ORIGINAL ACNWT-0138

OFFICIAL TRANSCRIPT OF PROCEEDINGS

NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON NUCLEAR WASTE

Title: **MEETING: 118TH ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)**

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Work Order No.: **NRC-1207**

LOCATION: Rockville, MD

DATE: Tuesday, March 28, 2000

PAGES: 106 - 261

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ADVISORY COMMITTEE ON NUCLEAR WASTE

MARCH 28, 2000

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON NUCLEAR WASTE

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118TH ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

U.S. Nuclear Regulatory Commission
11545 Rockville Pike
Conference Room 2B3
White Flint Building 2
Rockville, Maryland

Tuesday March 28, 2000

The committee met, pursuant to notice, at 8:32 a.m.

MEMBERS PRESENT:

B. JOHN GARRICK, Chairman, ACNW
GEORGE M. HORNBERGER, Vice Chairman, ACNW
RAYMOND G. WYMER, ACNW Member

PARTICIPANTS:

MILTON LEVENSON, ACNW Consultant

HOWARD J. LARSON, Acting Associate Director, ACNW/ACRS

JOHN RANDALL, ACNW Staff

JOHN T. LARKINS, Executive Director, ACRS/ACNW

RICHARD K. MAJOR, ACNW Staff

AMY SHOLLENBERGER, Public Citizen, Critical Mass Energy Project

CHRISTIANA H. LUI, NMSS

JAMES R. FIRTH, NC, Division of Waste Management

MS. DEERING

STEVEN KRAFT, NEI

LINDA A. VEBLEN, NRC, RES/DRAA

DR. BRADY

C O N T E N T S

P R O C E E D I N G S

[8:32 a.m.]

DR. GARRICK: Good morning. The meeting will now come to order. This is the second day of the 118th meeting of the Advisory Committee on Nuclear Waste.

My name is John Garrick, Chairman of the ACNW. Other members of the Committee included George Hornberger, Ray Wymer, and Consultant, Milt Levenson.

This entire meeting will be open to the public. Today we're going to first review the NRC Staff's plan for the development of a strategy to produce site characterization sufficiency comments on the Department of Energy's Yucca Mountain site recommendation.

We're going to hear a periodic briefing on the development of the NRC's Staff Yucca Mountain Review Plan, and we will review two projects by NRC's Office of Nuclear Regulatory Research on, first, the radioactive content of slag that is produced as byproduct of the manufactured metals; and, second, research on uranium plume attenuation.

Richard Major is the Designated Federal Official for the initial portion of today's meeting. This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act.

We have received one request from the Nuclear Energy Institute, to comment on the Staff's site sufficiency discussion. Should anyone else wish to address the Committee, please make your wishes known to one of the Committee Staff.

It is requested that each speaker use one of the microphones, identify himself or herself, and speak with sufficient clarity and volume so that he or she can be readily heard.

Unless other Committee members have some opening remarks, I think we will move right into the agenda. The Committee Member that's going to lead the discussion on the next two agenda items, namely, the strategy for site self-sufficiency and the Yucca Mountain review plan is George Hornberger, so, George, it's your show.

MR. HORNBERGER: Thanks, John. Our first topic is the strategy for site sufficiency, and, James, are you going to do this? Is Bill your assistant, or is he going to introduce you?

MR. FIRTH: I'm going to be running through the presentation. I basically want to talk to you about our broad outlines for our strategy for developing sufficiency comments.

And right now, we're in the development stages, so we'll be preparing this, and I will get to the schedule a little bit later.

The purpose of the review is basically to evaluate and comment on DOE's progress related to the sufficiency of data analyses and the design for the license application.

What we're going to be doing is considering both what DOE has at the they released the site recommendations Considerations Report, as well as their plans for either augmenting their documentation or collecting data.

Our focus is going to be on the foundations for DOE's safety case, and their performance estimates. So we're going to be focusing on the data and the conceptual models.

So, does DOE have the data and understanding for putting into a license application? The way we're structuring the review is to fold this into all of our other pre-licensing interactions with the Department of Energy.

So this review is going to be integrated with all of the other work that we're doing along the way.

And one reason why specifically we're doing a sufficiency review is that the Nuclear Waste Policy Act requires the Department of Energy, in any recommendation to the President of a site, to include preliminary comments of the Commission considering the extent of at-depth site characterization analyses, and the waste form proposal, and to what extent they seem sufficient for inclusion in the license application.

And, again, these are preliminary Commission comments.

And looking at how this review fits into our strategy for licensing, since we're doing a very broad review of DOE's data and conceptual models for developing our site sufficiency comments, that it's going to provide a progress report of where DOE stands on data analyses and plans, their understanding of the interactions between the geology and the engineered systems, and the status of our KTI resolution process.

And this is something that I will talk to a little bit more later, and that we will be trying to come back to the Committee after we meet with the Department of Energy in April.

And one thing that I wanted to emphasize is, even though we're doing a very broad review and we're looking at the sufficiency of DOE's data analyses and design, this is not a licensing review. We're not going to be able to go into the same depth or scope as we would for a licensing review.

So what we're trying to do is give a picture of where things stand. Do we feel that there is enough there in terms of understanding and data for developing a license application.

And the way that we frame this is, when DOE comes in with a license application, they are going to need to build an adequate case to support a regulatory decision on whether construction can be authorized.

So this means that the data design analyses, quality assurance, all of these together have to build a sufficient case for the Commission to grant the construction authorization.

We realize that there is going to be an opportunity for DOE to provide additional information; they can augment what they have submitted in the initial license application, and if a construction authorization were given, DOE would have an opportunity to collect data through performance confirmation or actual conditions as they build the repository.

And the Staff is going to be using a lot of information to review the -- make the decision in terms of data and design and analyses. What's going to focus this is that DOE is developing a Site Recommendation Considerations Report that they are going to publicly release.

At this time, they're going to ask for NRC to develop its preliminary comments on the adequacy of at-depth analyses and the waste form proposal.

In addition, DOE is going to have a repository safety strategy, technical basis documents such as their analysis model reports and process model reports. They will have a total system performance assessment supporting the site recommendation.

They are going to have QA audits that are underway. They're going to have a total system performance assessment and methods and assumptions report.

We're going to use all of this technical details that are the building blocks of DOE's Considerations Report, as well as what is in the Considerations Report itself.

So we're going to be using a lot of different information in terms of developing our assessment.

What the Considerations Report will do is, it will provide a description of the proposed repository, including the preliminary engineering specifications, the description of the waste form proposal, and packaging. And this is also going to include an explanation of the interactions and the relationship between the engineered system and the geology.

There is going to be a discussion of data obtained during site characterization, as well a discussion of the analyses related to repository performance.

Our review objectives are basically to provide preliminary comments on where the data analyses appear to be sufficient or insufficient, and if any areas that additional data or analyses may be needed, what is that information?

When would that be needed? Are the conceptual models supported? Because if the conceptual models are not supported, that's indicating that either another approach may be needed for DOE to take, or additional data may be needed.

And what is the status of DOE's QA efforts?

And since we're trying to develop preliminary comments on the sufficiency of the site characterization analyses and the waste form proposal, we need a yardstick by which to measure that. And the 10 CFR Part 63 sets up a risk-informed, performance-based framework, and it identifies the information that needs to be included in the license application, and it establishes an overall performance objective.

Then we start implementing the regulations with the Yucca Mountain Review Plan, which continues the implementation of the risk-informed performance-based framework.

And there the amount of information and support that we would be looking for in particular areas will reflect the degree of conservatism that DOE is using in certain areas, their treatment of uncertainty, the importance to the licensing case, as well as the risk contribution.

So we're able to apply a graded scale in terms of areas where we want to focus and make sure that we have greater assurance in DOE's case that they have laid out.

Again, I want to get into the scope of what we're going to be reviewing. Again, we're going to be focusing on the building blocks of DOE's assessment of repository performance, so we're going to evaluate both the at-depth site characterization and the engineering design.

We're going to be taking a very broad view of the data that would apply and the analyses that would apply for site characterization. So we'll look at at-depth data, analog data, laboratory data, expert elicitation.

So all of those pieces, we're going to be looking at in terms of is there enough information to support DOE's safety case?

. Then we'll look at the related analyses that DOE has assembled, as well as the conceptual models and plans for refinement.

And although we are going to be looking at DOE's screening analyses, throughout the repository system of the engineering, the geology and the interactions, what we've decided is that we would focus on the interactions between the engineering and the geology.

And this gets back to one of the requirements that DOE has under the Nuclear Waste Policy Act, and given the evolving nature of DOE's design, we felt that by paying a little bit of additional attention to the interactions, it will give us a good feeling about whether DOE has sufficiently understood its current design and how that might interact with the geology.

So this is an area that we're going to be focusing a little more on in terms of the analyses of features, events, and processes.

In terms of the performance assessment, we're going to be using the performance assessment analyses to look at the risk-informed performance-based context for evaluating DOE's data and analyses.

So we're using PA as a way of focusing our analyses of the building blocks, the data and the analyses that will be going into DOE's assessment, and we'll be looking at the relative importance of those building blocks to DOE's overall assessment and their possible eventual licensing case.

We will also evaluate DOE's conceptual models that they use to describe repository performance, and here, we're going to be looking at does the data support the models that they're using, and how are they treating uncertainty in the models and input?

And one reason we're looking at the treatment of uncertainty in the models and input is, how they treat that needs to be considered and evaluating whether they have enough data and analyses.

If they are conservative, and take very conservative bounds, then we may need as much information, but as DOE takes additional credit for certain areas and those are important to DOE's licensing case, we would want to focus in on those areas to see whether that is supported.

In terms of quality assurance, we're going to assess DOE's progress towards qualifying data, models, and codes. We'll evaluate DOE's capability of qualifying those things that they will rely in the license application.

The way we're reviewing this is, we're going to have to be looking at DOE's schedule for license application. So we'll look at h how much DOE has qualified at the point that they release the Site Recommendation Considerations Report, as well as their plans for continuing to increase the amount of qualifications.

DOE has also indicated that they would provide an assessment of what has been qualified, the effect of the group of the information that has not been qualified in terms of how significant that is, as well as what the impacts that may have on their Site Recommendations Considerations Report.

And as we review quality assurance, we may notice through our technical reviews, that we may want to look at little more closely at some of DOE's data and qualification.

But we would see that this is a limited effort, and there will be certain thresholds. We're not going to just go through and try and reconfirm DOE's qualification.

If there is something that arises as a question, then we may go back and look at that.

I wanted to highlight a couple of things in terms of what the review is not: And we're not planning on taking any position on DOE's dose calculations, so we will be looking at their performance assessment and the building blocks in terms of the data, the conceptual models, but we're not planning on taking a position in terms of whether we agree or disagree with DOE's final dose calculation.

Also, we don't feel that it's NRC's role to be evaluating DOE's compliance with 10 CFR 963, so we're not going to be getting into that in terms of our review.

This review is being focused on the adequacy of the site characterization, data analyses, and the design in terms of does DOE have enough there to develop a license application, and so we're not going into looking at all of the other things that DOE is pulling into their site recommendation process.

And I want to talk a little bit about our schedule. Basically, since DOE is developing their technology documents now, what we want to do is be using all of our review activities that are underway now to have them focus and lead to developing our site sufficiency comments. So, what we are trying to do is develop a strategy which is underway and what I am briefing you about today. We are going to then develop guidance that will implement this strategy and give the staff direction in terms of how we would use the strategy. And our objective is to have the guidance and the strategy be developed in parallel to the extent we can, because we see great benefit in having the guidance come early rather than right before DOE's ruling -- considerations report.

Then we are dependent on DOE's schedule. We will then move from our preliminary activities into a review of the site recommendation considerations report, which the current schedule has being released in mid-November. Our goal is to develop the staff comments on sufficiency by the 9th of April and we would transmit that in terms of a paper to the Commission. DOE's current schedule would call for NRC comments being provided to DOE by the 25th of May.

And one thing I will emphasize here is that there is going to be an opportunity for ACNW and the staff to interact throughout this process, and I will talk a little bit more later in terms of how we see that happening, but there is opportunities from now until we basically prepare our paper and provide that to the Commission to really have substantive input.

If the committee is going to want to have input in terms of providing input to the Commission, given that the comments have to go to DOE at the end of May, you may want to look at having your comments to the Commission by the end of April to allow that to be considered before we send anything to DOE.

And, again, as I said earlier, we are basically doing the pre-licensing activities now. Our plan is to provide DOE early review -- feedback on the reviews that we conduct now. And what this will do is it will establish the basis for, where do we feel that the information appears to be sufficient? Where do feel there is additional that is needed? And this would allow DOE to have some opportunity to consider that in developing their future plans for collecting additional information, augmenting their analyses and so forth.

We are observing their QA audits, and what this does is it gives us a view in terms of how the information is developing, and also on their quality assurance efforts. Also, we are trying to make sure that all of the issues within the KTIs are resolved at the time that DOE comes in with their license application.

So what we have underway and that we hope to brief the committee on in the summer of this year is our KTI issue resolution process. And this is a process where we are trying to work with DOE to identify what information is needed and to resolve the open items that we have before DOE submits a license application. And we have plans to meet with DOE in late April to discuss this process.

And the interactions that we are proposing to have with ACNW is today's briefing on the strategy. And from the strategy, we are going to be developing the details by the end of June. So there is opportunity for you to provide us input in terms of the scope and how we are structuring the review. Then we will develop the staff guidance. We would hope to come back to the committee after the guidance is completed. And given its current schedule of being completed in the end of September, we would look at coming back to the committee in October, and this would allow us to brief you on the guidance before DOE releases the considerations report. So this will help us so that we are not focusing on briefing you at the same time we are trying to pull everything together in terms of our site sufficiency comments.

Then we are looking at having a similar construct to what we used with the viability assessment, that as time goes on we would allow one-on-one interactions with the committee members on areas within their technical expertise. So this would allow you to stay well informed in terms of how our review is progressing, as well as to provide early input to the staff. And we have this starting, in essence, in November and ending in April. If you want to meet earlier to talk about our preliminary interactions and review efforts, we can do that as well.

Then we would look at briefing you in mid-April, which, again, if you want to have input to the Commission, you would want to have your comments submitted to the Commission at the end of April, so you may want to look at that timing.

We are also looking at trying to look at how we are going to involve stakeholders in this review. What we are planning on doing as part of our KTI issue resolution process is to hold public interactions in Nevada. And so we will meet with DOE on various topics and we will try and have those out in Nevada.

Then we are looking at holding at least one public meeting that will address our rule and approach to the sufficiency review and, currently, we are looking at attaching that to another previously planned public meeting out in Nevada in the summer of this year.

Then in terms of how we are going to document our results, we are going to develop preliminary statements on the sufficiency of DOE data and analyses for license application. Again, we are going to be looking at the data that is in hand, as well as DOE's plans. So, we are going to be considering how DOE is going to go from where they are at the time they release the considerations report, as well as to when they will submit the license application.

And while there is going to be -- while we want to provide a balanced view of where DOE stands in terms of where things are sufficient, or where things may additionally be needed, we are going to provide less documentation on the areas where we feel that there appears to be enough. So, even though we want to give a balanced view of where DOE stands, we are going to be spending more time documenting where we feel additional information is needed, because we feel that that is our burden, that we have to give some indication of why we feel additional information is needed. Where there appears to be sufficient information, we are going to acknowledge that, but we are not going to spend the effort documenting why we feel that there is enough.

We are going to be documenting the details in terms of where things are enough in the IRSRs, so we are still going to be working on establishing the basis and preparing for an eventual review of the license application by looking at how DOE's case is progressing, as well as documenting where we feel additional information is needed or where things appear to be adequate.

And we will comment on any significant open issues. And to be a significant open issue, basically, the benchmark is that those would be open items that would prevent the license application from being docketed potentially. So, we will comment on those and raise those at the time we do our sufficiency comments.

And, again, to summarize the things that I have gone through, this is not going to be a licensing review. We are not going to have the time or resources to go into the same level of depth or to cover everything that we would in a licensing review. We are going to be focusing on DOE's data analyses. Okay. So what we are going to do is be focusing on DOE's data, design analyses. We are going to be evaluating sufficiency in the context of our performance-based, risk-informed approach to licensing. The review of models is going to be primarily limited to the upstream pieces of it. We are not going to be emphasizing how DOE is going to get to their final dose calculation, but we want to make sure that they have enough data and information to get their.

The review is going to be fully integrated into our licensing strategy and KTI issue resolution process. And since this is going to be a broad look at DOE's program, it is going to be a progress report on their progress towards preparing a license application. And that concludes my presentation, and we will welcome any questions that you may have.

DR. HORNBERGER: Thanks very much, James.

It strikes me, from, well, a fairly casual observation, and I think it did come through to me fairly strongly, even in your presentation, that the sufficiency review in some ways could be considered a natural extension of the issue resolution status process. Is that a fair generalization?

MR. FIRTH: Yeah. What we are doing is we are having it take place, basically, within the issue resolution process.

DR. HORNBERGER: Right.

MR. FIRTH: Because the process is going to identify what information is needed. What do we feel about the case that DOE is assembling? And that is going to naturally lead into our sufficiency comments. It will be an extension because we will be able to look a little bit more broadly at the interactions with our sufficiency review. But, in essence, they are very well integrated, and the sufficiency review is just one point in time where we are going to assemble all of the information in one place in terms of where we feel things are sufficient or insufficient.

DR. HORNBERGER: So, in one sense, it is a synthesis, which, of course, the individual IRSRs don't necessarily see the integration. So I understand that. Now, the other side of it, the question that I would have is, is it also, do you also envision then providing, say, more detail? That is, if one looks at the issue revolution status reports and you see, well, all right, what needs to be delivered, and you have statements in there, well, the data and the conceptual models need to be sufficient. Are you now going to go in and, say, pick out examples where your conceptual model for flow and fractured tuff is insufficient?

MR. FIRTH: Yes, we would want to get into that level of detail in terms of identify those areas where we feel something more is needed. And it could be because the documentation process has not fully assembled the case that DOE will have at the time of licensing. It some cases it may be that we feel that there is not enough basis to support a conceptual model. Also, if there is limited data, DOE would want to look at alternate conceptual models to look at the range of performance. So, we will be looking at, and trying to say in our sufficiency comments, these are the areas where we feel that something more is needed, and try and characterize that in terms of whether it is going to be data that is needed, a new approach, or what-have-you.

DR. HORNBERGER: Do you have any sense, James, on when -- you outlined a process where you are going to focus in on some key points, rather than -- you are going to come to some decision relatively early on that there are some areas that are relatively sufficient, and you are going to pay less attention. Do you have a sense as to the timing of identifying the issues that you really want to hammer on?

MR. FIRTH: Okay. What we are doing now is looking at DOE's repository safety strategy, the TSPA-SR methods and assumptions report. We are going to be meeting with DOE in early June about their TSPA-SR. So, at that point in time, we will probably really start to get a good look at the information that DOE has in terms of their numerical analyses in terms of what appears to be more important for their case. So we will be using all of those pieces of information, but it probably won't be until early June that we will start really getting a full picture.

DR. HORNBERGER: John.

DR. GARRICK: James, I appreciate that a sufficiency review is not a licensing review. The one thing I am struggling a little bit with is, in the context of taking a risk-informed approach, a performance-based approach, it is very difficult for me to imagine how you can reach closure on the sufficiency of data, analysis and plans without doing some of the things you say you are not going to do, particularly with regard to decomposing the bottom line results, which would be the dose calculations, into the contributors, such that one could see more clearly where the uncertainties are, where they are coming from, and, therefore, reach a more supportive conclusion relative to the sufficiency of data, design and analyses.

MR. FIRTH: Yeah. It is a difficult point in terms of how far you go. The one thing that we do want to stay away from is taking a position on DOE's dose calculation itself. So, what we also want to do is make sure that we can inform our review, so we are going to be looking at DOE's TSPA, what the results are of that in terms of the contribution of the different components. So we will be doing some of the decomposition. But we are not going to be pulling apart DOE's actual calculation to the extent that we would do in a licensing review.

So, our hope is that we would be able to give our preliminary comments at the point of the sufficiency review, but it is only -- and it is starting the process of pulling apart DOE's whole safety case. It is not going to be until licensing that we will pull everything together for the review to definitively say this is what really is needed and this is actually adequate. So we are going to, at that point in time we are going to have to have everything assembled.

We are going to be trying to move towards that during our sufficiency review, however, we are not going to, again, pull apart everything and disassemble DOE's whole performance assessment. But we will be looking at it. We will be considering that, the results of that, in terms of prioritizing those conceptual models in terms of what is important.

DR. GARRICK: Yeah.

MR. FIRTH: And generally look at how much leeway is there.

DR. GARRICK: Yeah. Now, the point simply being that this will be an opportunity to test the genuineness, if you wish, of the NRC really invoking or adopting a risk-informed strategy.

The other thing I wanted to mention, just maybe an extension of what George was just getting to, obviously, through the technology exchange meetings that have been taking place, and the issue resolution reports and studies, there has been a lot of processing, if you wish, already of information and what has been going on in these areas of data, design and analysis. And all of these things are not going to be equally important. So I suspect that the attendees of these exchange meetings are pretty savvy right now on what the most important issues are, for example, something like QA, which seems to have been kind of a chronic issue and problem for a long time.

Is there feedback being developed and will the sufficiency review contribute to this, that allows the licensee to get a running start on the issues somewhat in terms of their importance, even though it is not a licensing review and you don't have that application yet or what-have-you?

MR. FIRTH: Yeah. Basically, as we are moving through the interactions now, we can help DOE understand areas we feel are important. And they also see things from their own performance assessment in terms of what they feel is important. But one thing that we wrestle with is, as DOE changes what they want to emphasize in their safety case, that also changes what is important. As the design gets modified, that also may change what is important and to what degree. So, we can give them information, and the sufficiency review will be a concrete example of things that we feel are most important, and for DOE to emphasize, to the extent they feel that they need to, but it is also subject to the changes that DOE makes in their own program.

DR. GARRICK: Thank you.

DR. HORNBERGER: Raymond.

DR. WYMER: I realize that you are well along on a long and arduous path of Issue Resolution Status Reports and discussions of Key Technical Issues, and there has been a lot of input and lot of meetings held. So things have been talked about and considered at great length But, usually, where you get into trouble is about the things that nobody thought of. Despite the fact that a lot of thinking has gone on, it has been by a fairly circumscribed group of people for the most part, who have particular points of view, particular backgrounds and knowledge.

And now you are considering things in the aggregate, sort of putting the whole package together. And while it is fairly easy to comment on what is in front of you, what is much harder is to come up with what is important that is not in front of you, as I am sure you know. And, so, what I am getting to ultimately here is, to what extent in this review will you bring in outside people, maybe even people from overseas, who are considering the same kinds of problems, just to make sure that the whole thing is really covered, now that you are getting down to sort of the nitty-gritty of this pre-licensing activity?

MR. FIRTH: Yeah. In terms of developing the strategy, we have not specifically identified a mechanism for doing that. That is something we can consider as we develop the strategy more fully and the guidance.

One thing that the staff is doing is evaluating DOE's analyses of their -- the features, events and processes that they wish to exclude from the performance assessment, and there is your review, what is being screened out. A question that you have to ask is, is the initial list complete? And one thing that we did in the near-field environment is to audit what DOE has done in terms of their database of features, events and processes, identifying that there are some things that DOE may want to also consider.

So, we are trying to put into our process, is that initial list that DOE has complete or is it not?

DR. WYMER: Yeah. A particular area that has been a concern to me is this business of coupled processes, as you know, and that is a very complex area and requires a lot of good people doing a lot of good hard thinking, I think, in order to be sure that it is adequately covered.

MR. REAMER: In my profession, process is important, and this going to be a public process. This is going to be built on interactions with DOE that we hope will stimulate feedback, not only from the potential applicant here, but also from the state, and potentially anyone who is interested in this project and wants to see it done safely.

So that would be one way that I would hope that we would be enlightened and hear more from others. Hopefully you'll be able to attend our technical exchange later this month on issue resolution, and continue to make the suggestions that you're making.

So in any event, in addition, we know that parallel to our review -- and our review is focused on sufficiency for a license application. We're not, under the statute, asked to take a position on this site recommendation, one way or another.

We're out of that. We have a potential licensing proceeding in front of us, and objectivity that we need to be sure that we bring to that.

So, the process doesn't ask us to take a position on the site recommendation, and we're not going to do that. But parallel, DOE will be running a public process as well on their site recommendation document. And I think it behooves us to be aware of what is coming out in that in the way of technical feedback, as well, and make sure that gets factored into our thinking.

DR. WYMER: Thank you. Milt?

MR. LEVENSON: I have a question that may just be for clarification. On your slide where you list the technical basis for DOE's recommendation, one of the bullets is description of the waste form or packaging proposal.

Is it really intended to be "or," or is it "and." And the context of my question, of course, is that the waste form is not singular. There are at least four major different waste forms. I wondered what part of that diversity gets into this picture?

MR. FIRTH: I mean, this gets back to a little bit in terms of what the Nuclear Waste Policy Act puts in place. So that was done well before the point where we are now in terms of what would go into a potential Yucca Mountain repository, so it's focused on that.

We would expect that DOE would include both the waste form in terms of the different waste forms, as well as the packaging that they would use. This is the minimum, but we expect that there will be actually more than that.

MR. LEVENSON: You will be looking for multiple waste forms?

DR. HORNBERGER: Yes, I mean, that would be what would be needed in the license application.

James, I have just one other question: In one of your slides, you had mentioned the treatment of uncertainty, and that you're going to be looking at that. And you mentioned the degree of conservatism in the same breath.

And I'm just curious, because one of the things that has always concerned me is having a treatment of uncertainty doesn't lead me inexorably to say, well, if you're uncertain, then you have to be exceedingly conservative in assumptions and models.

Did you mean that?

MR. FIRTH: Basically what we would consider is DOE's model and they way they've implemented that, conservative? If it's very conservative, even if there's a large number of uncertainties, we would not need to spend as much attention on that.

If it's very uncertain, then DOE isn't obligated to take the most conservative route, but we would look at how they have treated the uncertainty.

To the extent that DOE appears to be taking a non-conservative approach or to be taking additional credit for beneficial aspects, we would want to sharpen our pencil in terms of the review to see is there a basis for what DOE is doing, or are they being overly optimistic.

So while DOE is not driven to the most conservative, if they do take a bounding approach, even if it's uncertain, we won't have to pay as much attention to it, because it will be easier to say that it is conservative, so we're not going to have to spend a lot of time evaluating all of the details in terms of the process.

If that's only going to make it show how conservative it is, we don't need that to evaluate the conservatism that DOE is taking in terms of whether -- the approach that DOE has taken is conservative or not.

DR. HORNBERGER: So, a hypothetical portion of a question and then a followup: In my best of all possible worlds, DOE wouldn't use any bounding or conservative, overly conservative or conservative assumptions; they would simply take the uncertainty as they understand it into account, and do their analyses and present the results.

If my definition of the best of all possible worlds came to be, would the NRC have a problem with that?

MR. FIRTH: What we would do is, we would focus on areas that are most important to DOE's licensing case. So it's -- and evaluate, does DOE have enough basis in terms of is their description of the uncertainty appropriate?

There is the treatment of the uncertainty, but there is also getting down to the effective annual dose calculation in terms of would that be significantly changed by how DOE has treated uncertainty or developed their approach?

That's the main issue in terms of looking at compliance with our regulations, so is it resulting in a significant change that we would need to evaluate the regulatory compliance?

DR. HORNBERGER: Good. Thank you very much, James and Bill.

MR. FIRTH: Thank you.

DR. GARRICK: We're going to hear from NEI.

DR. HORNBERGER: Okay, Steve from NEI has some comments. Is Steve here?

DR. GARRICK: Yes.

MR. KRAFT: Thank you. I'm going to use the low tech apparatus here. I have some additional copies.

With all the preliminaries out of the way, thanks very much for the opportunity to speak to you all today. I am fascinated and interested in and pleased to hear what Mr. Firth had to say about the NRC's views on sufficiency.

I have some commentary on that. As we moved through it, I was jotting down in my notes here, that at the appropriate point I'll make some comments.

The Nuclear Energy Institute, of course, takes great interest in this project. As you know, we've appeared twice before this group in recent memory, and have found that they have been very useful exchanges. We learn a great deal from watching this body deliberate, and ourselves, and we greatly appreciate your interest in this topic and the work that you are doing.

I think that the country has gone to a very interesting location in this program. This program has become extraordinarily public in its debates, and that has only helped. And NRC has had a lot to do that.

We appreciate that. There is an early warning system in place now in terms of what the issue are, how they are going to affect the program, how they are going to affect the nation, and I think that's all very, very positive, and NRC and this body are to be complimented for being a part of that and bringing that about.

Why is sufficiency important? Why is such a decision important?

A decision on Yucca Mountain is urgent. Competition is reshaping the nuclear industry. Nuclear has proven that it can compete, and environmental energy supply stakes are high.

Five years ago, internal to our offices, and even to some extent, in public, we were making several statements about why we needed to solve the, quote, nuclear waste problem, unquote.

Nuclear power plants would start shutting down for lack of storage space. We couldn't pursue the economic life of our companies, we could not buy and sell nuclear plants, we could not seek license extension.

Well, maybe we've solved the problem, because all those things are happening. The only thing on the list that hasn't happened is the purchase of a new plant, and I suspect that will happen overseas in some few years.

So what has happened in the environment? What has happened in the broader environment?

It's not that we've solved the problem. I think what has happened is that the good news is that our industry has done an extraordinarily good job of managing its nuclear waste, high level and low level.

The bad news is that we have done an extraordinarily good job of managing our nuclear waste. Our country is at its best in times of crisis, and we have proven that over the centuries, time and again.

There is no nuclear waste crisis, but there is a need to move forward with solving the problem. In our discussions with the individuals on Wall Street, with the individuals in the regulatory community, with the individuals in our member companies who are pursuing what appears to be a renaissance in the use of nuclear energy in this country, and ask them about, well, how do you make these decisions in the face of the nuclear waste "problem"?

The answer is not, oh, forget it; it doesn't matter; the answer is, there is an expectation and a confidence that the nation will make the right decisions and move forward and solve the problem. The problem still exists, but it's not preventing us from going forward in ways that we want to go forward.

It will eventually work against the nation and the use of nuclear energy. That is a very, very important point.

As scientists and policymakers debate whether or not we ought to have an allowable dose in the vicinity of Yucca Mountain, plus or minus some percentage of background, that argument could delay this program and result in energy choices that have far-ranging, far more profound health impacts than the decision being made at Yucca Mountain.

That's an important point that policymakers need to keep in mind. And when we talk about sufficiency, we talk about suitability, what we are talking about is how policymakers will deal with this issue, and what information and advice they need in order to do so.

That is why NRC's view, and, by extension, the views of this body, is so very important. NRC is a source of objective expertise.

And what does NRC think of DOE plans is an extremely important question. I was pleased to see that Mr. Firth focused on the issue of their plans.

So, what is science telling us at this point? At face value, the case for going forward is very compelling.

Potential radiologic consequences are projected to be so low that they're almost hard to find. This is documented in the EIS.

Part of the problem with the EIS and part of the problem with the NRC letter on the EIS, as distinct from the viability assessment and NRC's review of the viability assessment, is that the EIS materials were darn near impenetrable.

The conclusion I just read to you is buried in Appendix Q on page 435 or something like that. Decisionmakers, policymakers, can't deal with information in that way. They can deal with information in ways that bring to their attention, the important factors and put them into perspective.

NRC, DOE, and the industry analysis through EPRI, all confirm that that is, in fact, the case. Even the EPA, while they didn't talk about radiological consequences, they did give the EIS a very high rating, and I think that whatever infirmities different agencies found in that EIS, are easily correctable as they prepare the final.

Uncertainties will remain. They always will, and the issue here is not elimination of uncertainty, but understanding of uncertainty. What do decisionmakers need to have in their hands in order to react to a decision, make a decision?

The first thing they need to know is, they need to know the nature of the decision. Think about what decisions are. A personal story, and I have used this before, so forgive me if you've heard it. I'm just a proud parent.

If the decision that my wife and I faced two years ago to allow our son to participate in Maryland Youth Hockey was based solely on NHL head injury rates, he'd never lace up the skates. But that's not how you make the decision, and that's not how you make the decision in your personal lives.

And I don't mean to say that making a decision such as Yucca Mountain is a matter equivalent to whether my son plays ice hockey, it is an example of how decisions are made.

Decisions, by their very nature, are holistic. If the entire decision on Yucca Mountain was the result of a model, we'd eliminate the policymakers, run the models, and turn the switch one way or the other.

Decisions, by their very nature, bring in every bit of evidence that the decisionmaker wants to bring into it, whether that evidence is presented to the decisionmaker in some formal way, whether it's a gut feel the decisionmaker has, whatever it is; that's how decisions are made.

But in order to do that, the decisionmakers must have concisely summarized and clearly communicated science. That is largely the role of the DOE; it is the role of NRC in its reviews; it is the role of this body; it is the role of the Board on Radioactive Waste Management, the Nuclear Waste Technical Review Board, the industry, and anyone else you can name who has a scientific credential, who might have something -- the state, didn't want to leave them out. They have very valid views -- and the counties -- on the merits of the science.

They also have to have confidence that the regulatory components are there to move forward, which is part of what the sufficiency decision is all about.

And they need a sense of perspective. Think about it; think who the decisionmakers are.

When we wrote the Nuclear Waste Policy Act in 1982, when we wrote it as a nation in Congress, I doubt very much that Congress had in mind that the President, at the time this decision went forward, was a geoscientist -- I doubt it. At the time, he was an actor.

Now, he's a former governor. I don't know what it is when this decision comes up. Maybe he'll be an oil man. Maybe he will be a former member of the Senate.

There was never a determination as to who that was going to be, so the information that comes forward has to have a sense of perspective for decisionmakers and the nation to understand, is this risk bigger than a bread box? Is it smaller than a bread box? What is its significance? Not whether it's 10-6 versus 10-7, whatever in the Vadose Zone. You know all the details far better than I.

That kind of information doesn't help decisionmakers make decisions.

Unfortunately, two bullets were left off of here. Also what is needed is an understanding of the future ongoing R&D, because there will be future ongoing R&D. There will be a confirmatory R&D program following the license application, following emplacement, if we ever get there.

And what that will be -- and there also needs to be an understanding of future technology development. We're not going to turn off the scientists and the National Labs and anyone else who has an idea about what to do in the future about nuclear waste.

I think the decision makers can take great comfort in knowing that there are all these things in place, especially a future R&D program to answer the question of, well, did we make a mistake? And secondly, that there is the potential for future technological development that might make it easier to deal with these materials in the future.

It is important to keep in mind, getting to the point of what this decision is, is that it is a four step process going forward. There have been prior steps, but going forward is a four step process. What is the site recommendation?

The site recommendation is in fact from the technical side a relatively limited decision. It is an important decision. It will be a difficult decision. It is going to be made at the highest policy levels. It is a politically-charged decision. But on a technical basis it is a relatively limited decision. It is not saying we are going to put nuclear waste in Yucca Mountain forever and a day and walk away from it. It is merely saying it is okay to go forward and ask the NRC to review the license application. That's all this decision is.

There are protections in the process beyond that point. There are protections in the site recommendation process, as you know, but there are also protections in the

NRC process beyond that point that will allow anyone who still thinks the project ought not go forward to challenge it, be a part of the NRC process, et cetera, et cetera.

Of course the political process is always available, even though Congress will have acted to allow it to go forward, and I have just laid out here the four steps -- the license to construct and the license to operate. The most important decision will be the license to close. The earliest that will happen is 2060. It may happen as late as 2300, so what we are seeing here is a step-wide process, probably with greater requirements for additional certainty in the data going forward which will be developed by the confirmatory R&D program beyond what is known, now what is known at license application.

What is needed to be known now -- is the site suitable and is the site sufficient but sufficient to begin the licensing process. I won't belabor suitability because it is not what NRC is doing but it is important for the record to understand. This is the sole language out of 180 some odd pages what suitability is, and from that we have to discern what is an appropriate suitability recommendation that DOE has to make.

Remember though what I said about decisions. Suitability, while a major component and a major input to the Presidential decision, is not the sole determiner. It is part of it. It is a major part. It is not the sole determiner. I can only guess what the President will have in mind when he sits there with his pen in his hand to decide to approve or disapprove going forward on the project, and only the President will be able to determine what this decision is really all about, subject to review by Congress and review by the state, et cetera.

It is a conclusion based on science, not merely a compilation of scientific information. It must be clearly communicated, as I just mentioned, and the uncertainty -- this is the key point.

It is an understanding of uncertainty, not an elimination of uncertainty. How important are the different uncertain matters? I particularly appreciated the questions posed to Mr. Firth on how getting into the numbers a little more deeply at sufficiency to understand where the uncertainties are, but I also completely agree with his answer, that we will do that to the extent we can, as I believe he said, but we will not comment on the final answer, and that is the right thing, because commenting on the final answer is inappropriate to a stage where there was no requirement to produce a final answer. If there was, we would be licensing, not making a site recommendation.

Of course, suitability has to be documented and it is a comparison against the criteria that DOE currently has out in draft and will probably publish before the SRCR is issued.

Well, NRC is in better shape than DOE. They have got about twice as many words to tell them what sufficiency is and they are right when they say it is preliminary in nature and that it is in fact something that they, too, have to discern as to what this decision is. It is by its very nature, the fact that it says preliminary comments concerning the extent to which at depth site characterization analysis and the wasteform seem to be sufficient for inclusion in any application to be submitted.

Those are all future words, what happens in the future, so I think to a large extent NRC has got it right, and that is a forward-looking decision about DOE's ability to file a license application, not the licencability of the project. If it was about licensability of the project, the law would have said give us a license application, and it does not say that. It is an interim step. It is, as I said before, a much less technically challenging decision.

But let's talk for a minute about some of the things, one or two of the things that I heard Mr. Firth say that I think are somewhat confusing to me, although I suspect their heart's in the right place. He indicated that it is not a licensing review because we don't have the time and resources. Well, excuse me, if it was a licensing review and you are not doing it because you haven't time and resources, that is an unacceptably weak answer.

You are not doing a license review, NRC, because it is not a licensing review. It is in fact a sufficiency review and it is not a sufficiency review in the nature of a Part 50 sufficiency review for a license application. It is a completely different animal, okay? Frankly, it is wrong to say that it is not part of site recommendation. Yes, I agree with what Mr. Reamer said when he says they are not commenting on the site recommendation, they are not commenting on suitability, but it is an important part of the site recommendation decision that the President has to make, which is in fact is DOE going to, if they follow the plans they have, going to get from wherever they are at the point of the site recommendation to filing an adequate license application. Are those plans in place?

I think that that confusion as to how the sufficiency determination fits into the greater scheme of things as part of informing a policy determination needs to be kept in mind, because it is very different than any other thing that NRC is used to doing, and they need to be very careful that they don't err on the wrong side of that line.

They ought to in their review close out questions if they can that they raised in the VA review, defining the path forward if there are any new or remaining questions and determine whether they think they will get there by LA and of course it is an opportunity for them to explain how the licensing process will address the uncertainties going forward. It is separate and distinct from suitability, which is a point that I just made, and it needs to be balanced.

Let's talk about balance. When we were contemplating NRC making a statement on the viability assessment, which was not something they were required to do by law but something that they knew as a responsible agency they had to do, we had several public meetings with NRC about that. Bill will remember that. The point we made, which I think they took to heart, was that if you go back over the decades that you have been working with DOE think about how many things you have asked DOE to do that they have done versus the number of things they have said to you we are not going to do those, and I guarantee you that the ones they are not going to do or haven't done are in the vast minority, but as a regulatory agency and as people in general there is a tendency to focus on the negative rather than the positive.

We suggested to them that what they do is they point out all the things that the DOE still has to do to get it right, but don't be afraid to point out all the things that DOE has done that they are getting right.

They took that advice to hear and the VA letter was extremely helpful to policymakers to allowing the project to then go forward beyond that point.

The EIS letter, however, was a disappointment in that regard. I heard the EIS presentation to this body and I was, frankly, shocked to hear the kind of negativity that was presented, and by the time that letter came out it still focused on here are the five or six things we don't like, and left to the reader to figure out what they did like.

If you read that letter between the lines, it is pretty clear they liked a lot about the EIS. One simple example -- in transportation what they are critical of was not radiological impact. Well, that must mean that they thought the radiological impact analysis was just fine. They never said that, but that is a conclusion you can draw.

I would just encourage NRC to take a balanced picture, a balanced view to what they are going to say about the SR, and of course it is a legally flexible approach, and I think that Mr. Reamer's profession is very adequate at doing things that are flexible and making sure that all the bases are touched in ways that the agency itself is not hamstrung in future licensing decisions because it said "x" or "y" at an earlier stage.

In conclusion, it is our view that this is an extremely important time. Sufficiency is one of the elements that will lay the groundwork for a decision on going forward on Yucca Mountain. It was important to inform that decision. NRC should not shy away from the role they are playing in informing that site recommendation decision.

We need to keep this decisionmaking process on track. We need to encourage the agencies to keep their meeting schedules and keep their interactions going and things like that, and then, most importantly, we need to prepare to implement the decision, whatever that decision is. Remember, the law allows that decision to go both ways, as it should.

Now it has got one sentence in it about what happens if the President makes a decision saying not to go forward, but we need to prepare to implement that decision however it comes out.

Those are my prepared remarks. Thank you very much.

MR. HORNBERGER: Thank you, Steve.

Are there questions from the committee? No?

DR. GARRICK: I would just like to make one comment. One of the criticisms levelled at industry in the waste field is that industry has not exhibited the same level of interest in waste, if you wish, as they have in doing what they have to do to keep their licenses in place and operate their facilities.

Part of the reason that sometimes I hear given is that when the Nuclear Waste Policy Act of 1982 came about the industry relaxed a little bit because that was supposed to be the solution -- for DOE to take the waste off their hands and dispose of it.

I am sort of one of those that has been a little critical at the absence of industry on this issue, and the absence of visibility of the industry on this issue. Do you see that changing? Do you see -- for example, we seldom hear from a utility executive on their concerns and interests and activities associated with trying to make a contribution to solving the waste problem. We do see NEI.

I have talked to a few utility executives and have sensed that they probably made a mistake, at least from some of them, of relaxing, if you wish, if I can call it that, on the waste issue in the mid-'80s when they should have continued to be very visible, very active, and proactive.

What is your thought on that?

MR. KRAFT: Well, Dr. Garrick, in the spirit of sufficiency as a forward-looking decision, let's look forward. Any views I would express on the past are purely my own and I would not want them to be taken as NEI's views or the industry's views of the past.

I will say this on behalf of my industry, that when we deal with industry problems that affect everybody there is a tendency in the industry to look to the central organizations to deal with it in a more concise, consistent and to some extent cost-effective fashion, and we see that in Part 50 as well.

I see the -- the only answer I can give you is that you have had your personal conversations with the executives of my industry and I have sat in their meetings and I can only tell you if you sat in their meetings I think you might have a somewhat different impression of their interest in the topic and their interest in helping DOE be successful, and I do see that there is more being put on the table in that regard, if I can use that term.

We have a group now in NEI of senior executives who form the committee who are working with DOE. We have a group of senior management people who are meeting with DOE every now and again about how they are -- DOE and TRW -- about how they are managing projects. The most recent of those meetings occurred about a month ago. We are going to be taking certain individuals within the agency and exposing them to practices at the best nuclear plants to help them understand how they operate.

We work tirelessly in Congress to obtain the needed appropriations -- it is that time of year so we are working on that now for this agency as well as for DOE.

I think it is instructive that there are two groups in the industry that have pursued their own interim storage projects, one in Utah and one in Wyoming, the Utah one being several years ahead of the Wyoming one, both of which are on a path for success, and I think those are really very quiet activities as many of the industry activities are in trying to help out DOE.

If what you are hinting at, and let's just put it out in the open, is that we have focused primarily on the legislation that might or may not become enacted as opposed to helping the program, I would say that the legislative activities by their very nature are simply more visible. The other activities are not.

I suspect that what happens in the industry in this waste program is that it tends to be a rather esoteric exercise not normally within the day to day activities of the typical utility senior nuclear officer and they would defer to competent and expert staff in the central organizations to deal with it.

We certainly hear a lot from them about helping DOE be successful, so maybe it is just more of a visibility question, Dr. Garrick, and I think we will have to correct that.

DR. GARRICK: Okay, thank you.

MR. HORNBERGER: Thanks very much, Steve.

MR. KRAFT: Thank you.

MR. HORNBERGER: Amy Shollenberger has asked for time to comment and this would be a good time. Amy?

MS. SHOLLENBERGER: Thanks, Dr. Hornberger, for allowing me to speak. My name is Amy Shollenberger and I am here representing Public Citizen's Critical Mass Energy Group. In the spirit of Mr. Kraft's suggestion to start with the positive, I will say there is one thing that I agree with him on and that is that there is no crisis that needs to push Yucca Mountain project forward. I was really happy to hear him say that.

It seems that a lot of the policy-makers maybe need to be told that a little more loudly. And I think it is especially true in light of yesterday's presentation showing the new planned ISFSIs around the country to store waste on-site, so I just wanted to start with that comment.

DR. GARRICK: I think there is a very important distinction. I think what he said, there is no nuclear waste crisis. I don't think he said there was no crisis relative to the need for Yucca Mountain.

MS. SHOLLENBERGER: Well, a lot of lawmakers on the Senate and House floors have claimed that there is a nuclear waste crisis and that is why we need Yucca Mountain, and I would just like to point out that NEI is saying that that is not the case.

On to my other comments, first of all, I think it is just really interesting that it is the industry actually here telling you all what the decision-makers need to make their decisions. And I think it is important to note that the decision-makers, at least those in Congress, supposedly represent their constituents and not necessarily only the industry, although it is very clear that the industry makes it a lot easier for them to get elected.

I think that I would like to add that what decision-makers need to make decisions is they need to know how the decisions affect their constituents and, also, the taxpayers who are also their constituents. I think the hockey-helmet thing was a good example, because it is true, you need to have all the pieces of the puzzle to make the good decision. You need to know how likely it is that your child is going to crack his skull open before you decide whether or not he can play hockey, and you don't only need to be told that there is padding on the walls, so if he runs into the wall, it is not going to crack his head open. You have to have the whole picture.

Also, I would just like to mention on the record that, in regards to suitability, there is a petition that was sent to the DOE signed by over 200 groups asking them to disqualify Yucca Mountain, and that petition was based on the guidelines in 10 CFR 960, which right now there is a proposal to change, as you all know. But both 10 CFR 960 and the Nuclear Waste Policy Act had -- well, the Nuclear Waste Policy Act called for individual disqualifiers for Yucca Mountain and those disqualifiers were listed in 960, and the petition was based on those disqualifiers.

The petition was, of course, denied by DOE, but it is important to know that part of the response was a proposed rule change to eliminate disqualifiers in 963, individual disqualifiers.

So I think it is just really important to keep that sort of in the forefront as you move forward and look at sufficiency and suitability, that there is a large group of Americans who believe that the information that is being put forward is not sufficient to make a decision and that Yucca Mountain is not a suitable place to store radioactive waste.

Also, I would just like to thank the NRC for its EIS comments. I think that, for once, it showed that the NRC was willing to stand up and say what was right instead of sugar-coating the comments to make DOE feel good. And, for one, was really glad to see those comments. I saw you all struggling with how they were going to be worded, and I would have liked to see them a little stronger. I heard some things in the meetings that actually were more strong than what you put in your letter, but I was really happy with the letter, and I would just like to thank you for the work that you did on that. Thanks.

DR. HORNBERGER: Thank you, Amy.

DR. GARRICK: I wanted to just comment on something that Amy said that I think is very important, and I will give my spin on it, and I will do it in the context of Steven Kraft's exhibit that he showed us, what decision-makers need in order to act.

I think the thing that is needed more than any other single thing, and that supersedes everything on the list, is the will of the people to want to solve the problem. I think the reason nuclear waste lingers on without a long-term solution is there is not a will out there to solve it. There is no a sense of urgency.

Steven points out that maybe one of the reasons for that is the good job that industry is doing in managing the nuclear waste, and I think, in general, that is so, particularly in the civilian side of the business. But I do think that the underlying and overarching problem that exists with respect to making a decision here is the lack of a public will to do so, and that we just can't escape that. If the public really wanted to do something, be it store it, dispose of it, Yucca Mountain or what-have-you, clearly, it could be done.

DR. HORNBERGER: Any other comments?

[No response.]

DR. HORNBERGER: Discussion? The last item on the agenda here is to discuss elements of a possible ACNW report on this topic. My own view is that that may be premature. It may be premature to have such a discussion. If there is no objection to that statement?

DR. GARRICK: Yeah. Unless the committee, some -- any of the members feel that there is an issue that has come up that would warrant some remarks at this time. Ray.

DR. WYMER: I doubt personally there is anything that warrants a report, probably some additional discussions with the staff, but not a report.

DR. GARRICK: Yeah. I think some additional discussion on this issue, that we got into a little bit of conservatism versus uncertainty, and the clarification of what all that means in the context of a risk-informed approach. I think there clearly needs to be more discussion about that, because I am still not convinced that the NRC has their heart in a risk-informed approach, because a lot of the process and a lot of the regulations continue to be incompatible with a genuine risk-informed approach. But, nevertheless, progress is being made. The steps are smaller than some would like, but at least they are in the right direction. But I do think some more discussion on that would be very constructive.

DR. HORNBERGER: I am sure that surprised you, Ray, that John raised that.

DR. WYMER: Right out of the blue.

DR. HORNBERGER: Other comments?

MR. LEVENSON: I suppose since we are making expected comments, I need to make mine on conservatism, and that is we have to recognize that large uncertainties are not, in any case, automatically a reason for conservatism. If the consequences of the uncertainty, even at the limits, are all fully acceptable, you don't need to add more conservatism. Uncertainty, by itself, is not necessarily a detriment.

DR. GARRICK: That is exactly correct, and that -- I am impressed that you have moved along so --

[Laughter.]

DR. HORNBERGER: Okay. I think we are caught up with this topic for now.

DR. GARRICK: Okay. I think we will take a break now and come back in 15 minutes.

[Recess.]

DR. GARRICK: We would like to come to order now. The next item on the agenda is the Yucca Mountain Review Plan. George Hornberger will continue as the member leading the discussion.

DR. HORNBERGER: Okay. As John said, we have the YMRP on our agenda for attention this year, and Christiana

Lui is going to give us a briefing. Christiana.

MS. LUI: Thank you, Dr. Hornberger.

I guess I am not going to have my branch chief here supporting me, I am flying solo today.

DR. GARRICK: He is here.

MS. LUI: Okay. I am Christiana Lui, I work for Bill Reamer in the High Level Waste Branch in the Division of Waste Management, and today we are giving you an update of the Yucca Mountain Review Plan development effort.

We last briefed the committee on November 18th, 1999 and, basically, during that particularly briefing, we gave you the approach that the staff is using to develop the YMRP. And, also, during that particular briefing, we laid out what are the major components of the YMRP. Here I am just reiterating that framework that we have adopted for YMRP.

On the next page you will see a chart, a schematic for the framework of the major components in the YMRP. As we go through this particular presentation, I am going to come back to this diagram from time to time. Basically, the YMRP is divided into introduction, where we lay out the purpose and scope of the RP, of the review plan and the review strategy.

And the next chapter is acceptance review. What is where we will evaluate whether DOE has submitted a complete license application, and the basis for that particular chapter will be a comparison to paragraph 63.21, that is where we lay out the content of license application.

And the next chapter is the general -- is the review plan for general information, which is basically laid out in 63.21(b), and there are five components to it, general description, schedule for construction, receipt and emplacement of waste, physical protection plan, material control and accounting, and a brief description of the site characterization work DOE has conducted.

And the real main focus of the review plan will be the chapter on safety analysis report review. And in that particular chapter, we have divided the review plan into three major sections, preclosure safety evaluation, postclosure safety evaluation, and evaluation of the administrative and programmatic requirements.

Before we go any further, I would just like to tell you where we are, the current status, and we will come back to a schedule at the end of this presentation. The staff is currently completing the Revision 0 postclosure sections, and we intend to have this particular postclosure portion of the review plan accompany the Draft Final Rule to the Commission by the middle of April this year. So approximately two weeks from now, it is going to accompany the rule to the Commission.

And we are working on the preclosure sections and all the other chapters of the review plan, and Draft Revision 0 of the preclosure sections is coming to us from the Center in the middle of April, and we will provide a quick review, and the Revision 0 of the preclosure sections, we believe, will be done by the end of May. And all the other sections of the review plan, such as QA, such as material control and accounting, the general information portion, we are looking at completing the Draft Revision 0 by the end of April and have a Revision 0 by the middle of June this year.

We intend to basically make the YMRP Revision 0, all the sections, publicly available after management approval. We are contemplating about transmitting the Revision 0 to DOE as information copy, and we want to put the Revision 0 on the web site. I will come back at the end of the presentation and talk about the public comment and the other revisions that we are planning to give you a more complete picture. Right now I just wanted to let you know where are in the process.

Just to reiterate, the principles that we have adopted for development of the Yucca Mountain Review Plan, most importantly that NRC is responsible for defending the license decision and DOE is responsible to ensure the adequacy of its license application and safety case. They are the ones with all the resources to carry out all the site characterization and experimental work, and they, in their license application, need to provide a sufficient safety case.

And 10 CFR Part 63 is a risk-informed, performance-based rule, and we fully intend to make the Yucca Mountain Review Plan a risk-informed and performance-based review plan. And what we are doing right now is using the total system approach and an integrated approach to formulate the review plan.

I will talk about the postclosure part, but it will be later, in great detail and give you a sense of how we are carrying out this particular process. And at the same time, we are incorporated all the experiences and knowledge that we have accumulated during the prelicensing consultation period and using a risk insight to help us formulate this review plan.

The purpose of the review plan is to provide guidance to the NRC staff, our methods for conducting and documenting the license review. This is not the equivalent of regulation. In other words, it does not have the force of law. In the review plan we present at least one approach for compliance demonstration, or, basically, how the staff is going to conduct the license application review. And other approaches are definitely acceptable if DOE can demonstrate the appropriateness of the alternative approaches.

And for each section of the review plan, for each of the topics that we are evaluating, there will be five subsections. Areas of review that will provide the scope, basically, what is going to be reviewed in that particular section of the review plan. We lay out the review methods that tells how the staff is going to conduct the review. And acceptance criteria, what the staff will find acceptable and the acceptance criteria are based on the regulatory requirements in the rule. We will present the general conclusions and findings in the evaluation findings portion to echo the areas of review that we have identified at the beginning of each of the review sections. And we, of course, will provide all the references that we have cited in that particular section.

Now, I'm going to turn the attention to the preclosure, which will be on the left-hand side of these charts.

As I have mentioned before the Draft Revision 0 of the preclosure sections will be coming from the center in middle of April, and we fully intend to provide a quick review and have a version out by the end of May.

Basically in the preclosure sections, we establish a set of criteria and review methods based on whether the preclosure performance objectives can be met. The preclosure performance objectives are identified in Section 63.111 of the rule, and 63.12 lays out the technical criteria for an acceptable preclosure safety analysis.

More importantly, we want to emphasize that DOE has the flexibility in selecting design details and methods for compliance demonstration. In the rule, we did not prescribe any of the design criteria in the review plan, and we will not be doing that either.

I note that that was one of the major concerns when we first developed Part 63 that people were asking, if you're going to have a risk-informed performance-based rule, are you going to be dropping all the prescriptive detail in the review plan?

We don't intend to do that; we want to provide DOE with the flexibility in defending and constructing its own safety case.

However, where appropriate, we fully intend to rely on existing guidance documents, and we are in the process of working with the Spent Fuel Project Office and Fuel Cycle Facility folks to help us identify what are the major components that we need to pay attention to in the preclosure portion.

And the evaluation will include the adequacy of site characterization, repository design, construction, operation, monitoring, and closure.

And also in the preclosure performance objectives, we have identified that DOE needs to provide a plan for retrievability, and they also need to -- and the design also needs to accommodate the implementation of a performance confirmation program and in the preclosure part, we will be looking for those pieces that DOE is required to address.

Now, I'm going to talk about the postclosure portion of the review plan. And this is where we have the most detail that I can discuss with the Committee today.

Like in the preclosure case, in the rule, we have postclosure performance objectives established for postclosure safety.

We are developing the acceptance criteria and review methods, based on whether these post-closure performance objectives can be met. And the evaluation will include the adequacy of ODOE's work such as site characterization, field testing, laboratory testing, and natural analog investigation.

Multiple barrier analysis, that is also another performance objective that we have laid out.

Demonstration of repository resilience to human intrusion events and also -- performance confirmation programs.

I now want to turn your attention to the performance assessment portion of the review plan. Basically let me go back to the diagram again. I'm looking at these particular blocks where we have all these detailed components supporting the evaluation of performance assessment.

We have divided up the review of performance assessment into four major pieces: System demonstration, system description and demonstration of multiple barriers; scenario analysis; model extraction, and lastly, demonstration of the overall performance objectives.

There are many different ways we can sequence the review. But the logic that we have come up with sequence our review in these particular order is that DOE has already, by the time of license application, DOE has already completed all the iterations and the required analyses.

Therefore, right up front, we want them to tell us what they are relying on, i.e., the barriers, in meeting the postclosure performance objectives on individual protection standards.

And that will help the staff to focus our review in the subsequent portion of the performance assessment. And in the scenario analysis portion, we want DOE to tell us what they have included or excluded from the consideration, and the probability of the scenarios.

Like Dr. Garrick's paper, in Dr. Garrick's paper, the risk triples, has scenarios, probability, and consequences. Here in this particular part, we want DOE to identify what are the scenarios that they are considering and what are the associated probabilities of those scenarios?

And once we have a good handle on what DOE is considering in their compliance demonstration calculation, we will be going into detail, looking at the model abstractions portion. That's where DOE would conduct its consequence analysis.

And at the end, we want DOE to put together the scenario, probability, and the associated consequences to give us the risk estimate.

That's going to be evaluated in the last portion of the performance assessment review.

Now let me go into more detail for each of those four subsections. Multiple barriers: We have formulated acceptance criteria and review methods that focus on whether DOE has identified all the barriers that they are taking credit for in the compliance demonstration.

Also, DOE is required to describe and quantify the capabilities of the barriers, using the information coming from the total system performance assessment. They can use intermediate outputs, or they can use sensitivity analysis results. Basically they need to quantitatively describe how the barrier is going to contribute to the performance of the repository over the compliance period.

And DOE needs to include technical basis to support the assertion of all the barriers' capabilities.

During the public comment period, we did receive a fair amount of comments on the clarity of the multiple barriers requirement. And in the final rule, the staff is doing -- is clarifying the requirements on the final rule in this particular area.

Therefore, we will develop additional criteria and review methods that are consistent with what is going to be included in the final rule, understanding that the Commission will have to make a decision on what options they want to go with, and based on that particular decision, the staff will carry the work in this area further.

The next piece is scenario analysis. In this particular portion, we are focusing on a methodology for inclusion or exclusion of features, events, and processes in the compliance demonstration, the informational scenarios.

There are five steps that DOE needs to carry out: The first part is DOE needs to identify a comprehensive list of facts that are applicable to the Yucca Mountain site.

Understanding that the subsequent steps here -- DOE does not require to carry out any of these subsequent steps, once they have identified the initial list of facts, but there are thousands of facts that are applicable to the Yucca Mountain site.

By doing the grouping and applying the screening criteria, that will basically streamline the performance assessment process and make the analysis more transparent at the end.

However, if DOE likes not to carry out any of the subsequent steps, they can certainly incorporate all the facts applicable to Yucca Mountain into their performance assessment.

And our understanding is that DOE will be characterizing or grouping the FEPs together to basically form FEP groups. And DOE can perform the screening of these categories, based on two separate criteria:

One, it has been laid out in the rule that if the probability is below 10-4, then DOE can screen that particular event out. Or DOE can perform a consequence analysis. It does not have to be a very detailed PA, however, if they can perform a bounding analysis to demonstrate that the exclusion of a particular FEP is not going to impact the timing or the magnitude of the dose, and based on that particular rationale, they can exclude the FEP from consideration.

Once DOE has a reduced set of FEPs, then we want them to start putting all these FEPs into scenarios. And again, they can screen, they can perform the screening based on the scenario classes, using the two criteria I have just mentioned before.

And also in this part, we want to examine DOE's assertion or their technical support on the probability of disruptive events.

The first thing is that DOE needs to provide a very defendable definition for what is being included, whether it's in a single event or a particular event group, to make sure that the characterization or the slicing up is technically defendable.

And we will be looking at the data, models and uncertainty in the probability estimates, based on how DOE has formatted its FEB Division, how DOE has come up with this definition.

So we're giving DOE tremendous amount of flexibility in coming up with a defendable FEP case going into the performance assessment.

The next piece I want to talk about is model abstraction. I'm sure that you have seen this diagram many, many times, and I probably don't need to spend a whole lot of time on this now.

But I just want to give you an idea that the model abstractions portion is being divided up based on the lowest tier of this flow-down diagram. This is basically where staff has utilized the experience and knowledge form reviewing DOE's analysis, doing our own analysis, and finding out what are potentially important to the repository performance.

And we want DOE to address all these different pieces. However, the level of the detail of these 14 topics is going to be different, because we want to incorporate the risk insight in terms of how much we go into basically specify what DOE needs to do.

And that level of detail will be commensurate with their impact on the performance.

Again, the model abstractions portion is based on the integrated subissues, the lowest tier of the flowdown diagram. We use five general technical criteria that focus on data and model justification, data uncertainty, model uncertainty, model support, and integration.

In data model justification, basically we're looking at whether DOE has conducted sufficient site characterization, analog investigation, field and laboratory testing, to basically define the models and the associated parameters that go into the performance assessment.

And in data uncertainty, we are looking at whether the parameter ranges in the performance assessment have captured the uncertainty existent in the database.

And in model uncertainty portion, we are looking at whether DOE has considered alternative conceptual models that can be explained, based on the existing information.

And in model support, we are looking at the evidence that the DOE has to support the models that they eventually used in the PA.

And in integration, we are basically looking at whether DOE has properly handled the interface between the various components of the TSPA. If you look at the 14 pieces here, none of them is a stand-alone piece that does not have any relationship with the prior piece.

For example, if you look at the quantity and chemistry of water contacting waste package and waste forms, and the model of radionuclide release coming out from the waste packages, those two are definitely related because the solubility and the release rate will depend on how much water actually gets into the failed waste package.

Therefore, the integration piece is looking at the interfaces between the 14 pieces.

And the approach that we have taken in formulating the model abstractions portion is to extract the review methods acceptance criteria from the issue resolution status report to strengthen the five generic technical criteria that we have chosen.

If you flip to the last page in your handout package, you will see a chart that will require a decoder.

And you can find the decoding information on the flowdown diagram.

The top line, you see ENG-1, 2, 3, 4. Here we have labeled ENG-1, ENG-2, ENG-3, and ENG-4. That's a shorthand for the 14 ISIs or integrated subissues that we're looking at.

And on the left-hand side, we see all the KTI abbreviations, and the three pages preceding to the last page, I have given you what these KTI subissues stand for. So by using these particular charts, staff basically is integrating the information from the various IRSRs, going to the particular KTI subissues, and integrate the information from the KTI IRSRs, based on the total system approach.

I know that is probably a lot of information to digest, and that's why I provided you with the detailed info there to give you an idea and a sense of the commitment that we have in terms of looking at the issues from the total system standpoint, incorporating the risk insight and integrated amount of various technical discipline.

Moving on to the last piece under performance assessment -- by the way, before I start here, I just want to mention that information in the cross reference -- in the cross -- flow chart, and the subissue definition has all been attached at the end of the TSPA Issue Resolution Status Report Revision 2, which was released the end of January, so that has been in the public domain for about two months now.

Okay, moving on to the last piece, overall performance objective, here we're looking at the compliance to the individual protection standard. This is where we will come together and make a determination of whether consistent assumptions, data, and models have been used in DOE's compliance demonstration calculation.

And this is also where the probability, scenarios, and consequences all come together to form the risk estimates over the compliance period.

In this part, we are also looking at the human intrusion analysis. Basically we are looking at whether DOE has used consistent approach compared to its PA for doing the human intrusion calculation.

The only exceptions on the deviation from what DOE has used in the PA calculation is where it will be appropriate to modify because of the intrusion scenario.

And again, this is also an area where we have received public comments during the Part 63 comment period, and the staff is working on clarifying the human intrusion analysis requirement. Once the Commission has made its final decision on what issue will be put into a final rule, we will further develop this piece to make sure that we have a consistent review approach compared to the final rule.

Now I want to talk about the last piece of the safety analysis report evaluation. The difference in this piece is that we do not have performance objectives for administrative and programmatic requirements as in the preclosure and postclosure case. In this particular section we are looking at mainly the procedural matters and there are numerous existing acceptable programs in the agency, and we are planning on using those existing programs modified to the extent necessary, so that they will be suitable for the high level waste repository at Yucca Mountain.

Also, I want to mention that a lot of the information contained in this section is going to directly impact the preclosure safety evaluation, therefore there is going to be a lot of looking back and forth between the preclosure part and the administrative requirements to make sure that during operation the preclosure performance objectives will be met.

In the evaluation in this particular section we include QA, training, recordkeeping, normal operation, emergency planning, and physical security. Those are the big topics in this particular section.

As I mentioned previously, the draft Revision Zero for this particular section will be coming to us from the Center by the end of April and we are hoping to have the Revision Zero done by the middle of June.

Scheduled activities -- I have mentioned that we are in the process of establishing coordination with other NMSS divisions and program offices for review of the preclosure safety and the administrative and programmatic procedures. We are consulting with NRR in terms of the emergency planning procedures and working with SFPO in the fuel cycle, the Part 72 and Part 70 folks, on the preclosure safety analysis portion.

We have assigned technical leads to integrate the multidisciplinary teams and build consensus for each of our review sections.

We will continue to work on the level of detail, integration and incorporation of risk insights.

In the future revision of the Yucca Mountain Review Plans will be modified as necessary so that you will be consistently implementing the final Part 63 because now we are on this schedule that we don't really know when the Commission is going to be making its final decision on Part 63. Therefore, we will be keeping an eye on that particular progress and make sure our future revisions capture the final position in Part 63.

I would like to bring your attention to a third bullet -- continue working on level of detail integration and incorporation of risk insights. As I have stated at the beginning of this presentation, we fully intend to make the Yucca Mountain Review Plan risk-informed and performance-based. However, we also need to give sufficient guidance to the Staff and indirectly to DOE on what is acceptable.

We don't want to be prescriptive but we also don't want to get into a situation where it is bringing another rock situation.

Compounding with the fact that the design is still evolving, the knowledge base is still evolving, and there is an inherent uncertainty for a 10,000 year repository, I believe this is where this particular committee can provide the most recommendations and guidance to the Staff on helping us achieve the goal of having a risk-informed and performance-based review plan, without being overly prescriptive providing sufficient guidance so that it will be clear to everybody what is necessary to demonstrate compliance and at the same time there is an appropriate level of flexibility for DOE.

I just want to conclude this particular presentation by giving you the schedule. Looking ahead, the Revision Zero of the Yucca Mountain Review Plan -- here I am talking about the postclosure sections only -- will be going to the Commission with the draft final Part 63 by the middle of April and we are planning on holding meetings with DOE, these are public meetings.

Right now on the book there will be a PA technical exchange in early June and we are also planning on an Appendix Y meeting on YMRP and the license application in the middle of June.

In Revision 1 of the Yucca Mountain Review Plan, that's where we have all the sections together. We are planning on having that particular version out by the end of FY 2000 and we will formally invite public comments on that particular version, so anything we release prior to the Revision 1 is going to be for information only, and then after we release Revision 1 we will be holding public meetings and also meeting with DOE to explain the approach that we have taken in the Review Plan and also to solicit comments.

In Revision 2 of the Yucca Mountain Review Plan we will address the comments that we have received and incorporate any information, whether it is going to be on design or site characterization, into consideration.

MR. HORNBERGER: What is the date for that one, Christiana?

MS. LUI: Revision 2 is September 30th, 2001 -- sorry, that is a typo.

MR. HORNBERGER: Otherwise you would do it very quickly.

[Laughter.]

MS. LUI: That's okay. That is an obvious mistake so that you won't notice anything else.

[Laughter.]

MS. LUI: That's it. That is the end of my prepared presentation. I will be happy to entertain any questions you may have.

MR. HORNBERGER: Thank you, Christiana.

MS. LUI: You're welcome.

MR. HORNBERGER: The first question that I have is that you were probably in the audience earlier this morning and you heard James give a presentation on the site suitability report, and there is obviously or it is obvious to me that there's an awful lot of overlap.

MS. LUI: Yes.

MR. HORNBERGER: I understand the different objectives, but there has to be an awful lot of overlap.

Can you just give us some insight on how you are coordinating?

MS. LUI: Okay. I believe a while ago that we have sent a letter up to -- I have to remember who was the recipient of that particular letter. I think it was a letter back to the Commission saying that we intend to use the Yucca Mountain Review Plan to formulate our sufficiency comments. If you remember that -- of course, I lost that particular page -- but the five technical acceptance criteria that we are using for model abstraction evaluation includes data and model justification, data uncertainty, and model uncertainty and model support and integration.

That is going to be the emphasis of how we are looking at the -- or to formulate our sufficiency comments. we are not going to carry everything to the last piece. That is where we are going to be looking at the overall performance objective but we want to look at the report and make a judgment whether we can proceed with the review that we have in mind when the license application comes in.x

MR. HORNBERGER: Okay, so the teams are clearly working together then?

MS. LUI: Yes.

MR. HORNBERGER: I have one other question, sort of a clarification for myself.

On one of your slides you mentioned that you were going to be looking at postclosure performance confirmation. Do you have ideas on what postclosure performance confirmation would look like? Are there any requirements or is there any guidance or could you just give us your preliminary thoughts on what would be required?

MS. LUI: Okay. Remember that DOE's responsible to define its safety case. Therefore, let me just look at this chart here, we have these two pieces in the postclosure review. One part is that there is going to be we require DOE to establish a program and schedule for closing any of the open issues, and that is clearly linked to the performance confirmation program that they are going to be implementing.

In the performance confirmation we certainly expect them to focus on those areas that they will need to further clarify or have more information in order to support a defendable safety case such as the heater test is still ongoing and the results are now going to be available by license application time. Therefore, that would be one area we are going to be carrying into the license application and when the information becomes available to us, well, to DOE, we certainly will expect DOE to utilize that information to update its performance assessment.

MR. HORNBERGER: Okay. Perhaps it is a misunderstanding on my part then. When I think of postclosure, I think of physically after the repository has been closed. That is not what you are talking about when you talk about postclosure performance confirmation?

MS. LUI: No, that is not what we are talking about at all. No, no, that is not.

Even though in Part 63 we do require DOE to establish permanent oversight --

MR. HORNBERGER: Right.

MS. LUI: -- but the performance confirmation program we are talking about here is not after closure. It is more to strengthen its safety case for postclosure.

MR. HORNBERGER: Okay, got you. Questions from the committee? John.

DR. GARRICK: We have talked quite a bit at this meeting about the positive aspects of the public review process associated with draft Part 63 and I assume that that has spun off as far as the Review Plan is concerned, and also you note in your presentation that there will be public comments on the revisions to the Review Plan.

Are there any other activities between Part 63 and the Rev. 1 for example where there has been deliberate effort to get public involvement and participation in the creation of the Review Plan?

MS. LUI: We did not have -- I mean up until this point we have not conducted any public meetings outside from the public meetings that we had with DOE, so in terms of the framework of the Review Plan pretty much we looked at how our Part 63 is structured --

DR. GARRICK: Yes.

MS. LUI: -- and also our conversation with you, from time to time, in terms of helping us focus on what we need to look at, so the structure portion, no, we have not gone out explicitly to ask for public comments, but that does not mean that during the Revision 1 public comment period that they will not be commenting on the structure of the Review Plan.

DR. GARRICK: Yes.

MS. LUI: But between Revision Zero and Revision 1, because Revision Zero is going to be for information only, we do not anticipate that we will be actively seeking public comments.

DR. GARRICK: Okay.

MS. LUI: However, if management decides that we can go ahead and put the Revision Zero on the website, whatever informational comments that we receive on Revision Zero we will take that into consideration when we address the comments together when we address the comments on Revision 1.

I think Bill has something else to add.

MR. REAMER: Bill Reamer, NRC Staff. I would just add one more point, kind of to build on something that Christiana mentioned during her presentation. That is, our plan to use the Review Plan in the sufficiency comments as well as issue resolution and both of those processes, sufficiency comments and issue resolution, are public processes that involve technical exchanges, meetings with DOE that are public, so we hope that they will also produce feedback on the way in which we are following up and implementing this draft review plan and could lead to improvements or changes in the review plan as well.

DR. GARRICK: Okay, thank you. A little more on the technical side -- when you talked about the scenario analysis with respect to postclosure safety evaluation, you indicated that you have a screening criteria or a cutoff for scenarios of 10 to the minus 4, I believe it was, that you mentioned, the number?

MS. LUI: The probability, but the bottom line is that the frequency is less than 10 to the minus 8 per year.

DR. GARRICK: Yes.

MS. LUI: So over the compliance period it would be 10,000 years, so I converted that to 10 to the minus 4 probability.

DR. GARRICK: And of course these I assume are mean values that you are talking about?

MS. LUI: No, we are looking at -- DOE needs to look at the full range.

DR. GARRICK: But I know you are looking at a range, but the specific number is a central tendency parameter?

MS. LUI: I don't want to commit ourselves to just looking at mean value at this point because there is a large uncertainty associated with any of the geologic processes and we really need to look at the supporting evidence DOE has before we will all be able to say whether it is a legitimate exclusion or DOE is basically dicing up its cases to the point that everything is going to be below 10 to the minus 8 per year.

DR. GARRICK: Yes, okay. I think that is a good answer, because among other things if you have an Epsilon amount on the proper side of the screening number, then one of the things you really want to look at of course is the variation in uncertainty between the scenarios.

MS. LUI: Right.

DR. GARRICK: The other thing I wanted to just get your early comment on is one of the elements that you are going to be looking at when you start looking at uncertainty of course is modeling uncertainty, and I think that was on one of your exhibits.

Can you give us a very abbreviated glimpse of how you are going to do that?

MS. LUI: Okay. I think doing a couple of public meetings we have with DOE -- I mean we have had with DOE, we definitely are not advocating assigning probability to the alternative conceptual models. What we want DOE to do is that for the alternative conceptual models that would actually lead to pretty significant differences in the consequence estimation, we want them to incorporate the results of those alternative conceptual models and we want to look at all the results rather than have them assign probability to alternative conceptual models and combine everything together, because to us that is not transparent and we will not -- what we really want to do is to understand what are the bases and if the current information cannot lead us to basically discriminate one from the other, then we definitely want to see the results of all credible alternative conceptual models represented individually.

DR. GARRICK: And you think this will give you some insight?

MS. LUI: Right.

DR. GARRICK: Yes.

MS. LUI: Right.

DR. GARRICK: One of the things that could be a major issue here is this issue of quality assurance. Quality assurance I notice was on your list of administrative and programmatic rather than technical, and of course many of us are much more inclined to think of quality assurance as an important issue from a technical standpoint more than an issue from a documentation and creating a record standpoint.

I guess the question that I have is that being an issue that is well-known and that has existed for quite some time, I assume that there has really been a great deal of exchange already on just what the NRC is looking for in terms of an acceptable quality assurance activity.

Is that correct?

MS. LUI: Okay -- I think, Dr. Garrick, you are probably leading to graded QA?

DR. GARRICK: Yes.

MS. LUI: Okay. Well, we had a meeting with DOE I think two weeks ago talking about a graded QA effort. Basically what we will be looking for is that there will be a set of minimum requirements DOE will have to meet no matter what. However, DOE can use the graded QA approach in terms of identifying what are the important structures, systems and components for the safety case, and the level of rigor for those that are important to the safety case we will certainly be paying a whole lot more attention to compared to the ones that have been identified to have minimal impact on any of the bottom lines.

Even though the QA is in the administrative and programmatic requirements area, it indicates that a lot of the pieces in that particular section are the underpinnings for the pre-closure and post-closure. So the level of rigor that we're going to be looking at is going to be dependent on how these supporting pieces feed into that preclosure safety case and postclosure safety case.

CHAIRMAN GARRICK: Okay; thank you.

Raymond?

DR. WYMER: Yes; as usual, your presentation was very well-organized and presented.

MS. LUI: Thank you.

DR. WYMER: I particularly appreciate -- it will be useful to me -- the presentation on the KTIs and how they tie together. Having said all that, let me get to a question.

MS. LUI: Okay.

DR. WYMER: Could you say just a bit more -- this isn't a question, exactly, but could you say just a bit more about the acceptance criteria? I think that there will be a great many people who will be interested in those, and particularly, the Department of Energy will be interested in those. And I wonder what you can say about the degree of detail that will be presented a little bit more.

MS. LUI: Okay; let me pick an area where you will be interested, so it will have to be one of a couple processes. Let me pick ENG3, the quality and chemistry or water compacting and packaging waste forms. Basically, if you look at the chart here, if you just count the number of dark boxes, ENG3 is probably one of the most complex integrated sub-issues that we have. So what we do is we go into each of these IRSRs and look at the acceptance criteria and review methods that have been documented in those IRSRs and organize them based on the five generic technical criteria in terms of model and data justification, data uncertainty, model uncertainty, model support and integration with other portions of the integrated sub-issues.

DR. WYMER: So from that, I would assume that there will be quite a bit of detail of --

MS. LUI: There's a lot of detail.

DR. WYMER: -- the acceptance criteria.

MS. LUI: And because also, according to our own sensitivity studies, these particular ISIs happen to be probably one of the very top ISIs, meaning that from both the uncertainty perspective and also how you could influence the dose -- I mean, how you could influence the risk computation, this is definitely on top of the list, so we would have a lot of detail associated with these particular integrated sub-issues.

DR. WYMER: Thank you.

MS. LUI: Okay?

MR. LEVENSON: I guess one of the advantages and disadvantages of being last is most everything has been said, both in challenging you and how good the presentation was, but I do have two left-over questions.

MS. LUI: Sure.

MR. LEVENSON: One, under administrative and programmatic requirements, you list physical security. Exactly what is the scope of that? Physical security for the property? Safeguards? What's intended there?

MS. LUI: Unfortunately, you asked a question that I really don't have a whole lot of background in, but I will try my best to answer your question. The physical security here is looking at during the operational period, the OE's program in terms of maintaining access to the site, and I believe that we do have existing programs in the agency.

MR. LEVENSON: Well, let me give you the context of my question.

MS. LUI: Okay.

MR. LEVENSON: There is a possibility that Yucca Mountain may be used to dispose of excess weapons-grade plutonium, and that could potentially, if you're thinking of safeguards, make a significant difference compared to defense-vitrified logs coming from Savannah River. So, I just wondered how -- what this issue is and how it might expand for what might be going to Yucca Mountain.

MS. LUI: Okay; the level of detail that we currently have, I understand, in the review plan is that based -- because earlier on, we do ask DOE to identify what kind of waste DOE is going to be receiving at the Yucca Mountain site, and based on the content of what's coming in, the DOE needs to develop a program that's consistent with the level of security necessary in order to have confidence that there is going to have a sufficient amount of safety and safeguard oversight.

MR. LEVENSON: Okay; so, in essence, it's DOE's responsibility to define the physical security program --

MS. LUI: Yes.

MR. LEVENSON: -- based on materials, and they would like to expand it if, indeed, they add weapons plutonium.

MS. LUI: Right; but however, there are certain minimal requirements DOE will still have to meet based on the existing agency's programs.

MR. LEVENSON: Yes; okay.

The second question I have has to do somewhat with the question John asked, and that is how much, how far you get into checking what's really in the models, and the context of that question is two and a half years ago, when I was doing a study for the National Academy in connection with the research reactor fuel disposal, I discovered that at that time, the Yucca Mountain PA did not have either conservation of mass or conservation of energy in any of their models. And as a result, they were overestimating consequences by huge amounts, and I presume by now they've put that back in. But will your review be in enough depth to catch things like that?

MS. LUI: I think so, because in our review plan, we have stated in our review method where appropriate, staff is going to use our TPA code to do our other calculation, because if there are -- for example, during the VA review process, we have looked at some of the graphs and charts, and trying to understand how has DOE come to those quantitative numbers, and in those cases, we use our TPA code to come by all of the calculations. So if there is something that is really obviously inconsistent about one module to another, basically wanting to intermediate -- once that will be open to intermediate to another, then, staff is going to go into more detail in looking at how DOE has conducted its analysis.

MR. LEVENSON: So you're confident that your TPA code does conserve mass and energy?

[Laughter.]

MS. LUI: I think so. I would say that Tim has worked really hard, and also, the other PA staff was working really hard to make sure that our code is going to be suitable to the license application review.

CHAIRMAN GARRICK: The next thing, Milt will be asking about the continuity equation.

[Laughter.]

DR. HORNBERGER: Questions from staff? John? Others? Carol?

MS. HANLON: Dr. Hornberger, committee, Christiana, I just wanted to thank you for your presentations. I think it will be very helpful. And I wanted to thank you for mentioning the upcoming interaction in June, where we will be working with Christiana to look at the Yucca Mountain review plan in the context of the license application to make sure that it's consistent.

And also, I wanted to mention that we have forwarded eight letters culminating on the IRSR. Each of the IRSRs that we have, we forwarded them to Bill Reamer last week, and that was at the invitation of the NRC to comment on those IRSRs. We regret that they're late in the process. We realize that they are late. We worked very hard to make sure that our comments were integrated, and it provided an integrated approach to you. So, some of the areas where we have commented were for questions or for simple clarification. Other places where we may have commented were where we thought perhaps the techniques discussed were more prescriptive than you may have meant, and in some other areas, there were some other areas where we felt that the performance-based aspects may have been vague.

So we provided you with those. We hope they will be helpful in financing the Yucca Mountain review plan and being part of the acceptance criteria. So, thanks for looking at those as you move forward, and again, we're sorry they're late.

MS. LUI: That's okay. I just wanted to emphasize that for revision zero, what we are trying to do is to basically synthesize and integrate what all of the work that has been done has done up to this point, and the two revisions that were -- and on revision one, we do intend to look at the level of detail, whether they are appropriate for the particular topic we are looking at using the risk-informed and performance based approach, and that's also where we're going to be interacting with the ACNW to also get their recommendation.

DR. HORNBERGER: Great; thank you very much, Christiana, and thanks to your silent assistant over here for his comments.

[Pause.]

DR. HORNBERGER: Back to you, John.

CHAIRMAN GARRICK: All right; I think what we would like to do, as many of you know, we're in the middle of writing several letters, and there's some word processing that I'd like to do on one of those letters. I think what I'm going to do now is essentially recess the meeting until our appointed time of 1:00, where we will talk about radionuclide content of slag and prepare ourselves better for the -- take advantage of this time to prepare ourselves better for the 3:15 session on the continued preparation of ACNW reports.

So with that, I think we'll adjourn.

[Whereupon, at 11:14 a.m., the meeting was recessed, to reconvene at 1:07 p.m., this same day.]

A F T E R N O O N   S E S S I O N

[1:07 p.m.]

CHAIRMAN GARRICK: Let's see if we can come to order here.

Leading our discussion this afternoon on radionuclide content of slag and uranium plume attenuation is committee member Dr. Ray Wymer.

Ray?

DR. WYMER: The next presentation starting this afternoon off is the status report on the characterization of radioactive slag, and we're going to hear about leach rater of uranium and thorium from slag, and I was a little surprised that it was limited to those until I looked at the list of the site decommissioning management plan items. It's something like two-thirds of those are, in fact, uranium and thorium slag, which explains why you're focusing on those. I would expect that in the future, as the clearance rule comes along, there will be other types of slags that will rise to the top in importance, but for right now, these are the two front-runners.

MS. VEBLEN: That's right.

DR. WYMER: This is Linda Veblen. Please give us your report.

MS. VEBLEN: Well, thank you, and I'm happy to have the opportunity to speak to you. I did bring some samples here of slags that are not radioactive, but we have one -- just I thought you can pass them around and look at them -- this is slag from Maryland that's about 100 years old. It's from Ashland, and this slag is from Sudbury, which we will see in one of the next slides just to give you --

DR. WYMER: From where?

MS. VEBLEN: Sudbury, Ontario, Canada.

Okay; so, I'd like to acknowledge my colleagues. Dori Farthing is a Ph.D. student at Johns Hopkins University. Dr. O'Donnell has been looking at this, and Professor Veblen at Hopkins has provided a lot of input and also the facility and people from the department.

Well, as Dr. Wymer mentioned, there are a lot of mountains of waste slag being produced in the United States, and these contain toxic metals and, in some cases, radioactive waste or radioactive elements. And so, one of the concerns is how stable is this waste? And we know from areas around the world where there are large slag piles that some of these toxic elements are leaching into the groundwater and contaminating groundwater and land areas.

So the NRC has several decommissioning sites that contain slags. There are about 17 of them, and they contain uranium and thorium in quantities that exceed the old regulatory limits, so -- and the owners of these sites would like to have the site material license released from the NRC, so the NRC, then, needs to try to understand or to determine what the long-term stability of these slags are and how uranium and thorium will then leach from the slags.

Well, so what? And how difficult is that to determine uranium and thorium leaching rates? Well, there are three different standard leach tests that are currently being used. One is ANSI, which -- 16.1, which is use for leachability of solidified low-level waste, and in this case, a cylindrical plug or an intact piece of slag or low-level waste is placed in deionized water and leached for a period of time, and then, the leachate is decanted off and determined how much has come out of the slag, and generally, in these cases, we see that not much has come out: 10-12 to 10-10.5 for a thorium leach rate.

And these studies were done by the center. They were also studying the slags and trying to determine which of these methods might be the best for characterizing the uranium and thorium loss from the slag.

DR. HORNBERGER: What are the units on that rate, Linda?

MS. VEBLEN: I believe it's grams per meter squared per day. The EPA method, the TCLP, is the second one. In this case, the sample is crushed to a fine grain size and leached in acetic acid at a very low pH. The third type of test is also using crushed material and with a slightly than higher closer to neutral pH. And as we see, there is a range of leach rates, anywhere from 10-8 up to 10-12. That's four orders of magnitude, which makes it kind of difficult when you're running performance calculations to determine which one to use.

So, why are we doing this? What's the bottom line? Well, we didn't know what was in a slag. What is a slag in the first place? Three years ago when we -- four years ago, we were starting this, people said, well, it's glass, or it's this and that. Well, is it? We don't know. What's in a slag? What are the phases? Where is the uranium and thorium? And even the licensees didn't know where these were.

So where is the uranium and thorium? Is it evenly distributed? These are some of the questions that we're trying to find out. What's the leach rate for a slag, and how does it change with time? Or does it change with time? And what standard tests should we use, if any? And, as I mentioned before, there are 17 of these SDMP sites. Are they all the same? Is it the same slag? The same phases that are in them? And if they're not, can we use the same licensing criteria, then, for all of the different slag sites?

And so, ultimately, we really wanted to identify or understand how a slag weathers. With that in mind, we come to the objectives of this study, and that's to identify the solid phases in the slag, both radioactive and nonradioactive and get an idea of the weathering mechanisms in the slag, try to determine that, and also estimate what I call in situ leach rates or instantaneous leach rates from the slag for input into the RESRAD code for performance calculations. And these are not actually leach rates, but what we would be determining is the mass loss over distance for a period of time, and I'll show you later how we might be able to calculate a leach rate from that.

I'd like to run through some of the sites, what they look like. This is an example of one of the SDMP sites. They were smelting tin slags that had been brought over from Malaysia and were extracting niobium and tantalum from these slags. That's done by crushing up the tin slags, adding fluxes and heating it to 1,500 to 1,700 degrees centigrade. That forms essentially a lava. It's poured off; allowed to cool, and while it's still in its molten state, of course, the niobium, the tantalum and the heavy metals drop to the bottom.

They then go in and break up the slag with sledgehammers; take off the metal separate, which is also known as the blooms, and then throw the waste slag away. This is the site, one of the sites we're studying, and you can see the slag pile right along the edge of this major river.

These are pictures from 1967. This is an example of a slag pile being built, and these are what the loughy slags look like. This is the slag that's been -- the pour that's finally been cooled and broken up into about 10 kilogram-sized blocks. There are railroad tracks right down here, and the river is just beyond that.

And then, this was a picture taken three years ago by the center. We were up there investigating the site, and you can see that we're parked on top of the slag pile roughly about where that is, so it's changed a lot. There is a lot of vegetation that's grown up on it.

What do slags look like? Well, I just passed around some samples. These are two of the samples from the SDMP site. Notice that they're blocky, glassy. There's an upper weathered portion in both of these. These slags resemble the salts, quickly-cooled igneous rock.

We have another site that has what I'm calling reprocessed slag, where you start with that blocky slag. They crush it up in a bow mill; leach it, then, with hydrofluoric or hydrochloric acid to extract the last remnants of niobium and tantalum and then throw the waste back into a settling pond, and it settles out along with the leachate. And so, what we end up with here actually are sedimentary rocks, but they're made up of slag components. The grains are glass or slag phases. And you see, it looks just like a very nice crossbedded, layered sedimentary rock. It even has a nice weathering line that's about a centimeter to two centimeters thick on the surface.

DR. HORNBERGER: Is it all glass or amorphous, or do you have some crystalline stuff?

MS. VEBLEN: There is a lot of crystalline stuff in both of them.

Okay; so, we set out then to determine, identify the phases, and these were the research methods that we used. We're looking for elemental variation and the distribution in the slag. We did that using a light microscope; x-rayed the fraction to determine the crystalline phases that are in that slag. We used an electron microprobe, both SEM and wavelength dispersal of the EDS analyses to get quantitative chemical analyses on about a micron spot size, so we can do very detailed chemical analyses as we go across these samples.

And finally, to understand really the weathering mechanism, we've gone to using the TEM, which can analyze the slag on an angstrom level, and we can look at here elemental variation on a very small scale. We can also look and determine the species of an element, for instance, uranium, whether it's in a +4 or +6 state, which I think would be a powerful tool to use in this weathering study. We haven't gotten to that point yet, but hopefully, we will.

So, these are the different tools, the Hans scale, the light microscope, and with the light microscope, we're looking at very thin slices of the rock, and they're about 20 millimeters by 40 millimeters and 30 microns thick. We use that same thin section on the electron microprobe, but then, finally, when we go to the TEM scale, we have a copper grid that's about 3 millimeters in diameter and glue that onto the thin section and then bore a hole in the center of the copper grid with an iron beam and thin it down to electron transparency; so, several angstrom-thin layers.

This is just a pretty slide that's an example of one of the SDMP slags. These are aluminum, chromium, titanium spinels, almost similar to a ruby, which is mostly an aluminum spinel basically. We see perovskites, which are opaques, in here. The white is glass, and we also have magnesium iron spinels, and I'll show you electron microprobe back-scattered image of this a little bit later and show you what's happening with the weathering here of these.

This is an example of one of the other slags; slightly different chemistry. The white is glass. These dark, opaque areas are perovskite, and we have a gehlenite, which is a calcium aluminosilicate, and basically, just using two techniques of a light microscope, plain polarized light and cross-polarized, we can identify the glass phases and the crystalline phases, which is very helpful, because you can't do that with an electron microprobe. You can do that with a TEM, but you're on a much finer scale.

So this is the same area that we're observing. Here's a scale bar of 100 microns, and this is what the thin section looks like; the slag looks like under a plain polarized light microscope. There's lots of glass, this white area. We see beautiful uhedral crystals of this brown uhedral crystal, which turns out to be a clonopirixine, but it's a rare clonopirixine that contains zirconium titanium and is similar to pirixines that are seen in meteorites.

The long, black dendritic crystals are the perovskites, just an image in cross-polarized light, again, to give you an idea of what's glass versus what are the crystalline phases. Then, we go to a back-scattered electron image. This was taken on the microprobe, electron microprobe, and the electron microprobe basically shoots an electron beam down on the sample, and the electrons are back-scattered, and the heavier elements the electrons much more easily, so we end up with a much higher intensity.

So what this tells you is that when you look at a back-scattered image, the very bright phases, then, are those that have the heaviest elements in them. So we know right away that this long dendrite contains heavy elements, and it turns out that it contains uranium and thorium. This is one of the perovskites. We can also tell from this that this phase that I've labeled -- well, I didn't label it; sorry, it's gehlenite -- doesn't have many uranium and thorium. And the glass, which is the medium gray area in here, does contain uranium and thorium.

So from here, we can go down, then, and actually obtain quantitative analyses, elemental analyses, on little points. In fact, that's a point that we analyzed right there, that little tiny dot, and there's a little tiny dot.

MR. LEVENSON: Are all of these on one particular slag?

MS. VEBLEN: This slide are all on one slag. This is all the same image at the same scale. But we've done this; we have multiple slag samples, so we've looked at quite a few.

The bottom right is a high-resolution TEM image, and we're essentially looking at angstrom scale here. These little tiny white blebs in here represent silica tetrahedra that are strung together in a chain, and this is a clonopirixine. This, actually, is the old TEM that's at Hopkins. The new TEM that went in has essentially -- can resolve about an atom, so we could be looking at uranium atoms on that scale. But the real beauty of the TEM for this particular -- one of the beauties for this particular study is that we really didn't know what this clonopirixine was, what kind of phase it was.

We knew its elemental chemistry, but we didn't know any structural information about it. So, you go to the TEM; you can do electron defraction there on very small crystals, and this is actually an electron defraction pattern from that very crystal right there, and that's what showed us that it was in fact a clonopirixine but just one that has very rare chemistry, and I think, Dori, that this actually has some thorium in it, very small amounts. Dori is the graduate student working on this.

This is another thing that we have done is looked at a back-scattered electron images and x-ray mapping. You can go in with a certain area and set up wavelength dispersive and energy dispersive analyses to determine silica, calcium, all these different phases. And then, you just basically plot up that particular element on a map, so let's go over to this bottom right image, which I've labeled thorium, and what this shows, then, the bright areas show that those phases contain thorium. The relative intensity corresponds to the relative amount of thorium that's in a particular phase, so right here, from this map, we can see, yes, thorium is in the perovskites; thorium is in the glass; it's not in this, you know, there's not much in some of these other phases.

One thing I would like to point out in this particular slide is if you go up to the back-scattered image, we notice that this light gray area is glass. Coming off there are some crystals, and there are also some holes, and there are some very bright spots. And what's happening here is the glass is devitrifying. As it devitrifies, the volume changes. It decreases, so it's opening up a little bit of porosity. Now, the uranium and thorium is in the glass, but what looks like is happening here is that as the glass devitrifies or dissolves, whatever it's doing, the uranium and thorium and in this case cerium tend to go into a silicate phase, so they're held in that phase, it seems. So that's a nice thing.

All right; these are the phases, then, that we've identified, and I don't expect you to -- you know, we're not going to go through this. It's just -- I wanted to show you the number of phases that are in these things. In some of the slags, there are 20 individual phases. So it really is a mess when you try to characterize an x-ray defraction or something else.

But one of the things that we noticed right away was that the phases are kind of interesting. We have calzirtite, zirconolite, perovskite, spinel, and this is the chemical formula for them over here; barium aluminate, which is like a barium, well, okay, barium aluminate and glass. And these phases are all found in SYNROC. Now, SYNROC is a synthetic rock, hence its name, but it's a ceramic waste form that's being considered for high-level waste, perhaps the Hanford waste tanks and also for excess plutonium.

So we thought that actually, the study of these slags might be a nice analog to the study of SYNROC. There is a lot of data on SYNROC that's been done in the laboratory, but SYNROC has only been in existence for the last 30 years. So this might be a way that people could look at long-term leaching of SYNROC. Vice-versa, it's a way that we can use -- determine leach rates for the slags, because they are so similar to SYNROC.

DR. HORNBERGER: Just a clarification.

MS. VEBLEN: Yes.

DR. HORNBERGER: On the previous slide, Ce, cerium?

MS. VEBLEN: Ce is cerium. There is a lot of cerium.

DR. HORNBERGER: A lot of cerium?

MS. VEBLEN: One thing I didn't -- I didn't show you the analyses we did, but we analyzed for 29 elements, and these are -- the slags are all very heavy in light rare earths. I mean, in some of these, there's 18 weight percent cerium -- not in the bulk slag but in the slag phase.

DR. WYMER: The slags must come from a very peculiar and specific kind of refining.

MS. VEBLEN: Well, actually, a lot of them come from carbonotites, which are, you know, fairly unusual rocks that are very high in rare earths. The slags were originally smelted for tin. They extracted the tin from them. But there was so much rare earth and everything else, that that went into the waste, and they figured, well, they can certainly turn around and use that. So that's why we ended up with these.

DR. WYMER: Okay.

MS. VEBLEN: Okay; so, then, our ultimate goal here is to determine a leach rate, and we do that by measuring the elemental variation in weathered SDMP slags with a microprobe and the TEM. Also, we have looked at the elemental variation in slags, these SDMP slags that were leached by one of our research contractors at Pacific Northwest National Lab, and I'll show you some examples of those, so we looked at solid phases there and also looked for alteration.

And finally, we can get an idea of what long-term leach rates might be by analogy to archaeological slags, and we've collected tons, it seems, of archaeological slags. We also can get an idea of leach rates based on what leach rates might be for SYNROC. And finally, we can look at leach rates or study leach rates of slags by looking at natural minerals such as hibonite, and Dori will be doing some of that for her Ph.D.

This is an example of a weathered SDMP slag, and I'd just like to show you this back-scattered image, and what I'd like you to notice is that, of course, we have a hole there but some large crystals. These are those red spinels that I showed you in one of the first thin sections, and these long areas that used to be dendrites, which are now -- these are actually holes -- this was the area where the magnesium iron spinel was, and in this outer edge of the thin section, it's been leached out preferentially, I would say.

We can look at the interior, and you see these light or gray areas. These are the spinels that are intact that have not yet been leached. But up in the upper slide, which is at the weathered edge, they're weathered out. So, there's evidence of weathering along the grain boundary.

This slide just shows the transition from where these -- well, here's a nice one where the magnesium iron spinels are still intact, and here's the same grain, the same crystal, but it's finally been leached out here. So, what happens with this? Well, if there is preferential leaching of a particular phase, the fluids move along the grain boundaries, and within the grains, it can open up fluid access to the interior of the slag.

Some examples of microprobe data that we have: this is variation, elemental variation in glass, and I've kind of flipped this slide around; I'm sorry, but the right side of each graph is the outer edge of the slag, so that's the weathered edge. The left edge of the chart is 40 millimeters, and what we're looking at is the variation of aluminum, titanium, zirconium, all of these elements: silicon, calcium, thorium and uranium as you go from a weathered edge into an unweathered area of the rock, the slag.

And what we notice is that in the outer 10 millimeters, silica is depleted compared to what is seen in the interior, the same as calcium, thorium is depleted, and uranium is slightly depleted. And from that, I've measured -- and do I have it here? I didn't plot it up. We have measured the difference in mass between uranium and thorium over that distance. You can use that, then, and this -- I'm sorry; this graph is wrong. It should be concentration over distance. We get a plot. We can put a point there. We know that what the concentration for a certain distance is at a particular period.

If we go to the next slag that's 100 years old or 50 years old, we can plot its concentration loss or its elemental loss over a certain distance and likewise do that for numerous slags. We may find a line, but this is hypothetical data. We haven't gotten to this point yet, but we're moving in that direction.

Another way of looking at the leach rate is to determine kind of a bulk leach rate, and these are measured modal abundance of one of the particular slags. There are about 40 weight percent gehlenite, 36 weight percent glass. Notice the calcium and thorium bearing phases; perovskite, calzirtite and pyrochlore are all total less than about 18 weight percent. They do contain most of the uranium and thorium. So, if we were to weather out one particular phase or leach out one particular phase, this much of 25 percent of the uranium and thorium would be released of that phase were gone. If you weathered out all of the glass, 25 percent of it would be gone. If you weathered out all of the perovskite, that would be gone.

So, this is data that might be used also in RESRAD to give us an idea of how things might change with time.

Just real quickly, some examples of the slags that were leached at PNL. These are slags that have hibonite in them. These are these big brown crystals, and they're not brown, they're gray, dark gray. There's lots of glass; again, zirconolite, perovskite and rutile in here. And what we're looking at, this was a crushed. The slag was crushed. You can see the size of the particular grain here is maybe

500 microns across, and it sat in water for a period of time, and what we're doing is looking at the -- seeing if there is any depletion of elements along this outer edge, so we do traverse this across here to see if there has been leaching.

Also, PNL did some leaching experiments at pH, leach where the pH ranged from 0.05 up to 12, and these are SEM images of the surface of these slags, what happened to them after they'd been leached. The top -- yes, SEM image is glass that's been leached at a pH of 2, and this shows classic hydration and corrosion of the glass, where you get these cracks. There's dissolution going on. We actually see precipitation of some secondary phases on the surface of the glass.

We move down to the bottom image, and this is -- was leached at a pH of 6, and again, it doesn't seem like there's a lot of damage to the glass here, but there are a lot of secondary phases that have grown on the surface. And finally, at a pH of 12, again, the glass looks to be very corroded, and we're left with these rutile perovskite needles sticking up in the air.

Just some more images. This is what the slag looks like unleached. There's pH of 5. That's been leached in deionized water on the glasses, dissolving a little bit, leaving zirconolites.

And so, finally, we can compare this data -- glass that has been unleached and glass that has been leached. Now, this is a little confusing. The two graphs on the left are weight percent oxide versus distance across a thin section, and they had two graphs on the right. I plotted weight percent oxide versus pH, okay? So, on the first one, really, the unleached, I'm just showing this to show that there is not a whole lot of variation between -- of any one particular element: silica, aluminum, calcium, cerium. Thorium varies all over the place. Uranium is fairly constant.

But you get to the leached glass, I mean, that is that -- at the middle pHs, it's fairly constant, but at a pH of 4 or below, calcium decreases; silica actually increases. Aluminum decreases as well. But the key thing here is that at about a pH of 4 and below, thorium decreases rapidly, and uranium -- we lose uranium as well.

MR. LEVENSON: Is there any explanation for the spiked behavior of the zirconium?

MS. VEBLEN: Zirconium? I think to some extent, it depends where you are, how far away from a crystal, a crystalline, the crystal you are in the slag, that what happens if a gehlenite was growing in the slag, it doesn't take the zirconium; it doesn't take uranium or thorium. So it tends to exclude those as it crystallizes, and you get this huge chemical profile building up in front.

So if I were a couple of microns like right next to the grain boundary, there might be a lot of zirconium in that particular glass, whereas, if I was further out in the glass away from the crystal, it may be slightly less, so it's just --

MR. LEVENSON: And it doesn't happen to any of these other elements?

MS. VEBLEN: Well --

MR. LEVENSON: Zirconium seems to be unusual in its behavior there.

MS. VEBLEN: What does?

MR. LEVENSON: Zirconium.

MS. VEBLEN: I'm sorry; zirconium.

MR. LEVENSON: Yes.

MS. VEBLEN: Yes; I don't know; I can't really say. I mean, this is my guess about what's going on with it, but I think it's essentially exclusion of these elements from crystals as the crystal is growing.

DR. WYMER: It seems to be pH dependent.

MS. VEBLEN: It's definitely pH dependent.

DR. WYMER: Which would argue against it being an exclusion mechanism, don't you think?

MS. VEBLEN: Yes; okay.

So, moving on from there, then, onto

archaeological slags, we've decided to look at these because they've been smelting tin for 2,000 to 3,000 years, ever since the onset of the bronze age. So it gives us a good time scale of interest. For SDMP sites, we're interested in a 1,000 year period of time, and how did we identify analogous slags? We looked at bulk chemistry. We do have tin slags at one of the sites, and so, tin slags were an obvious thing to look for. We also looked for similarity in crystalline phase, such as spinel zirolovines, and we looked for similarity in glass chemistry, because we know from the literature that glass is not glass is not glass; that cerium glasses corrode or weather more readily than calcium and much more readily than titanium glasses, so that if we look at a particular chemistry, if we find a glass that has a chemistry similar to these slags, we could use that as an idea.

Then, okay, so, that's how we've selected sites. We're in the process of identifying the phases in these archaeological slags. They weren't all that easy to find in the first place, and we're identifying alteration; and then, finally, we go on to quantification of the alteration.

These are two of the slag sites that we studied. The first one is a tin slag in Cornwall that's roughly 1,000 years old. This is the site of an archaeological dig that was being studied by Bradford University in the UK, and they happened to come across slags, and they went and dated it with some carbon dating, so they have a pretty good idea of what the date is. Hard to find here, because this area is highly vegetated. It's very damp, and any slag piles that are there were there 1,000 years ago most likely are in somebody's back yard right now.

The second area we went was to Pribram in the Czech Republic, and it's a site of lead and silver mining and smelting. They have huge piles there. They've been doing this for on the order of 500 years, and the piles are very well dated. There's a student at Charles University who is studying the slags over there, the mineralogy, so we thought that would be a good jumping off point. It turns out those slags aren't quite as similar as we thought they would be, so we're not looking at those in much detail.

We are looking at Malaysian tin slags. They're at least 50 years old; have the same phases as the slags we're looking at. We're also looking at numerous Cornish tin slags, and they vary in age, as I said, from 50 to 1,000 years. This is just an example of the type of alteration that we look for. This is a copper slag from Cyprus that's approximately 1,000 years old, and what you see are these beautiful uhedral crystals of olivine and black in between, and the black is where the glass would have been. However, in this sample, it's no longer glass, but it's oxyhydroxides; it's devitrified glass, and that's due to oxidation and devitrification.

We also ran an XRD analysis of this particular slag, and there is no glass, typical glass hunk that you would see in an XRD spectrum.

Other types of evidence of alteration, we see evidence of oxidation and alteration around fractures. This is a nice wide fracture going down through this particular slag. Glass away from the fracture is clear, but as you get closer to the fracture, we see this bright oxidation zone, and then, finally, perhaps, some alteration and leaching occurring in this area.

Another thing we look for is secondary minerals. I showed you some growing on the surface of the other slags. This is an example of secondary minerals growing in a vesicle in a basalt. We also look for fluid pathways that are provided by cooling cracks or fractures, and we do see a lot of alteration, in some cases, along these. This is actually -- the lower example is one of the SDMP slags, and we see alteration along this fracture, indicating that there is fluid movement or some type of movement through the fractures.

And the archaeological slags aren't perfect. We certainly have numerous uncertainties. We don't know what the original composition of the slag was, and we don't know the original uranium and thorium content. We have found slags that are still radioactive, and we have found a lot that aren't, so we're in the process of doing that.

As I mentioned, one of the problems with tin slags, if you try to look for really ancient ones, we haven't found them. We've talked to archeometallurgists, and for the most part, they find only very small soil size fragments. The question I have is, well, is that because the slag has all weathered, and we're left with these resistant phases, or is it because the Cornish and the Turks were so smart that they knew there was more that they could get out of it, and they ground it up and reused it?

And the archaeologists think one thing, and I don't know. So, that's where we are on that.

Okay; just an example of SYNROCK. This is taken from Smith, et al. and a scientific basis for nuclear waste management. It's an example of SYNROCK, which is, as I mentioned before, a synthetic ceramic waste form that's being considered for high-level waste in other countries and for the Hanford tank wastes and weapons plutonium here. Notice the phases P is perovskite; we've seen that in our SDMP slags. R is rutile, which is a titanium oxide that actually can be a weathering product of perovskite, and Z is zirconolite. We've seen that also. H is a hollandite, which is a barium aluminate in this case, and M stands for metallic leads, pieces of metal also known as pearls.

These investigators leached this particular SYNROC for several days at 90 degrees centigrade and found a leach rate of 4 x 10-3 grams per meter squared per day, which they found, then, to be the same leach rate or very similar to the leach rate of flow-through perovskite, so that told them that what was happening here is the perovskite is weathering preferentially.

We know that perovskite is not stable at near surface conditions. All of these phases are phases that have formed at high temperature, and they tend to weather when they're in oxidized conditions and also at low temperature. Perovskite is one mineral that goes from a calcium-titanium oxide to the calcium weathers out, and it forms -- releases calcium and forms anatase or rutile, which is a titanium oxide.

One of the other things I didn't mention is that these slags were produced under extremely reducing conditions, and we notice that as soon as we cut them up, they begin to oxidize. So, that may be good, or that may be bad. We may find that initial oxidation will release uranium, for instance, or certain elements, but since there are enough reducing materials, then, they have precipitated out or remained behind in stable phases.

All right; so, conclusions: the characterization:

we've used many different techniques. I would also mention that we've done, on one and several of the slags, BET analyses to determine surface area and permeability of these slags, but I haven't done them on all of them so that was another thing I'd like to do. And we found that the slag in some of these cases, whether it's by dissolution of the glass, and there's also preferred dissolution of spinels and perovskites along grain boundaries.

Chlorine is found in these slides and glass. Perovskite storianite, which is a thorium oxide, thorium dioxide, and pyrachlora, which is a calzertite; it's a thorium, well, anyway, you've got it in there, in your list of minerals.

[Laughter.]

MS. VEBLEN: And as I mentioned before, glass and perovskite are not stable under near surface conditions, so we'd expect those to be some of the first to weather out, and I've said here that although thorium is present in several stable phases, such as thorianite, it is also present in glass and these unstable phases, and as that dissolves, there is a question as to what happens to the thorium. We don't know yet. But we do know that the dissolution of the glass and other unstable phases provides fluid pathways for water or different fluids to get deep within a slag.

Okay; uranium, then, is found in calzertite, pyrochlore, perovskite and glass, and it does appear to be leaching from the glass at a rate of -- and I've got a question mark. We don't really know what that rate is just yet. We haven't finished tackling it yet. We have done characterization of the solid phases of the PNL leach tests, and one of the things that PNL found was that they saw calcium and aluminum coming out at rates that they -- calcium, specifically, they said it's not a calcium carbonate; what is it?

Well, it turns out it's the hibonite, which is a calcium aluminate. The calcium is leaching from that. So, by studying the solid phases, we can help to identify controlling phases for solubility calculations, calculations that might be done, an EQ36 type of calculation, where we look at solubility-controlled leaching or solubility-controlled uranium and thorium release. So, we know, for instance, we could calculate the solubility of these different ones: perovskite, calzortite, pyrochlore, we put them into a code like RESRAD or a code like EQ36.

So, we're back to so what? What's the bottom line? Well, what is a slag? Well, I think we've taken a look at these tin slags, and we have an idea of what they are now, and we've looked at the slags; we see that they're, you know, a certain number of phases that are in there.

They're not just glass, and they're not just crystalline, but it's a mixture of both.

What's in the slag? Multiple phases. Where is the uranium and thorium? Well, it's not evenly distributed. It's in discrete phases: perovskite, calzertite, glass, pyrochlore, thorianite. So, the release of that will be determined by the rate at which those minerals degrade. What's the leach rate for a slag, and does it change with time? Well, we're beginning to determine that for archaeological slags. My guess is sure, it changes with time, but I don't really have an answer for that.

What standard tests should we use, if any? And I think that this research will help us discuss this with NMSS and the center at PNL, all groups that have been involved in the study, and hopefully, we'll be able to provide NMSS with some useful information on that.

There are 17 SDMP sites. Are they all the same? No, they're not all the same, but we have managed to characterize the slags by their bulk chemical analysis. Now, this is very similar to what a petrologist does, when they go collect a rock, crush it, get a bulk chemical analysis, and because they've studied so much about a particular rock like a basalt and know what phases are in it, and based on the chemistry from many, many previous studies can then go in and characterize an unknown rock based on its chemical analysis, and I think we're beginning to see that with these slags.

For instance, I took the bulk chemical analyses that we did; XRF data, plotted them up on a ternary diagram with the calcium aluminum, and a thalmycie within certain areas. So, from the numerous slags, we can say well, it looks like we've got two or three different types, and if someone else were to come in with a chemical analysis, we could put it on a plat and say oh, well, it's probably a tin slag, or it's probably this kind of slag or whatever, and these are the phases that might be in it. So that's kind of where we're heading with that.

And how does the slag weather? You've seen a grain boundary diffusion, glass to solution and preferential leaching of certain phases. Future work? There is still a lot to be done. I don't think we've answered any of the questions, all of them to my satisfaction. Let's see: we still have to calculate some estimated leach rates, and that, I will be doing. We'll be applying those leach rates to RESRAD, and I've been running the RESRAD codes for some of these sites, and we'll continue with the microprobe analyses on the elemental variation of the slags, both weathered and the archaeological slags, and yes, then, Dori will be continuing this study on archaeological slags for her Ph.D. dissertation at Johns Hopkins University, which, yes, she'll be doing on her own.

And then, finally, we can determine long-term alteration mechanisms, and this is a very interesting area of research, I think, applicable not only to the slags but to any soils or other solids that contain uranium or thorium or elements of concern. So, I think that's all I have to say. I'd be glad to entertain questions.

DR. WYMER: Well, thank you very much for that presentation. There's some nice research that you're carrying on or you and other people.

MS. VEBLEN: Thank you.

DR. WYMER: I have two observations. I don't expect you to be able to respond to them necessarily, but I want to say them anyway. One is while I think it is very unlikely that SYNROC will be used to fix the Hanford tank waste site, they won't vitrify it, and I think some of your results lead to results in some of these phases would be directly applicable to leaching of some of the vitrified waste from the Hanford tanks, because I recognize a number of the phases as being similar to those that are found in the vitrified waste. So that's one thing.

The second point is that this slag is in amount, while it may be in an absolute amount like the large, it's trivial compared, of course, to the flash from coal fire and steam plants which also have uranium and thorium in their decay products, and, of course, there is no mandate to do anything about --

MS. VEBLEN: Right.

DR. WYMER: -- those, and it's sort of like sticking a Band-Aid on when what you need is a tourniquet, so that was my second observation.

Let me ask if there are any comments.

CHAIRMAN GARRICK: The last time you were here, and you were talking about future research, you did mention microbial action and a great deal of interest in knowing what the impact would be on degradation and stability. Have you anything to report on that?

MS. VEBLEN: No, other than we see evidence of it, but we haven't identified what it might be.

CHAIRMAN GARRICK: Do you expect -- has there been any analysis that would indicate what the expectations might be?

MS. VEBLEN: For the slags?

CHAIRMAN GARRICK: Yes.

MS. VEBLEN: I just could go from literature, you know, what we might be seeing, but I really don't -- can't say. I would love to get further into that, but we really are at the point where we have to get moving further on the TEM stuff, and that's where we could start analyzing that a little more.

CHAIRMAN GARRICK: Okay.

MS. VEBLEN: It's taken a long time. As I mentioned, the phases were fairly unusual, and we analyzed for a lot of elements, so the analysis, the microprobe analysis, has been very difficult. I thought oh, when I first, you know, started working on this problem, I thought oh, they're like basalts; it'll be easy, you know. We'll have some beans, this, that, no; they're really different, and it's been quite a learning experience for me, certainly.

CHAIRMAN GARRICK: Yes; you had mentioned the last time trying to get some indication of whether microbial action would precipitate out some of the --

MS. VEBLEN: Yes, it might.

CHAIRMAN GARRICK: -- toxic substances.

MS. VEBLEN: There is a nice volume of the material research, not material research, the mineralogical society of America just did a short course on uranium minerals, and they had several papers in there on uranium and thorium microbes that tend to -- in some cases, they actually help to precipitate out the uranium, thorium, and other cases. They mobilize it. So it really depends on which bug is present.

CHAIRMAN GARRICK: Thank you.

DR. HORNBERGER: You say you did see some evidence of --

MS. VEBLEN: Yes.

DR. HORNBERGER: -- microbially mediated -- these are what? Weathering etches?

MS. VEBLEN: Well, what we're seeing are very small precipitates.

DR. HORNBERGER: Precipitates?

MS. VEBLEN: On the surface; we had someone at Hopkins about a year ago that was a microbial geochemist, and she took a look at them and said yes, it looks like, you know, it could be microbial activity, but I haven't honestly done any more. I'm sorry; I'm just --

DR. HORNBERGER: No, I was just curious. Just curious. So, you don't know what it is, then, going after? I mean, typically, I mean, what little I've read of Jill Banfield's work and stuff --

MS. VEBLEN: Right.

DR. HORNBERGER: -- it appears that the microbes are going after something in particular phases that are of interest to them.

MS. VEBLEN: Right; they certainly like elements that have multivalence states, because they use that.

DR. HORNBERGER: They use that as an energy.

MS. VEBLEN: Exactly, so, you know, certainly, they could be going after the uranium.

DR. HORNBERGER: Right.

MS. VEBLEN: And it's in the glass where we, you know, we find these precipitating on the glass. The glass would be certainly much easier to extract the uranium from than, for instance, a calzertite, most likely.

DR. HORNBERGER: I assume that all of the leach tests that are done are done abiotically; is that right?

MS. VEBLEN: I would think so. I would hope that they were autoclaved or something.

DR. HORNBERGER: Right.

MS. VEBLEN: But I really don't know.

Brett, do you know with the Setter which tests -- I saw him in here. Put him on the spot.

John, do you know?

Nobody knows.

Do you know?

DR. WYMER: Milt?

MR. LEVENSON: One question out of ignorance base. Are these slags principally from tantalum and tin mining and so forth, are they typical of what exists at the sites that have licenses, NRC licenses?

MS. VEBLEN: Well, I think of the 17 sites that have slags, a good half of them have niobium and tantium slags there.

MR. LEVENSON: But that's not the basis of the license, right? The license was for something else at the same site.

MS. VEBLEN: Well, no, the license was because their ore material that they used for the smelting contained uranium and thorium, and it contained uranium and thorium in levels that exceeded what was allowed at the time. So, 30 years ago, they had to obtain a nuclear materials license.

DR. WYMER: Any other questions? John?

DR. RANDALL: Yes; I know that you've got samples from some SDMP sites, and you weren't able to get some from other sites.

MS. VEBLEN: Right.

DR. RANDALL: How does that, not being able to get some of those other samples, limit your research results?

MS. VEBLEN: Well, I think it would be useful for NMSS if we had samples of most of the sites, but I know that there is one site in particular that we can't get a sample from, but they've described it, and it sounds very much like the sedimentary reprocessed slag that we found. So, you know, my guess is that we could perhaps apply that, but without knowing a chemical composition, you really can't say a whole lot. You have to have some information on this.

DR. HORNBERGER: It strikes me that you're going to have a tough time with your archaeological reconstruction of leach rates, primarily because of the problems that you already pointed out. You know, if you don't know what you started with --

MS. VEBLEN: Yes.

DR. HORNBERGER: -- it's hard to say the path that you've gone on.

Now, I suppose what -- I assume that what you're going to do is make some assumptions of what you started with by looking at more recent samples and then reconstructing that way.

MS. VEBLEN: Yes; there are two ways that we're thinking of going. We actually have started trying to smelt some of these things ourselves in the lab, not with a lot of success, because I've had it up to about 1,550 degrees centigrade, and it's not melting it yet, so we -- you know, that's a little bit of an experimentation. But we did collect ore from the sites in Cornwall, so we can go and smelt those and see what, you know, if you start with an original composition like this, what ends up in the slag.

The other thing we can do is get an idea of the isotopic composition of the original ores that were being used and make an assumption of how much of that original uranium and thorium in the ore went into the slag, and that would be, you know, basically just based on partitioning, melt versus solid.

DR. HORNBERGER: It also strikes me that you'd have to make well, I think for example, Michael Velbel's work on weathering, sort of a whole history in terms of what leaches out when, and it's, as you know, a very complicated geochemical problem.

MS. VEBLEN: Yes, that is.

DR. WYMER: If that's all, thank you very much for an interesting presentation.

MS. VEBLEN: Thank you.

[Pause.]

DR. WYMER: Our next presentation is on historical case analysis of uranium plume attenuation of uranium plumes from ore bodies and from contaminated sites, and considering the wide diversity in the geology and hydrology and in the types of sources of uranium, the results that you're going to hear are a little bit remarkable, I think. This presentation will be given by Dr. Patrick Brady from Sandia.

[Pause.]

DR. WYMER: For those of you I've forgotten, Dr. Patrick Brady will make this presentation, I think.

DR. BRADY: Yes.

[Laughter.]

DR. BRADY: I'm part of a large group that's working at Sandia on the prediction of metal sorption in soils. This is a project that's been funded through the Nuclear Regulatory Commission for several years. There's a whole host of people on it, some whose names are written;

some people just recently, because I realized I left them off.

The important names to remember here or the important name to remember is Carols Colon. He's my postdoc who's done a lot of the difficult work here going through the data. Now, the overall objective of our work is to follow a semi-classical approach to understanding how plumes move in the subsurface.

DR. WYMER: Why don't we put the mobile mike on him?

DR. BRADY: I'd rather stand.

[Pause.]

DR. BRADY: We follow a semi-classical approach, where we presume that if we understand what happens between radionuclides and mineral surfaces, we might be able to predict sorption better in the field. Now, sorption is critically important because for a lot of the radionuclides we care about, it's the primary sink. So, in theory, if we can understand sorption, we can understand a lot of other things, like how big plumes get and what's the relative risk they might present.

Now, in the process of looking at the mechanistic controls on sorption, we also gain clues as to what types of characterization are needed and what types of remediation are possible and what kind are not. Now, tomorrow, I'm going to talk about the mechanistic work we've done with spectroscopy, with molecular modeling and with performance assessment code SEDSS to try to take a crack at what are the possible variations in the parameters that go in one end of a reaction transport calculation.

What I'm going to do for about the next 30 minutes here is to focus instead on what nature tells us the answers have to be in the case of uranium, and the tool I'm going to use is a historical case analysis. It's one we've found very useful for doing a couple of things: one, identifying mechanisms that control transport in the subsurface, and two, I think you'll find that this looks to be a singularly compelling way to communicate risk posed by plumes to stakeholders without presuming a great deal of technical knowledge.

So, that being said, I've got to point out that the historical case analysis approach is not original. We've taken it from Dave Rice at Lawrence Livermore. This is a top-down approach that looks at plumes and worries about the mechanisms later, and what the Livermore group did -- some of you may be familiar with it -- they were funded by the State of California and a number of other agencies to look at the benzene plumes that emanated from leaking underground fuel tanks where no remediation had been done.

Now, several underground plumes were examined, and the only question that was really asked was how big do the plumes get, followed by a secondary question, which was are these plumes stable or not? Now, what they found was somewhat surprising. They found that the plumes moved -- and I should point out this was after the fuel tank was removed, and there was no fluid product left. It was just a dissolved plume. The dissolved plumes tended to move out to about 200 feet maximum. They would become static, and then, they would collapse.

Now, as scientists, we look at this and say that makes perfect sense, because fuel hydrocarbon components are quite biogradeable. Indigenous microorganisms are very effective at breaking them down, ultimately, to CO_2. What was striking, though, was how much these plume lengths tended to cluster, despite the wide variation in hydrologic, geochemical and microbiological parameters that were inherent in the data set.

Now, biodegradation was ultimately ascribed to the plume stasis. I'm going to, in the case of uranium, I'm going to lump all four of these together under the umbrella of natural attenuation. These are the processes which tend to decrease the bioavailable concentrations of a particular contaminant in the subsurface. Biodegradation seems to do it for a lot of the fuel hydrocarbons. When I refer to natural attenuation for uranium, though, I'm referring primarily to sorption, dilution and formation of mineral phases, which I forgot to leave in.

All right; the other thing that was striking about the Livermore study was the impact that it had on regulators. Almost immediately, the State of California ceased all active treatment at dissolve phase leaking underground fuel tanks. That's a $2 billion market. It just basically vanished in the space of about 6 months. A majority of the states in the U.S. have followed suit. The last time I counted, nine months ago, I think it was around 37 states that had monitored natural attenuation as a de factor presumptive remedy for fuel hydrocarbon plumes.

EPA has subsequently issued monitored natural attenuation guidelines for contaminants other than fuel hydrocarbons, well, fuel hydrocarbons, coordinated solvents, metals and radionuclides as well, and a lot of it all came from this historical case analysis approach.

Keeping in mind the mechanistic differences between attenuation mechanisms, biodegradation versus sorption plus mineral growth, we proceeded on the hypothesis that we could apply the same approach to the inorganic contaminants, and this is a hypothetical graph of what we thought plumes would look like. This was possibly a year ago. We said, well, lead is a priority pollutant; lead has very high KDs and is a high solid sorption coefficients that typically goes very short distances in the environment. We guessed that if you looked at all of the plumes that one could find good data for and plot up the number of sites that were a given length, lead would plot here.

Things which sorbed less effectively, such as uranium, would spread out. There would be sort of a chromatographic separation, and we'd see slow movers here; fast movers out there. One of the upshots of this talk is going to be that this conceptual model needs some modification to make it actually explain the data, but this is what we thought we'd see, and this encapsulates the focus of our study: uranium, strontium and cesium. The uranium results, I have today.

What we did was we tried to --

DR. HORNBERGER: Actually, for lead, I mean, that conceptual model obviously doesn't work as an example, because as long as you have water movement, you don't have stability in the sense of being frozen in time.

DR. BRADY: So you're saying that ultimately, this thing will just start moving along. We don't see many examples of that, and you'll see for uranium here that we've got cases where there have been, well, I'm going to come back to this.

DR. HORNBERGER: Unless you're talking about precipitating out stable phases, if you're talking -- I mean, you're talking as if this were just sorption.

DR. BRADY: Yes; let me just -- for lead, lead tends to form hydroxycarbonates, but as you say, that would keep on going. Reversible sorption, you would still have an advancing plume. Irreversible sorption is one of the largest factors that affects lead. In other words, lead sticks to the surface; becomes overcoated and stays there. In effect, it's an insoluble phase that no longer sees the groundwater that's therefore entered.

Now, I'm not going to talk a whole lot later on unless people keep asking questions, but irreversible uptake actually applies to a lot of these things. Uranium is one of the -- irreversible uptake effects these three more than uranium, but that does give the otherwise seemingly incorrect assumption of anchoring plumes. That's what happens when you have irreversible sorption.

All right; so, what we did was we looked for every single uranium plume that we could find data on. The data we looked for was groundwater concentrations, and we typically found these at the UNTRA sites and at natural analogue sites, uranium ore bodies, the Oakland natural reactor and what have you.

I'm going to hit this stuff towards the end, so I'll come back.

Now, let me give you a little bit of chemical background on uranium. This is important to look at here, because it's almost illegible on the handouts that I've given you because of the printer size. The upshot here is that oxidized uranium, the most mobile forms of uranium, tend to sorb right around pH 5 to 8, 5 to 7. Above that pH, uranium forms carbonate complexes, and it becomes anionic. Since most of the mineral surfaces are anionic to begin with, there is an electrostatic repulsion. Hence, there is manual retardation that occurs that way.

Down here, below pH 5, preuraneal, which is positively charged; it sees positively charged mineral surfaces at the low pHs, and there's a repulsion as well. In other words, the only place where uranium tends to drop out of oxidizing solutions is right around in here. Under reducing conditions, uranium forms lots of insoluble phases.

Okay; this came out of the most-recently published EPA guidelines for Kds for inorganic contaminates, from King, Krupka, et al. at PNL. This shows the pH. PH is where Kds are measured from 3 to 10. There's a minimum and a maximum. Essentially, these folks look at every measured Kd they could find for uranium, and what they see kind of follows out, drops out of the speciation diagram I showed in the previous slide.

Basically, there is maximum sorption about pH 6 and 7. And it drops off at low pH and at high pH. I'm going to come back to this, but I should emphasize: uranium is one of the more mobile of the inorganic contaminants. The anionic contaminates protechnitate and iodide are much more mobile, but of the cations, uranium tends to move a lot further and a lot further than things like lead, cadmium or cesium or strontium.

I just want to briefly point out what the phases are that uranium shows up as in subsurface. Urananite, the reduced form, the reduced form of uranium typically goes in urananite. Pitchblende shows up in some of the ore phases. Schoepite is a hydrated uraneal oxyhydroxide. It's theorized that this might limit transport of some uranium at some of the ore bodies. Let's see; other important ones here: uranophane, uranium silicate and soddyite are probably two of the most important of the other solid phases.

All right; our objective at this point was, again, to see how big the plumes got, and there were a number of problems that we had to deal with that added uncertainties to what we measured. First of all, there's little long-term monitoring. We'd like to have had -- if we could have had a time series monitoring such that we could look at a plume as the source as it emanated from the source; dilution occurred at the edges; the thing spread out, became static and then stayed there, collapsed, this whole story would be a lot clearer. There is not enough data to do that at any single site that we are aware of.

At every single site, you end up with spotty monitoring oil locations. The DOE well, it seems like there's almost a three-strike rule. They analyze three times, and then, they either yank the well or lose the location. So we never have the perfect site to say how the typical plume goes. So when we tried to determine what the life cycle of a uranium plume is, we're limited.

Another one of our big problems is rivers. A lot of the data set comes from the UMTER sites. Most of the UMTER sites are very close to rivers. Sometimes, this truncates our plumes. Our ultimate objective is to be able to give some idea as to how far dissolved uranium is going to move from a point source. Well, if a river truncates your plumes, you really don't get a whole lot of useful information. But it turns out that there are only a couple of sites where this is a problem, and our primary friend here was the fact that in the west, where most of the UMTER sites are, not all of the streams are gaining. Some are losing; in other words, the plumes don't always, by default, go right into the rivers that are adjacent to them. Quite often, they go parallel; sometimes they go away.

So, some of our data, it's an annoyance rather than an obstacle. This is something we knew going in. The geologies, the hydrologic parameters, permeabilities, hydraulic gradients are all going to be vastly different for all of the sites. We're using both the milltailing sites, DOE plumes as well as the natural analogue sites. These things are geologically quite different. Their ages vary by several orders of magnitude.

Now, keeping that in mind, we wanted to see if there were some general features that described all of them. And the way we measured them was we looked at the 10 to 20 part per billion contour, and where we found a plume, we assumed this was the plume, and the source was somewhere in here. The maximum axial difference was the plume length if the border is defined by the 10 to 20 part per billion contour.

We tried to err on the side of greater plume length. Now, the last thing -- this assumption, we assumed that the plumes were at steady state. This assumption is a tough one. We only had one site where we had 15 years of sufficient monitoring data that indicated that the 10 to 20 part per billion contour was not moving. Now, so, when I go forward, keep in mind this has an asterisk on it, and if anyone can think of a better way that we can independently verify that this is true, I'd like to know it.

Let me show you three or four of our sites. This is typically how it was done. This is a view of the city.

We take the UMTRA report, their contours. That right there is the -- it's the 10 to the 20 part per billion contour. The big point to get from this slide is that we're just taking the maximum value.

I mentioned river truncation being a problem. Riverton, Wyoming was one of those places that gives us an anomalously small plume. Note, though, that there is a fair bit of spreading away from the river, so, you know, it's not a completely gaining stream.

This is one of the better sites. This is Slick Rock, Colorado. It was a two-fer. We had two plumes there. Note that the plumes spread parallel to the river.

All right; in each of these cases, we take that measurement and then consider them all as a group. I forgot. I've got to show at least one of the natural analogue sites. This is from the Alligator Rivers project. We've -- there is -- this has been funded by NRC for several years, so there is a great deal of data. There is basically an ore bodies being weathered; there is a plume that extends out this way. The maximum axial plume length is on a -- I don't have it shown here, because it's better seen in plaid.

All right; these are all of the data plotted up in the histogram fashion. The red ones -- this is the number of sites. The red ones are the natural analogues. There are a couple of natural reactors here. We have Pacos de

Caldas, Cigar Lake, Condara. At Pocas de Caldas, those are all down on this side. Now, over here are all of the UMTRA sites, and these are the ones that are neither UMTRA sites or natural analogue sites. These are typically DOE sites: Weldon Springs, Lawrence Livermore; many others. Fernald and Hanford are incorrectly put up here. They should be down here.

I put on a leach from Konigstein, Germany. This is where sulfuric acid was used to leach out the uranium inside the aquifer, not on top of the milltailings. Now, there are bound to be sites that there is good data for that we have missed. When I spoke to the EPA this morning, they had a couple of sites that they didn't provide data for. We expect to get some more data from Savannah River sometime in the near future. We don't expect this picture to change. There are a couple of important features about this. First of all, we don't see that bell-shaped curve like Rice, et al. at Livermore saw for benzene and the fuel tanks.

Now, part of that is due to the fact that there is some skewing, really small sites, well, the increment of measurement is almost half a kilometer here, so if you had a site that was -- things -- since the increment of measurement is about half a kilometer, then, if it was a plume that was 10 meters long, it would get buried in here. The upshot is we can't see incredibly short plumes.

Let's see; what else is there that's --

DR. WYMER: In each of these cases, the source stays put.

DR. BRADY: Yes.

DR. WYMER: And in the case of the petroleum tanks, you took the source away.

DR. BRADY: Yes; but the source has been taken out of most of the UMTRA sites, too. So, they have shipped away the milltailings, and we've got fresh recharge going through, and it's --

DR. WYMER: Well, it's time-dependent.

DR. BRADY: Well, the -- I think part of it is the semantics of how one defines the source. We would like to have plumes that came out of single spots and moved, but the plumes for the UMTRA sites, these are sometimes -- sorry, the sources, the milltailings piles are sometimes hundreds of meters across. Now, there are a couple of points about that. One, it means that these maximum plume lengths often include the imprint of a factory, and so, again, if we're searching to find how far is uranium going to move from a single point source release, it would be a lot less than this.

All right; going back to, I think, the third or fourth slide, all of these sites differ greatly in their hydrologic parameters and the time and extent of source loading. The natural reactors in Gabon were over a billion years old. Most of the UMTRA sites, a couple or two or three decades. The DOE sites were typically 10 to 15 years old. The hydrologic conductivities, we haven't looked at the measurements. My guess is they're all over the board. The fluid chemistry where we can find data, we might be able to put together a clear picture.

The point here is that although a lot of the input parameters that go into a classical transport model would vary by several orders of magnitude, it looks like the plume lengths seem to cluster. Now, this is -- we think this is more than fortuitous. I think it suggests that basically, the uranium chemistry is the more important control. The -- so, at this point, we're basically looking to find any more data we can to add to this. But in the meantime, it suggests that plumes for uranium tend to go out to about two kilometers top and then stop.

The small amounts of data we do have that look at the temporal movement of the plumes suggests that these things reach data states in about 5 to 10 years. That comes from the UMTRA sites. And this suggests that if we are to consider long-term transport of the uranium, I would argue for all of the other inorganics as well, we've got to change the way we model or rather change the way we think of the inorganic plumes.

This is a classic, the classical approach. A plume starts at the source. Groundwater flow in that direction moves it off; dispersion spreads it in a couple of different directions. From what we can see, for uranium, it looks more like an ore body case. And sure, the data set included ore bodies, but if it had just included UMTRA sites, we would have gotten about the same results.

So, we think that in fact, what these contaminant plumes are, they're more like ore bodies. There's a concentrated source; there's a halo that seems to be stable over time. Again, that's the weak point. We'd like to know what happens over 10 to 100 to 1,000 years. The gap between the UMTRA sites and the natural analogues makes this somewhat difficult to bridge.

All right; lastly, what we're doing right now is trying to again expand the uranium plume database. We honestly don't think we're going to find any 10-kilometer long uranium plumes, and we don't think that's an accident. Although uranium moves faster and further than a lot of the other radionuclides, there are substantial chemical processes that cause its retardation, and I mean retardation in the biggest sense: the formation of ore minerals, irreversible reversible sorption, what have you.

We are about neck-deep into doing the same thing for the strontium and cesium plumes. Now, the time factor becomes less of an obstacle here, because all of our plumes occurred in the last 40 to 50 years. I was promised a view graph for this talk by Dr. Colon, but I never got it. I can tell you what we've seen so far. It's probably better that I tell you what we've looked at so far first. We looked at strontium data from Chalk River and the Canadian program. We looked at strontium coming out of various low-level waste facilities.

There is a strontium plume at Brookhaven that we've got data for, and there's about 10 other ones. The data is not nearly as good looking as it is for the uranium. The cesium, we're getting a lot of those analyses from the Hanford tank farm leaks. And I will quote the folks who do the monitoring at Hanford and who spotted the, I guess, it was the last spring or the spring before with I think it was the cesium that got so much press.

We described what we were doing, and we asked them, well, how long do you think the plumes get? They said the strontium, it probably goes 40 meters, the cesium maybe 20. That begs a couple of questions; I've pointed to here the exceptions. There are exceptions to small plumes for cesium, and cesium is transported as a colloid quite frequently. Strontium is not. A lot of the attention has been paid to the colloids. I think if we look at the great mass of the cesium data, once we get that done, in 3 months' time, we're going to see something like this, and then, we're going to see a bunch of outliers showing colloidal transfers.

But otherwise, I think we're going to see a much more compressed plume trajectories for cesium and strontium, and that's going to be a direct outgrowth of the fact that both soared much more strongly than uranium; both are taken up irreversibly much more readily than uranium.

All right; lastly, the references -- the two Livermore reports, the idea on which this was based, are listed there in your packet. This is our Webpage. Since some of the things are illegible on the stuff I handed out, that will all get posted on our Webpage as soon as I get back.

In conclusion, if we can confirm that this is all, in fact, the way uranium plumes work, we think we'll have a useful tool for considering the potential transport and potential remediation of uranium. We'd say uranium, the maximum movement, oh, it's on the order of about 2 kilometers. It's very easy to explain to somebody who lives 4 kilometers away and is worried about the uranium plume about the level of risk they're exposed to. It's also very easy to tell somebody he's inside of two kilometers, too, without a whole lot of extra modeling.

The other aspect of this approach that we think will be useful is that we believe it drives these discussions towards the technical realm. If this were the Hanford plume, and I lived here, I think the argument would be couched in terms of not DOE's polluting my water, but it would be more one of what makes my site different than all of the others? In other words, if we can provide a broad picture of the natural life cycle of plumes, this might couch what is and is not a risk somewhat more simply for stakeholders.

And that's all I have to say.

DR. WYMER: Thank you very much. It's an encouraging presentation.

DR. BRADY: Yes.

DR. WYMER: I presume with respect to cesium, since it doesn't form colloids, you're talking about pseudocolloid transfer.

DR. BRADY: Yes; getting stuck on the sites, yes.

DR. WYMER: Yes.

DR. BRADY: Yes; I'm sorry, but when I mean that, yes, it's going on the silicate lattice with its --

DR. WYMER: Okay.

DR. BRADY: I suspect that's what happened at Hanford.

DR. WYMER: That's reasonable.

Are there any questions? John?

CHAIRMAN GARRICK: Well, I was just curious. Has your work had any impact on the more recent performance assessment modeling, particularly with respect to waste package degradation rates, the corrosion model?

DR. BRADY: No, because we've -- this was -- our deadline was the end of February; correct me if I'm wrong, Ed, but this has all been done in the last 5 weeks, in getting the NUREG report done. If the question you're asking is what does this mean for Yucca Mountain, we haven't had enough time to think about it. I can sketch what one would do. You'd go back and compare what were the absolute masses of uranium and planned for one, observed in the other, and make some assessment of whether the same process has prevailed for this suite is likely to occur at Yucca Mountain, but I haven't done that, because that wasn't part of our charge.

CHAIRMAN GARRICK: Yes; well, I was just curious, because when we had our working session on engineered barriers, we got a considerable amount of information on the importance of secondary phases with respect to the solubility of uranium and some of the fission products, and it sounds like at least with respect to uranium and what it does in the reducing environment, even though the mountain is an oxidizing environment, the mechanisms at the mechanistic level, it's not clear that that couldn't be a substantially reducing environment, and some of the data that you have could be kind of interesting in terms of addressing some of the uncertainties of the effects of these secondary phases.

DR. BRADY: Yes; I should point out that most of the -- well, you're right. Typically, uranium is -- it is more retarded and is rather less mobile in reducing conditions --

CHAIRMAN GARRICK: Yes.

DR. BRADY: -- and more mobile in oxidizing conditions.

CHAIRMAN GARRICK: Right.

DR. BRADY: And you're also right; if you look at our knowledge of the thermodynamics of the various uranium phases, it's just not where it needs to be. Most if not all of those sites that I showed are in oxidizing environments. So one could develop a story from there. I think Cigar Lake is fairly reducing.

CHAIRMAN GARRICK: Maybe an opportunity.

DR. BRADY: Yes.

DR. WYMER: George?

DR. HORNBERGER: Just, first of all, a comment. I think that your cartoon where you compared plumes and ore bodies is a bit misleading.

DR. BRADY: Oh.

DR. HORNBERGER: Because if you think about the way you defined the plumes, it was with a fixed concentration, and so, on your top schematic, it's impossible that that would continue to grow. You don't -- you wouldn't -- you'd be violating conservation of mass. It might grow for a short while, but then, it has to shrink to nil.

DR. BRADY: Right.

DR. HORNBERGER: Just because of dispersion. That's number one.

DR. BRADY: Right.

DR. HORNBERGER: The second thing is that at these UMTRA sites, as you pointed out early on, you have dilution, and if you take dilution into account, then surely, your upper cartoon doesn't hold.

DR. BRADY: Yes; yes; I'll apologize right now for that being anatomically incorrect.

[Laughter.]

DR. BRADY: Yes; I could have put in all of the isopacks, but I don't know if I'm addressing your question there but --

DR. HORNBERGER: It wasn't a question; it was a comment.

DR. BRADY: Okay; yes, you're right. But the big point that I wanted to make out of this slide there is that these plumes tend to get out and stop fairly quickly. When I think of a plume, I think of something that is -- its potential for movement is almost unlimited.

Now, these things don't seem to be all that mobile, national the's the upshot here, and if you use a straight Kd model like the world uses right now, you will in fact predict that the remaining concentrations, albeit lowered, can leave off, and it will be a chromatographic front. You don't see that.

DR. WYMER: Which makes your analogy with an ore body pretty sound.

DR. BRADY: Yes, again, keeping in mind that that's wrong there.

DR. HORNBERGER: And the other, well, partly comment, partly question, because of that, what you just said, it strikes me that you have to distinguish here between dilution on one hand and some form of however you want to characterize of what you called irreversible sorption, because you simply need processes that you either form an insoluble phase, or you sequester a soluble phase behind an armoring that prevents it from being dissolved. And you have to distinguish, then, between those two mechanisms, because I still think that even if you took a Kd model with dilution, and you defined your plume by a fixed concentration that you would not predict it going off forever and ever.

Your prediction would be that as long as you had the source there, it would be relatively stable, and when you took the source away, it would just all go away.

DR. BRADY: Yes; well, I guess presumably, you'd fix the concentration by, say, the presence of schoepite or uranophane or something like that, okay? In response to the other part that it would go away, maybe we haven't waited long enough for the UMTRA sites to go away, because -- and I kind of alluded to it, you know. We'd really like to know what's going to happen in 250 years. All accounts right now say it's not going.

Now, as for determining mechanisms, this came up with the VA this morning. One could not use a graph like the one I showed to make site decisions. One could use it to say this is what we typically expect. And as a property owner, what I would say is prove it to me. Prove to me that those mechanisms that you've seen there apply here, whether it's irreversible sorption measures or a leach test or XRD at a spot schoepite formation or what have you. So I absolutely agree with you.

DR. WYMER: Anyone else?

[No response.]

DR. WYMER: Well, thank you very much. I think that's -- although there's a lot of science yet to be done, it's an encouraging sort of gross result.

CHAIRMAN GARRICK: We've got a question over here.

MR. LESLIE: Oh, Dr. Wymer, I wanted to actually address Dr. Garrick's comment. DOE is looking at the Nopaul I site in terms of using it as a qualitative information for their license application. They are planning to drill that site within the next 6 weeks looking for a plume from Pina Blanca.

DR. BRADY: Very good.

MR. LESLIE: Brett Leslie from the NRC staff.

DR. WYMER: Actually, some of the stuff I've seen sort of looks like maybe there is some plume information already available out there. I don't know whether he has that or not.

DR. BRADY: I can't remember if we had the Nopaul stuff. If it's not on that graph, we don't have it, but I know that we looked. Let's see; if I can find the graph --

DR. CAMPBELL: I'll provide you the information.

DR. BRADY: Okay; thanks.

DR. WYMER: Anybody else I missed? Did you want to say anything?

DR. CAMPBELL: I think going back to Linda's presentation, the ability to characterize this stuff going from this macro scale, very large macro scale approach, down to the microscopic approach, where you can actually identify particular mineral phases which are taking up uranium or thorium or whatever you're interested in is potentially a very powerful tool for establishing a mechanism for the phenomena that Pat's data to this point seems to be indicating. I would say that Pat's got to have more information about ore bodies and other stuff to kind of fill in the details about uranium and for example, how far do uranium deposits move with time? Now, I don't have a handle on that, but they may actually move further than a couple of kilometers, or maybe all of the uranium is coming from a halo of within a few kilometers of the ore pocket. That's a question you might address.

DR. WYMER: I want to support one other thing you said. I certainly, too, believe that there is a great lack of good thermodynamic information; that you simply don't have data that we need to have in order to do the kind of analysis that we would like to do.

DR. BRADY: I agree.

DR. WYMER: Well, if that's all the questions, thank you very much.

That's the end of this.

CHAIRMAN GARRICK: All right; the committee has a great deal of letter work and report work to do, so I think we're going to take advantage of that time, since there are no comments or questions, and we will move into a report writing phase, but before that, we'll declare a break.

[Whereupon, at 2:44 p.m., the meeting was recessed, to reconvene at 8:30 a.m., Wednesday, March 29, 2000.]

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

NAME OF PROCEEDING: 118TH ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

CASE NO:

PLACE OF PROCEEDING: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Jon Hundley
Official Reporter
Ann Riley & Associates, Ltd.

STRATEGY FOR DEVELOPING NRC SUFFICIENCY COMMENTS

Presented to the Advisory Committee on Nuclear Waste

March 28, 2000

Presented by:
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High-Level Waste and Performance Assessment Branch

PURPOSE OF REVIEW

- Evaluate and comment on DOE progress related to sufficiency of data, design, and analyses for LA
  - Consider both current information and DOE plans
  - Focus on foundations for safety case and performance estimates (i.e., data and conceptual models)
- Continue prelicensing consultations focused on issue resolution prior to DOE's submittal of LA

NUCLEAR WASTE POLICY ACT PROVISIONS

- DOE's comprehensive statement of the basis for the site recommendation shall include
  - Preliminary comments of the Commission concerning the extent to which at-depth site characterization analysis and waste form proposal seem to be sufficient for inclusion in any LA

RELATIONSHIP TO NRC'S STRATEGY FOR LICENSING

- NRC's sufficiency review provides a progress report on:
  - Sufficiency of DOE data, analyses, and plans
  - DOE understanding of interactions between engineered components and geologic medium
  - Status of the KTI issue resolution process
- Is not a licensing review

INFORMATION NEEDS AT LA

- DOE licensing case must be adequate to support a regulatory decision on construction authorization, including adequate:
  - Data
  - Design
  - Analyses
  - QA

DOE'S SRCR

- Provides technical basis for DOE's recommendation, including:
  - Description of the proposed repository
  - Description of the waste form or packaging proposal
  - Discussion of data obtained during site characterization
  - Discussion of analyses related to repository performance

NRC REVIEW OBJECTIVES

- Provide preliminary comments on:
  - Where data and analyses appear sufficient/insufficient
  - What additional DOE data or analyses are needed
  - When additional DOE data or analyses are needed
  - Whether conceptual models are supported
  - Status of DOE QA efforts

PERFORMANCE-BASED APPROACH TO LICENSING

- NRC has proposed risk-informed, performance-based rule (10 CFR Part 63), which:
  - Identifies information to be included in any LA
  - Establishes overall performance requirement
- YMRP Implements risk-informed, performance-based approach with review considering:
  - Degree of conservatism
  - Treatment of uncertainty
  - Importance to licensing case
  - Risk contribution

SCOPE OF NRC REVIEW: DATA AND ANALYSES

- Evaluate for both at-depth site characterization and engineering design:
  - Existing DOE data and collection plans
    - At-depth data
    - Analog data
    - Laboratory data
    - Expert elicitation
  - Related analyses
  - Conceptual models and plans for refinement

SCOPE OF NRC REVIEW: WASTE FORM PROPOSAL

- DOE understanding of interactions between engineered components and geologic medium
  - DOE screening of features, events, and processes
    - Limited to interactions between engineered components and geologic medium

SCOPE OF NRC REVIEW: PERFORMANCE ASSESSMENT

- Use PA to establish risk-informed, performance-based context for evaluating DOE data and analyses
  - Evaluate relative importance of models and data to DOE's licensing case

- Evaluate DOE conceptual models used to describe repository performance
  - Support for models provided by DOE data
  - Treatment of uncertainty in models and inputs

SCOPE OF NRC REVIEW: QA

- Assess DOE progress towards qualifying data, models, and codes
- Evaluate DOE's capability to qualify all data, models, and codes relied on in DOE's licensing case
  - Based on DOE's schedule for LA

SCOPE OF NRC REVIEW: AREAS NOT EVALUATED

- No position will be taken on DOE's dose calculation
- No evaluation of DOE compliance with 10 CFR Part 963

NRC SCHEDULE

- NRC sufficiency review

Preliminary review activities	Present -11/13/00

- Selected NRC review milestones

Complete review strategy	6/30/00
Complete review guidance	9/29/00

<u>Based on DOE Schedule</u>

Begin SRCR review	11/13/00
Complete staff sufficiency comments (Paper to Commission)	4/9/01
Provide sufficiency comments to DOE	5/25/01

REVIEW EFFORTS BEFORE DOE RELEASES SRCR

- As part of prelicensing consultation process, staff is reviewing DOE data, models, and codes through:
  - Early review and feedback to DOE
  - Observation of OCRWM QA audits
  - KTI issue resolution process to resolve open items

PROPOSED ACNW INTERACTIONS

Brief ACNW (outline of strategy)	3/31/00
Brief ACNW (final staff guidance)	10/19/00
One-on-one meetings (Technical issues)	11/00 - 4/01
Brief ACNW (staff comments)	4/18/01

PROPOSED STAKEHOLDER INVOLVEMENT

- Staff is considering:
  - Holding public interactions in Nevada
    - Meetings with DOE on KTI issue resolution process
  - Holding at least 1 public meeting in Nevada for stakeholders
    - Discussing NRC's role and approach to sufficiency review (Summer 2000)

DOCUMENTATION OF NRC REVIEW RESULTS

- Preliminary statements on sufficiency of DOE data and analyses for LA

- Less documentation for areas where data and analyses appear sufficient
  - Document details in IRSRs

- Comment on significant open issues, if any
  - Open items that could prevent docketing of LA

SUMMARY

- NRC sufficiency review:
  - Focus is on DOE data, design, and analyses
    - Sufficiency will be evaluated in context of NRC's performance-based approach to licensing
    - Review of models will be limited to process models and conceptual models
  - Review is fully integrated into the NRC's licensing strategy and KTI issue resolution process
- Result will be a progress report on DOE progress towards LA

Industry Perspectives on Yucca Mountain Sufficiency

Advisory Committee on Nuclear Waste

March 28, 2000

Steven Kraft - NEI

NEI

Why sufficiency is important

- A decision on Yucca is urgent
  - Competition is reshaping our industry
  - Nuclear has proven it can compete
  - Environmental & Energy Supply Stability stakes are high
- Decision-makers value NRC's view
  - NRC is source of objective expertise
  - What does NRC think of DOE's plans?

NEI

Yucca Mountain -
What the science tells us

- At face value, the case for going forward is compelling
  - Potential radiological consequences projected to be a small fraction of background levels and proposed regulatory limits
  - DOE, NRC, and EPRI analyses in agreement
- Uncertainties remain
  - They always will

NEI

Yucca Mountain -
what decision-makers need to act

- Understanding of the nature of the decision
- Concisely summarized and clearly communicated science
- Confidence in the regulatory components needed to move forward
- Sense of perspective

NEI

Yucca Mountain -
The nature of the decision

- It is a four step process
  - Site recommendation - 2001
  - NRC License to construct - 2006
  - NRC License to operate - 2010
  - NRC License to close - 2060 to 2300
- What needs to be known at this step
  - Is the site **suitable**
  - Is the work-in-progress **sufficient** to <u>begin</u> the licensing process

NEI

NWPA Expectation for Yucca Mountain Suitability

- Sec. 114. (a) (1)

  "The Secretary shall make available to the public, and submit to the President, a comprehensive statement of the basis of such (site) recommendation…"

NEI

Suitability is...

- The basis for the President's decision
- A conclusion based on science, not merely a compilation of scientific information
- Something that **DOE** must clearly communicate
- An understanding of uncertainty, not an elimination of uncertainty
- To be documented for comment in the SRCR
- A comparison against criteria proposed by DOE

NEI

NWPA Expectation for Yucca Mountain Sufficiency

- Section 114. (a) (1) (E)

  "preliminary comments of the Commission concerning the extent to which the at-depth site characterization analysis and the waste form proposal for such site seem to be sufficient for inclusion in any application to be submitted by the Secretary for licensing of such site as a repository;"

NEI

Sufficiency is...

- forward looking
  - about DOE's ability to file a license application, not about the licensability of the project
  - an opportunity to close questions raised in VA review and define path forward for new/remaining questions
  - an opportunity explain how the licensing process will address uncertainty going forward
- separate and distinct from suitability
- balanced
- legally flexible

NEI

Conclusion - Enabling a decision

- Lay the groundwork for a decision on Yucca Mountain
- Inform the decision
- Keep the decision-making process on track
- Prepare to implement the decision

NEI

YUCCA MOUNTAIN REVIEW PLAN DEVELOPMENT UPDATE

Presentation at the 118th ACNW Meeting

March 28, 2000

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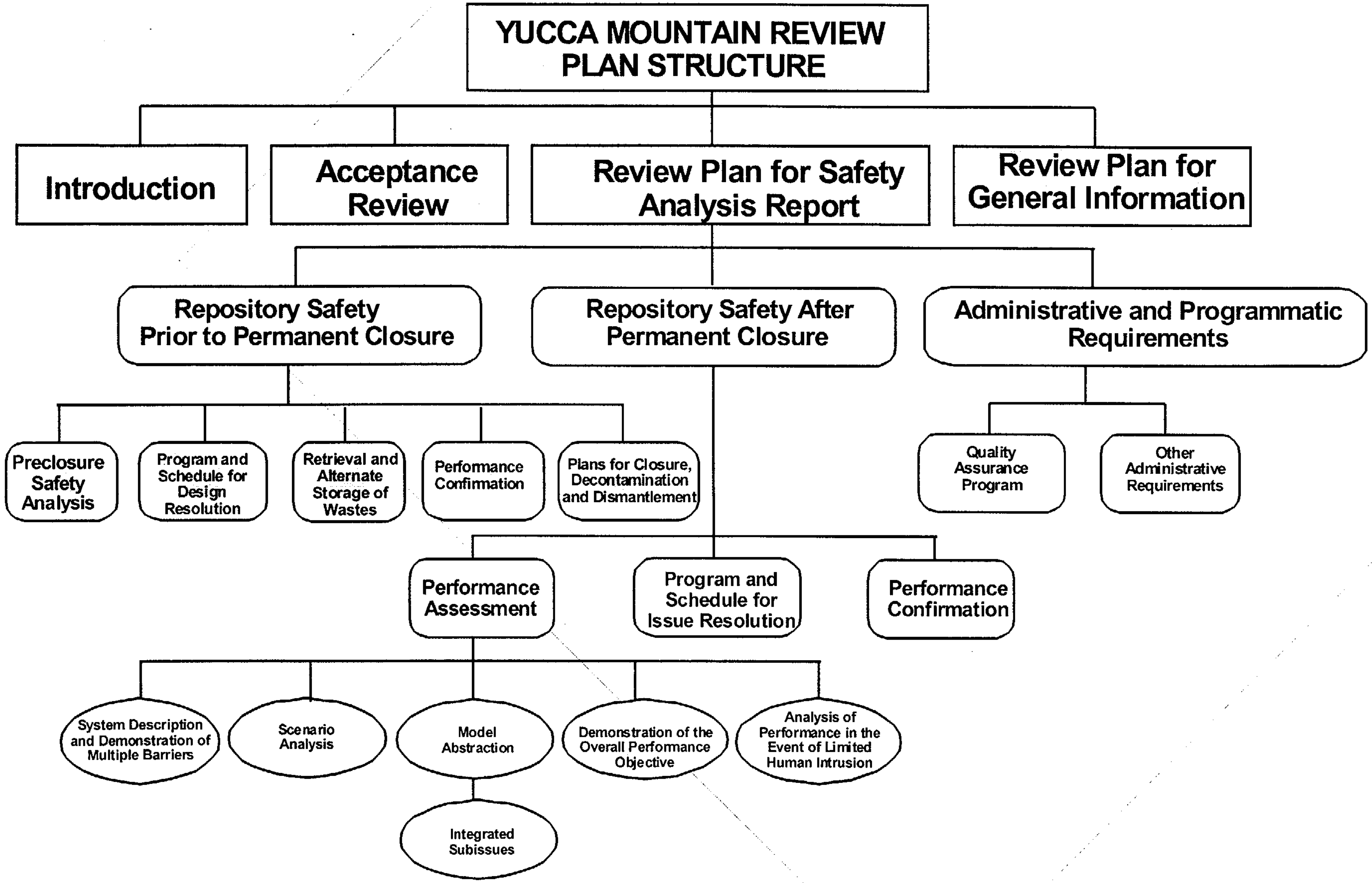
Introduction

- Last briefed the ACNW on November 18, 1999
- Major Yucca Mountain Review Plan Chapters
  - Introduction
  - Acceptance Review
  - General Information Review
  - Safety Analysis Report Review
    - Preclosure Safety Evaluation
    - Postclosure Safety Evaluation
    - Administrative and Programmatic Requirements


YUCCA MOUNTAIN REVIEW PLAN STRUCTURE
Introduction
Acceptance Review
Review Plan for Safety Analysis Report
Review Plan for General Information
Repository Safety Prior to Permanent Closure
Repository Safety After Permanent Closure
Administrative and Programmatic Requirements
Preclosure Safety Analysis
Program and Schedule for Design Resolution
Retrieval and Alternate Storage of Wastes
Performance Confirmation
Plans for Closure, Decontamination and Dismantlement
Quality Assurance Program
Other Administrative Requirements
Performance Assessment
Program and Schedule for Issue Resolution
Performance Confirmation
System Description and Demonstration of Multiple Barriers
Scenario Analysis
Model Abstraction
Demonstration of the Overall Performance Objective
Analysis of Performance in the Event of Limited Human Intrusion
Integrated Subissues

Current Status

- Completing the Rev. 0 Postclosure sections; it will accompany the draft final Part 63 to the Commission in mid-April 2000
- Draft Rev. 0 Preclosure sections by 4/14/2000; Rev. 0 by 5/30/2000
- Draft Rev. 0 of all other sections by 4/28/2000; Rev. 0 by 6/15/2000
- YMRP Rev. 0 will be publicly available after management approval

Principles for Development

- NRC is responsible for defending its licensing decision; DOE is responsible for ensuring adequacy of its safety case
- 10 CFR Part 63, a risk-informed and performance-based rule, should be accompanied by a risk-informed and performance-based review plan
- The review plan should follow a total system approach and provide for an integrated review process
- The review plan should incorporate the knowledge gained during the prelicensing period and avoid unnecessary prescriptive acceptance criteria

Purpose and Framework

- Guidance to NRC staff on methods for conducting and documenting licensing review
  - Not the equivalent of regulations
  - Presents at least one approach for compliance demonstration
  - Other approaches acceptable if appropriate
- Subsections
  - Areas of Review
  - Review Methods
  - Acceptance Criteria
  - Evaluation Findings
  - References

Preclosure Safety Evaluation

- Evaluation include
  - Adequacy of site characterization
  - Repository design, construction, operation, monitoring, and closure
  - Retrievability
  - Performance Confirmation
- Establish acceptance criteria and review methods based on whether the performance objectives (dose limits) are met
  - Evaluate DOE's preclosure safety analysis
  - DOE has flexibility in selecting design details and methods for compliance demonstration
  - Where appropriate, relying on existing guidance documents

Postclosure Safety Evaluation

- Evaluation include
  - Adequacy of performance assessment for compliance demonstration (site characterization, data, and models)
  - Multiple barrier analysis
  - Human intrusion analysis
  - Issue resolution
  - Performance confirmation
- Establish acceptance criteria and review methods based on whether the performance objectives are met using an integrated approach

Postclosure Safety Evaluation: Performance Assessment

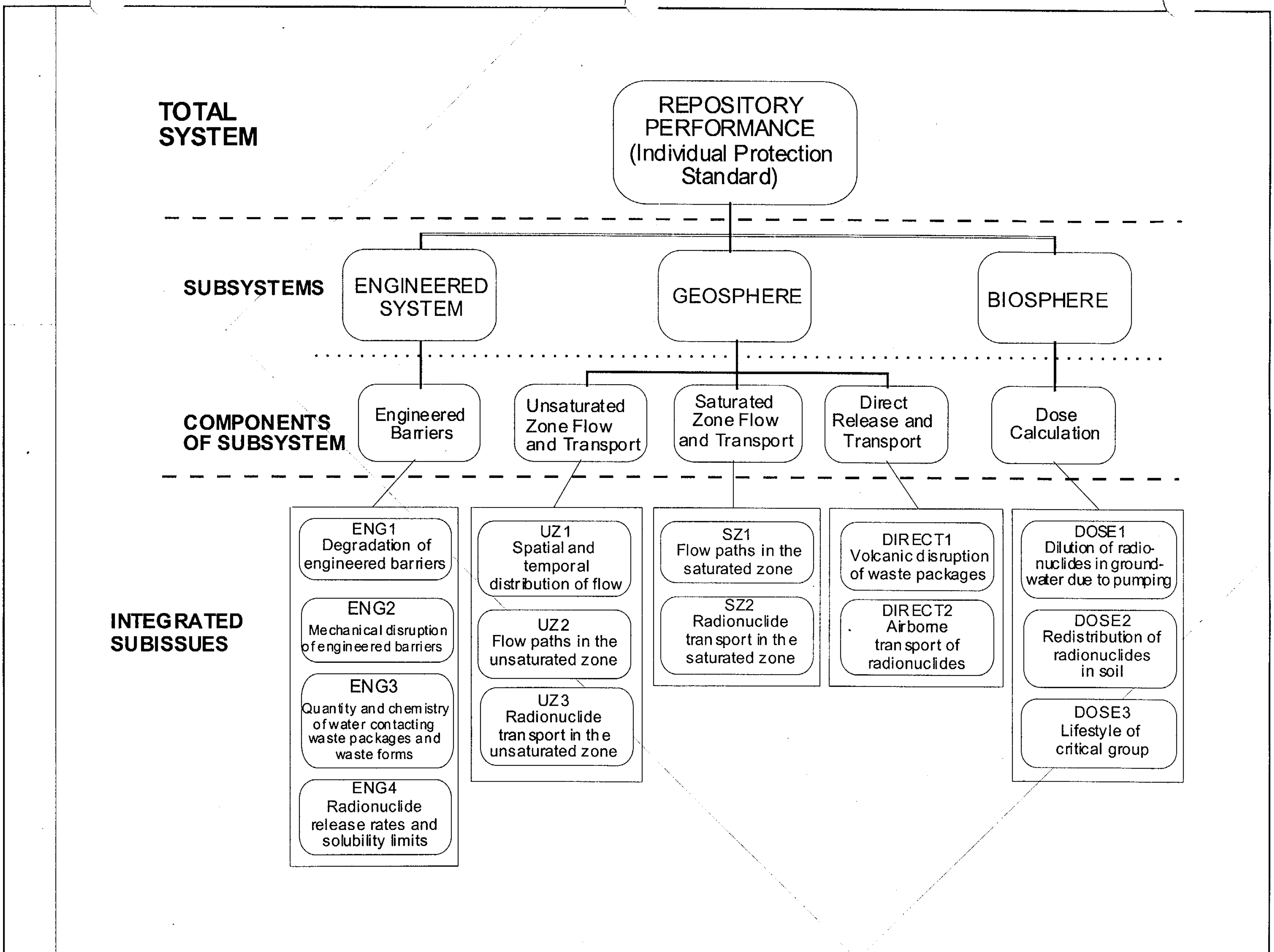
- System Description and Demonstration of Multiple Barriers
- Scenario Analysis
- Model Abstraction
- Demonstration of the Overall Performance Objective

Postclosure Safety Evaluation: Multiple Barriers

- Identify all barriers
- Describe and quantify capabilities of the barriers
- Include technical basis for barrier capabilities
- Develop additional acceptance criteria and review methods, as needed, that are consistent with the final Part 63

Postclosure Safety Evaluation: Scenario Analysis

- Methodology for inclusion or exclusion of features, events and processes (FEPs) in the compliance demonstration and formation of scenarios
  - Identification of an initial list of FEPs
  - Categorization of FEPs
  - Screening initial FEPs
  - Formation of scenario classes
  - Screening of scenario classes
- Probability for disruptive events
  - Definition
  - Data, models and uncertainty in probability estimates


TOTAL SYSTEM
REPOSITORY PERFORMANCE (Individual Protection Standard)
SUBSYSTEMS
ENGINEERED SYSTEM
GEOSPHERE
BIOSPHERE
COMPONENTS OF SUBSYSTEM
Engineered Barriers
Unsaturated Zone Flow and Transport
Saturated Zone Flow and Transport
Direct Release and Transport
Dose Calculation
INTEGRATED SUBISSUES
ENG1 Degradation of engineered barriers
ENG2 Mechanical disruption of engineered barriers
ENG3 Quantity and chemistry of water contacting waste packages and waste forms
ENG4 Radionuclide release rates and solubility limits
UZ1 Spatial and temporal distribution of flow
UZ2 Flow paths in the unsaturated zone
UZ3 Radionuclide transport in the unsaturated zone
SZ1 Flow paths in the saturated zone
SZ2 Radionuclide transport in the saturated zone
DIRECT1 Volcanic disruption of waste packages
DIRECT2 Airborne transport of radionuclides
DOSE1 Dilution of radionuclides in groundwater due to pumping
DOSE2 Redistribution of radionuclides in soil
DOSE3 Lifestyle of critical group

Postclosure Safety Evaluation: Model Abstraction

- Base on Integrated Subissues (ISIs)
- Use 5 general technical acceptance criteria that focus on
  - Data and model justification
  - Data uncertainty
  - Model uncertainty
  - Model support
  - Integration
- Extract review methods and acceptance criteria from Issue Resolution Status Reports to strengthen the 5 general technical acceptance criteria

Postclosure Safety Evaluation: Overall Performance Objective

- Compliance to the individual protection standard
  - Consistent assumptions, data, and models
  - Combining probability and consequence for each scenario class to estimate risk over the compliance period
- Human intrusion analysis evaluation
  - Analysis is identical to the compliance demonstration except those modifications appropriate for human intrusion
  - Develop acceptance criteria and review methods that are consistent with the final Part 63

Administrative and Programmatic Requirements Evaluation

- Evaluation include
  - Quality Assurance
  - Personnel training and qualification
  - Record keeping
  - Plans for normal operations
  - Emergency planning
  - Physical security
- No performance objectives established in the implementing rule
  - Address procedural matters; existing acceptable programs
  - Underpinning of acceptable preclosure and postclosure safety demonstration
- Use existing guidance and review plans from other NRC programs with modification to suit Yucca Mountain

Schedule and Activities

- Establish coordination with other NMSS Divisions and Program Offices for review of Preclosure Safety and Administrative/Programmatic Procedures

- Assign Technical Leads to integrate multidisciplinary teams and build consensus for each review section

- Continue working on the level of detail, integration and incorporation of risk insights

- Future versions of the Yucca Mountain Review Plan will be modified, as necessary, to be consistent with the final Part 63

Schedule and Activities (Cont.)

- Yucca Mountain Review Plan **Rev. 0** (Postclosure Chapter only) — April 14, 2000
- Public Meetings/Meeting with DOE
- Yucca Mountain Review Plan **Rev. 1** (Complete Review Plan) — September 30, 2000 (will formally invite public comments)
- Public Meetings/Meeting with DOE
- Yucca Mountain Review Plan **Rev. 2** (Complete Review Plan) — September 30, 2000 (will consider public comments received and new information)

Unsaturated and Saturated Flow under Isothermal Conditions (USFIC)

USFIC1 Climate change

USFIC2 Hydrologic effects of climate change

USFIC3 Present-day shallow groundwater infiltration

USFIC4 Deep percolation (present and future)

USFIC5 Saturated zone ambient flow conditions and dilution processes

USFIC6 Matrix diffusion

Thermal Effects on Flow (TEF)

TEF1 Sufficiency of thermal-hydrologic testing program to assess thermal reflux in the near field

TEF2 Sufficiency of thermal-hydrologic modeling to predict the nature and bounds of thermal effects on flow in the near field

TEF3 Adequacy of total system performance assessment with respect to thermal effects on flow

Evolution of the Near-Field Environment (ENFE)

ENFE1 Effects of coupled thermal-hydrologic-chemical processes on seepage and flow

ENFE2 Effects of coupled thermal-hydrologic-chemical processes on WP chemical environment

ENFE3 Effects of coupled thermal-hydrologic-chemical processes on chemical environment for RN release

ENFE4 Effects of thermal-hydrologic-chemical processes on radionuclide transport (RT) through engineered and natural barriers

ENFE5 Coupled thermal-hydrologic-chemical processes affecting potential nuclear criticality in the near field

Container Life and Source Term (CLST)

CLST1 Effects of corrosion on the lifetime of the containers and the release of RNs to the near-field environment

CLST2 Effects of materials stability and mechanical failure on the lifetime of the containers and the release of RNs to the near-field environment

CLST3 Rate of degradation of spent nuclear fuel and the rate at which RNs in spent nuclear fuel are released to the near field environment

CLST4 Rate of degradation of high-level waste glass and the rate at which RNs in high-level waste glass are released to the near field environment

CLST5 Design of WP and other components of the engineered barrier system for prevention of nuclear criticality

CLST6 Effect of alternate design features on container lifetime and RN release

Radionuclide Transport (RT)

RT1 RT through porous rock

RT2 RT through alluvium

RT3 RT through fractured rock

RT4 Nuclear criticality in the far field

Total System Performance Assessment and Integration

TSPAI1 Demonstration of multiple barriers

TSPAI2 Scenario analysis within the TSPA methodology

TSPAI3 Model abstraction within the TSPA methodology

TSPAI4 Demonstration of the overall performance objective

Igneous Activity (IA)

IA1 Probability of future igneous activity

IA2 Consequences of igneous activity within the repository setting

Structural Deformation and Seismicity (SDS)

SDS1 Faulting

SDS2 Seismicity

SDS3 Fracturing and structural framework of the geologic setting

SDS4 Tectonics and crustal conditions

Repository Design and Thermal-Mechanical Effects (RDTME)

RDTME1 Implementation of an effective design control process within the overall quality assurance program

RDTME2 Design of the geologic repository operations area for the effects of seismic events and direct fault disruption

RDTME3 Thermal-mechanical effects on underground facility design and performance

RDTME4 Design and long-term contribution of repository seals in meeting post-closure performance objectives

	ENG1	ENG2	ENG3	ENG4	UZ1	UZ2	UZ3	SZ1	SZ2	Direct1	Direct2	Dose1	Dose2	Dose3
USFIC1					■			■						
USFIC2														
USFIC3					■									
USFIC4			■		■	■	■	■						
USFIC5								■	■			■		
USFIC6							■		■					
TEF1	■		■		■	■								
TEF2	■		■		■	■								
TEF3														
ENFE1			■		■	■								
ENFE2	■		■											
ENFE3			■	■										
ENFE4				■			■							
ENFE5				■										
CLST1	■	■	■							■				
CLST2	■	■								■				
CLST3			■	■										
CLST4			■	■										
CLST5		■		■										
CLST6	■	■	■	■										
RT1							■		■					
RT2									■					
RT3							■		■					
RT4							■		■					
TSPAI1														
TSPAI2														
TSPAI3	■	■	■	■	■	■	■	■	■	■	■	■	■	■
TSPAI4														
IA1										■				
IA2		■								■	■		■	■
SDS1		■								■				
SDS2		■			■									
SDS3		■	■		■	■	■	■	■					
SDS4		■						■		■				
RDTME1														
RDTME2		■												
RDTME3	■	■	■		■									
RDTME4														

Characterization of Radioactive Slags

Linda A. Veblen, RES/DRAA/RPERWMB

UNITED STATES NUCLEAR REGULATORY COMMISSION

Presented to ACNW March 28, 2000

Acknowlegements:

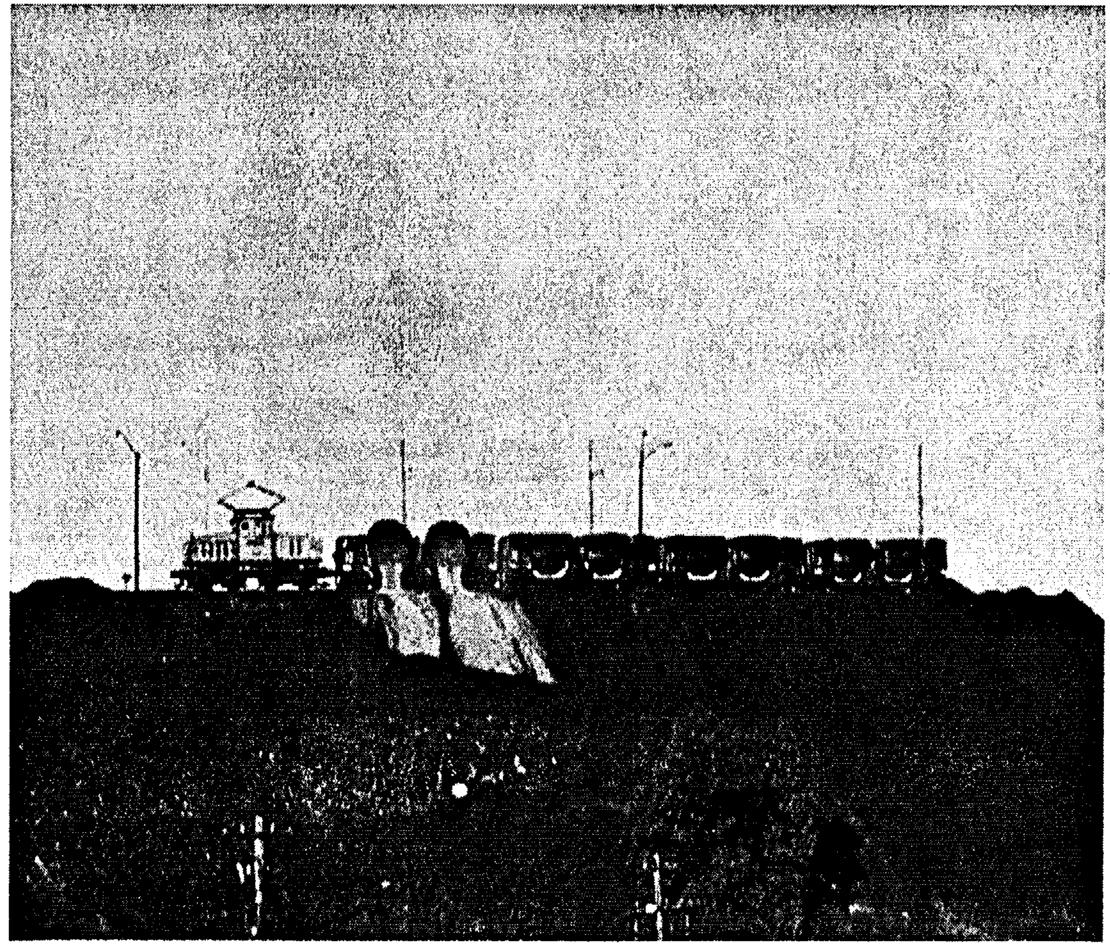
- Dori J. Farthing, Johns Hopkins University
- Dr. Edward O'Donnell, NRC/RES/DRAA/RPERWMB
- Prof. David R. Veblen, Johns Hopkins University
- Johns Hopkins University, Microbeam Facility
- Department of Earth and Planetary Sciences, JHU

Characterization of Radioactive Slag

The Problem: How stable is the waste?

Metallurgical processes produce mountains of waste slag containing: toxic metals and in some cases radioactive waste

- Several SDMP sites contain U and Th in quantities exceeding old regulatory limits
- Owners seek termination of nuclear materials license from NRC
- NRC must determine long-term stability of U and Th in wastes



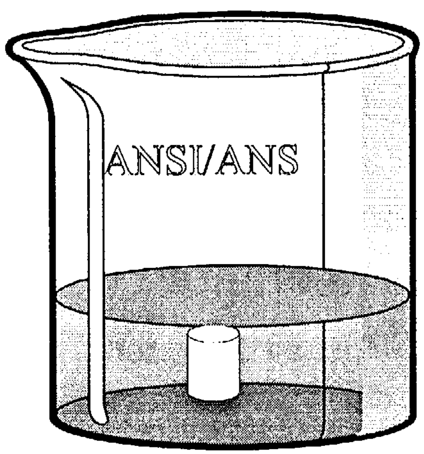
Sudbury, Ontario

SLAG LEACHING TESTS

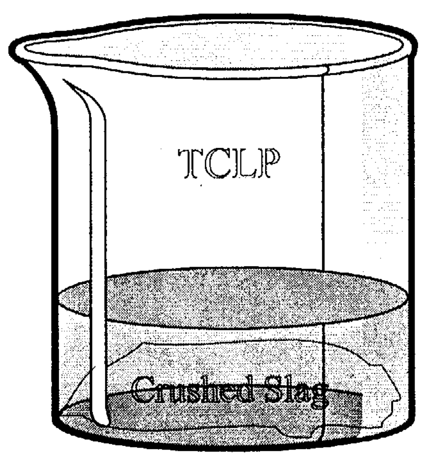
The Problem: How to determine U/Th Leach Rate from slag

- Standard Leach Tests:

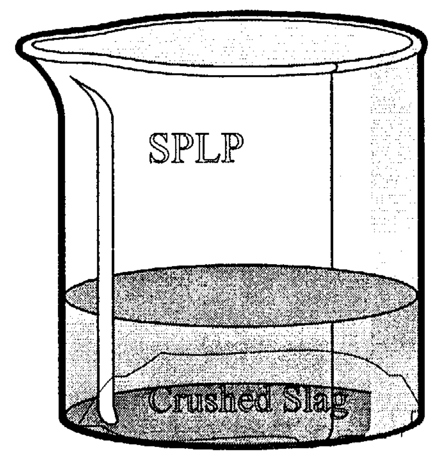
		Th Leach Rate (CNWRA)
ANSI/ANS-16.1-1986	Leachability of Solidified LLW	10^{-12} - $10^{-10.5}$
EPA Method 1311	Toxicity Characteristic Leaching Procedure	10^{-8}
EPA Method 1312	Synthetic Precipitation Leaching Procedure	10^{-9}



Cylindrical plug of slag
Deionized H_2O



Acetic Acid
pH 2.88 OR 4.93



Sulphuric/Nitric ACID
pH 4.20 OR 5.00

So What?

What's the Bottom Line?

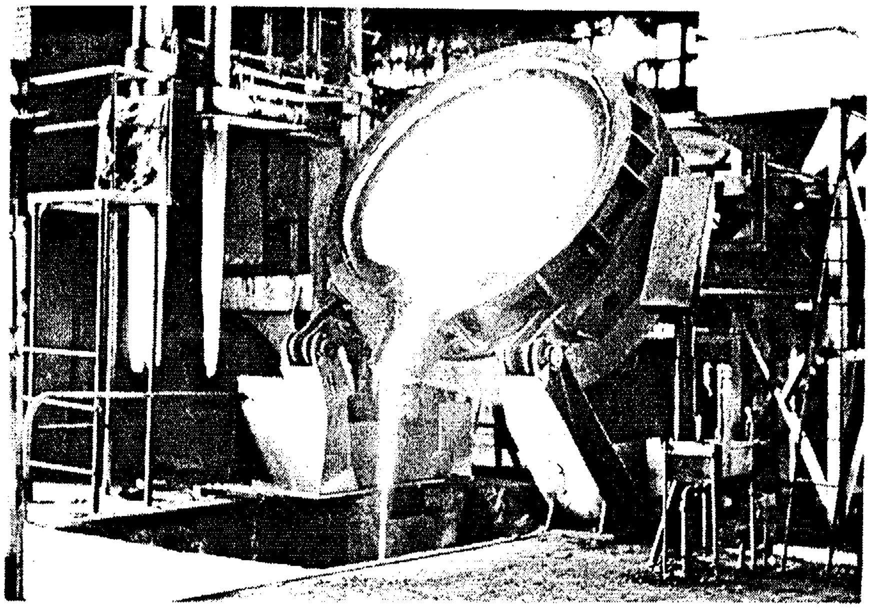
- What IS a Slag? What is IN a Slag?
  - Even the licensees did not know.
- Where is the U and Th? Evenly distributed?
- What is the Leach Rate for a Slag? Does it change with time?
- What standard tests should we use, if any?
- 17 SDMP Sites: Are they all the same?
  - Can we use the same licensing criteria for each site?
- How does a Slag weather?

Characterization of Radioactive Slag

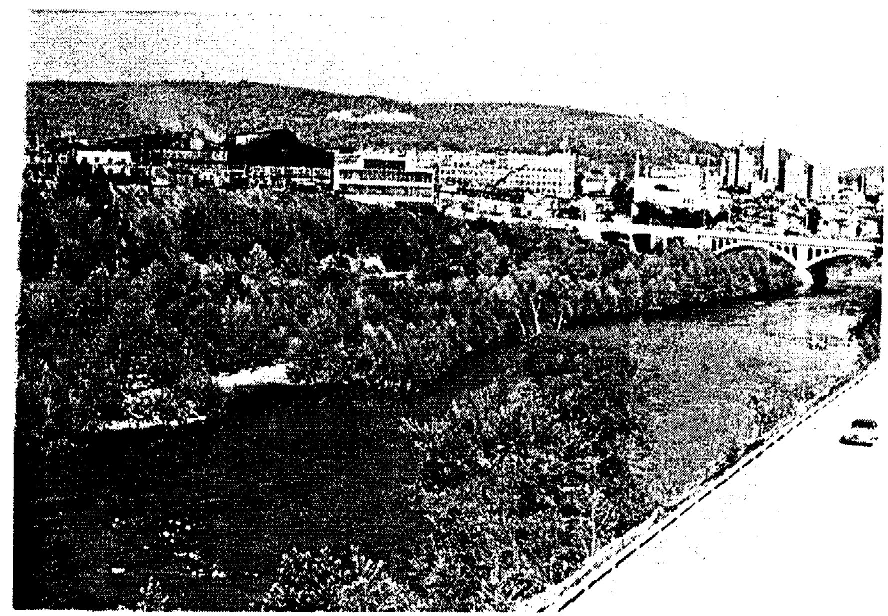
Objectives of Study:

- Identify phases in slag
  - Radioactive
  - Non-radioactive
- Determine weathering mechanisms of slag
- Estimate "in-situ" leach rate of U and Th from slag for input to RESRAD

Smelting Process and Dump Site



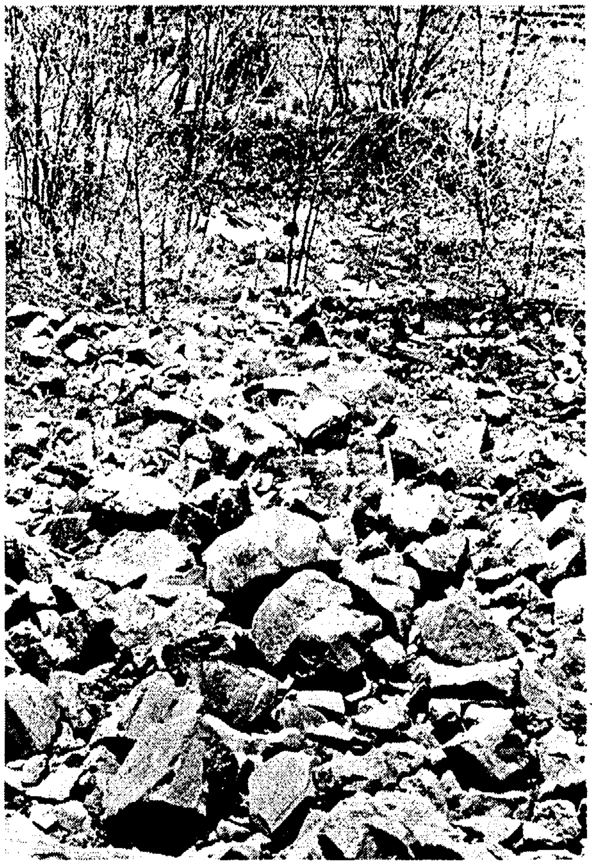
Melt pour 1967

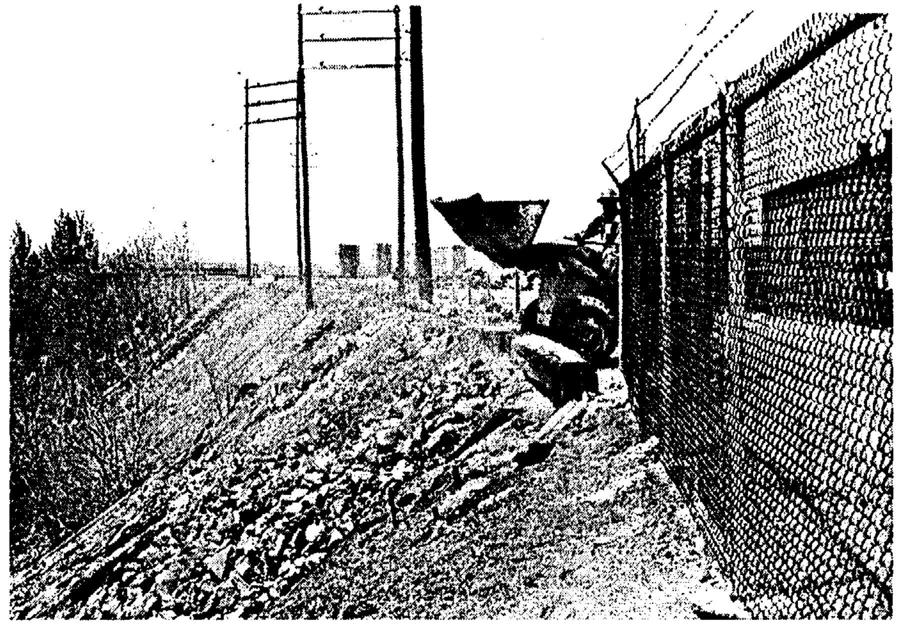


Site of smelting operation in 1967

Creation of a Slag pile

Slag blocks at base of dump.
Each block is ~ 10 kg





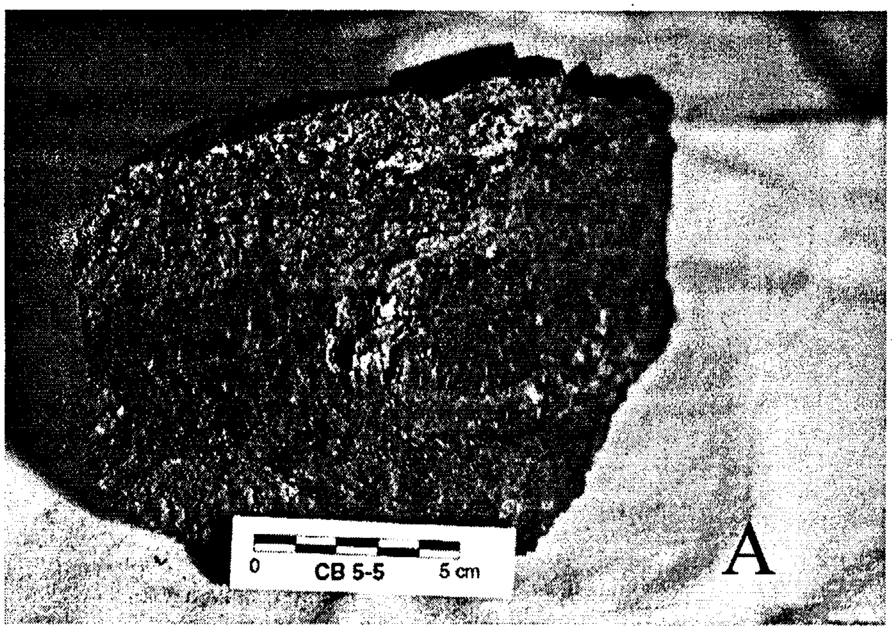
Slag pile in 1967 during smelting operation

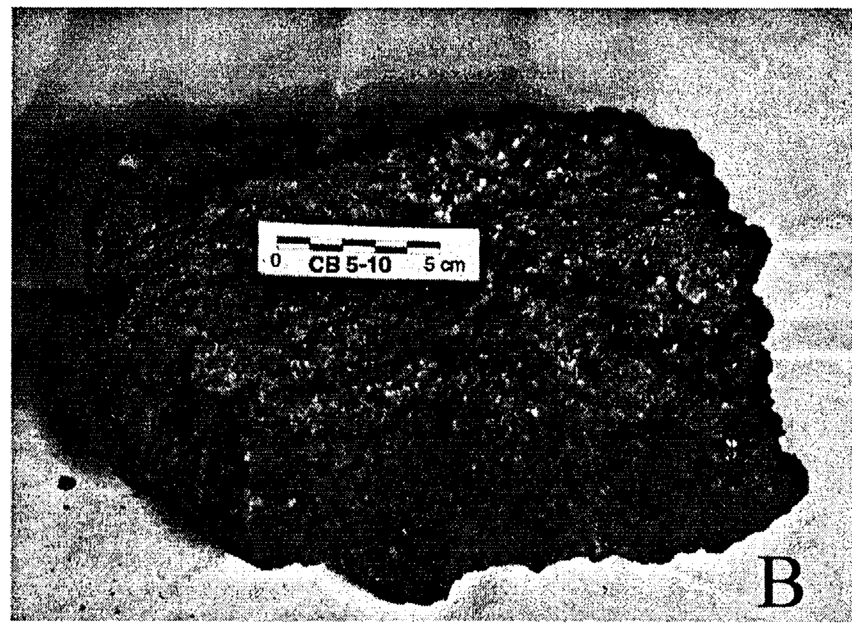
Slag pile Oct. 1997

Characterization of Slag

Hand Samples

- (A) Glassy slag - weathered upper portion
- (B) Crystalline slag - weathered upper portion



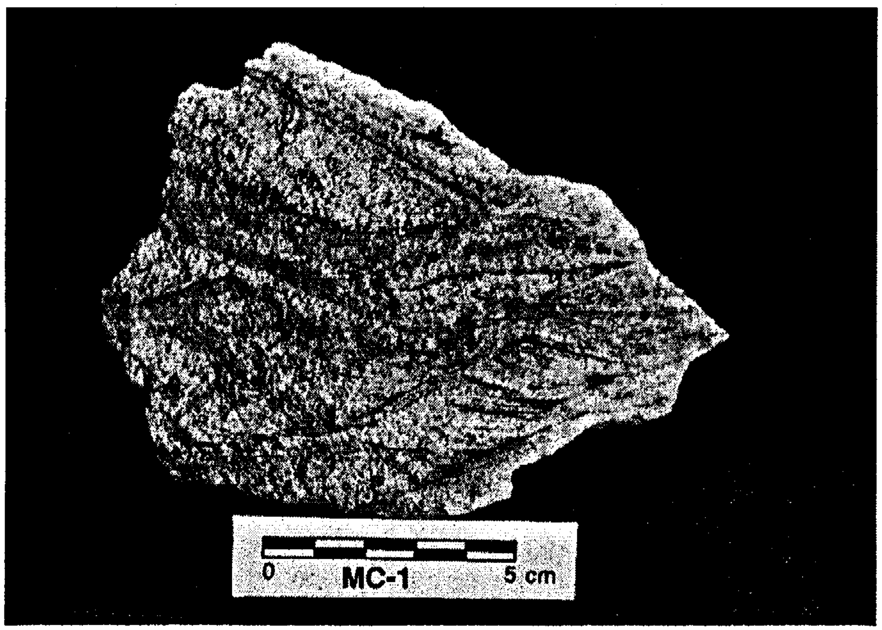


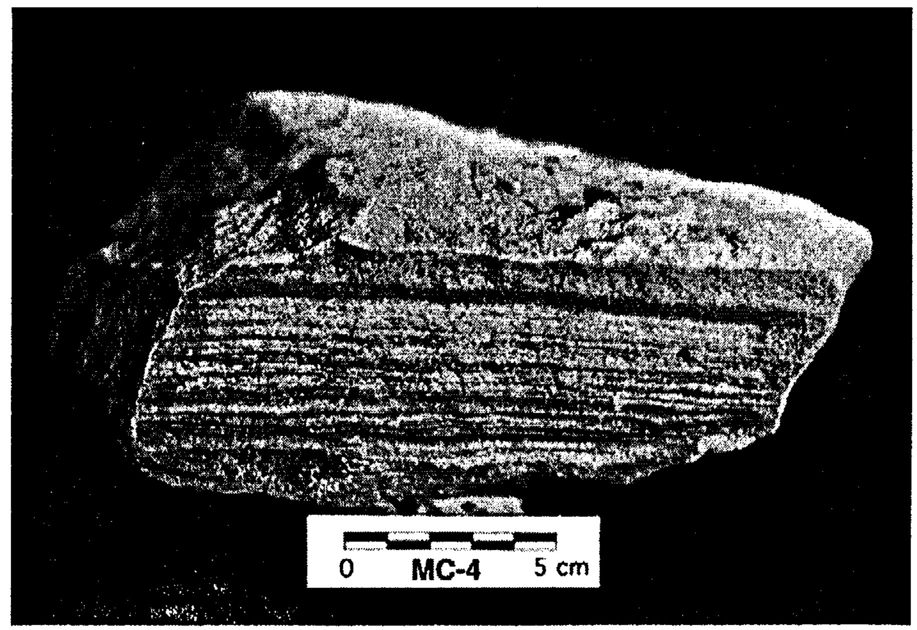
Photographs CNWRA, 1997

Characterization of Slag

Hand Samples

- Weathered Reprocessed Slag
  - Note: Cross-bedded, sedimentary features





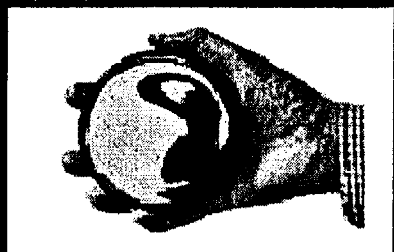
Photographs: CNWRA, 1997

Characterization of Radioactive Slag

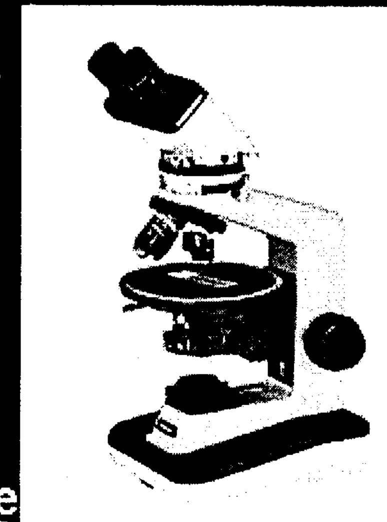
Identification of Radioactive Phases: Research Methods

- Identify phases and elemental variation and distribution in slag:
  - Light Microscopy
  - X-ray Diffraction
  - Electron Microprobe: SEM and EMPA (WDS and EDS)
  - Transmission Electron Microscopy: HRTEM, Electron Diffraction, EDS, X-ray mapping, Electron Energy Loss Spectroscopy (EELS)

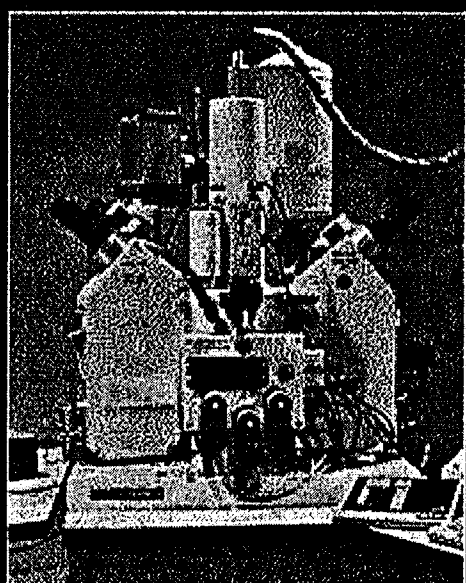
Investigation Tools



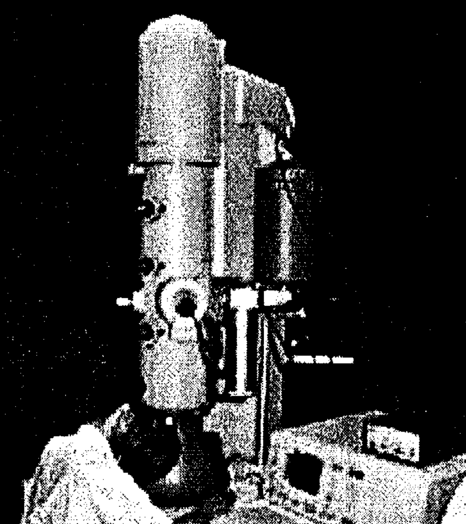
Macroscopic Scale
Hand sample studies



Microscopic Scale
Petrographic Microscope studies

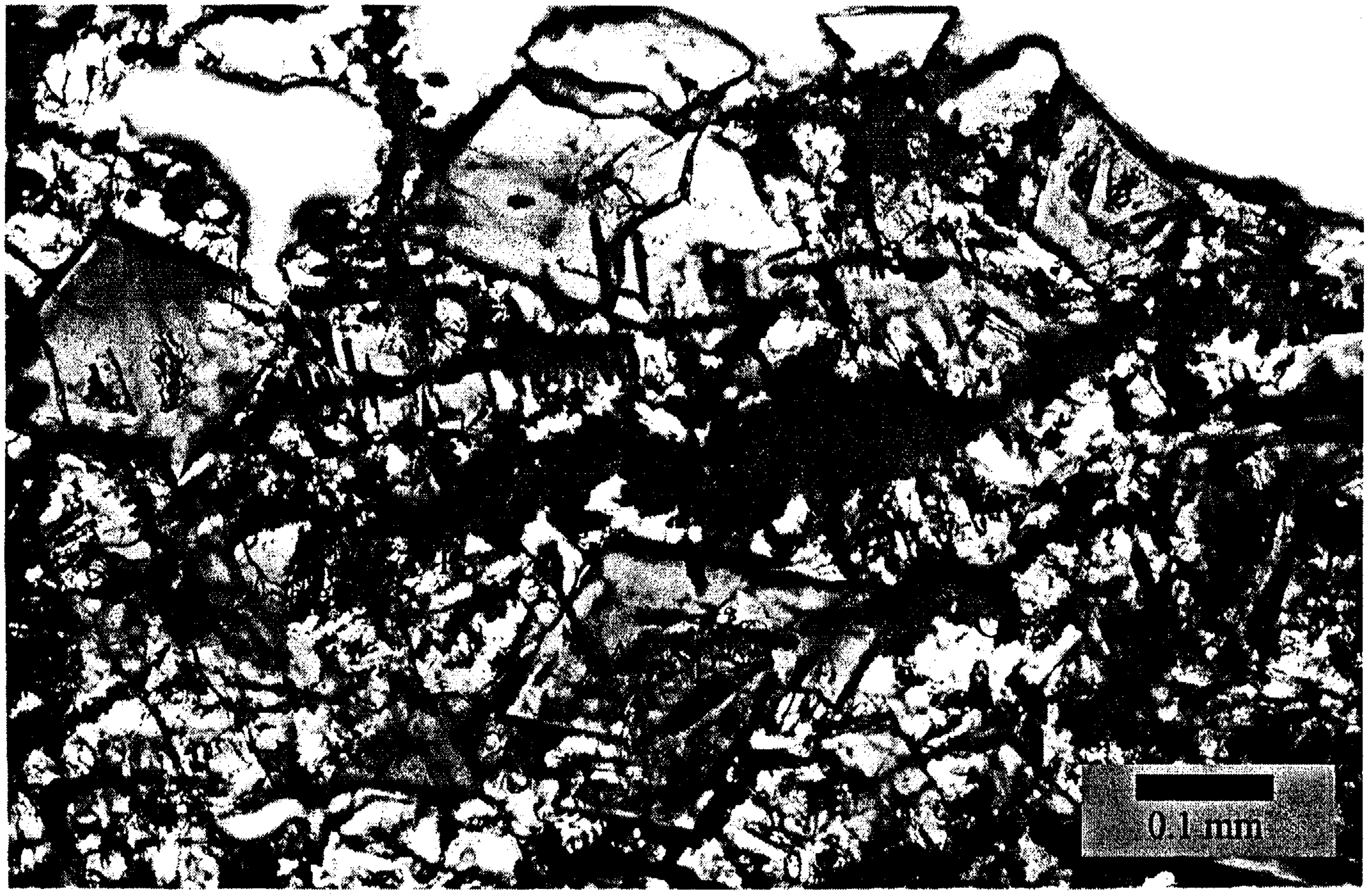


Microscopic Scale
Electron Microprobe Studies



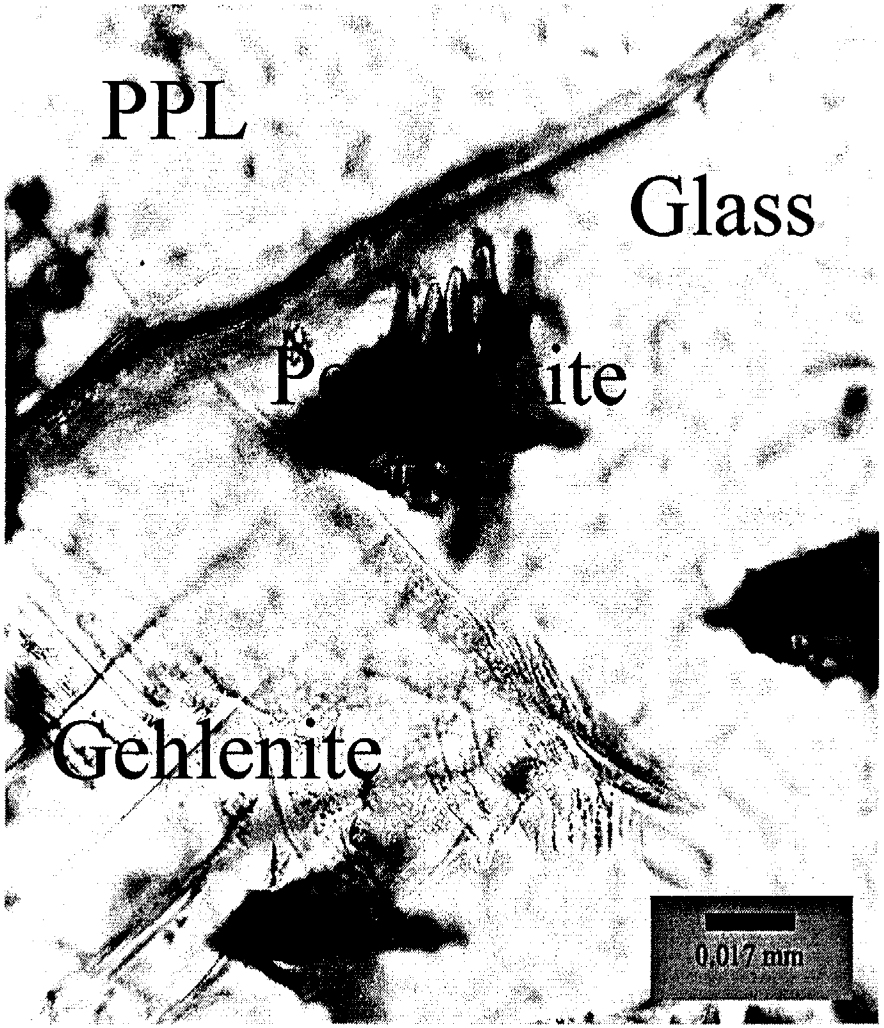
Microscopic Scale
Transmission Electron Microscope studies

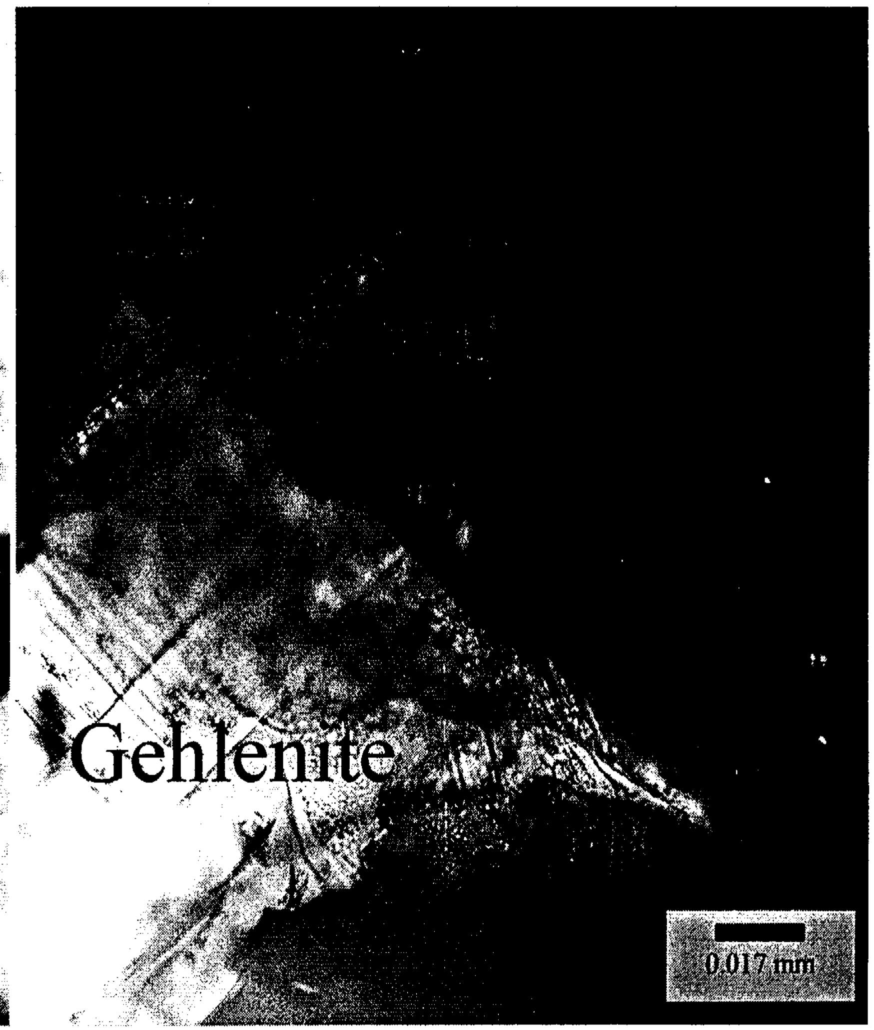
Photomicrograph of SDMP slag



Al-Sp	= Spinel	Al,Cr,Mg,Ti
Mg-Sp	= Spinel	Mg,Fe,Cr
Pv	= Perovskite	Ca,Ti,Th
G	= Glass	Ca,Al,Si,Fe

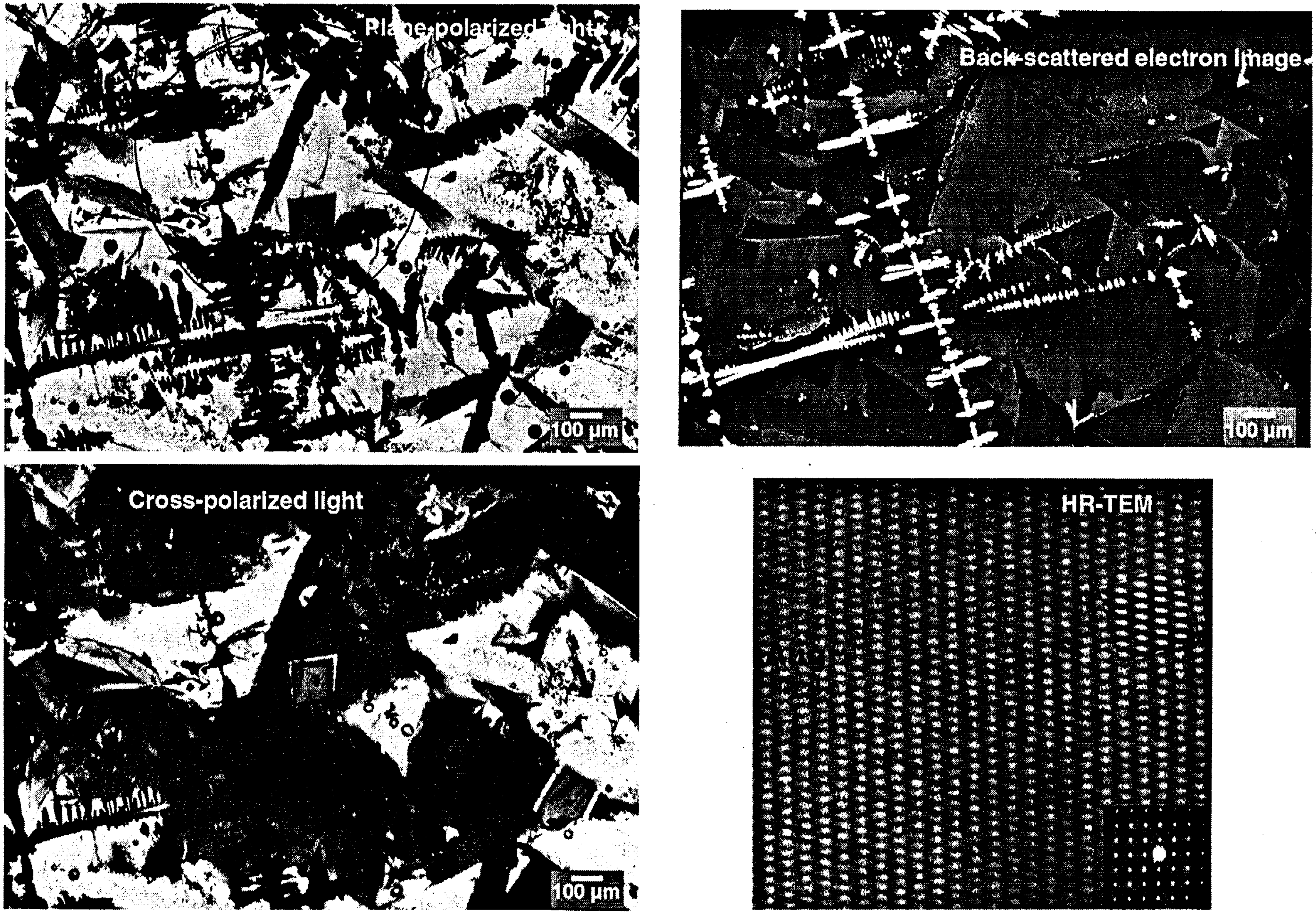
Slag Phases under light microscope



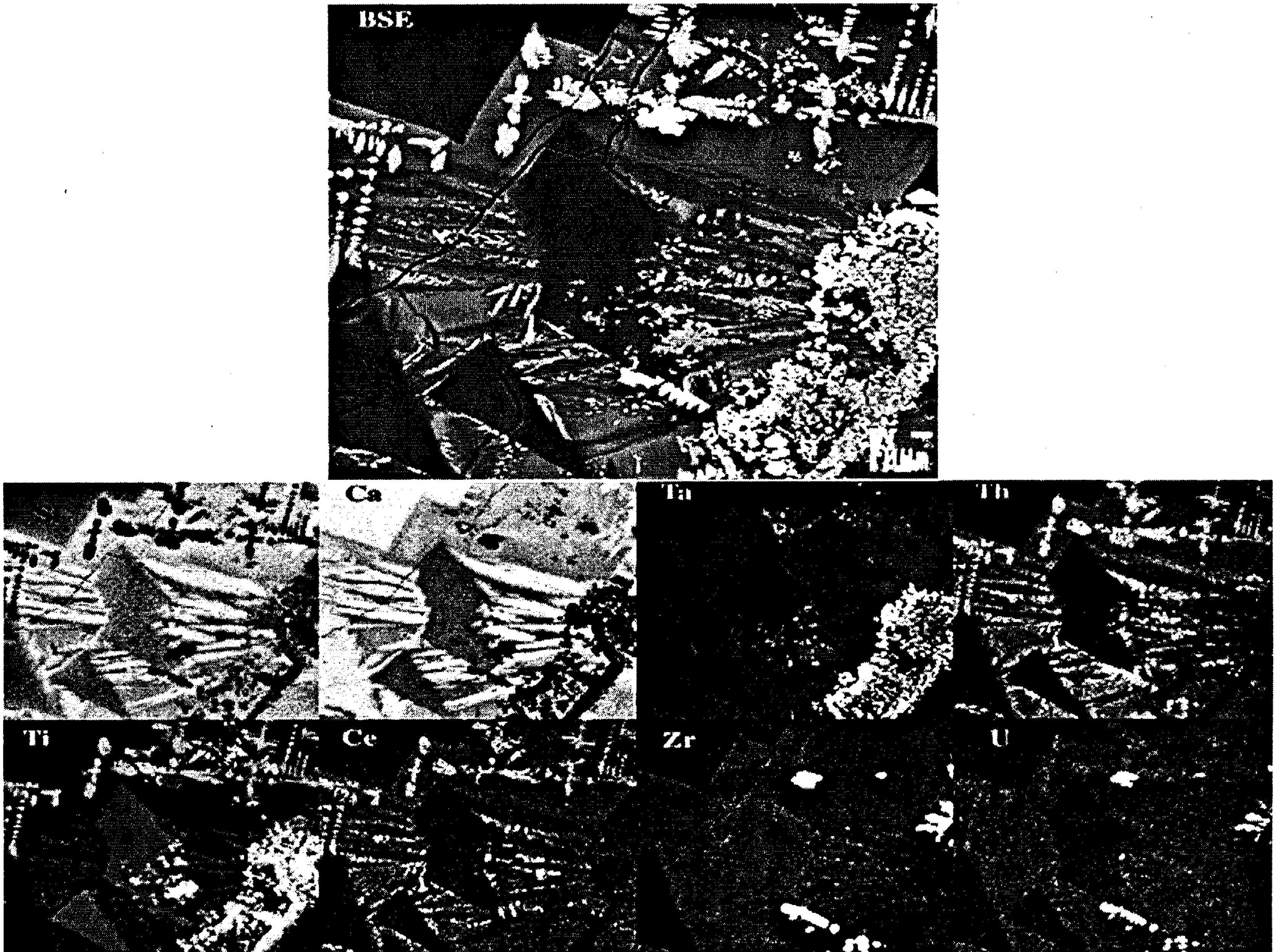


Alteration of Glass along Fracture

Light and Electron Microsopy



BSE and X-ray Map



Phases in Slags

* SYNROC Phases

Calzirtite*	$CaZrTi_2O_7$	All
Zirconolite*	$(Ca,Th,Ce)Zr(Ti,Nb)_2O_7$	All
Perovskite*	$CaTiO_3$	All
Perovskite(Loparite)	$(Ca,Ce,Th)(Ti,Nb)O_3$	M
Pyrochlore(Betafite)	$(Ca,Th,Ce)_2(Nb,Ti)_2O_6$	C,M,A
Pyrochlore	$(Ca,Th,Ce)_2(Nb,Ti)_2O_6$	All
Hibonite	$(Ca,Ce)(Ti,Al)_{12}O_{19}$	C,M
Spinel*	AB_2O_4 A:Co,Fe,Mg,Mn,Ni	
	B:Al,Cr,Fe,Mg,Mn,V	All
Olivine	$(Fe,Mg)SiO_4$	
Gehlenite	$Ca_2Al(AlSi)O_7$	All
Melilite	$(Ca,Na)_2(Mg,Fe,Al,Si)_3O_7$	W,A
Clinopyroxene	$Ca(Zr,Ti,Al)(Al,Si,Ti)_2O_6$	C,A
Feldspar	$CaAl_2Si_2O_8$	All
Wollastonite	$CaSiO_3$	W,A
Ce-Silicate	Ce,Si	C
Ce-Aluminosilicate	Ce,Si,Al	C
Barium aluminate*	$Ba,Ce(Ti,Al)_{12}O_{19}$	M
BariumAluminosilicate	$BaAl_2Si_2O_8$	M
Gypsum	$Ca(SO)_4$	M
Tridymite	SiO_2	M,W,A
Groundmass	Ca,Ba,Al; Ca,Ba,S,Cl,Al;	M
Glass*	Si,Al,Ca,Ti,U,Th	All

Determination of Leach Rate of Slag

- Measurement of Elemental Variation in Weathered SDMP Slag
  - EMPA, TEM

- Measurement of Elemental Variation in PNNL Leached Slag Samples
  - Solid-phase characterization of leached slag - EMPA
  - Identification of alteration - Light Microscopy, BSE, SEM, TEM

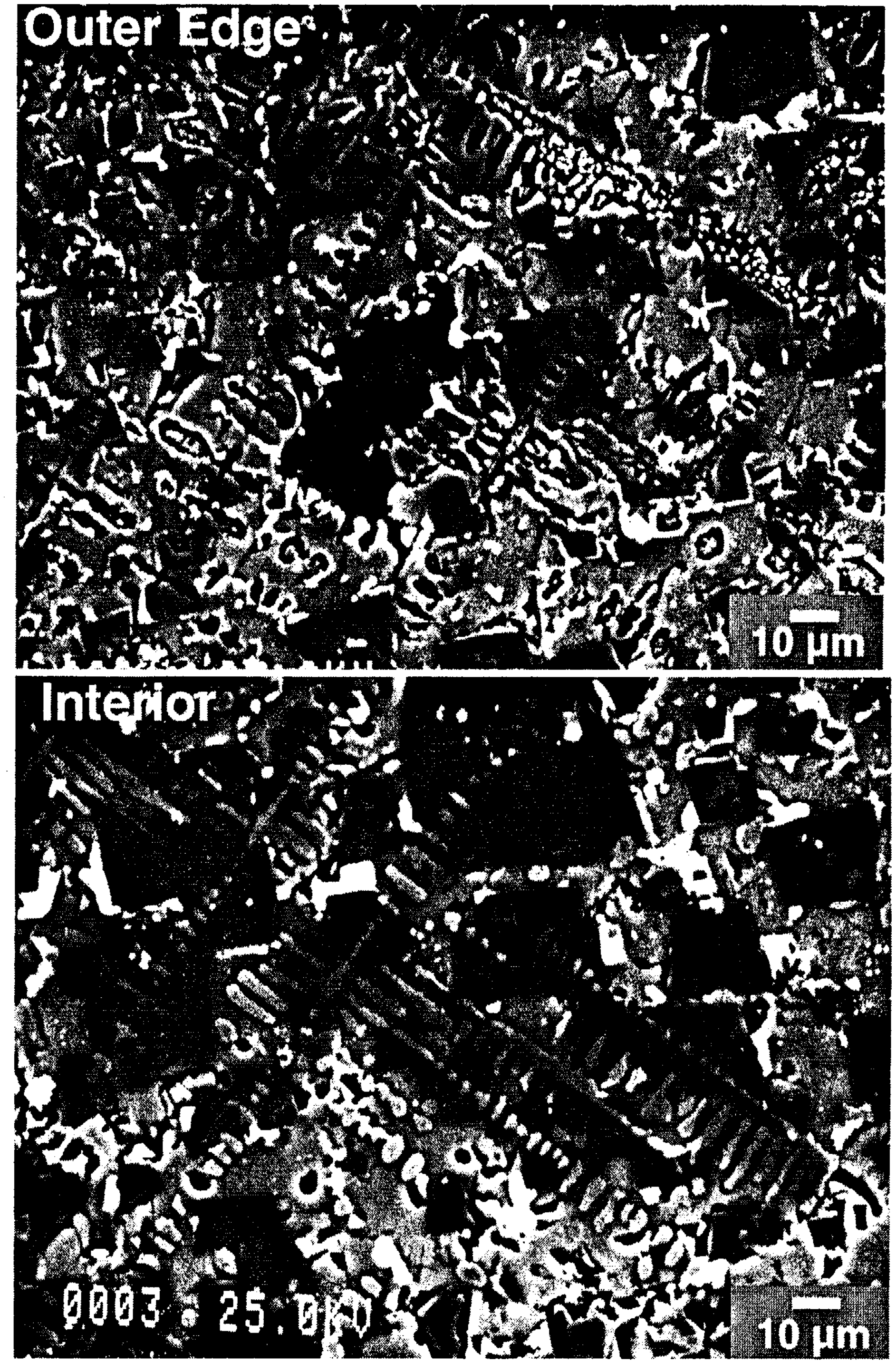
- Analogy:
  - Archaeological Slag (spanning 100 - 1000 years)
  - SYNROC
  - Natural Mineral Samples (hibonite - D. Farthing, JHU)

Weathering of Slag

SDMP Slag - 30 years old

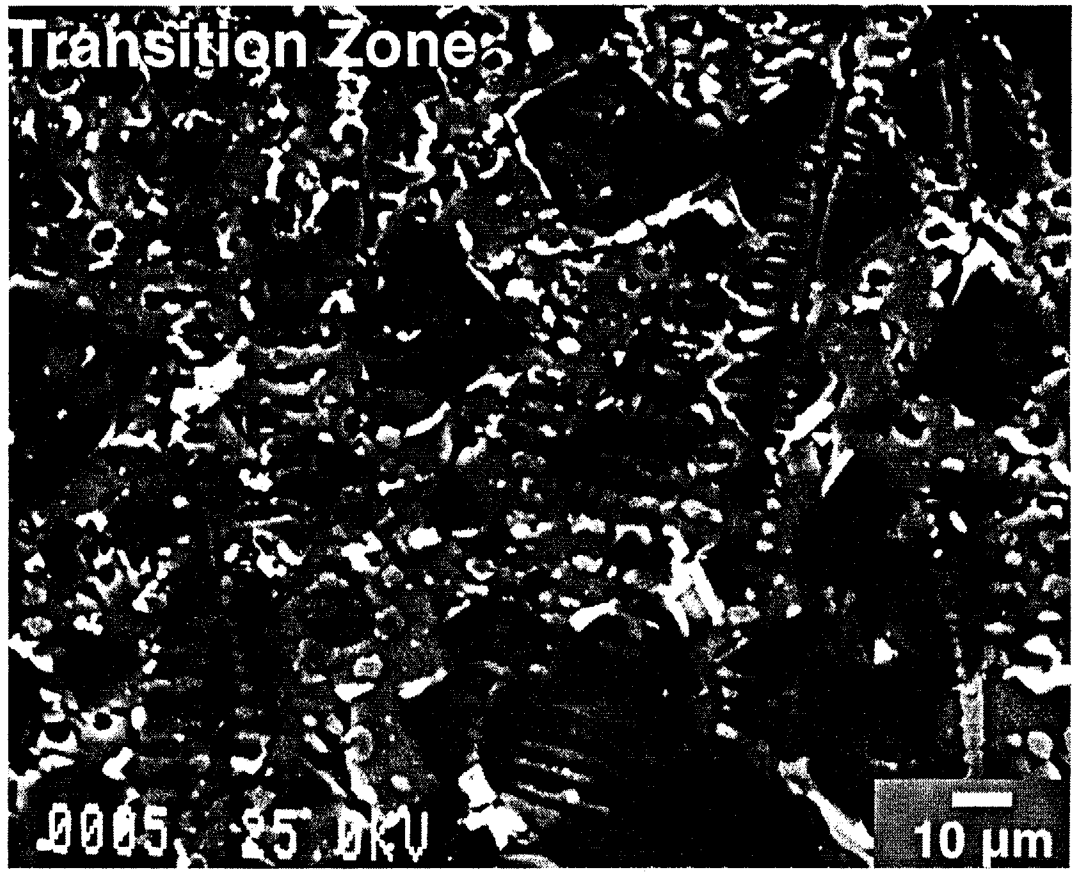
- Outer Edge
  - Mg-Fe Spinel dentrites -Corroded

- Interior
  - Mg-Fe Spinel intact
  - Weathering along grain boundaries



Weathering of Slag

Slag - 30 years old

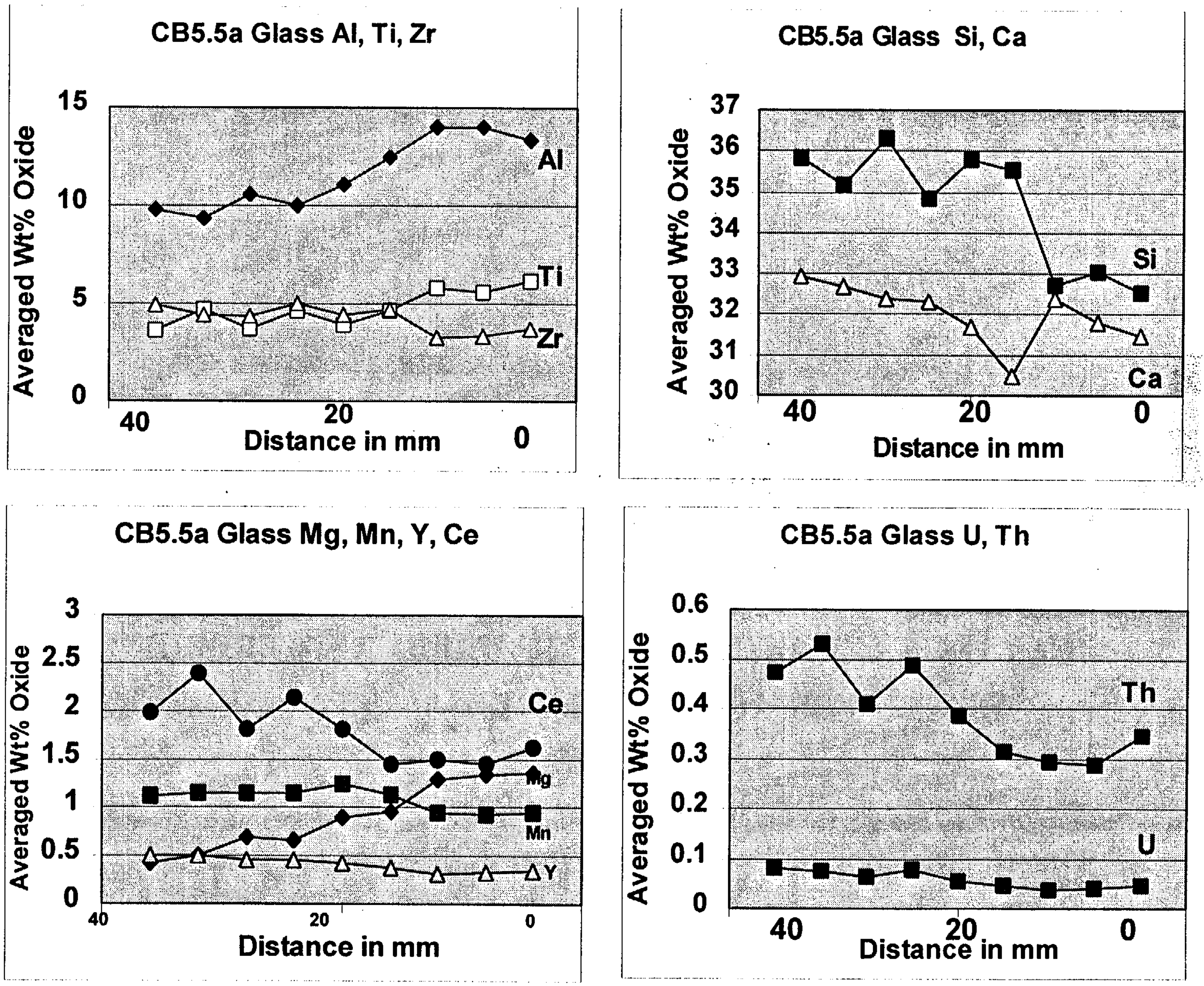


- Transition Zone
  - Some corroded Mg-Fe Spinel dendrites
  - Some intact Mg-Fe Spinel dendrites

- Fluid movement along grain boundaries and within grains

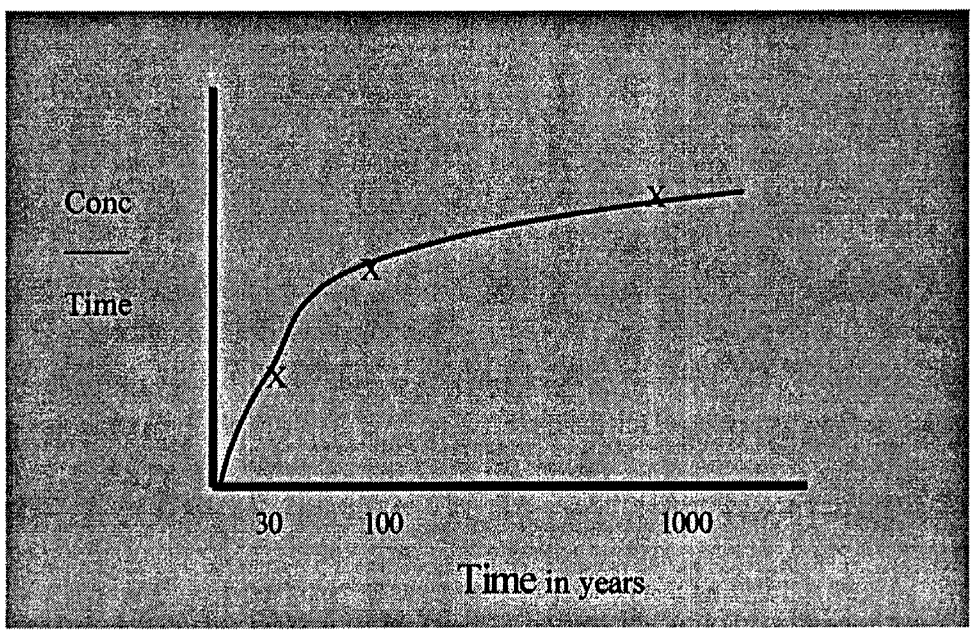
Weathering of a slag

Elemental variation in glass from weathered edge of sample



Calculation of In-Situ Leach Rate

- Data from WDS Microprobe analyses provides instantaneous Change in Concentration with time
- Data from different times
- Change in Conc/Time integrated over Distance

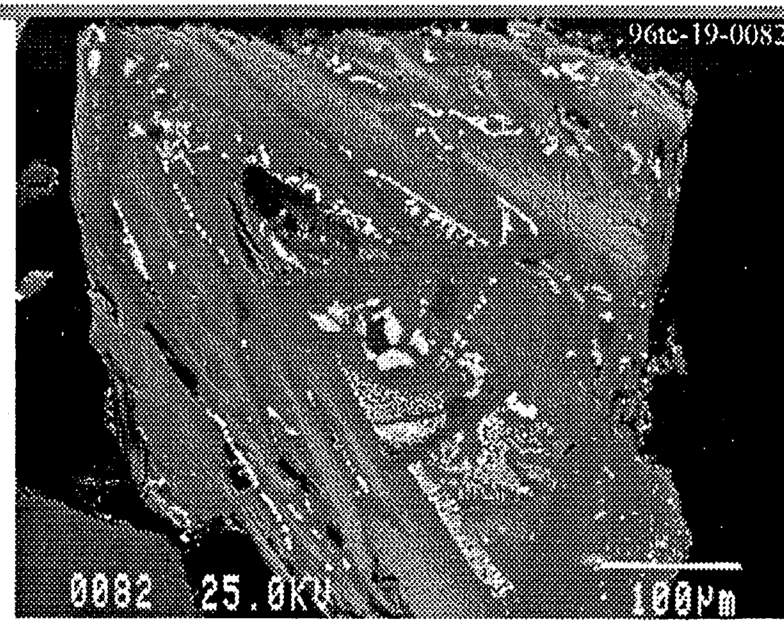


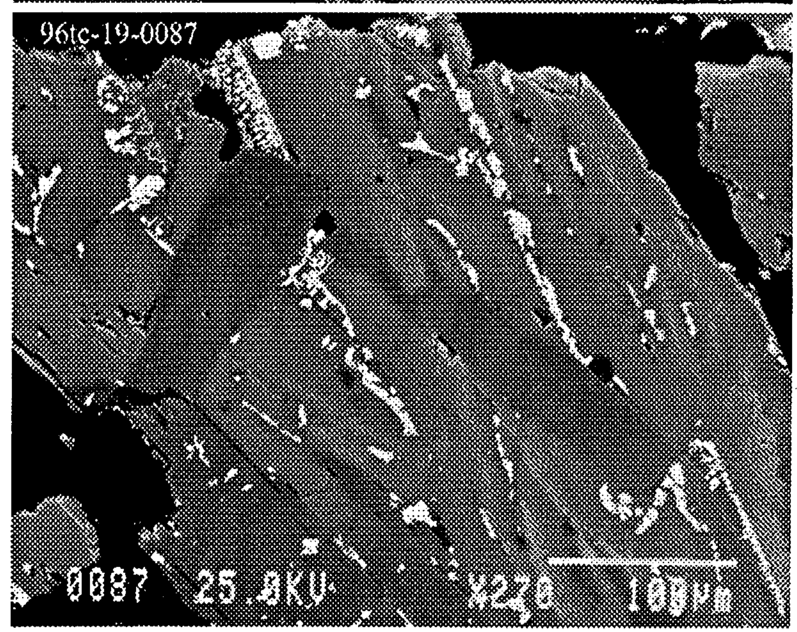
Bulk Leach Rate

Phase	Modal Abundance	Wt% U + Th	% in Slag
Gehlenite	38.8	-	
Glass	36.3	0.5	~0.25
Cpx	10.1	-	
Perovskite	9.5	~2	~0.35
Calzirtite	4.4	~2	~0.35
Rutile	1.9	-	
Pyrochlore	0.05	1.5	~0.05
Alteration	0.4		
Cracks & Holes	2.1		

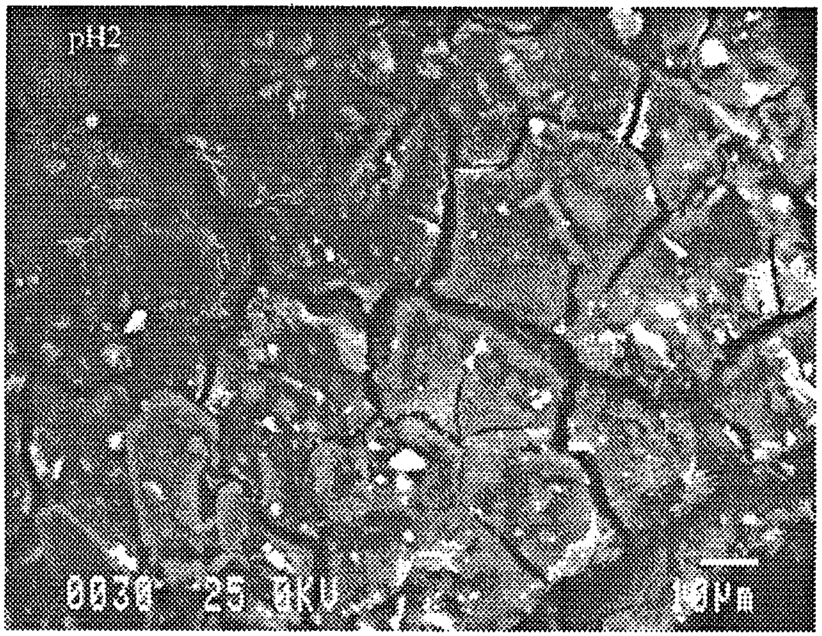
Solid-phase characterization of leached slag

96TC19 Leached with
Deionized H_2O





A



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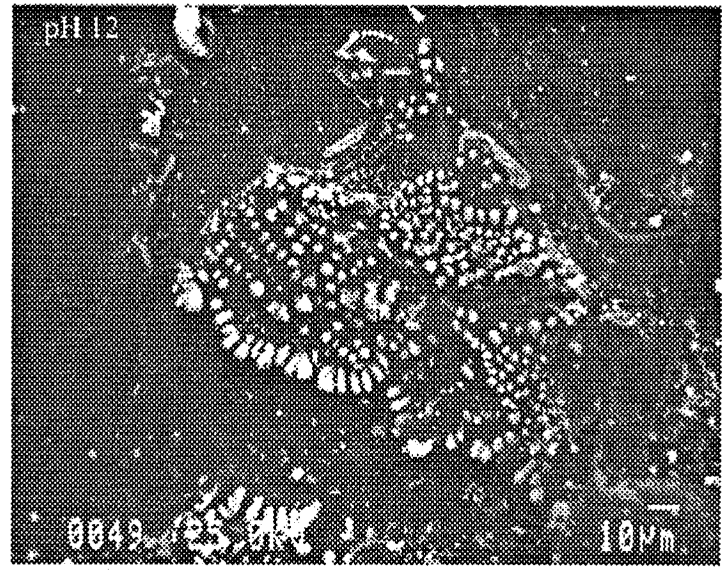
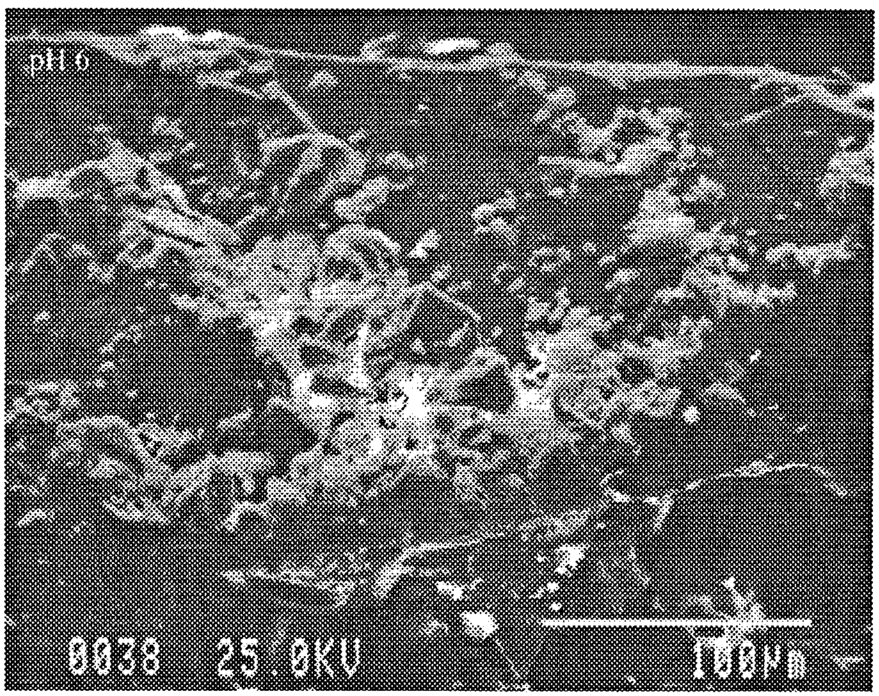


C



Leached Slag

SEM - SE Images

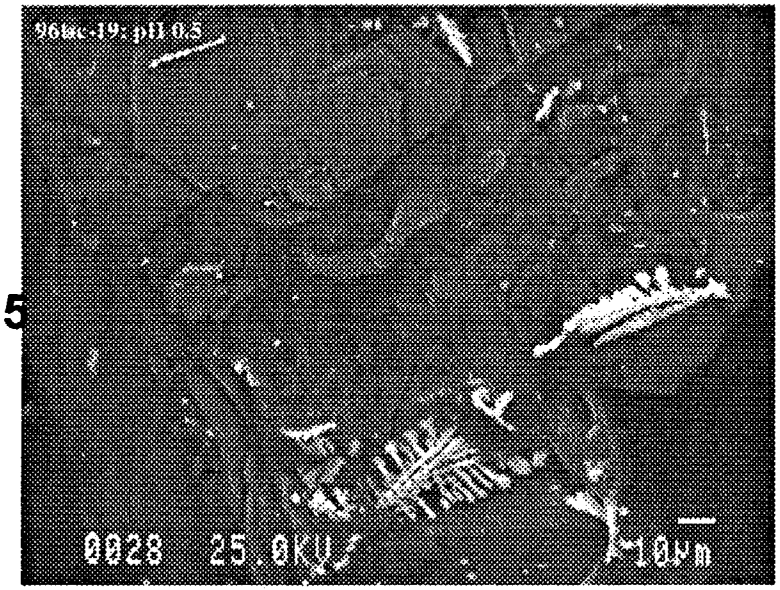
A - Corroded glass

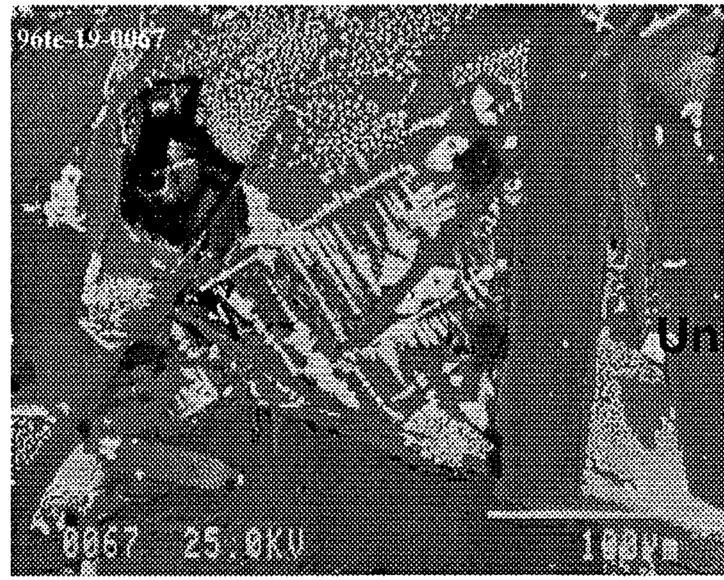
B - Perovskite and Rutile Needles

C - Clays on surface

Solid-phase characterization of leached slag

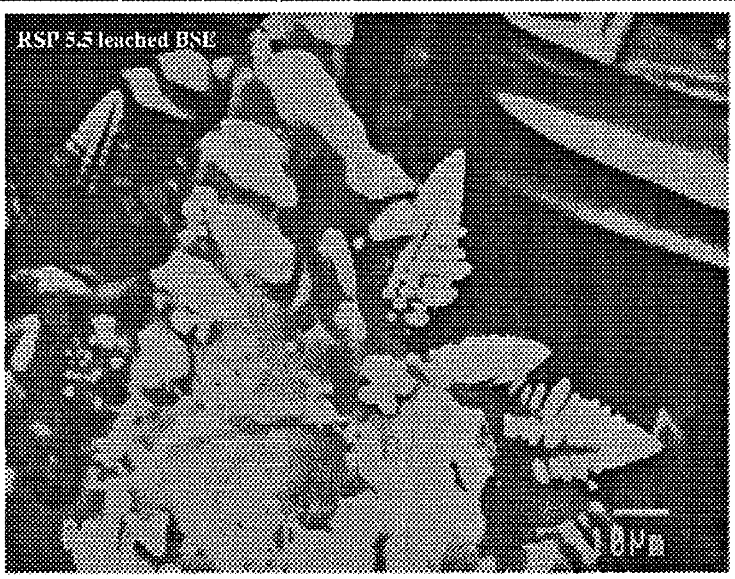
pH = 0.5

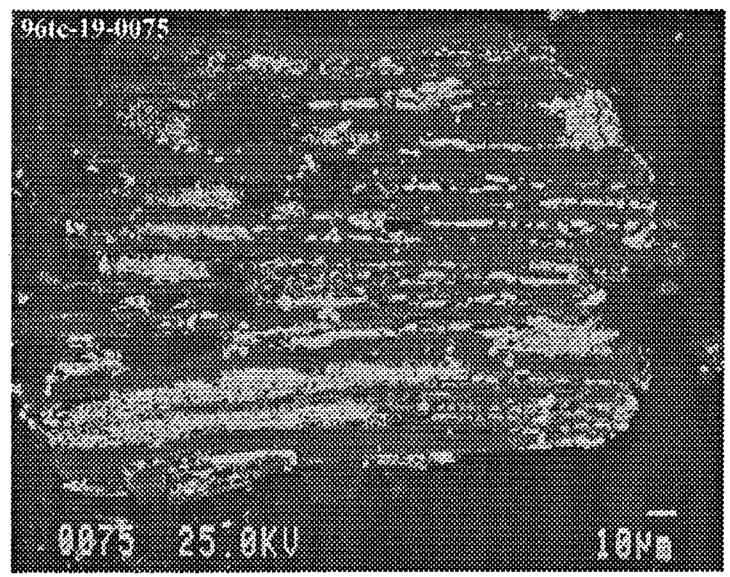




Unleached

D.I. H_2O

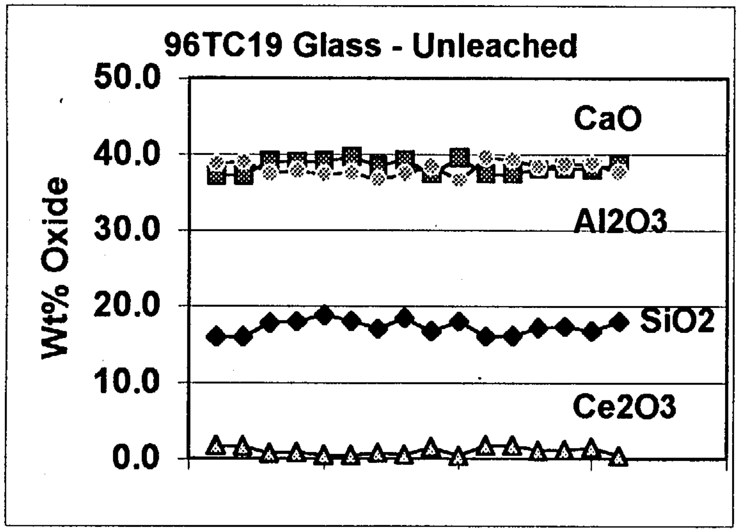


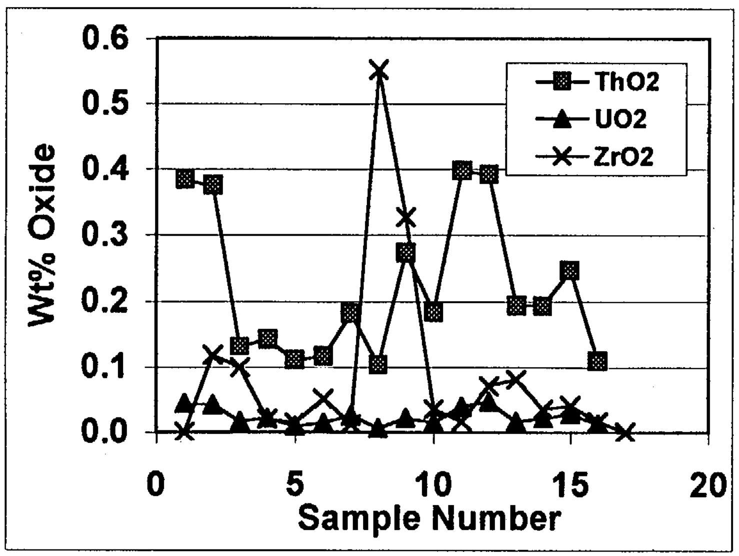


pH = 2

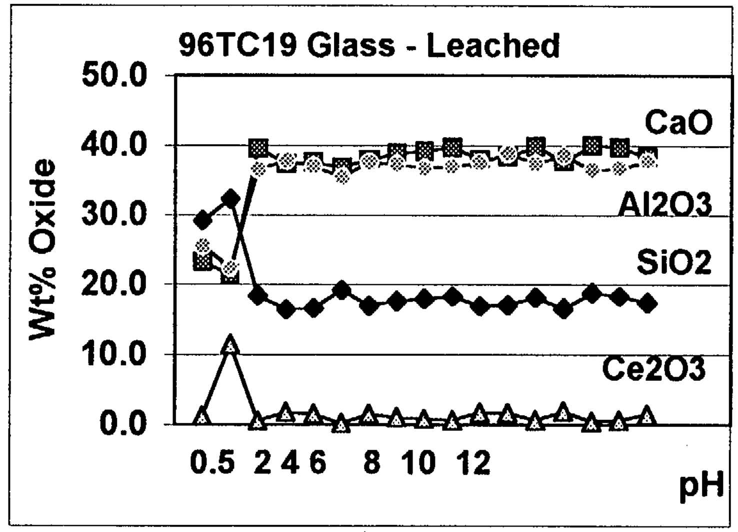
Solid-Phase Chemical Analyses

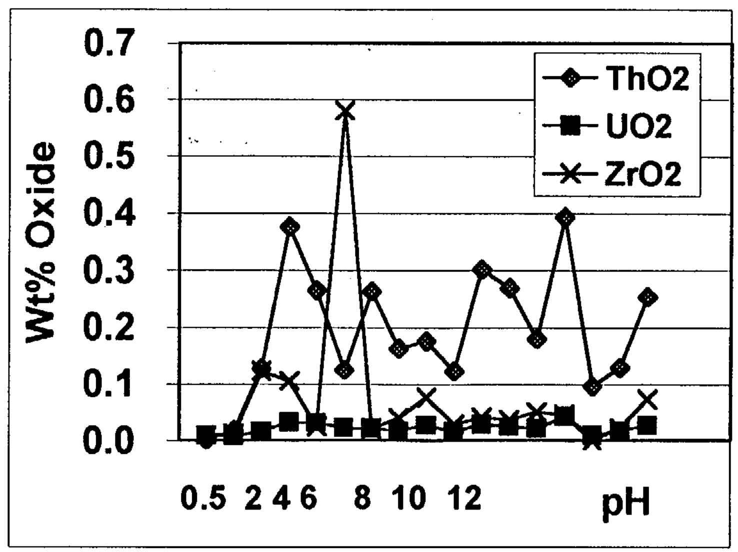
Glass: Unleached





Glass: Leached





Characterization of Radioactive Slag

Archaeological Slags

- Provide Weathering over Time-Scale of interest to SDMP ~ 1000 years
- Identification of Analogous Slag
  - Similarity of Bulk Chemistry - Sn slag
  - Similarity of Crystalline phases - e.g., Spinel, Olivine
  - Similarity of Glass Chemistry - e.g., Ca-Al-Silicate glass, Na-Al-Silicate glass vs. Ti-glass
- Identification of Phases
- Identification of Alteration
- Quantification of Alteration

Archaeological Slags

Slags studied:

Sn Slag Cornwall, UK - 8 Sites

Crift Farm
1000 years old

Pb-Ag Slag, Pribram, Czech Rep

500 years - present

Archaeological Slags

Slags Studied:

	Phases	Ages
Malaysian Sn Slag	Perovskite Pyrochlore Spinel Glass Pyroxene	>50 years
Cornish Sn Slag	Mellilite Olivine Pyroxene Metallic Phases Glass	50 - 1000 Years

Archaeological Slag

Evidence of Alteration

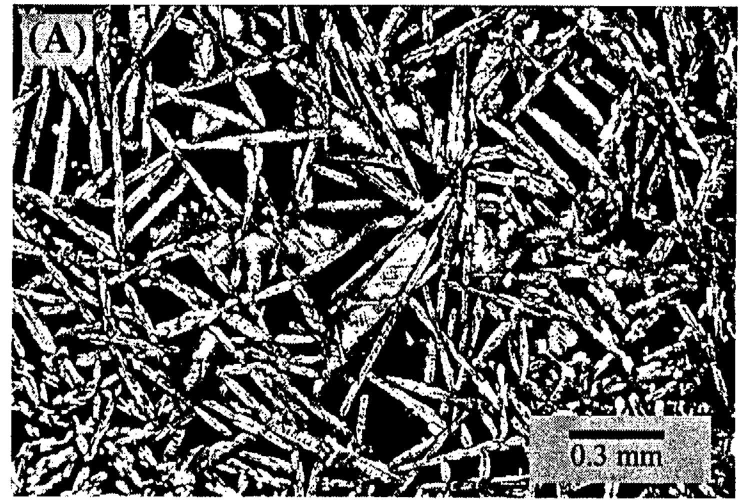
Glass Stability:

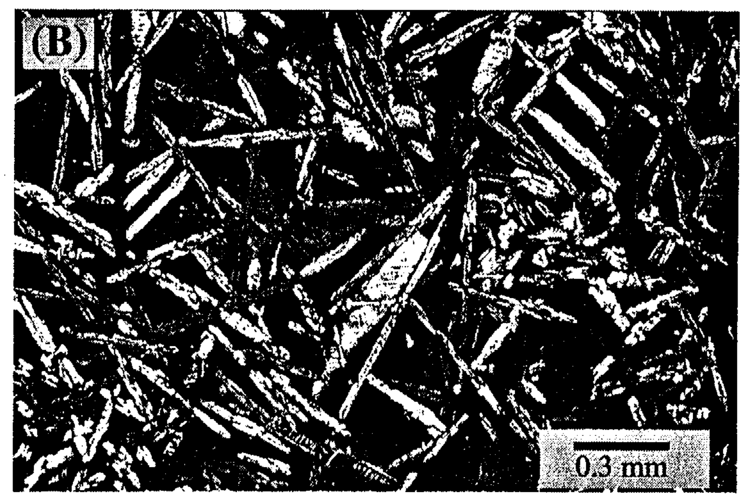
1000 year old Copper Slag - from Skouritossa Mine, Cyprus

(A) ppl photomicrograph
(B) xpl photomicrograph

Note the glass is no longer present due to oxidation and devitrification

XRD - no evidence of glass

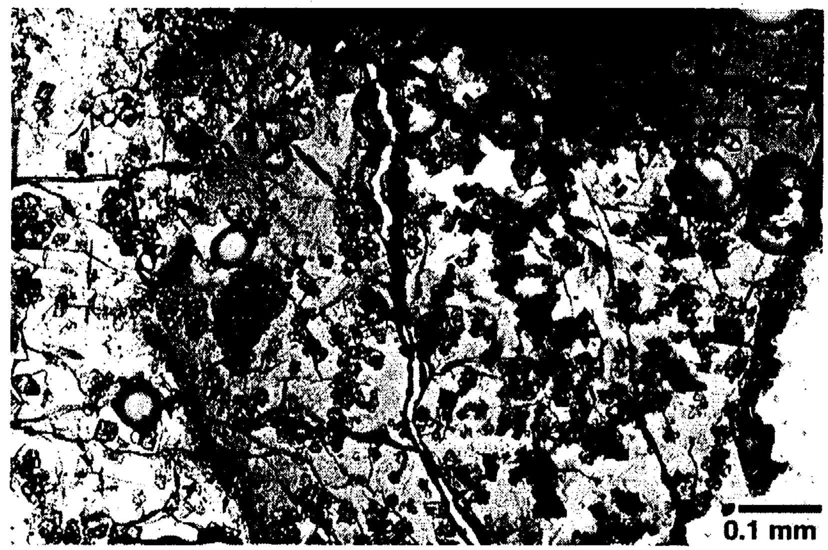




Weathering of Slag

Evidence of Alteration:

Oxidation and alteration of glass around fracture
Lamb and Flag, Cornwall, UK



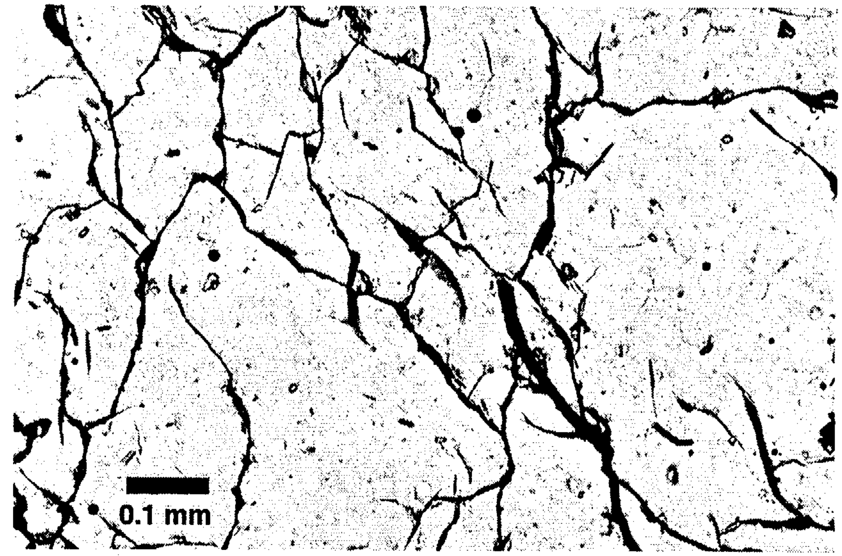
Secondary minerals grown in vesicle
Altered basalt

Weathering of Slag

Evidence of Alteration

Fluid Pathways

Cooling cracks and fractures



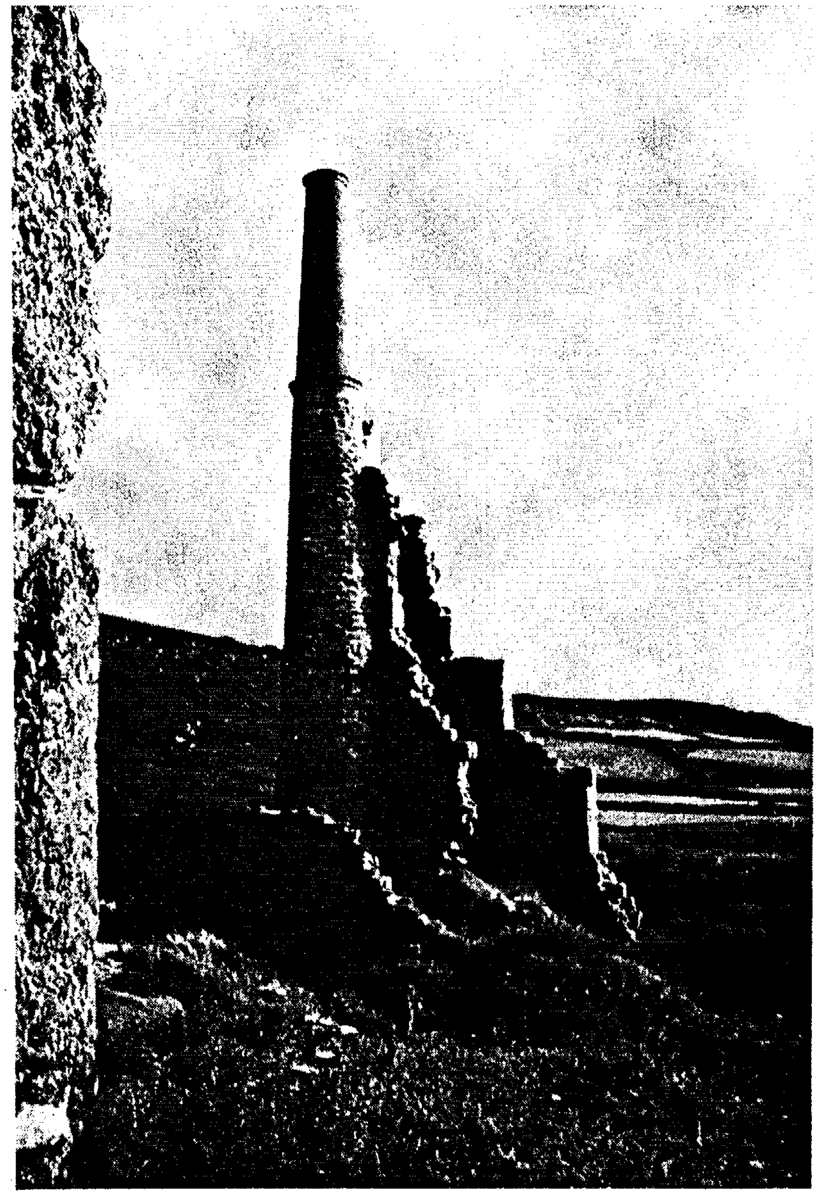
Alteration along fracture

Archaeological Slags

Uncertainties:

- Original composition
- Original Th, U content

Remains of 19th Cornish Furnace and slag piles



Analogous Material

- Synthetic ceramic waste form being considered for HLW, Hanford Tank Wastes, excess weapons-Pu
- Experimentally determined Leach Rate=4x10-3 g/m2d at 90 C
- Leach Rate~flow through leach rate for perovskite

P=Perovskite
R=Rutile
Z=Zirconolite
H=Hollandite
Ba(Al,Ti)2Ti6O16
M=Metallic

SYNROC

K.L. Smith, et al., 1996, MRS

Characterization of Slag

Conclusions

- Characterization requires many different techniques, leach experiments, solid-phase characterization
- Slag weathers by dissolution of glass, preferred dissolution of (spinel and perovskite) phases along grain boundaries
- Th is found in glass, perovskite, thorianite and pyrochlore
  - Glass and perovskite are not stable under near-surface conditions.
  - Although Th is present is several stable phases (thorianite) in slag, the dissolution of glass and other unstable phases provides fluid access to deep within the slag

Characterization of Slag

Conclusions: cont'd

- U is found in calzirtite, pyrochlore, perovskite and glass
  - U appears to be leaching from the glass at a rate of
- Characterization of solid phases of slag from PNNL Leach tests indicate that glass, hibonite, are unstable at pH<4, corroborating leachate chemistry and provide limiting phase for solubility calculations

So What?

What's the Bottom Line?

- What IS a Slag? What is IN a Slag?
  - SDMP slag phases characterized
- Where is the U and Th?
  - In discrete phases - Pv, Calz, Glass, Pyrochlore, Thorianite
- What is the Leach Rate for a Slag? Does it change with time?
  - Beginning to determine these for archaeological slags
- What standard tests should we use, if any?
  - Will discuss findings with NMSS, CNWRA, and PNNL
- 17 SDMP Sites: Are they all the same?
  - No, but slags may be characterized by bulk chemical analyses, now that phases are known
- How does a Slag weather?
  - Grain boundary diffusion, glass dissolution, preferential leaching of certain phases

Characterization of Slag

Future Work

- Calculation of estimated leach rate from EMPA data (RES)
- Application of estimated leach rates to RESRAD for 3 sites (RES)
- Detailed EMPA characterization of elemental variation in leached and weathered slags
- Continued characterization of Archaeological Slags (JHU)
- Determination of long-term alteration mechanisms by HRTEM, EELS

Prediction of Metal Sorption in Soils

NRC Spring Visit
March 28-29, 2000

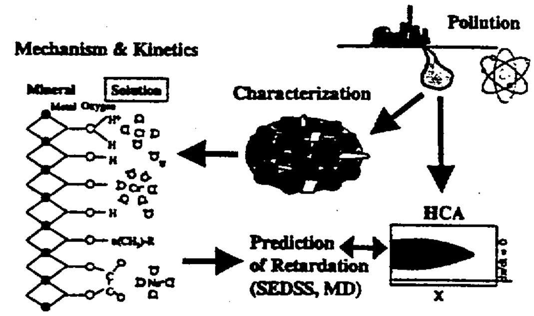
Westrich, H. R, Anderson, H. L., Arthur, S. E., Brady, P. V., Cygan, R. T., Liang, J. J., N. Yee*, Zhang, P. C., and C. F. Jové-Colon

Geochemistry Department
Sandia National Laboratories, Albuquerque, NM 87185-0750

*Department of Civil Engineering and Geological Sciences
University of Notre Dame, Notre Dame, IN 46556

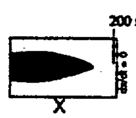
Supported by US Nuclear Regulatory Commission, NRR/RAA/RPERWMB

Metal Retardation and Migration



Background: LLNL Historical Case Analysis for Fuel Hydrocarbons

Examined several hundred LUFT plumes in California and showed that in the absence of remediation plumes stabilized at <200 ft, then collapsed.



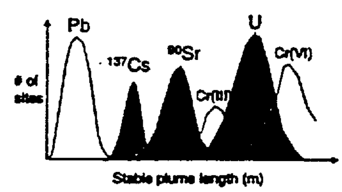
biodegradation
+ sorption
+ decay
± dilution
= natural attenuation

MNA = monitored natural attenuation

Impact

1. California immediately ceased active treatment of dissolved phase LUFT plumes
2. A majority of states have followed suit
3. MNA is now a de facto presumptive remedy for fuel hydrocarbons
4. EPA issued MNA guidelines for all contaminants.

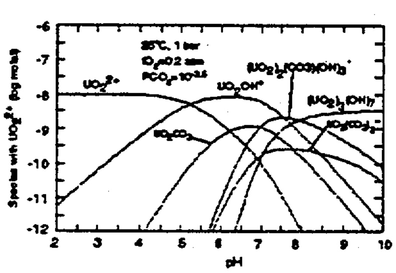
Metal and Radionuclide Historical Case Analyses (NRC-SNL/LLNL/EM40)



Compile large number of plume case studies to:
1. Identify general controls on plume movement, and
2. Determine limiting plume lengths.

Compelling Features

1. Presumes zero technical knowledge on the part of stakeholders/legislators.
2. Provides transparent and persuasive picture of risk.
2. Drives dialogue to technical realm.



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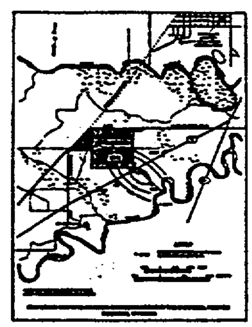
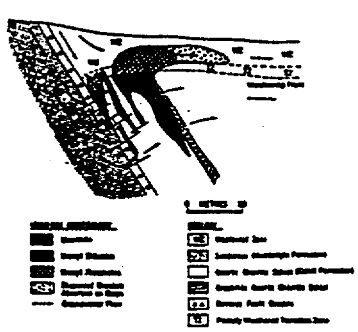
Problems

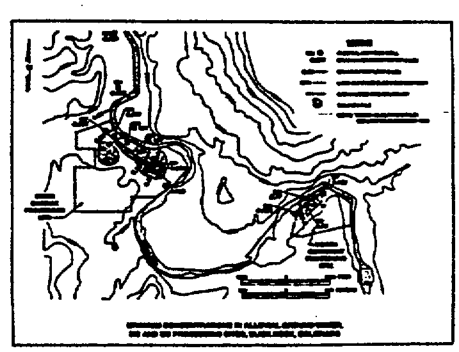
1. Little long-term monitoring
2. Sometimes poor location of wells
3. Rivers!
3. Vastly different geologies, permeabilities, K_d's, hydraulic gradients, source terms, fluid influxes, times…

Plume measurement Approach

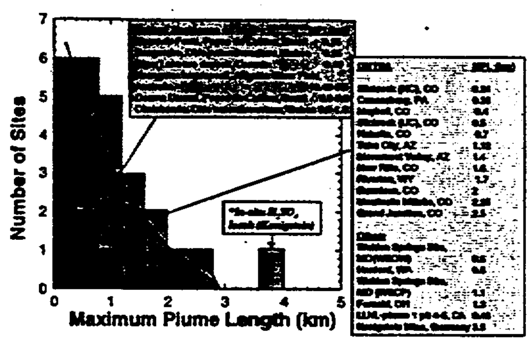
1. Maximum Plume Length = Maximum separation of 10-20 ppb contour
2. Err on the side of greater plume length
3. Plumes appear to be at steady state.



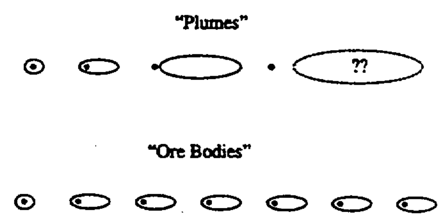




HCA for UMTRA and Natural U Sites



A New Approach to Conceptualizing Groundwater Transport of Inorganic Contaminants



Further Work

1. Finish U plume Data Base
2. Develop ^{90}Sr and ^{137}Cs plume analyses
3. Explain exceptions

Web References

LLNL LUFT HCA - http://www.llnl.gov/environment/erd/nco/

LLNL CVOC HCA - http://www-erd.llnl.gov/library/AR-133361.pdf

SNL Natural Attenuation Project - http://www.sandia.gov/eesector/gs/gc/snap.html