry facility	Heavy ion physics. ^{41}Ca analysis of rocks and bone
Sputtered-atom resonance ionization mass spectrometry (SARISA) facility	Trace surface analysis: used as isotope microprobe for meteorite studies
Ion microprobe	High-level nuclear waste programs

Needed by FY2000	Projected Use	Cost (M$)
Thermal ionization mass spectrometer	Lithium. boron. strontium. lead. uranium. thorium isotopes	0.40
Noble gas mass spectrometer	Noble gas isotopes	0.25
Gas source mass spectrometer	Carbon. oxygen. hydrogen isotopes	0.25
Gamma spectrometers	Instrument neutron activation analyses. uranium. thorium isotopes	0.10
Renovated laboratory space and sample preparation facilities	Geoscience programs	0.50
	Total	**1.50**

B. Berkeley Center for Isotope Geochemistry, Lawrence Berkeley Laboratory, and University of California

Principal areas of investigation

- **Global climate change** — isotopic record of surface temperature changes as recorded in layered terrestrial and marine deposits
- **Isotope hydrogeology** — regional groundwater flow regimes. modeling of solute transport with emphasis on mixed wastes
- **Geochemical cycles of CO_2** — geological sources and sinks of CO_2 with emphasis on roles of weathering and rock alteration on global warming
- **Active geothermal systems** — patterns of hydrothermal fluid flow and implications for exploration and development. identification of natural hydrothermal laboratories. definition of fossil hydrothermal alteration
- **Fluids in sedimentary basins** — circulation pathways. role of fluids in secondary permeability. cementation. diagenesis; significance of convective heat flow and implications for basin modeling
- **Isotopic correlations** — correlation and provenance of rock masses from outcrop to continent scale. implications for hydrocarbons and minerals
- **Continental scientific drilling** - isotopic studies of samples from Continental Scientific Drilling Program holes at Long Valley. Valles Caldera. Creede. Katmai. etc.

Current staffing — The Berkeley Center for Isotope Geochemistry presently employs 1.25 FTEs. 2.5 support staff. and 0.5 postdocs in basic research in isotope geochemistry.

Anticipated FTE requirements — Program growth for the next decade will require 4.75 additional FTEs ($200K/yr/FTE). 2.5 postdocs ($50K/yr/postdoc). 3.5 support staff ($100K/yr/staff). and 4 students ($25K/yr/student). Total funding for full staffing (6 FTEs. 3 postdocs. 6 staff. 4 students) will be $2.05 M/yr in FY1990 dollars.

Staffing for Berkeley Center for Isotope Geochemistry, Lawrence Berkeley Laboratory, and University of California

	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	1.25	4.75	6	200	1.2M$
Postdocs	.5	2.5	3	50	150K$
Staff	2.5	3.5	6	100	600K$
Students		4	4	25	100K$
Total					**2.05M$**

Berkeley Center for Isotope Geochemistry, Lawrence Berkeley Laboratory, and University of California Equipment

Current	Principal Uses
Thermal ionization mass spectrometers (2 at UCB)	Geoscience programs: rapid. precise isotope ratios (neodymium. strontium. lead. calcium)
Gas source mass spectrometer (LBL)	Geoscience programs: rapid. precise stable isotope ratios (carbon. nitrogen. oxygen. sulfur. hydrogen)
Instrumental Neutron Activation Facility	Environmental studies. trace elements

Need by FY2000	Projected Use	Cost (M$)
Thermal ionization mass spectrometer	Uranium. thorium isotopes	0.40
Noble gas mass spectrometer	Rare gas isotopes in rocks	0.25
Gas source mass spectrometer	Large samples. waters	0.25
Gamma spectrometer	Neutron activation	0.10
Sample preparation facilities	Waters. carbonates. etc.	0.30
Inductively coupled plasma mass spectrometer with laser ablation	Geochemistry. trace elements. lead-isotopes	0.50
	Total	**1.80**

C. Lawrence Livermore National Laboratory

Principal areas of investigation

- **Global climate change** — transfer functions of cosmogenic nuclides to polar ice sheets
- **Radionuclide migration** — migration rates in saturated and unsaturated zones using tritium, ^{36}Cl, ^{129}I, and other tracers; contaminant plume definition; mixing of surface waters; trace element partitioning in fluid rock systems
- **Isotopic Geochronology** — ages of waters, rocks, and minerals; exposure ages of young geologic surfaces; mantle-crust evolution
- **Material properties** — oxygen isotope partitioning; oxygen diffusion rates; reaction progress; dissolution/reaction rates
- **Verification applications**

Current staffing — Lawrence Livermore National Laboratory currently has ~10 FTEs performing basic and applied research in isotope geochemistry; they are supported by DOE waste management, classified weapons, and verification program funds.

Anticipated FTE requirements — To redirect the scientific effort of the 10 FTEs ($200K/yr/FTE) and the addition of 5 postdocs ($50K/postdoc). Total funding requirements for full staffing (20 FTEs, 5 postdocs) will be $2.25M/yr in FY1990 dollars.

Staffing for Lawrence Livermore National Laboratory

	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	10		10	200	2M$
Postdocs		5	5	50	250K$
Total					**2.25M$**

Lawrence Livermore National Laboratory Equipment

Current	Principal Uses
Center for Accelerator Mass Spectrometry (AMS)	Measurements of cosmogenic nuclides for groundwater dating, radionuclide migration, surface water mixing, biology programs, verification studies
Noble gas mass spectrometers (4)	Dating groundwaters/young surfaces, contaminant plume definition/migration, mantle degassing, test program
Ion microprobe facility (Cameca 3F)	*In-situ* trace element and isotopic analyses
Inductively coupled plasma mass spectrometers (ICPMS) (2)	Rapid trace element and isotopic analyses, fluid chemistry, rhenium-osmium measurements, verification
Thermal ionization mass spectrometers (3)	Test program work and geoscience programs, uranium-thorium-series, rubidium-strontium, uranium-thorium-lead, samarium-neodymium, titanium-, magnesium isotopes

Needed by FY2000	Projected Use	Cost (M$)
Gas-filled magnet for AMS	AMS studies	0.10
Laser ablation and electrochemical sources for ICPMS	ICPMS studies	0.10
Gas source mass spectrometer	Carbon, nitrogen, oxygen sulfur, hydrogen isotopes	0.30
	Total	**0.50**

D. Los Alamos National Laboratory

Principle areas of investigation

- **Geochronology of modern processes** — age dating young (<1 Myr) carbonates, deep sea deposits, volcanic rocks secondary minerals

- **Geochemistry of rare nuclides** — studies of the production and geochemistry of rare radionuclides such as ^{239}Pu, ^{99}Tc, ^{97}Tc, ^{129}I, ^{3}He

- **Environmental chemistry and physics** — the use of isotopes to study the retention and transport of elements in near-surface environments

- **Atmospheric chemistry and physics** — use of anthropogenic and natural isotopes study atmospheric mass transport and chemical processes

- **Groundwater studies** — dating groundwaters, groundwater mixing, tracer studies, uranium-exploration, sources of salinity and hydrocarbons

- **Reaction kinetics and biologic cycling** — isotope tracer studies of the rates of chemical reactions and elemental cycles in biologic systems

- **Geomorphology** — studies of weathering and erosion rates and processes

- **Nuclear explosion phenomenology** — use of stable and long-lived nuclides to characterize the physics of underground nuclear explosions

- **Analytical methods development** — new methods for element isolation, design/construction of new instruments to measure isotope abundances

- **Isotope separation facility** — production of isotopically enriched substances

Current staffing — Los Alamos National Laboratory currently has 10 FTEs and 10 support staff working in the production of isotopes, measurement of isotopic compositions, and applications to scientific and technical research. Of the 4 FTEs and 1 support staff supported by nondefense related programs, 2 FTEs and 0.5 support staff are working on basic research in isotope geochemistry programs.

Anticipated FTE requirements — The Los Alamos group projects no growth over the next decade. Anticipated needs emphasize a shift of support for existing staff within the DOE as the use of the capabilities shifts from the mission of one DOE office to that of another. Total funding requirement for full staffing (10 FTEs and 10 support staff) will remain at $3.00M/yr in FY1990 dollars.

Staffing for Los Alamos National Laboratory					
	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	10		10	200	2M$
Staff	10		10	100	1M$
Total					**3M$**

Los Alamos National Laboratory Equipment

Current	Principal Uses
Thermal ionization mass spectrometers (5 multiple stage, 3 single stage)	Sensitive/precise measurements of actinides (uranium, plutonium, curium, neptunium); other elements (neodymium, lead, strontium, ruthenium); uranium/thorium-series; instrument development
Gas source mass spectrometer	Silicon isotope abundances
Mattauch-Herzog mass spectrometer	Noble gases, instrument development
Laser-based mass spectrometry	R&D in laser-based techniques for ionization and detection

Needed by FY2000	Cost (M$)
Los Alamos capital costs projections are based on the replacement of current equipment at a rate of 10%/yr	
Total	**10.0**

E. Oak Ridge National Laboratory

Principal areas of investigation

- **Surface and subsurface hydrology** — isotopic compositions of natural or introduced radioactive and stable elements in shallow groundwaters
- **Environmental transport** — migration of contaminants and natural components in shallow groundwater systems
- **Biogeochemical cycles** — tracing the sources and sinks of natural and anthropogenic materials in terrestrial, marine, and freshwater environments
- **Paleo-environments** — isotopic indicators of paleo-climate as recorded in fossil soils
- **Water/rock interaction** — experimental and modeling studies of isotopic exchange equilibria and kinetics in mineral/fluid systems
- **Active geothermal systems** — relationship between fluid flow, alteration, and the duration of hydrothermal activity
- **Fluids and faulting** — generation and migration of hydrocarbon-bearing fluids along thrust faults, evolution of secondary porosity

Current staffing — Oak Ridge National Laboratory presently has 4 FTEs funded by the Office of Health and Environmental Research, the Environmental Protection Agency, and the National Science Foundation and 2 FTEs funded through the Office of Basic Energy Science at DOE—all of whom perform basic research in isotope geochemistry.

Anticipated FTE requirements — Needs for program growth over the next decade are 6 additional FTEs ($200K/yr/FTE) and redirection of 4 FTEs now funded from non-DOE sources. Total funding requirement for full staffing (10 FTEs) will be $2.00M/yr (FY1990 dollars).

Staffing for Oak Ridge National Laboratory

	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	4	6	10	200	2M$
Total					**2M$**

Oak Ridge National Laboratory Equipment

Current	Principal Uses
Thermal ionization mass spectrometer	Uranium, lead, neodymium, strontium, hafnium, calcium isotope ratio measurements
Gas source mass spectrometers (2)	Isotope ratio measurements on carbon, nitrogen, oxygen, sulfur, and hydrogen
Alpha-beta-gamma spectrometers (6)	Uranium-series, cosmogenic isotope tracers
Ion microprobe facility	Isotopic and elemental microanalysis of geologic samples
Inductively coupled plasma mass spectrometer with laser ablation	Spatially resolved trace element and isotopic analysis of solids
Resonance ionization mass spectrometers (6)	Spatially resolved part-per-trillion trace element, rare isotope, rare earth element analysis

Needed by FY2000	Projected Use	Cost (M$)
Gas source mass spectrometer	Oxygen, hydrogen isotopes in waters	0.25
Gas source mass spectrometer	Deuterium/hydrogen measurements	0.25
	Total	**0.50**

F. Pacific Northwest Laboratories

Principal areas of investigation

- **Groundwater studies** — groundwater ages, travel times, and flow regimes; inferred geochemistry of source regions; microbial resperation
- **Hydrothermal systems** — timing of secondary mineral formation; solute retardation; identification of mixing zones; transport modeling
- **Environmental actinide chemistry** — speciation and behavior of natural and anthropogenic actinides in surface waters and shallow groundwaters; role of colloids

Current staffing — Pacific Northwest Laboratories presently has 2 FTEs performing basic research in isotope geochemistry.

Anticipated FTE requirements — Needs for program growth over the next decade at Pacific Northwest Laboratories are 3 additional FTEs ($200K/yr/FTE). Total funding requirements for full staffing (5 FTEs) will be $1.00M/yr (in FY1990 dollars).

Staffing for Pacific Northwest Laboratories

	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	2	3	5	200	1M$
Total					**1M$**

Pacific Northwest Laboratories Equipment		
Current	**Principal Uses**	
Thermal ionization mass spectrometers (3)	Isotope measurements on actinide and fission and fission products	
Alpha-beta-gamma spectrometers	Uranium- and thorium-decay series studies, groundwater monitoring, nuclear waste	
Double resonance ionization mass spectrometry	Measurements of very rare isotopes	
Inductively coupled plasma mass spectrometer with laser ablation	Trace element geochemistry of fluids, spatially resolved analysis of solids	
Needed by FY2000		**Cost (M$)**
Pacific Northwest Laboratories expects to replace obsolete instrumentation over the next 10 yr		
	Total	**3.5**

G. Sandia National Laboratories

Principal areas of investigation

- **Fluid sources in evaporites** — identification of fluid sources and water/rock ratios in groundwater systems associated with evaporites
- **Hydrothermal alteration** — degree of recrystallization of host carbonate rocks in response to groundwater movement
- **Radiocarbon dating models** — determination of the carbon-isotope composition of host carbonate for use in radiocarbon-dating models for groundwater
- **Groundwater investigations** — recharge phenomena in unsaturated zones, relations of groundwater systems to paleoclimate changes

Current staffing — Sandia National Laboratories presently has 1 FTE performing basic research in isotope geochemistry.

Anticipated FTE requirements — Sandia National Laboratories requires 2 additional FTEs ($200K yr FTE) for program growth over the next decade. Total funding requirement for full permanent staffing (3 FTEs) will be $0.60M/yr (in FY1990 dollars).

Staffing for Sandia National Laboratories

	Current	Additional Needed	Total Anticipated FY2000	Cost per Individual (K$)	Total Cost (FY1990 $)
FTEs	1	2	3	200	600K$
Total					**0.6M$**

Sandia National Laboratories Equipment

Current	Principal Uses
Gas source mass spectrometer	Isotope measurements on carbon, nitrogen, oxygen, sulfur, and hydrogen from geologic samples

Needed by FY2000	Projected Use	Cost (M$)
Gas source mass spectrometer	Past climates, hydrogeology	0.30
Laboratory equipment	Past climates, hydrogeology	0.20
	Total	**0.50**

APPENDIX
COMMITTEE ON ISOTOPE GEOCHEMISTY IN THE DOE

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