CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Fourth Quarterly Meeting of the University of Nevada at Las Vegas (UNLV)/U.S. Department of Energy (DOE) Fluid Inclusion Studies Group (20.01402.471)

DATE/PLACE: June 21, 2000; University of Nevada at Las Vegas

AUTHOR: Mary Elizabeth Gray, Bucknell University, Consultant for the Center for Nuclear Waste Regulatory Analyses (CNWRA)

DISTRIBUTION:

CNWRA

W. Patrick
CNWRA Directors
CNWRA Element Managers
J. Stamatakos
D. Ferrill
D. Sims
W. Murphy
D. Pickett
L. Browning
B. Hill
M. Nugent
P. Maldonado

NRC-NMSS

J. Linehan
D. DeMarco
E. Whitt
B. Meehan
J. Greeves
N. Stablein
T. Essig
S. Wastler
D. Brooks
P. Justus
W. Reamer
B. Leslie
J. Bradbury

SwRI

T. Nagy (Contracts)

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Fourth Quarterly Meeting of the University of Nevada at Las Vegas (UNLV)/U.S. Department of Energy (DOE) Fluid Inclusion Studies Group (20.01402.471)

DATE/PLACE: June 21, 2000; University of Nevada at Las Vegas

AUTHOR: Mary Elizabeth Gray, Bucknell University, Consultant for the Center for Nuclear Waste Regulatory Analyses (CNWRA)

PERSONS PRESENT:

Jean Cline (UNLV), Nick Wilson, (UNLV), Sarah Lundberg (UNLV), Joel Rotert (UNLV), Terry Mueller (UNLV/QA), Marie Roosa (UNLV)

Robert Bodnar (Virgina Tech, Independent Consultant for the UNLV Study)

Richard Parizek (Pennsylvania State University, NWTRB), Leon Reiter (NWTRB)

Drew Coleman (DOE), Maralyn Kavchak (DOE/YMP/QATSSS), Raymond Keeler (DOE/YMP/UCCSN)

John Fisher (DOE/OCRWM)

Mary Elizabeth Gray (Bucknell University, Consultant for the CNWRA)

Leonid Neymark (USGS), Jim Paces (USGS), Zell Peterman (USGS), Ed Roedder (Harvard University, Consultant for the USGS), John Stuckless, (USGS), Joe Whelan (USGS), William Scott (USGS)

Yuri Dublyansky (Nevada), Jerry Szymanski (Nevada), Susan Zimmerman (Nevada)

Reina Downing (Nye County), Don Shettel (Nye County)

Engelbrecht von Tiessenhausen (Clark County)

BACKGROUND AND PURPOSE OF TRIP:

Because of ongoing controversy concerning the age and origin [pedogenic (e.g., Paces et al., 1996) vs. epithermal (e.g., Hill et al., 1995)] of secondary mineralization at Yucca Mountain, the DOE has awarded a grant to Jean Cline (UNLV) to conduct an independent study of secondary mineralization at Yucca Mountain. The study aims to determine the origin, ages and temperatures of secondary mineralization while seeking consensus from interested parties (e.g., State of Nevada, USGS, DOE) on the appropriateness of

planned methods and procedures. One of several occurrences of secondary minerals is within fault zones. Since my work with collaborators at the CNWRA has focussed on fault rocks at Yucca Mountain, our work has direct bearing on Dr. Cline's study. I attended this meeting to share the results of our work, engage in the general discussion regarding secondary mineralization at Yucca Mountain, and relate the meeting content to interested individuals at the CNWRA and NRC.

SUMMARY OF PERTINENT POINTS:

The small working group, consisting of Bob Bodnar, Yuri Dublyansky, Jean Cline, Nick Wilson, Joe Whelan and Ed Roedder, met on June 19 and 20. They apparently spent the bulk of both days in discussions, comparing data and giving progress reports.

Jean Cline began the meeting by distributing the agenda (Attachment 1). She followed by giving an update on their progress toward meeting the formal study objectives:

1. Do populations of fluid inclusions, that indicate the recent influx of thermal waters into the repository site, exist?

2. If these inclusions are present, what minimum fluid temperatures do they indicate?

3. If present, when were these inclusions trapped, i.e., when did this influx occur?

4. If an influx occurred, how widespread, within the repository site, was this influx?

Jean reported that the answer to question #1 was "yes" and that the answers to questions 2 and 4 would be given today "for the most part". Various attendees took exception to the Jean's answer to Question #1. It was pointed out that no dates had yet been determined and therefore, there is no indication of a "recent" event. Jean capitulated. Discussion of the meaning of "recent" followed. John Stuckless explained that NRC's 10 CFR 60 defines recent as younger than the QuaternaryTertiary boundary, which has been variously defined as between 1.6 to 2.0 Ma. Joe Whelan took further exception to the phrase "influx of thermal waters." He said that the USGS believes that the mountain did not undergo an "influx of thermal waters." If anything, the mountain may have undergone some heating in the past without any required assistance of an "influx of thermal waters." Jean Cline took the USGS position into advisement.

155 thick sections have been prepared. Half of these contain two phase fluid inclusions. $\delta^{13}C$ and $\delta^{18}O$ data using the secondary ion mass spectrometer (SIMS) at the Royal Ontario Museum will be collected in the very near future. Fluid inclusion microthermometry, U-series and U-Pb geochronology procedures are now QA approved. Quantitative use of the microprobe is not yet QA approved.

Nick Wilson discussed his rationale for dividing the ESF and ECRB into 6 zones with apparently discretely different character:

Zone 1: North Portal of ESF, STA 0+00–8+00

Zone 2: North Ramp of ESF, STA 10+75.2–16+46.4

Zone 3: Lithophysal rich area of ESF, STA 21+68.8–40+21

Zone 4: Intensely fractured zone of ESF, STA 40+68.5–56+63

Zone 5: South ramp of ESF, STA 57+00–78+41

Zone 6: ECRB (ESF STA 30+00 approximately underlies the STA 08+00 ECRB crossover.)

I asked why the data had been grouped based on position in the repository rather than, for instance, based on occurrence or lithology. Nick said that lithologic contacts roughly correspond with boundaries of "zones" and that each zone was dominated by a particular kind of occurrence. This meant that partitioning the data by "zones" implicitly took into account occurrence and lithology.

Nick Wilson presented the results of qualitative microprobe point, line and X-ray mapping. He remarked that the microprobe will not be used quantitatively until the instrument and procedures meet QA approval. The aim of this investigation was to look for chemically distinctive calcite and then try to correlate that calcite from one locality to the next. Magnesium is the only minor or trace element to show significant variations in abundance above detection limits. Magnesium is enriched in patches surrounding tridymite grown at the base of crusts, in sparry calcite in breccias, and the outermost part of crusts. Nick mentioned that some calcite is cathodoluminescent, but deferred detailed discussion of these results for a different meeting.

Fifty percent of all samples contain two-phase fluid inclusion assemblages. Two, two phase fluid inclusion assemblages are hosted by fluorite (ESF STA 5+57.1 and ECRB STA 25+30), one by quartz (ESF STA 5+57.1), and all others are in calcite. No two-phase fluid inclusion assemblages are found in Mg-enriched zones in the outermost calcite crusts in lithophysae. Fluid inclusion microthermometry has been conducted on 40 thick sections. Zone 3, 5, and 6 tend to yield homogenization temperatures (Th) between 45–60°C and modes of about 50° C. Zones 1 and 2 yield higher average Th and Zone 4 yields lower average Th. Data from representative samples from each zone were displayed in the form of histograms. These data are summarized below:

Zone 1: ESF STA 1+62.3: Th range 53°– 80°C, mode = 63°C

Zone 2: ESF STA 14+75.8: Th range 47°–73°C, mode = 57°C, breccia occurrence

Zone 3: ESF STA 28+81: Th range 47°–53°C, mode = 49°C

Zone 4: ESF STA 41+49: Th range 30°– 50°C, vertical fracture occurrence.

Zone 5: ESF STA 77+03: Th range 50°– 60°C, vertical fracture occurrence.

Zone 6: ECRB STA 4+87: Th range 43°– 61°C, mode = 51°C

Zell Peterman wondered why fluid inclusion data is not discussed in terms of arithmetic means with standard deviations. Jean Cline and Bob Bodnar responded that their approach to displaying and discussing fluid inclusion data is standard practice.

All data has been gathered from primary fluid inclusions (i.e., trapped when the crystal grew). All liquid fluid inclusions are most common. All vapor fluid inclusions are also present. Two-phase fluid inclusion assemblages are not present in the outermost, magnesium enriched layers. No two-phase fluid inclusion assemblages have been observed in the magnesium-enriched patches around the "early" tridymite.

The rest of the meeting consisted of a series of presentations by non-UNLV scientists. Dick Parizek gave a presentation on the potential importance of colloids as corrosion products and as means of transport for radionuclides. Plutonium from the underground Benham test at Pahute Mesa traveled 1.3 km in 28 years affixed to colloids. Dick made a special point that colloids travel faster than dissolved ions. He cited the ongoing work on the transport of microspheres in the Calico Hills Formation at Busted Butte. Apparent "dusty" material in secondary calcite may in fact be trapped colloids. He noted that this phenomenon is very common in cave deposits.

At this point the group broke for lunch. Jim Paces and I ate lunch together, alone. We engaged in frank discussion about the USGS data and interpretations to date. I asked Jim how he intended to incorporate elevated Th into the USGS model for the origin of secondary minerals at Yucca Mountain. He said he saw only two choices for interpretation: either the upwelling hydrothermal fluid hypothesis (e.g., Hill et al, 1995) is valid or the fluid inclusion microthermometry data is invalid. He stressed that the USGS ruled out the hydrothermal hypothesis years ago (e.g., Stuckless, et al., 1997). In his opinion, it's inconceivable and contrary to many lines of evidence. Jim feels that the microthermometry data must therefore be bogus. He said that it's possible that the method just isn't appropriate for use in the unsaturated zone. He cited early misuse of many now established dating methods in the past and mentioned that this may be one of those instances when the method isn't yet sophisticated enough to generate accurate data from Yucca Mountain.

As specifically requested by the NRC, I met briefly with Drew Coleman to discuss the YMP approach to addressing the Yuri Dublyansky/Jerry Szymanski hypothesis. I asked when the technical exchange related to the PMR on UZ flow and transport was scheduled to occur. He responded that it is scheduled for July 12–13. I asked, "Do you plan to directly address the Szymanski hypothesis at the technical exchange?" He said he didn't now but he could make sure that they did if the NRC wanted them to. I said that I felt that the NRC was planning to ask questions along these lines at the technical exchange. I asked, "Can you discuss DOE's technical argument for the exclusion of the hydrothermal activity FEP?" He said he could not discuss it at this time but he could make sure it would be discussed at the technical exchange.

Following lunch, Joe Whelan presented $\delta^{13}C$ and $\delta^{18}O$ data and observations of cathodoluminescence from calcite in lithophysal cavities. He noted that the USGS recognizes four stages of mineral growth. The first is an early vapor phase mineralization apparently from outgassing of tuff. This phase is associated with minerals such as tridymite, apatite, fluorite, hematite, and zircon deposits on the base of lithophysal crusts. The second phase involved deposition of "early calcite," quartz and chalcedony. Early calcite has average values of $\delta^{13}C = 5-8‰$ and has a faint luminescence. The intermediate stage of mineralization is dominated by non-luminescent calcite with average $\delta^{13}C$ values of -3‰. Late stage mineralization is characterized by strongly luminescent calcite and opal. Calcite is in some instances corroded and opal is draped on top of the corrosion surface. Average $\delta^{13}C$ values are -7‰. The Topopah tends to contain only calcite in steeply dipping fractures. The Tiva contains the whole suite of minerals and stages in lithophysae and shallowly dipping fractures. Individual fractures can be traced from steeply dipping to shallowly dipping. The steeply dipping portion tends to record only calcite mineralization. As the steeply dipping fractures begin to shallow,

the shallow portion acquires minerals representative of the entire paragenesis. For this reason, the USGS believes that the fractures and lithophysal cavities have related parageneses. UNLV agrees with this assessment.

The USGS has approximately 50 thick sections from the ESF. The area of the north portal of the ESF exhibits mean Th of 85°C and 89°C. In general, all of the USGS fluid inclusion microthermometry data agree with the UNLV results thus far. The USGS has modeled the expected values of $\delta^{18}O$ for the Th values observed and assuming a meteoric source. They predict for a Th of 55°C, $\delta^{18}O$ should be 10–11‰. This is in fact the case in the sample cited. A participant asked Joe how he explained the apparent elevated temperatures of mineral deposition. He stated that they clearly indicated that the minerals exhibiting the elevated temperatures must be "old." The USGS acknowledges three thermal events that may be relevant to the secondary minerals studied: (1) initial cooling and development of fumeroles, (2) Tiva deposition, and (3) 10.5 Ma +/- 1.0 Ma Timber Mountain eruptions. The USGS plans to conduct fission track analyses on apatites and zircons and have contracted Ken Farley (Cal Tech) to perform U-Th/He thermochronology in lithophysal occurrences. They report finding 100 μ diameter apatite crystals in pumice fragments. USGS microprobe analyses confirm the UNLV observation of magnesium zoned calcite. The USGS notes that they indentify the boundary between youngest and intermediate stage calcite by the disappearance of two-phase fluid inclusions. Leonid Neymark offered that "youngest calcite" (i.e., outermost) yields 2.0 Ma average ages while the "intermediate calcite" yields average ages of 1.5 Ma. This appears to them to indicate some resetting of ages. The cause is unknown.

Yuri Dublyansky presented work done in collaboration with Yuri Smirnov (affiliation unknown). His presentation consisted of three parts: remarks on growth rate as a function of crystal habit, scanning electron microscope with energy dispersive system (SEM-EDS) results, and evidence for colloid involvement in the deposition of secondary minerals. He noted that bladed crystals would grow upward faster per volume increment of mineral deposition than for instance, rhomb-shape or other shape crystals as a geometric necessity. His SEM-EDS analyses revealed that several previously unrecognized minerals are deposited on the outermost surfaces of lithophysal cavity crusts. They include gypsum on opal, dolomite on calcite, heulandite on opal, and fluorite on opal. Yuri closed by stating that he believes the presence of colloids was suggested by the hemispherical shape of opal (indicating surface tension), cauliflower form of fluorite, and immiscible fluids indicated by the large (1 mm diameter) gas bubbles trapped in quartz crystals on the surface of lithophysal crusts. Leonid Neymark offered that the Tiva lithophysae often to not appear to record the entire paragensis. Some crusts have outermost surfaces dated at 5.0 Ma.

Jim Paces presented the continuous deposition model for the mineralization in lithophysae in the ESF (Neymark and Paces, 2000). They obtained ages of 10–15 Ka from the outermost layer of opal by etching the surface of opal. Based on the extent of etching, the ages obtained they estimate a growth rate of 2.5 mm/yr. Leyonid Neymark has a manuscript in press at *Geochemica, Geocosmica Acta* further corroborating these average growth rates of between 1 and 5 mm/yr using the $^{207}Pb/^{235}U$ method on the SUMAC SHRIMP. He notes that they have observed no evidence of Quaternary pluvial cycles in unsaturated zone minerals.

Leonid Neymark presented his investigation of the applicability of U-Pb methods to dating calcite. He concluded that generally, the method is not accurate for calcite. His analyses yielded ages as extreme as 6 Ga. due to the abundant ^{206}Pb. The uranogenic and thorogenic ^{206}Pb is suspected to be a decay product of

radium isotopes. The $^{207}Pb/^{204}Pb$ method can however be used in calcite to establish the common lead correction for opals. Leonid also remarked that documented low thorium concentrations in calcite argue against colloid assisted deposition, because thorium is know to be attracted to colloidal particles.

I gave a presentation on secondary mineralization in fault rocks in the ESF and ECRB. The substance of the talk is given by copies of the overheads I used (attachment 2). I was asked several questions regarding specific faults, lithologies, and Quaternary seismicity. Joe Whelan remarked that he had isotope data for one of our Class B fault localities (ESF STA 76+12.4). He said $\delta^{13}C$ varied from −7‰ to +7‰.

The next quarterly meeting will take place on November 30, 2000, in Las Vegas. The small working group will meet November 28–29. Zell Peterman encouraged attendees to consider submitting papers for consideration for the International High Level Radioactive Waste Symposium in spring of 2001. Papers should be four pages in length and are due in early November 2000. There will be three sessions of unsaturated zone flow and transport and at least one session on "critical issues." Jean Cline encouraged attendees to submit abstracts for the upcoming GSA theme session on secondary mineralization in the unsaturated zone at Yucca Mountain.

The group retired to the press conference. Keith Rodgers, *Review Journal*, Mary Manning, *Las Vegas Sun*, and a News 13 TV crew (Attachment 3 and 4) attended the press conference. Jean Cline distributed a written press release (Attachment 5). Joe Whelan read a statement for the press. He said that the calcite deposits were inconsistent with upwelling water and more consistent with unsaturated zone (UZ) rather than saturated zone (SZ) mineralization. Only a small number of lithophysal cavities are filled. This is not indicative of a rise in water table in the past. He said that the USGS "remains convinced" that calcite formed by percolating meteoric water. He said that this conclusion is substantiated by the fact that atmospheric gasses in addition to N_2 and CH_4 are present in the two-phase fluid inclusions. Yuri Dublyansky argued that the fluid inclusions do not resemble UZ fluid inclusions. Two-phase fluid inclusions formed in the UZ should indicate heterogeneous entrapment (air and water). Instead, the YM fluid inclusions contain a vapor bubble at non-atmospheric pressure. After the press conference ended, Mary Manning approached me and asked if I would agree to share our results from Class B fault breccias. I agreed. I spoke with her for about ten minutes and restricted all of my comments to science and did not make any representations on behalf of the CNWRA or NRC. I was not asked nor did I share my impressions of other findings related to the UNLV project.

IMPRESSIONS/CONCLUSIONS

The fluid inclusion microthermometry data collected thus far appears to be reproducible. Results from sample splits are similar and all three parties (UNLV, Nevada, USGS) are in agreement that Th values are valid. Notably, Ed Roedder (USGS consultant and founder of the fluid inclusion microthermometry method) is in agreement that the results are reproducible and valid. The USGS will have difficulty dismissing the microthermometry data (as suggested by Jim Paces) under these circumstances. The data collected thus far uniformly indicate calcite precipitation at elevated temperatures. In some cases, homogenization temperatures are in excess of 80°C. Joe Whelan feels that all of these data must have been collected from "old" calcite (in excess of 10.5 Ma), however the fluid inclusion assemblages are found in what they call the young and intermediate stages of calcite growth. Work by Neymark and Paces is in direct conflict with the interpretation that all calcite bearing two-phase inclusions are "old." They believe that growth of calcite was continuous and

steady throughout the post-depositional history of Yucca Mountain. "Intermediate" stage calcite comprises the volumetric bulk of sample material from lithophysae and must range several million years if Neymark and Paces work is correct. I believe that the USGS will need to resolve these differences in interpretation in the near future.

The USGS scientists are on record as saying the secondary minerals were formed in the unsaturated zone and were sourced by meteoric waters. This is despite the fact that their independent, parallel study is not yet complete.

It is my opinion Class B faults may be highly pertinent to the UNLV study on the significance of secondary mineralization at YM. Class B faults record deformation at elevated temperatures, contain two-phase fluid inclusions and exhibit unique paragenesis among YM occurrences. UNLV did not discriminate between breccias formed in fault zones, breccias formed in fractures and breccias formed in lithophysal cavities when they collected and labeled their samples. It is now impossible for them to go back to their notes and determine which of their breccia samples came from Class B faults. Nevada has no samples from Class B fault breccias. The USGS has only one known sample from a Class B fault. Their $\delta^{13}C$ isotope data from that sample ranges from -7‰ to +7‰. Their own work on lithophysal cavities indicates that "late calcite" averages -7‰. The possibility exists that some of the calcite in Class B breccias is "young." I believe that Class B fault breccia occurrences should be examined in detail and that the age of the deposits in the breccias should be determined.

PROBLEMS ENCOUNTERED

The meeting was held without incident.

PENDING ACTIONS

Yuri Dublyansky requested that I send some of my Class B samples to him for the purposes of conducting fluid inclusion microthermometry analyses. I said that I felt that we would be willing to assist him in some fashion but I would have to consult with the NRC prior to making any arrangements. I hesitate to send my samples to Yuri only because I did not collect my samples for the purposes of fluid inclusion microthermometry and therefore did not observe QA guidelines for sample collection, transport and storage similar to those written for the UNLV project. Furthermore, fluid inclusions in strained calcite such as is found in Class B fault breccias may yield inaccurate Th due to strain induced volume changes in the inclusions. It is possible that the data collected by Yuri on our samples may be called into questions based on either of these grounds.

Minutes for the June 21, 2000, meeting have not been distributed yet. I will forward a copy when I receive them.

RECOMMENDATIONS:

I am convinced that it will be important for the NRC or related individuals to maintain a presence at future quarterly meetings. These meetings cover material that will provide necessary context for the eventual findings of Dr. Cline's study. Nevada representatives (Dublyansky and Zimmerman) stated that the "recent

hot water" issue would likely be the focus of Nevada's eventual opposition to licensing. It will then be important for the NRC to understand the bases for that opposition.

REFERENCES:

Hill, C.A., Y.V., Dublyansky, R.S., Harmon, and C.M. Schluter, 1995, Overview of calcite/opal deposits at or near the proposed high-level nuclear waste site, Yucca Mountain, Nevada, U.S.A., Pedogenic, hypogene, or both? *Environmental Geology*, v. 26, p. 68–88.

Neymark, L.A., and Paces, J. B., 2000, Consequences of slow growth for 230 Th/U dating of Quaternary opals, Yucca Mountain, NV, USA, *Chemical Geology*, v. 164, p. 143–160.

Paces, J. B., L.A., Neymark, B.D., Marshall, J.F. Whelan, and Z.E. Peterman, 1996, Ages and origins of subsurface secondary minerals in the Exploratory Studies Facility (ESF), *U.S. Geological Survey—Yucca Mountain Project Branch 1996 Milestone Report 3GQH450M*, Denver, CO, U.S. Geological Survey.

Stuckless, J.S., B.D., Marshall, Vaniman, W.W. Dudley, Z.E. Peterman, J.B. Paces, J.F. Whelan, E.M. Taylor, R.M. Forester, D.W. O'Leary, 1998, Comments on Overview of calcite/opal deposits at or near the proposed high-level nuclear waste site, Yucca Mountain, Nevada, U.S.A., Pedogenic, hypogene, or both? *Environmental Geology*, v. 34, p. 70–78.

ATTACHMENTS:

Attachment #1: Meeting agenda distributed by Jean Cline

Attachment #2: My presentation overhead transparencies

Attachment #3: *Las Vegas Sun* article

Attachment #4: *Review Journal* article

Attachment #5: UNLV working group press release

SIGNATURES:

for MB Gray

Mary Beth Gray

7/25/00
Date

CONCURRENCE:

H.L. McKague
Manager, GLGP

7/25/00
Date

Budhi Sagar
Technical Director

7/25/2000
Date

MBG/HLM/BS/rae

D:\Rebecca\Stamatakos\TRIPRPT\TR062100mbg.wpd

ATTACHMENT 1

6/20/00

Thermochronology of Fluid Inclusions Quarterly Meeting Agenda

Wednesday, June 21, 2000
UNLV Technology Building, Rm 104

9:00	Introduction of attendees
9:10	Overview of project progress, Jean Cline, UNLV
9:20	Review of paragenetic work and discussion, Nick Wilson, UNLV
10:00	**Break**
10:15	Review of electron microprobe analyses and discussion, Nick Wilson, UNLV
10:45	Review of fluid inclusion study and discussion, Nick Wilson, UNLV
11:30	Is There Evidence of Trapped Colloids in Secondary Mineral Deposits at Yucca Mountain?, Richard Parizek, NWTRB
Noon	**Lunch**
1:00	USGS parallel study and discussion, Joe Whelan, USGS
1:45	State of Nevada parallel study and discussion, Yuri Dublyansky, Nevada
2:30	**Break**
2:45	Presentation of "constant depositional rates" concept, Jim Paces/Leonid Neymark, USGS
3:15	Pb isotope data from fracture zone calcites, Leonid Neymark, USGS
3:30	Mineralized fault rocks in the ESF/ECRB, Mary Beth Gray, NRC
3:45	Schedule next meeting; final discussion
4:30	Press Conference, Bigelow Physics Auditorium, Rm 102

Our Evaluation of Faults in the ESF and ECRB

What Are We Doing?

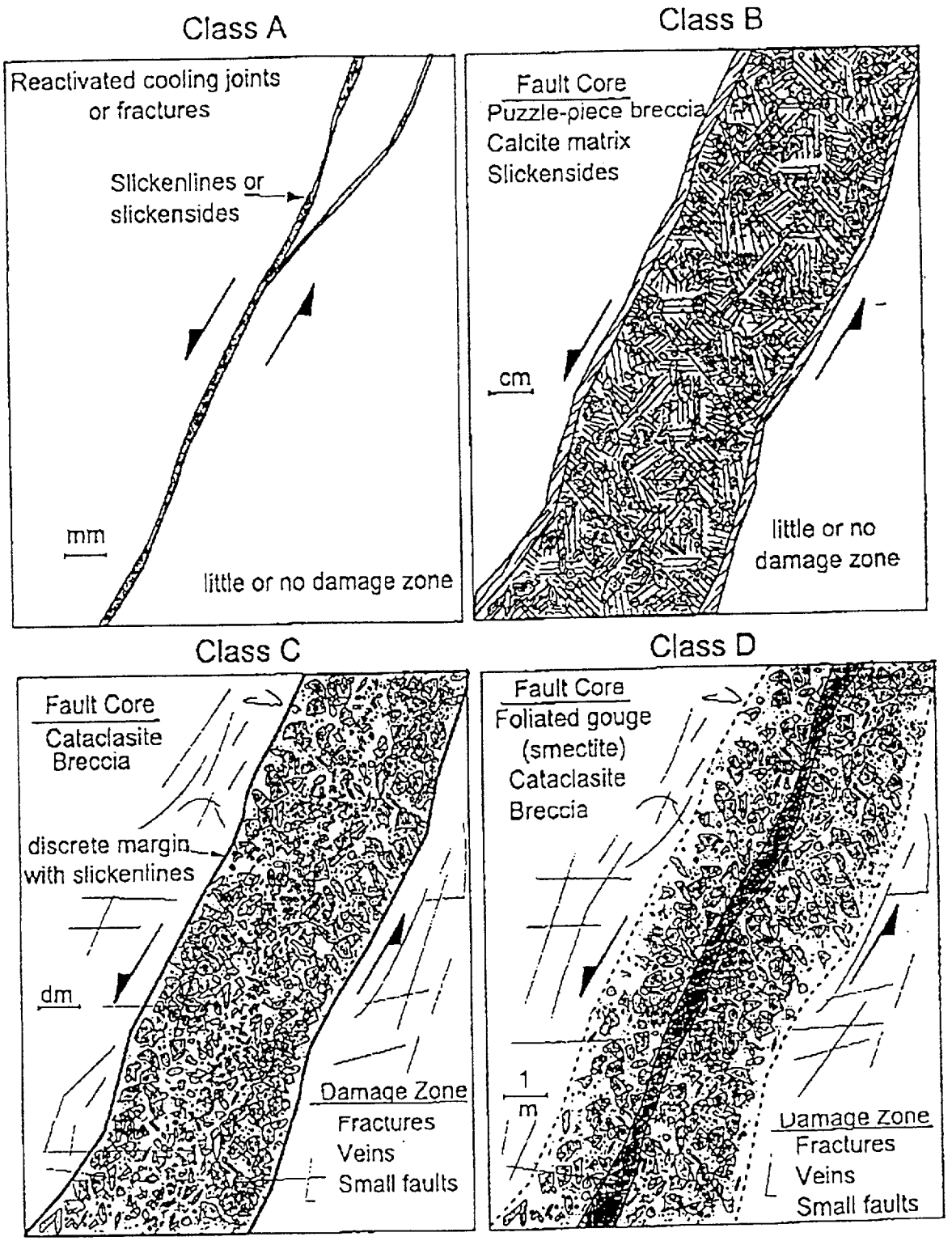
- Evaluating uncertainties in the direct rupture of waste packages by faulting (e.g., SDS IRSR rev. 2)

- Evaluating significance in uncertainties of fault and fracture control of groundwater flow (e.g., Farrell et al., 1999; Ferrill et al., 1999; SDS IRSR rev. 2)

Yucca Mountain Team Meeting
May 31, 2000

Our Evaluation of Faults in the ESF and ECRB, cont'd.

- We recognize four general fault zone morphologies (Classes A, B, C, and D) (Gray et al, 1999).
- Not all faults are related.
- Classes A, C, and D can be genetically linked (a breccia-cataclasite-gouge progression with increased displacement) and are generally not associated with calcite mineralization.
- Class B faults are unique and associated with abundant secondary calcite (~ 65%).
- Most calcite is synkinematic and is known to contain thick mechanical twins indicative of deformation at elevated temperatures (~150°C, e.g., Ferrill, 1991).

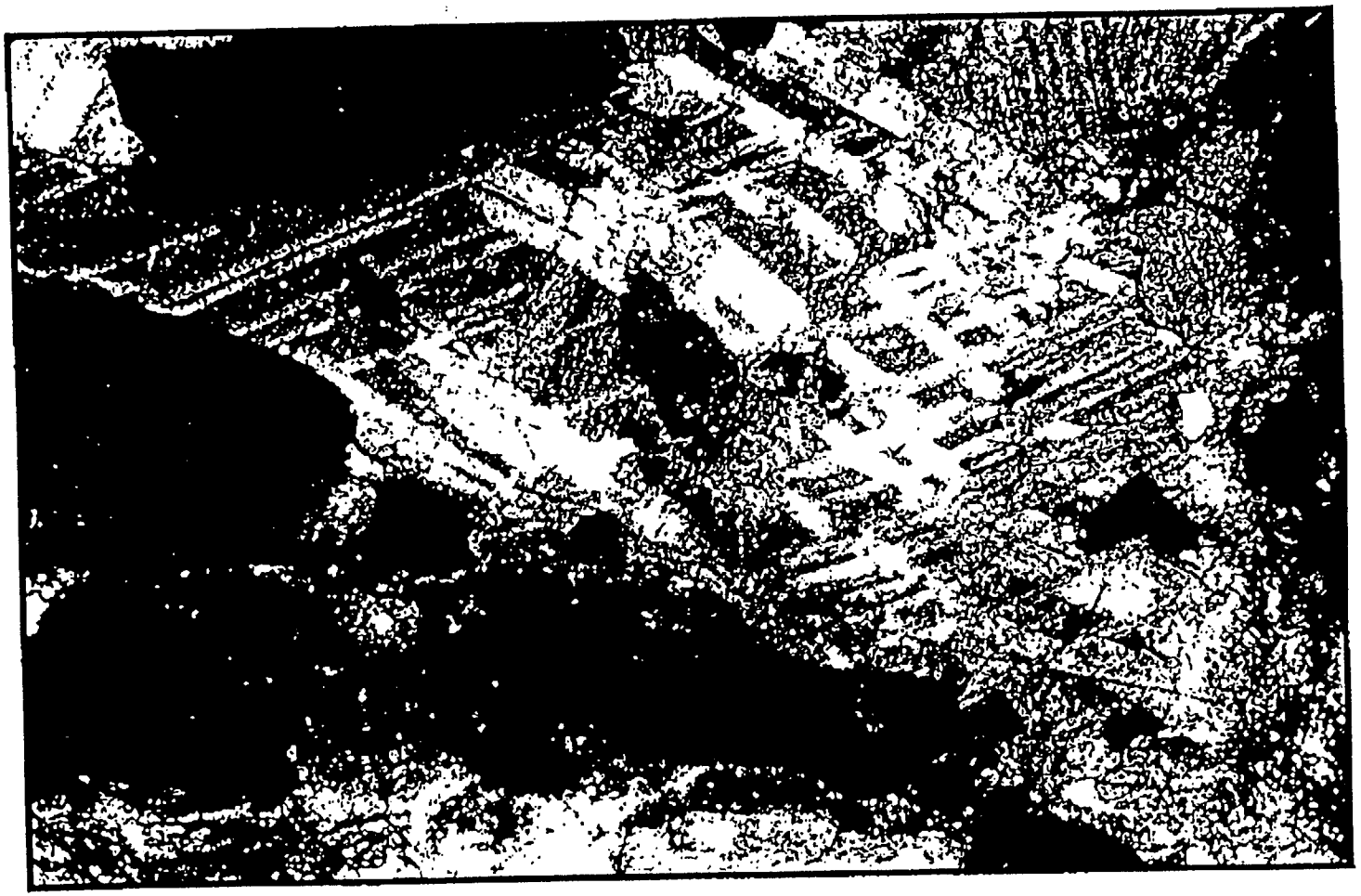


Photomicrograph of Class B Fault Breccias

1 mm

Yucca Mountain Team Meeting
May 31, 2000

Photomicrograph of Calcite with Thick Mechanical Twins



1 mm

Yucca Mountain Team Meeting
May 31, 2000

Our Evaluation of Faults in the ESF and ECRB, cont'd.

- Two-phase fluid inclusions are observed in some twinned calcite.
- The calcite is poikilotopic, possibly indicating some recrystallization.
- The mineralized faults are predominantly NW-striking.
  N-S striking faults do not tend to be mineralized.
- Class B faults are among those that have been identified as possible ^{36}Cl fast paths (Levy et al., 1999).
- Textures in Class B faults do not meet the agreed upon criteria for unsaturated zone mineralization.

Agreed Upon Criteria for Distinguishing Phreatic from Vadose Mineralization*

Phreatic	Vadose
isopachous mineralization	meniscus
gravity asymmetry?	onlapping
	pendant
	gravity asymmetry

* Third Quarterly Meeting of the UNLV Study Group, November, 1999

Yucca Mountain Team Meeting
May 31, 2000

UNLV Study Objectives

Questions:

- Do populations of fluid inclusions, that indicate the recent influx of thermal waters into the repository site, exist?
- If these inclusions are present, what minimum fluid temperatures do they indicate?
- If present, when were these inclusions trapped, i.e., when did this influx occur?
- If an influx occurred, how widespread, within the repository site, was this influx?

Other Objectives:

- Seek consensus on sampling and analytical procedures from interested parties.
- Split samples and share splits with USGS and Nevada geologists to permit parallel studies.
- Complete all analyses by 7/1/01

Dating bubbles in Yucca Mountain key to nuke debate

By Mary Manning
LAS VEGAS SUN

Scientists studying microscopic bubbles of water and gas trapped in minerals inside Yucca Mountain have not found evidence of deposits younger than 2 million years old.

That could be crucial in determining whether the Department of Energy will request a license from the Nuclear Regulatory Commission to build and operate the proposed high-level radioactive waste repository.

Almost one-third of the way through research, the scientific team, led by UNLV geoscience professor Jean Cline, gave an update Wednesday to colleagues on both sides of the debate on its work studying the possibility of water seeping into Yucca Mountain.

If they find bubbles, called fluid inclusions, younger than 1 million years old, the ability of the repository to keep plutonium, uranium, strontium, cesium and other deadly radioactive elements out of the environment and away from people would be called into question.

If the minerals are older, their ages would help support the DOE's view that Yucca can safely store the waste for thousands of years.

"Dating the minerals is the last step," Cline said after the daylong meeting at the university.

Whether the fluid-inclusion studies clinch the argument of how quickly water travels inside Yucca Mountain is months away, Cline said.

With only 44 of a total of 155 rock samples examined after they were removed from the mountain, 90 miles northwest of Las Vegas, the scientists said they cannot draw a conclusion on when water invaded Yucca.

And deciding if the mountain is suitable as a repository is out of the scientists' hands, she said.

"Some engineer or policy person will determine that," Cline said, adding that decision may not come for years.

The Royal Ontario Museum Laboratory in Canada has agreed to date a few samples at a time of Yucca's rock over the coming months, Cline said. By measuring uranium's radioactive decay and dating uranium and lead content of the minerals, the laboratory could answer the question of when the bubbles formed.

The scientific team including university, U.S. Geological Survey and independent experts expect to publish study results about April 2001, she said.

There are more questions than answers raised in the past year by the team, which received a $1.4 million grant from the DOE to put the bubbles to the test.

The U.S. Geological Survey believes the bubbles formed 12.7 million years ago, when volcanic ash formed the mountain. USGS Project Manager Zel Peterman said the nearby volcanic activity created extremely hot rock, eight times hotter than the boiling point. It could have taken tens of thousands of years to cool down, he said.

The bubbles could have formed from rainwater invading the hot rock, Peterman said.

But Yuri Dublyansky, a Russia geologist who was hired by the Nevada Agency for Nuclear Projects, said water from deep within the earth flooded the repository site within thousands of years.

Dublyansky said he has studied such bubbles in unsaturated rock all over the world. The fluid inclusions found in drier rock and in Yucca do not shrink, remaining the same size because they do not undergo cooling, he said.

"At this time we cannot conclude water moved up or down," Cline said. "The data can be interpreted a number of ways."

Mary Manning covers environmental issues for the Las Vegas Sun. She can be reached by phone at (702) 259-4065 or by e-mail at manning@lasvegassun.com

Yucca hot water report could burn Richardson

By Keith Rogers
Review-Journal

While Energy Secretary Bill Richardson was treading political hot water Wednesday over his agency's handling of a nuclear secrets security lapse, scientists studying what some believe is ancient evidence of hot water rising within the proposed Yucca Mountain nuclear waste site were still at odds over their observations.

The team of scientists who met Wednesday at the University of Nevada, Las Vegas are in the midst of a two-year, $1.4 million study led by associate professor Jean Cline. The study should be completed in April, she said.

The team of experts from federal agencies, universities and the state — including Yuri Dublyansky, Nevada's consulting geologist from the Siberian Branch of the Russian Academy of Sciences — probably won't have their conclusions ready for an agency report this year. Richardson will use the report when considering whether to recommend Yucca Mountain as the place to entomb the nation's high-level radioactive wastes.

Some 77,000 tons of the waste — mostly spent fuel pellets encased in metal rods from nuclear power reactors — will be destined for a repository in the mountain, 100 miles northwest of Las Vegas, by 2010 if the site is deemed suitable and a repository can be licensed by the Nuclear Regulatory Commission.

Richardson, who called for the UNLV study in 1998, said then that his recommendation for the Yucca Mountain site "will be based on science, pure science, not politics."

More recently, on a Feb. 11 trip to the agency's Nevada Operations Office in North Las Vegas, Richardson said he will remain on course to make his recommendation this year even though the findings from Cline's group probably won't be part of the report he will consider.

"I've got a lot of good science. I'll have sufficient information," he said in February.

But Nevada officials say Richardson should wait until questions about the rising thermal water theory are answered — if they can be answered conclusively. Richardson could face legal action from the state if he makes a recommendation without knowing the answers.

At issue are tiny bubbles in mineral deposits from deep within the mountain. Scientists want to know whether those bubbles hold fluids that show hot water rose in the recent geologic past — 1.6 million to 2 million years ago — and flooded what would be the repository floor.

If that's the case, state scientists fear it could happen again, after waste packages have been put in the mountain, risking a potential release of deadly nuclear remnants into the environment.

Joseph Whelan, a geochemist from the U.S. Geological Survey's Denver office, said his associates believe the calcite mineral features stem from rain or snowmelt that percolated downward from the rocks above the proposed repository site.

"If this calcite formed from upwelling water flooding these rocks, as has been proposed, then that water would have entirely filled all of those fractures and cavities and it would have deposited calcite in them all. This is not what we observe," he said during a briefing at UNLV.

Dublyansky, who has been gathering samples from the mountain independent of the team, said he disagrees with Whelan's statements.

Cline, however, said the group's results concerning the temperatures of the fluids trapped in the minerals "are very consistent with Yuri's. They're also very consistent with Joe Whelan's. All three parallel studies are consistent," she said.

The temperatures that were measured average about 122 degrees, but a few of the 40 samples that have been analyzed contained fluid that was about 176 degrees, or 36 degrees less than the boiling point of water.

Dublyansky believes this bolsters his theory that hot water came from below the repository site and not above, as the federal scientists contend.

ATTACHMENT 5

6/21/00

Press Release

Yucca Mountain Fluid Inclusion Thermochronology Project

The Problem

Minerals in some openings in the volcanic rocks at the Yucca Mountain nuclear waste repository site contain small droplets of fluid known as fluid inclusions. These fluid inclusions record the passage of fluids through the minerals throughout geologic time and can be used to estimate the temperature of those fluids. If fluids with elevated temperatures moved through the rocks in the recent geologic past, they might do so again in the future, possibly posing problems if the fluids interact with nuclear waste.

Project Overview

The goals of this project include: 1) confirming *whether or not* fluids with elevated temperatures moved through the rocks in the geologic past, 2) if yes, determining the *temperatures* of these fluids, 3) determining the distribution of high temperature fluids throughout the repository site, and 4) determining *when* the fluids moved through the rock.

Progress to Date

We have examined 155 samples from throughout the repository site to determine formation conditions of the minerals that contain the fluid inclusions. We have analyzed fluid inclusions in about 40 samples and have identified the former passage of fluids with temperatures of about 45 to 60°C in most samples. A few samples record fluid temperatures of about 70 to 80°C. We emphasize that we have not determined the absolute time at which these fluids moved through the rocks, but the fluid inclusions are *not* in the very youngest minerals that precipitated.

Future Work

Future work will include studies to constrain the absolute ages of the fluid inclusions and the timing of fluid movement through the rocks. We will also collect additional fluid inclusion temperatures and will continue to refine the growth history of the samples.

Personnel

This project is being conducted by Dr. Jean S. Cline, Associate Professor, Dr. Nicholas Wilson, post-doctorate fellow, Sarah Lundburg, microbeam analyst, and Joel Rotert, graduate student, University of Nevada, Las Vegas. Participating in project oversight and/or conducting parallel studies are: Dr. Robert Bodnar, Virginia Tech, Dr. Yuri Dublyansky, Siberian Branch of the Russian Academy of Sciences, Dr. Edwin Roedder, Harvard University, and Dr. Joe Whelan, US Geological Survey.