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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Nuclear Waste Technical Review Board (NWTRB) Meeting on Natural Analogs and Geochemical Analogs Research Project Field Trip to McDermitt Caldera and Virgin Valley

DATE/PLACE: April 16-17, and 18-19, 1991
Reno, McDermitt Caldera, and Virgin Valley, Nevada

AUTHORS: William M. Murphy, English C. Pearcy, and Ronald T. Green

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PARTICIPANTS: At the TRB Meeting: William M. Murphy, English C. Pearcy (CNWRA); George Birchard, Bill Ott, Norman Eisenberg (NRC); The NWTRB and staff, and representatives of the State of Nevada, DOE, and the public; On the field trip: William M. Murphy, English C. Pearcy, Ronald T. Green, Bill Ott, and Steve Castor (Nevada Bureau of Mines)

AUTHORS: William M. Murphy, English C. Pearcy, and Ronald T. Green

BACKGROUND AND PURPOSE OF TRIP:

The NWTRB meeting was announced on March 8, 1991 to discuss use of analogs in high-level waste disposal. The CNWRA was invited to present their natural analogs research program and the work at Peña Blanca. The field trip was conducted as part of Task 2 of the CNWRA Geochemical Analogs Research Project, an objective of which is to select a site for natural analog research in the advanced stages of the project. The McDermitt Caldera area has been identified as a potential analog site with particular relevance to the proposed Yucca Mountain repository (e.g. Alexander and Van Luik (1989); Pearcy and Murphy, 1990). General objectives of the trip were to assess similarities between the McDermitt Caldera/Virgin Valley and Yucca Mountain environments, and to evaluate potential geochemical analog research projects. Steve Castor, an expert on the field area was invited to lead the trip. Bill Ott attended the trip on behalf of the NRC staff.

NWTRB MEETING

The meeting agenda is given in Attachment A. The meeting was formally recorded, so a full transcript should be forthcoming. The following is a general commentary on presentations and discussions at the meeting.

Assisting Peter Hummel (who discussed the oil potential of Nevada) was Alan Chamberlain who gave an enthusiastic talk offering confident predictions that huge quantities of oil and gas exist near Yucca Mountain in the central Nevada overthrust belt. His analysis was based on stratigraphic measurements, well data, geophysical data, and balanced cross sections.

Ike Winograd gave an entertaining talk extolling unsaturated environments and archaeological analogs. He showed photos of numerous ancient and delicate artifacts preserved at unsaturated sites. In private discussions between him and CNWRA staff, the CNWRA Akrotiri archaeological analog proposal received hearty endorsement and encouragement.

Norman Eisenberg noted that analogs help performance assessment (PA) with regard to the source term, transport and flow processes, and scenarios. The use of analogs in PA is in model validation: models are the principal means to predict safety; usual validation is impossible; proof testing is impossible. Potential uses of analogs in order of increasing difficulty and decreasing demonstration are: process and phenomenon identification, parametric quantification, component submodel validation, and system model validation.

George Birchard gave a talk on the behalf of NRC Research and Linda Kovach on the scope of natural analog research activities.

Copies of the text slides, and a list of photographic slides presented by William M. Murphy are given in attachment B.

Numerous speakers from DOE institutions and from institutions partially or marginally associated with the DOE discussed research related to analogs. An effort was made to illustrate that analogs permeate the DOE's Yucca Mountain Project. Most Yucca Mountain Project analog research or proposed research appeared to be related to paleohydrologic (and future hydrologic) conditions using analog sites from north and south of Yucca Mountain (cf. D. Hoxie). In addition, mass spectrometric analytical work at LANL supports or will support a number of international analog projects (cf. D. Curtis). Work presented by Bill Bourcier on natural glass analogs of waste glasses, and by Dave Bish on a paleogeothermal system at Yucca Mountain showed significant applicability of results. Carol Bruton proposed study of New Zealand hydrothermal systems as near-field analogs. Carl Johnson of the State of Nevada interjected that the Tacopa Hot Springs near Yucca Mountain may be more relevant.

The round table discussion was brief and focused on a few topics including management structures, quality assurance, model validation, and applicability of analog studies. No consensus of opinion was evident from the TRB.

McDERMITT CALDERA AND VIRGIN VALLEY FIELD WORK

Field trips to the McDermitt Caldera and Virgin Valley areas of Nevada were made to assess the usefulness of potential natural analog research at the sites. Specifically, three locations were examined and rock samples were collected: the Horse Creek claims and Moonlight Mine at the McDermitt Caldera and outcrops at and near the Royal Peacock Mine in Virgin Valley.

HORSE CREEK CLAIMS

We met with Jim Labrett at his home in Orovada, Nevada, on the way to the McDermitt area. Labrett controls the uranium claims at Horse Creek and has the core, maps, cross sections, and chemical and radiometric analyses produced by Chevron during their exploration of the area in the late 1970's. Chevron produced about 5 miles of core, several volumes of well logs and assay data. The core and the accompanying information are stored at Labrett's residence.

Horse Creek is located on the southwestern margin of the McDermitt Caldera, immediately north of the Moonlight Mine. Uranium mineralization at Horse Creek is associated with brecciated portions of a tabular intrusion referred to as the "porcelain rhyolite." According to mapping by Chevron this intrusion cuts across several rhyolitic and andesitic formations as well as the granodiorite which forms the local basement. Castor mapped it as a stratigraphic unit. According to Castor, it is likely that a ring fracture of the caldera controlled placement of the uranium deposits. The Horse Creek deposits are in the northern extension of the ore-controlling structure at the Moonlight Mine.

The ore is brecciated, with abundant silica and occasionally abundant sulfides. No uranium minerals (primary or secondary) were observed. Fine-grained uraninite is reported by Labrett in some of the ore, as well as possible autunite.

Exposure at Horse Creek is limited to occasional outcrops and hillside cuts made by Chevron drill roads.

The hydrogeology of the Horse Creek Mining area has been tentatively interpreted using borehole well logs and depth-to-water measurements compiled as part of the mineral exploration activities by Chevron in the late 1970's. Based upon review of portions of this information, virtually all of the identified mineralized zone in the Horse Creek Mining area is located below the water table. Only the upper few feet of the mineralized zone has been found to be present in isolated occurrences in what is currently the unsaturated zone.

MOONLIGHT MINE

The Moonlight Mine property is adjacent to the South Drill Area of the Horse Creek Claims. Moonlight is the only area at the McDermitt Caldera with recorded uranium production, about 1500 lbs of U_3O_8 from ore with an average grade of about 0.13% U_3O_8 (Dayvault, Castor, and Berry, 1985).

Ore at Moonlight is localized along the same structure described above at Horse Creek and occurs in a brecciated zone a few meters wide which dips about 60° to the northeast. There is good exposure of the ore along the working face of the mine and in several inclined adits. The longest of the adits was inaccessible due to its steepness but is reported to be about 80 m long; the upper 50 m is reported to be above the local water table (Dayvault, Castor, and Berry, 1985). The hanging wall rock is a rhyolite whereas the footwall rocks are rhyolites, dacites, and granodiorites.

The ore is composed of a well-silicified breccia with prominent quartz veins and crystal-filled pockets. Much of the quartz is quite dark, perhaps from radiation damage. Fluorite and iron sulfides also occur; some of the sulfides are altered to iron oxides. No primary or secondary uranium minerals were observed. Uraninite is reported from Moonlight (Castor, personal communication). Alteration directly associated with the ore body was difficult to identify, but extensive hydrothermal alteration of portions of the enclosing rocks (largely to clay minerals) exists in some areas.

The mineralized portion of the Moonlight Mine has been interpreted to be located in both the saturated and unsaturated portion of the subsurface. This interpretation is based upon the observation that a good portion of the downward-inclined adit of the Moonlight Mine was located below the water table. Insufficient information was available to determine the location of the mineralized zone of most interest to this project relative to the water table.

VIRGIN VALLEY AREA

Several areas were examined in Virgin Valley. The first stop was at outcrops west of the main road opposite the Royal Peacock Mine. At this location, unwelded airfall and water-worked tuffs contain opal layers which are locally enriched in uranium. Some of the tuffaceous units appear to have been altered to smectites (based on the weathering textures) and perhaps some zeolites (clinoptilolite, based on the greenish color). Fragments of charcoal occur in the tuffs and are sometimes enriched in uranium. Other than the possible occurrence of carnotite, no uranium minerals were observed.

In mined outcrops on the Royal Peacock Mine claims, opal has replaced some ash beds. In one outcrop, uraniferous opal has partially replaced the ash along a clearly observable reaction front. These beds have the highest levels of radioactivity of those we visited in the Virgin Valley area.

Opal beds and the underlying tuffaceous units are exposed in the side walls of the flood plan of the Virgin Creek, located in Virgin Valley. The brown opal beds are approximately 25 m and the green tuffaceous units are about 15 m above the valley floor. Both units are interpreted, therefore, to be located in the unsaturated zone above the water table. The water table beneath the valley side walls has been presumed to be at the approximate elevation of Virgin Creek.

CONCLUSIONS

The NWTRB meeting reflected that natural analog studies receive broad and diverse interest in the technical community. The natural analogs project at the CNWRA received good support, and its emphasis on specific applicability to the Yucca Mountain environment was notable in relation to many other projects. Announcement of the CNWRA/NRC workshop on natural analogs was received with interest.

The McDermitt/Virgin Valley area offers a number of interesting uranium occurrences in volcanic and volcanogenic environments. In particular, a mineralogic study of uranium in clinoptilolite could be of significance to the CNWRA analogs and/or geochemistry research programs. However, field observations suggest that extensive analog research relevant to Yucca Mountain may be hampered by the broad dissemination and fine-grained nature of the mineralization, poorly defined uranium mineralogy, and poor access to the ore zone, much of which is apparently below the water table.

REFERENCES

Alexander, D. H., and Van Luik A. E. (1990) Natural analog studies useful in validating regulatory compliance analyses. Proceedings GEOVAL, Stockholm, Sweden. In press.

Pearcy, E. C., and Murphy, W. M. (1990) Geochemical Natural Analogs Literature Review. CNWRA 90-008 (draft).

Dayvault, R. D., S. B. Castor and M. R. Berry. 1985. Uranium associated with volcanic rocks of the McDermitt Caldera, Nevada and Oregon. *Uranium Deposits in Volcanic Rocks.* Austria: International Atomic Energy Agency, proceedings of a technical committee meeting, El Paso, TX April 1984. IAEA-TC-490: 379-409.

SIGNATURES AND DATES

William M. Murphy

Ronald T. Green

English C. Pearcy

CONCURRENCE:

John Russell
Manager, Geologic Setting

Attachment A-1

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

Full Board Meeting Agenda

Natural and Archaeological Analogues

April 16, 1991

Peppermill Hotel
2707 South Virginia Avenue
Reno, Nevada
(702) 826-2121

8:30 A.M.

Welcome & Opening Remarks
Don U. Deere, Chairman of the Nuclear Waste Technical Review Board (NWTRB)

State of Nevada Update

Status Report on Nevada Repository Programs
Bob Loux, Nevada Agency for Nuclear Projects (30 min.)

Possibility of Petroleum Reserves at Yucca Mountain
Peter Hummel, Nevada State Commission on Mineral Resources (45 min.)

U.S. Geological Survey (USGS) Update

Status of USGS involvement at Yucca Mountain
Gene Roseboom, USGS (20 min.)

10:30 A.M. (approximately) **BREAK**

- over -

Telephone: 703-[illegible] Fax: 703-235-4495

Natural Analogue Session

Opening Remarks
Ellis D. Verink, Chair, Morning Session
NWTRB

Nevada Test-Site Studies
Larry Ramspott
Lawrence Livermore National Laboratory (LLNL)
(30 min.)

Archaeological Analogues/Yucca Mountain Alternative Perspective
Isaac Winograd, USGS
(30 min.)

Nuclear Regulatory Commission (NRC) Natural Analogues Program Plan
Linda Kovach, Office of Nuclear Regulatory Research, NRC (30 min.)

Topics:

- Status of Alligator River Project
- Vallez Caldera
- NRC Natural Analogue Workshop - 1991 Summer

12:30 P.M. (approximately) **LUNCH**

1:15 P.M.

Opening Remarks
Donald Langmuir, Chair, Afternoon Session, NWTRB

Overview and Status of Piña Blanca Project
William Murphy, Center for Nuclear Waste Regulatory Analysis (30 min.)

NRC Staff Perspectives on Analogues
Norman Eisenberg, NRC
Office of Nuclear Material Safety and Safeguards (NMSS) (30 min.)

Introduction to the Department of Energy (DOE) Participation in Natural Analogue Studies
J. Russell Dyer, DOE, Yucca Mountain Project Office (YMPO) (10 min.)

Topics:

- Differing definitions of "natural analogue" for international programs, INTRAVAL, and Yucca Mountain Project (YMP)

Natural Analogue Advisory Group
Robert Levich, DOE/YMPO (5 min.)

International Program
Robert Levich, DOE/YMPO

3:00 P.M. (approximately) **BREAK**

Study Areas: (40 min.)

- Oklo
- Alligator River
- Cigar Lake
- Poco de Caldas

Mike Shea, University of Chicago

Geochemistry & Transport of Naturally Occurring Pu, I, Tc at Natural Analogue Sites
David Curtis, Los Alamos National Laboratory (LANL) (30 min.)

INTRAVAL Perspective
Charles Voss, Golder Associates (15 min.)

Introduction to the YMP Philosophy
J. Russell Dyer, DOE/YMPO (15 min.)

Role of Analogues in the Radionuclide Transport Program
Julie Canepa, LANL (20 min.)

Topics:

- Processes for which analogues may exist
- Selection criteria for analogues
- Recommended analogues for these processes
- Analogues for which planned studies exist

5:30 P.M. (approximately) **ADJOURN**

Attachment A-4

FULL BOARD MEETING AGENDA

Natural and Archeological Analogues

April 17, 1991
Peppermill Hotel
2702 South Virginia Avenue
Reno, Nevada
(702) 826-2121

8:30 A.M.	**Welcome & Opening Remarks** D. Warner North, Chair, Morning Session Nuclear Waste Technical Review Board (NWTRB
	Introduction to the YMP Use of Natural Analogues J. Russell Dyer, DOE
	Role of Analogues in the Radionuclide Transport Program J. Canepa, LANL
	Studies Involving Natural Analogues
	- **Natural Hydrothermal Analogues** C. Bruton, LLNL
	- **Paleoclimate and Hydrology Analogues** D. Hoxie, USGS
	- **Ancient Materials: Analogues for Repository Materials** A.B. Johnson, PNL
10:15 A.M. - 10:30 A.M.	BREAK
10:30 A.M.	- **Natural Analogues for Nuclear Waste Glass** W. Bourcier, LLNL
	- **Anthropogenic Analogues - Radionuclide Transport at DOE Sites** E. Springer, LANL
	- **Yucca Mountain as a Natural Analogue to Repository-Induced Alteration** D. Bish, LANL
	Summary J. Russell Dyer, DOE
11:45 A.M.	Natural Glass Systems Rod Ewing, University of New Mexico
12:15 P.M. - 1:15 P.M.	**LUNCH**

1:15 P.M.	Afternoon Session Clarence R. Allen, Chair NWTRB
1:15 P.M.	General Round-Table Discussion All Meeting participants

NATURAL ANALOG RESEARCH

AT THE

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

William M. Murphy and English C. Pearcy

Presented to the Nuclear Waste Technical Review Board

Reno, Nevada
April 16, 1991

Attachment B-1

NATURAL ANALOG RESEARCH
AT THE
CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

William M. Murphy and English C. Pearcy

Project: Geochemical Analog of Contaminant Transport in Unsaturated Rock

Objective: Design and Conduct an Analog Study Relevant to Yucca Mountain to Evaluate the Use of Analogs in Site Characterization and Model Validation

Sponsor: Nuclear Regulatory Commission Office of Nuclear Regulatory Research

NRC Program Manager: Linda Kovach
CNWRA Project Manager: John L. Russell
Principal Investigators: William M. Murphy and English C. Pearcy

Project Status: Literature Review Completed
Site Selection Investigations Initiated

Project Forecast: Selection of Site(s)
Formulation of Site-Specific Research Objectives and Design
Collection and Interpretation of Data

OBSERVATIONS ON NATURAL ANALOG STUDIES

A repository for high-level nuclear wastes requires knowledge and confidence in a system over a time scale exceeding that of human civilization. Only geologic systems permit direct study of chemical isolation and transport phenomena over the required time and space scales.

The concept of a geologic repository is based on natural analog reasoning. Many geologic systems are proven to have been stable for millions or billions of years. Analogous systems could safely isolate nuclear wastes.

Geology can also provide useful analogs of unfavorable systems. For example, the genesis of ore deposits illustrates massive elemental migration and concentration processes.

Natural analog research can be conducted at small and specialized scales as well as large and interdisciplinary scales.

Key uses of natural analog studies are the identification and evaluation of large space- and time-scale processes and mechanisms, and the validation of qualitative and quantitative models of repository performance.

Natural analog studies suffer basic limitations including the incomplete geologic record, difficult assessment of initial and boundary conditions, partial or imperfect analogy, and nonunique interpretations.

COMPARISONS OF A YUCCA MOUNTAIN REPOSITORY AND POSSIBLE GEOCHEMICAL ANALOG SITES

SITE	ROCK TYPE	ALTERATION MINERALOGY	HYDROLOGY; CLIMATE	TIME SCALE (years)	CONTAMINANT OR ANALOG	PROCESS
Yucca Mountain Waste Repository	Silicic Tuff	Clinoptilolite, Smectite	Unsaturated; Semi-arid	10^3-10^4	Spent fuel/ Vitrified Waste	Contaminant Transport
Peña Blanca Uranium Deposits	Silicic Tuff	Kaolinite, Smectite, Heulandite	Unsaturated; Semi-arid	10^6-10^7	Uraninite	Oxidation of Uraninite, Migration of U
Akrotiri Archaeological Site	Silicic Tuff/ Paleosol	Clinoptilolite, Smectite	Unsaturated; Semi-arid	3.6×10^3	Metallic or other Artifacts	Trace Element Migration

THE PEÑA BLANCA URANIUM DISTRICT

Location:	**Northern Mexico, 50 km North of Chihuahua, 250 km South of El Paso, Texas**
Physiography:	**Uplifted Block in the Basin and Range Province**
Climate:	**Semi-arid; Average Rainfall 24 cm/year; Average Temperature 19°C**
Geology:	**Faulted Silicic Tuffs 35 to 44 Million Years Old Overlie Cretaceous Limestones and Paleozoic Clastic Sedimentary Rocks**
Hydrology:	**Regional Aquifer Approximately 200 m Below the Surface; Intermittent, Discontinuous, Topographically Controlled, Perched Water Table at Shallow Depths**
Mineralization:	**Numerous Uranium Deposits Consisting Dominantly of Uranyl Silicates Associated with Zones of Faulting and Hydrothermal Alteration; Occasional Primary(?) Reduced Uranium Minerals**

THE NOPAL I MINE AT PEÑA BLANCA

Geology:	High-Grade Mineralization Localized in a Vertical, Roughly Cylindrical Breccia Zone Associated with Intersecting Faults Near the Contact of the Nopal and Coloradas Formations
Uranium:	Uraninite or Pitchblende in Irregular Pods; Uranyl Silicates (Especially Uranophane and Weeksite) in Altered Tuffs on Fracture Surfaces and Replacing Primary Silicate Minerals
Alteration:	Primary Silicates (Mainly Alkali Feldspars) Hydrothermally Altered to Clays (Especially Kaolinite) with the Degree of Alteration Diminishing Radially Away From the Breccia Zone; Pitchblende Altered to Uranyl Silicates
Exposure:	Located on a Steep Hillside; Exploration and Mining Operations Generated Several Shafts and Adits over a Vertical Interval of About 100 m; Surface Excavations Expose Large Vertical and Horizontal Cross Sections Through the Breccia Zone
Access:	Property Controlled by the Mexican *Consejo Recursos Minerales* (Mineral Exploration Agency); No Current or Planned Mining Activity; Shafts and Adits are Unmaintained; Exploration Core and Mined Ore are Preserved

Additional slides

Geologic map of the Chihuahua and Sierra Peña Blanca area

Topographic and geographic map of the Peña Blanca uranium district

Overview of the Nopal I mine, looking north

Mineralized breccia at the entry of the 0 level adit at Nopal I

Rock sample of the Nopal Formation

Rock sample of pitchblende and uranyl silicate assemblage from Nopal I

Rock sample of highly altered mineralization from Nopal I

View east from the crest of the Sierra Peña Blanca Range