

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**

**PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

**SUBJECT: INTERNATIONAL NATURAL
ANALOGUE PROGRAM**

PRESENTER: ROBERT A. LEVICH

**PRESENTER'S TITLE
AND ORGANIZATION: INTERNATIONAL PROGRAMS MANAGER
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT OFFICE
U.S. DEPT. OF ENERGY, LAS VEGAS, NEVADA**

**PRESENTER'S
TELEPHONE NUMBER: (702) 794-7946**

**RENO, NEVADA
APRIL 16-17, 1991**

INTERNATIONAL NATURAL ANALOGUE PROGRAM

- **MUCH OF DOE'S CURRENT INTERNATIONAL NATURAL ANALOGUE PROGRAM IS DERIVED FROM THE CRYSTALLINE REPOSITORY PROJECT (CRP), DOE'S FORMER SECOND REPOSITORY PROGRAM**
- **THE CRP'S NATURAL ANALOGUE PROGRAM WAS DEVELOPED BECAUSE OF TWO BASIC CONCERNS:**
 - **DO NUMERICAL MODELS AND DATA COLLECTED IN LABORATORIES REALISTICALLY PORTRAY GEOLOGIC, HYDROLOGIC, AND GEOCHEMICAL PHENOMENA OVER GEOLOGIC TIME?**
 - **ARE THERE INTERACTIONS BETWEEN MATERIALS AND PROCESSES WHICH CONTROL THE TRANSPORT OF RADIONUCLIDES IN NATURE BUT HAVE NOT BEEN IDENTIFIED?**

U.S. DOE INTERNATIONAL NATURAL ANALOGUE PROGRAM

ORGANIZATIONS

- **NATURAL ANALOGUE WORKING GROUP (NAWG)**
- **NATURAL ANALOGUE PEER REVIEW GROUP**

PROJECTS

- **ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)**
- **CIGAR LAKE ANALOGUE STUDY**
- **OKLO AS A NATURAL ANALOGUE PROJECT**
- **POÇOS DE CALDAS PROJECT**

NATURAL ANALOGUE WORKING GROUP (NAWG)

**SPONSOR: COMMISSION OF EUROPEAN COMMUNITIES
(CEC)**

PARTICIPANTS: CEC NATIONS
AUSTRALIA
CANADA
FINLAND
JAPAN
SWEDEN
SWITZERLAND
U.S.A.

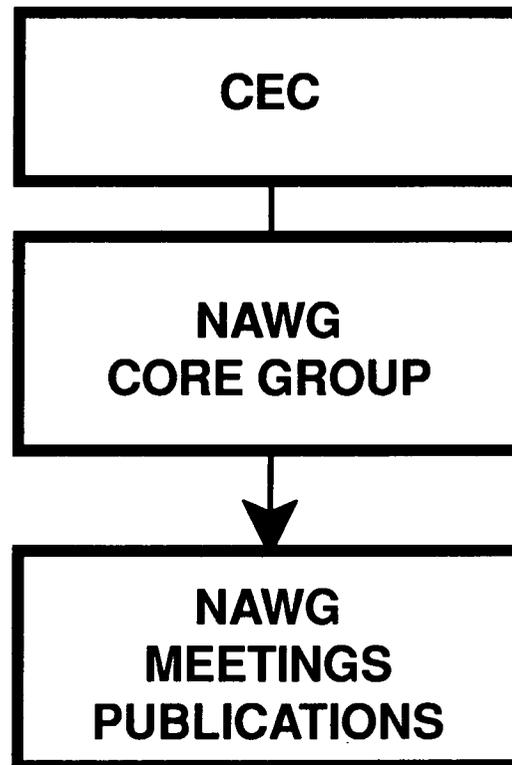
NATURAL ANALOGUE WORKING GROUP (NAWG)

OBJECTIVES

- **FACILITATE INTERACTION AMONG INVESTIGATORS ACTIVELY INVOLVED IN NATURAL ANALOGUE STUDIES**
- **PROMOTE DISCUSSION AMONG INVESTIGATORS, REGULATORS, AND TECHNICAL MANAGERS OF NUCLEAR WASTE PROGRAMS**
- **PROVIDE A FORUM FOR COMMUNICATION BETWEEN SAFETY ASSESSMENT MODELERS AND NATURAL ANALOGUE INVESTIGATORS**

NATURAL ANALOGUE WORKING GROUP (NAWG)

STRUCTURE:



NATURAL ANALOGUE WORKING GROUP (NAWG)

PROGRAM HISTORY:

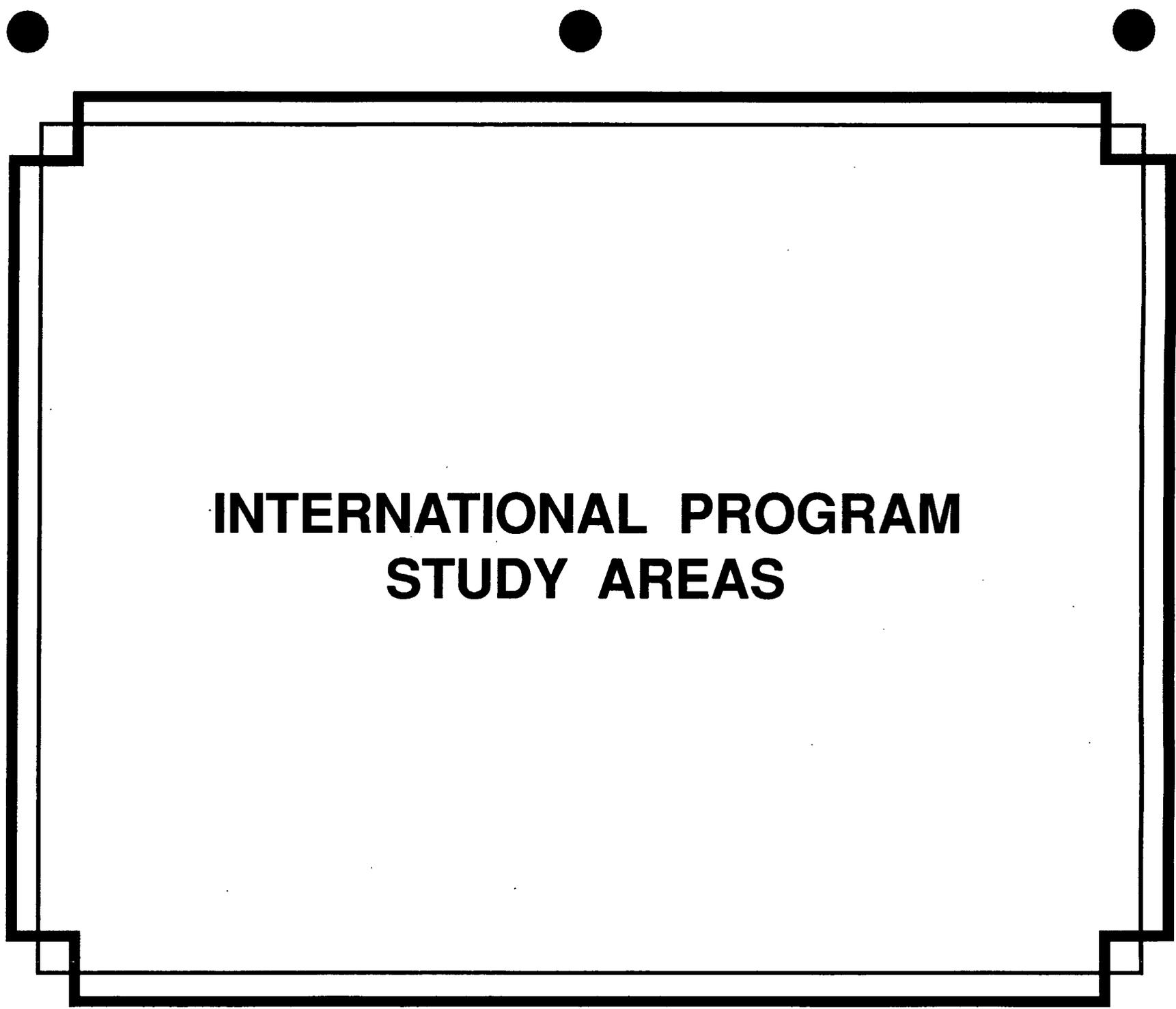
- 10/84 LAKE GENEVA, WISCONSIN, U.S.A.
PLANNING MEETING**
- 11/85 BRUSSELS, BELGIUM
1ST NAWG MEETING**
- 06/86 INTERLAKEN, SWITZERLAND
2ND NAWG MEETING**
- 04/87 BRUSSELS, BELGIUM
CEC-SPONSORED SYMPOSIUM**
- 06/88 SNOWBIRD, UTAH, U.S.A.
3RD NAWG MEETING**
- 06/90 PITLOCHRY, SCOTLAND
4TH NAWG MEETING &
POÇOS DE CALDAS SYMPOSIUM**

NATURAL ANALOGUES PEER REVIEW GROUP

**DOE IS DEVELOPING A PEER REVIEW GROUP
COMPRISED OF RECOGNIZED INTERNATIONAL
NATURAL ANALOGUE EXPERTS WHO HAVE BROAD
EXPERIENCE IN CONCEPTUALIZING, PLANNING, AND
IMPLEMENTING MULTIDISCIPLINARY NATURAL
ANALOGUE PROGRAMS. THESE EXPERTS WILL
PROVIDE DOE THE BENEFIT OF BOTH THEORETICAL
AND PRACTICAL EXPERIENCE.**

ROLE OF THE NATURAL ANALOGUE PEER REVIEW GROUP

- **REVIEW DOE'S DRAFT NATURAL ANALOGUE STRATEGY PLAN AND NATURAL ANALOGUE PROGRAM**
- **INTERACT WITH YMP PARTICIPANTS ENGAGED IN TECHNICAL ACTIVITIES FOR WHICH NATURAL ANALOGUE STUDIES MAY BE BENEFICIAL**
- **ADVISE DOE ON REVISING THE DRAFT NATURAL ANALOGUE STRATEGY AND DEVELOPING A PROGRAM DIRECTLY APPLICABLE TO THE YUCCA MOUNTAIN SITE AND OTHER PROGRAM NEEDS**
- **WILL SAVE TIME AND COST IN DEVELOPMENT OF STRONG AND WORKABLE STRATEGY ACCOMPANIED BY PRACTICAL FIELD PROGRAM THAT INCLUDES BOTH ONGOING INTERNATIONAL PROJECTS AND PROPOSED DOMESTIC OR INTERNATIONAL SITES FOR NEW PROJECTS**



**INTERNATIONAL PROGRAM
STUDY AREAS**

ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)

LOCATION: KOONGARA URANIUM DEPOSIT, NORTHERN
TERRITORY, AUSTRALIA

DURATION: 1987 – 1992 (PHASE 2: 1990 – 1992)

**MANAGING
PARTICIPANT:** AUSTRALIAN NUCLEAR SCIENCE & TECHNOLOGY
ORGANIZATION (ANSTO)

SPONSOR: OECD/NEA

ORGANIZATION: MULTINATIONAL AGREEMENT

PARTICIPANTS: AUSTRALIA: ANSTO
JAPAN: JAERI
PNC
SWEDEN: SKI
U.K.: UKDOE
U.S.A.: U.S. NRC
U.S. DOE (ASSOCIATE)

ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)

PRINCIPLE OBJECTIVES

- **CONTRIBUTE TO DEVELOPMENT OF RELIABLE AND REALISTIC MODELS FOR RADIONUCLIDE MIGRATION**
- **DEVELOP METHODS OF MODEL VALIDATION USING LABORATORY AND FIELD DATA FROM KOONGARA**
- **ENCOURAGE MAXIMUM INTERACTION BETWEEN THOSE CONDUCTING MODELING AND THOSE CONDUCTING FIELD AND LABORATORY STUDIES**

ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)

SUB-PROJECTS

- **MODELING OF RADIONUCLIDE MIGRATION**
- **HYDROGEOLOGY OF THE KOONGARA URANIUM DEPOSIT**
- **URANIUM/THORIUM SERIES DISEQUILIBRIA STUDIES**
- **GROUNDWATER AND COLLOID STUDIES**
- **FISSION PRODUCT STUDIES**
- **TRANSURANIC NUCLIDE STUDIES**

ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)

DOE PARTICIPATION

- **IN FINAL TWO YEAR PHASE 2 OF ARAP AS AN ASSOCIATE PARTICIPANT**
- **SUPPORT FOR LANL MEASUREMENTS OF PLUTONIUM, TECHNETIUM, AND IODINE-129**
- **SUPPORT FOR PNL TO:**
 - **VALIDATE CONCEPTUAL AND NUMERIC MODELS OF HYDRAULIC FLOW THROUGH FRACTURED ROCK AT FIELD SCALE USING DISCRETE AND EQUIVALENT CONTINUUM APPROACHES**
 - **MODEL TRANSPORT USING DISCRETE AND EQUIVALENT CONTINUUM APPROACHES INTEGRATED WITH KOONGARA'S GEOCHEMISTRY**
 - **PARTIALLY VALIDATE FLOW/TRANSPORT/GEOCHEMISTRY FOR GEOLOGIC TIME SCALES**

ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)

DOE BENEFITS

- **DATA SET PROVIDES INPUT TO DOE'S SITE CHARACTERIZATION AND PERFORMANCE ASSESSMENT STUDIES**
- **TESTING MODELS IN HYDROLOGY, GEOCHEMISTRY, AND RADIONUCLIDE MIGRATION**
- **DEVELOPING APPROACH TO SUCCESSFULLY OBTAINING FIELD-SCALE VALIDATION DATA SET FOR USE IN MODELING STUDIES**
- **PROVIDING FORUM TO TEST MODEL VALIDATION METHODOLOGIES**
- **DEMONSTRATING WHICH DATA ARE NEEDED TO ADEQUATELY CHARACTERIZE A SITE AND PROVIDING CONFIDENCE IN MODELING RESULTS**

ALLIGATOR RIVERS ANALOGUE PROJECT (ARAP)

DOE BENEFITS

(CONTINUED)

- **DEVELOPING TRANSFERABLE APPROACHES TO PREDICTING THE EVOLUTION OF GEOHYDROLOGIC AND GEOCHEMICAL SYSTEMS**
- **PROVIDING DATA ON PAST CLIMATIC EFFECTS ON THE FORMATION OF URANIUM DEPOSITS AND RADIONUCLIDE TRANSPORT**
- **DEVELOPING SITE-BINDING APPROACH TO SORPTION APPLICABLE TO LABORATORY-MEASURED K_d VALUES AND THE PREDICTION OF RADIONUCLIDE TRANSPORT**

CIGAR LAKE ANALOGUE STUDY

LOCATION: CIGAR LAKE URANIUM DEPOSIT,
SASKATCHEWAN, CANADA

DURATION: STUDIES BEGAN IN 1984
CURRENT PROJECT: 1989–1992, 1992–1996

**MANAGING
PARTICIPANT:** ATOMIC ENERGY OF CANADA LIMITED (AECL)

ORGANIZATION: BILATERAL AGREEMENTS

PARTICIPANTS: CANADA: AECL
SWEDEN: SKB
U.S.A.: U.S. DOE
U.K.: NIREX (ONGOING NEGOTIATIONS)

CIGAR LAKE ANALOGUE STUDY

CIGAR LAKE URANIUM DEPOSIT

- **IS EXTREMELY LARGE AND RICH. CONTAINS ca. 147 MILLION kg (323 MILLION lbs) URANIUM AT AN AVERAGE GRADE OF 14% U_3O_8 (RANGE: 1 – 65% U_3O_8)**
- **LIES AT DEPTH OF 430 METERS WITHIN ATHABASCA SANDSTONE JUST ABOVE CONTACT WITH ARCHEAN CRYSTALLINE ROCKS**
- **NO DETECTABLE INDICATORS AT SURFACE EVEN THOUGH URANIUM ORE BODY IS 1.3 BILLION YEARS OLD**
- **ISOTOPIC DATA INDICATES URANIUM ORE HAS SURVIVED SEVERAL MAJOR GROUNDWATER INCURSIONS DURING PAST 1 BILLION YEARS**
- **COLLECTED DATA CONCERNS: MINERALOGY, GEOCHEMISTRY, HYDROGEOLOGY, AND GROUNDWATER CHEMISTRY**
- **DEPOSIT HAS BEEN EXTENSIVELY DRILLED (MORE THAN 180 BOREHOLES AND 80 km OF DRILLCORE ARE AVAILABLE)**

CIGAR LAKE ANALOGUE STUDY

OBJECTIVES AND BENEFITS

- **OBSERVE PROCESSES IN BOTH FAR-FIELD AND NEAR-FIELD ENVIRONMENTS INVOLVING RADIONUCLIDE MIGRATION AND RETENTION, AND FRACTURE AND POROUS MEDIA FLOW**
- **FURTHER DEVELOPMENT OF ANALYTICAL CAPABILITIES FOR MEASURING RADIONUCLIDES IN GEOLOGIC SAMPLES**
- **COLLECT DATA FOR TESTING AND VALIDATING RADIONUCLIDE TRANSPORT MODELS**
- **MAY LEAD TO DEVELOPMENT OF AND VALIDATION FOR IMPROVED ASSESSMENT MODELS AND DATA**
- **MAY SUPPORT OVERALL RESULTS OF PERFORMANCE ASSESSMENTS**

CIGAR LAKE ANALOGUE STUDY

STUDIES INCLUDE

- **TRACE-ELEMENT DISTRIBUTION AND TRANSPORT VIA ROCK/WATER INTERACTION**
- **MIGRATION OF SELECTED RADIONUCLIDES**
- **EFFECTS OF INTRODUCING OXYGEN-RICH GROUNDWATERS ON REDUCED URANIUM ORE DURING SHAFT-SINKING**

CIGAR LAKE ANALOGUE STUDY

DOE (LANL/LLNL) PARTICIPATION

- **MEASURE CONCENTRATIONS AND CALCULATE EQUILIBRIUM ABUNDANCES OF Tc-99, Pu-239, AND I-129 IN ROCK AND WATER SAMPLES**
- **MEASURE NEUTRON PRODUCTION RATE IN URANIFEROUS SAMPLES**
- **USE MEASUREMENTS TO EVALUATE UNCERTAINTIES ASSOCIATED WITH MATHEMATICAL TRANSPORT MODELS FOR THESE RADIONUCLIDES**
- **MODEL GEOCHEMISTRY OF GROUNDWATER COMPOSITIONS UNDER UNPERTURBED AND PERTURBED (OXIDIZING) CONDITIONS**
- **CALCULATE SPECIATION AND SOLUBILITY EQUILIBRIA EMPHASIZING U, Tc, Pu, AND I**
- **PREDICT STABLE MINERAL ASSEMBLAGES EMPHASIZING SECONDARY U MINERALS**
- **PERFORM PARTIAL VALIDATION EXERCISE BY COMPARING MODELING CALCULATIONS TO FIELD OBSERVATIONS**

OKLO AS A NATURAL ANALOGUE PROJECT

LOCATION: OKLO URANIUM MINE, GABON, EQUATORIAL AFRICA

DURATION: 1991 – 1994

MANAGING PARTICIPANT: FRANCE'S ATOMIC ENERGY COMMISSION (CEA)

SPONSOR: COMMISSION OF EUROPEAN COMMUNITIES (CEC)

PARTICIPANTS:

FRANCE:	CEA/ANDRA
	CEA/IPSN
	CEA/CEN-FAR
	ECOLE DES MINES
CANADA:	AECL
SWEDEN:	SKB
SWITZERLAND:	NAGRA
U.K.:	NIREX
U.S.A.:	U.S. DOE
	U.S. NRC

OKLO AS A NATURAL ANALOGUE PROJECT

THE OKLO NATURAL FISSION REACTORS

- **UNIQUE OCCURRENCE DISCOVERED DURING OPEN PIT URANIUM MINING IN 1972**
- **ONLY KNOWN LOCALITY FOR STUDYING THE TRANSPORT OF FISSION DAUGHTER PRODUCTS OVER MILLIONS OF YEARS**
- **REACTORS ARE CONTAINED IN URANIUM DEPOSITS WHICH OCCUR IN THE 2.1 BILLION YEAR OLD SEDIMENTARY ROCKS OF THE FRANCEVILLE BASIN**
- **THE URANIUM ORE THAT FORMS THE REACTORS ACHIEVED CRITICALITY BETWEEN 1.9 AND 2.0 BILLION YEARS AGO**
- **THE FIRST DISCOVERED REACTOR ZONES LIE NEAR THE GROUND SURFACE. RADIONUCLIDES HAVE BEEN PARTIALLY REDISTRIBUTED BY THE EFFECTS OF TROPICAL WEATHERING**

OKLO AS A NATURAL ANALOGUE PROJECT

BENEFITS

- **PROVIDE UNIQUE DATA FOR USE IN VALIDATING DOE'S PERFORMANCE ASSESSMENT MODELS RELATED TO NEAR-FIELD TRANSPORT**
- **DEVELOPING APPROACHES FOR UNDERSTANDING THE RELATIONSHIP BETWEEN NEAR-FIELD AND FAR-FIELD RADIONUCLIDE TRANSPORT**
- **UNDERSTANDING EFFECTS OF CLIMATE AND WEATHERING ON RADIONUCLIDE TRANSPORT**
- **UNDERSTANDING EFFECTS OF REGIONAL AND LOCAL GEOLOGY, HYDROLOGY, AND CLIMATOLOGY ON RADIONUCLIDE TRANSPORT OVER MILLIONS OF YEARS**

OKLO AS A NATURAL ANALOGUE PROJECT

OBJECTIVES

- **BASELINE STUDIES OF GEOLOGY, HYDROLOGY, AND GEOCHEMISTRY TO FULLY UNDERSTAND TRANSPORT OF FISSION DAUGHTER PRODUCTS IN THE GEOSPHERE**
- **CONCENTRATE ON PREVIOUSLY UNSTUDIED REACTOR ZONES WHICH LIE DEEP UNDERGROUND AND ARE UNDISTURBED BY WEATHERING**
- **STUDIES OF CONTEMPORANEOUS AND DIAGENETIC TRANSPORT OF RADIONUCLIDES USING MINERALOGY, MICROMINERALOGY, AUTORADIOGRAPHY, FISSION TRACK MAPPING, FLUID INCLUSIONS, CLAY MINERALOGY, AND STABLE ISOTOPES**

OKLO AS A NATURAL ANALOGUE PROJECT

OBJECTIVES

(CONTINUED)

- **NEAR-FIELD STUDIES BY ION MICROPROBE MAPPING OF URANIUM, LEAD, AND FISSION PRODUCTS IN AND NEAR THE REACTOR ZONES**
- **STUDIES OF RECENT RADIOELEMENT MIGRATION USING AQUEOUS TRACERS FOUND IN THE REACTOR ZONE, AND EVALUATING THEIR FAR-FIELD MIGRATION IN VERTICAL AND LATERAL DIRECTIONS**
- **THERMODYNAMIC MODELING OF SOLID-SOLUTION EXCHANGES AND HYDRODYNAMIC MODELING TO EVALUATE GROUNDWATER FLUX THROUGH REACTION ZONES**

OKLO AS A NATURAL ANALOGUE PROJECT

DOE PARTICIPATION

- **SUPPORT THE UNIQUE CAPABILITY BY LANL TO MEASURE THE EXTREMELY SMALL AMOUNTS OF NATURAL PLUTONIUM AND TECHNETIUM THAT OCCUR AT OKLO AND OTHER URANIUM DEPOSITS**
- **SUPPORT LLNL STUDIES RELATED TO NEAR-FIELD TRANSPORT OF FISSION DAUGHTER PRODUCTS**
- **CEA WILL PROVIDE ALL DATA COLLECTED AT OKLO TO DOE**
- **CEA'S INVITATION FOR THE U.S. TO PARTICIPATE IN THE PROJECT IS AN EXCEPTIONAL OPPORTUNITY. DOE PARTICIPATION IS CURRENTLY DEPENDENT ON BUDGETARY PRIORITIES**