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Agency: Nuclear Regulatory Commission
Advisory Committee on Nuclear Waste

Title: 64th ACNW Meeting

Docket No.

LOCATION: Bethesda, Maryland

DATE: Tuesday, May 17, 1994 PAGES: 1 - 206

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UNITED STATE NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

DATE: May 17, 1994

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE

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64th ACNW Meeting

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Nuclear Regulatory Commission
7920 Norfolk Avenue
Room P-110
Bethesda, Maryland
Tuesday, May 17, 1994
8:30 a.m.

ACNW MEMBERS PRESENT:

Martin Steindler, Chairman
Paul W. Pomeroy, Vice Chairman
B. John Garrick
William J. Hinze

ACNW STAFF PRESENT:

Richard Major
Howard Larson
George Gnugnoli
Lynn Deering, Designated Federal Official

ACNW CONSULTANT:

Robert Hatcher, ACNW Consultant

P R O C E E D I N G S

MR. STEINDLER: The meeting will come to order.

This is the first day of the 64th meeting of the Advisory Committee on Nuclear Waste. Most of today's meeting will be open to the public, except the portion pertaining to the appointment of new members.

During today's meeting, the Committee will be briefed by the NRC staff on research and technical assistance related to the tectonics of the proposed Yucca Mountain site and hear a report on recent activities of the National Academy of Sciences' Yucca Mountain Standards Panel; discuss anticipated and proposed Committee activities, future meeting agenda, administrative and organizational matters, and appointment of ACNW members.

That session will be closed to discuss organizational and personnel matters that relate solely to the internal personnel rules and practices of this Committee and matters, the release of which would represent a clearly unwarranted invasion of personal privacy.

Ms. Lynn Deering, who will be here in a second, is the designated Federal official for the initial portion of the meeting.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. We have received no written statements or requests to make oral statements from members of the public regarding today's session.

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.

Before proceeding with the first agenda item, I would like to cover some brief items of current interest, but before I do, if there is anyone in the audience or elsewhere who has an interest in making a statement or contributing to the topic of discussion today, he should let Lynn Deering know, and we will try and make arrangements for that information to be passed to us.

As far as items of current interest are concerned, there has been a new group that has been formed in the NRC's Office of the General Counsel. This new group is called the Nuclear Waste Management Staff. This group will provide legal advice and recommendations regarding high- and low-level radioactive waste disposal, spent fuel storage, and transportation issues, a sharp focus of the Office of General Counsel on issues that pertain to the business of this Committee.

It will serve as a focal point for analysis of legal issues associated with nuclear waste and spent fuel storage, and the group will be headed by Mr. C. William

Reemer.

Another item is that the Office of State Programs is developing an electronic mail system between OSP, the Office of State Programs, and the Agreement States using Internet. This e-mail file transfer capability is expected to greatly improve the NRC's communication with the Agreement States by reducing the time to convey information to and from the States.

The Department of Energy and Envirocare have recently signed a $23-million contract for disposal services for mixed radioactive and hazardous waste generated as a result of environmental remediation and waste management activities of the DOE sites nationwide. This contract is going to cover 15,000 cubic yards of material to be deposited over the next 5 years.

INPO indicators have shown a continued drop in utility low-level waste generation, an interest which we have had for some time in this general trend. The 1993 marked the fourth year in a row that PWRs have produced less low-level waste in their target level and the third year for the BWRs.

As a matter of rule of thumb, for those of you who follow that, PWRs produce an average of 45 cubic meters of low-level waste in a year, and the number for the BWRs is 159 cubic meters.

There are two other items which I think we need to note. John Greeves, who is currently Deputy Director of the Division of Waste Management, was presented a 1993 Presidential Meritorious Executive Rank Award, and Norm Eisenberg, who spent considerable time with us yesterday, who is a section leader in the Performance Assessment and Health Physics Section of the Division of Waste Management, was presented an NRC Meritorious Service Award for Scientific Excellence. Both of those awards, I am sure, are well deserved.

With that, let me turn to the first agenda item. As is our practice, a member of the Committee will, in effect, chair that portion of it. In this case, this is Bill Hinze.

Bill, the meeting is yours.

MR. HINZE: Thank you, Marty.

Tectonics, as we all know, is very much involved in the nature and processes going on at the Yucca Mountain site, and we also know that there are many unknowns in the tectonics area, and thus, it is appropriate that NRC does conduct research in the tectonics area.

Today, what we will be doing is receiving an overview of the NRC Research Program. The purpose of this review or overview is part of our continuing evaluation of certain segments and certain elements of the High-Level

Waste Research Program evaluation that we are performing at the request of Chairman Selin to look at the High-Level Waste Research Program in terms of its relevancy, to licensing concerns, the development of regulatory guidance, also the timeliness and the sufficiency of that research.

We have already looked at volcanism. We have also had a chance to review some of the work in natural analogs, and at the June meeting, we should be hearing some more on the tectonics, but today, what we have is the staff of NMSS to make a presentation to us. That will be followed by Research's presentation of the overview of the Research Program, and then we will look at some of the specifics in terms of the work that is being conducted by the Center and its staff, as well as its contractors.

This is a terribly exciting topic, and I know it is particularly exciting to my colleague on my left, who is Robert Hatcher, the consultant in tectonics to the Committee.

I apologize for not introducing you before.

We will move now to try to keep on schedule. The Committee does have an appointment at 12 o'clock, and so we will have a guillotine at that time. This is a terribly interesting topic. We could go on for some time, but we are going to have to limit our discussion.

Unless my colleagues have anything to add, what we will do is ask Keith McConnell, who is the section head of Geology and Geophysics -- and I don't know that that has changed in terms of its title, Keith. Keith, what we are particularly interested in is learning from you the principal concerns that you and your staff have in terms of tectonics, in developing guidance for DOE's work, and looking forward to the licensing problems. It is also very important that we learn about the uncertainties that you feel are present in these identified concerns.

With that, the floor is yours.

MR. McCONNELL: Like Dr. Hinze said, we are here this morning to brief you on both the technical assistance and Research activities in the topical area of tectonics.

Just to make sure you are clear, technical assistance is directed and managed out of NMSS, the Division of Waste Management. Research is directed out of the Office of Research.

This isn't in your vugraph, but I have been asked to briefly introduce the speakers that will be making presentations today. I am Keith McConnell. I am going to speak to the definition of licensing needs, basically the systematic regulatory analysis and the development of the license application review plan with respect to tectonics.

Following that, Bill Ott will then speak to the licensing needs and how that relates to the research activities that are ongoing. I have been informed that Brian Wernicke now will speak after Bill to address the GPS, global positioning satellite activities. Brian, of course, is with Caltech. That will be followed by Larry McKague, who is the project manager down at the Center for Geology and Geophysics work. He will give you an overview of CNWRA tectonics activities. Then Steve Young and David Ferrill of the Center will provide you more detail on the status of various tectonics technical assistance and research activities. Finally, Bill Ott will try to sum things up.

The objectives of the overall presentation today, basically, are fourfold. First, we would like to demonstrate to you that there is a framework in existence for licensing needs to drive the technical assistance and research activities in the topical area of tectonics. Second, we would like to demonstrate that there is a method of prioritization of technical assistance and research activities. Thirdly, we would like to demonstrate that the technical assistance and research activities that the Center is performing, now and has in the past, are providing timely and valuable input to address licensing issues and needs. Finally, we would like to demonstrate that technical assistance in the topical area of tectonics is integrated with other disciplines and also with the performance assessment activities.

MR. HINZE: I guess we can quit at that point, then, if we have got the problem solved, right?

MR. McCONNELL: I am sure you won't have any questions after this either.

[Laughter.]

MR. McCONNELL: My particular presentation will follow this outline. Basically, I will go through with you the license application review plan activities that we have done to date, the status of the LARP development in the area of tectonics, the identification of what we call key technical uncertainties related to tectonics, and it is the key technical uncertainties, again, that drive the technical assistance and research activities. I will then discuss the user needs that we have identified to date, and the user needs, of course, are the factors or the mechanism that we use to transfer our licensing needs to the Office of Research, so that they can then develop their research statement of work. Finally, I will briefly discuss the CNWRA technical assistance to the Division of Waste Management, and that will include both some of our reactivities, very briefly, and then the proactive activities including the SEISM 1 code development work and the tectonic modeling and data analysis efforts that are ongoing now.

MR. HINZE: Keith, before you remove that, let me make certain that we are together. The Center is now working on the basis of user needs that have been presented by you and your staff previously.

The KTUs are being detailed by the NMSS staff and may lead to additional user needs or more specificity to the current user needs?

MR. McCONNELL: It could lead to either.

MR. HINZE: It will supplement the user needs then -- is that the proper term, the "user needs"? -- the existing user needs?

MR. McCONNELL: Well, there is a hierarchy to meet.

If I can jump ahead, this is the last diagram in your package. There is a specific hierarchy that we are trying to develop in this framework, and it starts out with the compliance determination strategy which is in the LARP, License Application Review Plan.

In that strategy, we have identified the key technical uncertainties, and then there are a series of user needs that are in existence that we have tried to tie to addressing the uncertainty that these key technical uncertainties represent, and these are represented by user needs 607, 612. Again, this is research. It feeds into this key technical uncertainty which then feeds into the overall strategy for the review of structural deformation.

So it so both down and up.

Going down, identification of the key technical uncertainties and the development of the user needs, they are then feed to research. Coming back up, research would give us the results. It would feed into this key technical uncertainty and then into the review of structural deformation.

MR. HINZE: That bottom line, then, may come up with no new user needs? It wouldn't necessarily come up with it?

MR. McCONNELL: Potentially, but I suspect that we are, and I have a vugraph that addressees that. I think we will.

MR. HINZE: I think we are together now.

MR. McCONNELL: Okay.

This is the status of the LARP development to date. Compliance determination strategies for the potentially adverse conditions related to structural deformation and seismicity have been completed and are in the License Application Review Plan Rev. 0.

Compliance determination methods, which is the details that fill in the strategy have not been completed, and they are scheduled for FY '95 through FY '98.

The existing compliance determination strategies, those that relate to the potentially adverse conditions, do not address the probability of structural deformation in the future or the consequences of fault displacement or structural deformation, and that is because of the way the rule is worded. Potentially adverse condition with respect to structural deformation says is there evidence for structural deformation in the quaternary, and a strict interpretation of that requirement says you only look at what has happened in the past.

So, to this point, the key technical uncertainties related to fault displacement of structural deformation, basically, only apply to the pass, the quaternary record. We haven't addressed to this point in the CDSs the projection of fault displacement or structural deformation.

MR. POMEROY: How do you propose to do that, Keith?

MR. McCONNELL: Let me move to the next vugraph.

MR. POMEROY: Sorry.

MR. McCONNELL: It is under discussion at the staff or in the staff how we are going to do that, and there has not been any clear resolution. It could come in several forms.

One, it could be part of the overall geologic system description, compliance determination strategy, or it could be another PACs or FACs. At this time, it hasn't been resolved where the projection of structural deformation is going to occur and where those key technical uncertainties would be identified.

To address Bill or, maybe, Paul's comment, there are additional key technical uncertainties that we think will be identified when we do get into looking at the projection of fault displacement hazard or fault displacement, and these review plans or these key technical uncertainties will probably require independent analyses and possibly research activities.

All key technical uncertainties were planned to be developed by the end of this fiscal year, and there was supposed to be an integration effort this year to make sure they were all of the same level and same scope, an evening-out process, and at the input of the ITA effort was integrated into the identification of the KTUs, all by the end of this fiscal year.

MR. POMEROY: Keith, is that the process that Margaret just described to us earlier of the sharpening of the KTUs, more focussed KTUs to make it more specific and pointed towards the needs of licensing?

MR. McCONNELL: Yes.

In order, I think, to develop this framework, there was a great deal of effort last year, last fiscal year, in the development of the compliance determination strategies, and there was a recognition at that time that there would be a need for some fine-tuning of these KTUs.

The identification of the key technical uncertainties that exist to date that have fallen out of our compliance determination strategy development are listed in this and the following vugraph, and there are basically seven. I have annotated them as either a Type V or a Type IV review.

This is the prioritization mechanism that is in place in the SRA work. A Type V review is the highest review level, and it relates to those uncertainties that are so great and have such a large risk of not meeting the performance objectives that the staff considers that there is a need for independent evaluation, and therefore, we develop independent review capabilities.

So it is the Type V's, and those are the ones I will focus on in reading through them, that are the primary drivers of research and technical assistance activity.

To date, I think there have been four Type V key technical uncertainties. One relates to the evaluation of fault mechanisms in alluvium. This relates to the difficulty, particularly at Yucca Mountain, in determining both the style and magnitude of displacement in the faults there.

A second KTU relates -- and this is similar to you because there is one, I guess, opposite or parallel igneous activity, and that is the development and use of conceptual tectonic models as they relate to structural deformation. Again, it is having a range of structural models out there and not knowing which model is the most applicable or the most real, how do you handle that uncertainty in your review and your assessment of repository performance.

The correlation of earthquakes with tectonics features at Yucca Mountain, the historical seismicity does not correlate well with the observed faults at the surface. The uncertainty in what the seismic hazard is, is rather large, and we have to deal with this in our review, and DOE is going to have to deal with it in their demonstration of compliance.

The last Type V review relates to the paleofaulting data, which indicates that seismic activity has migrated randomly from one major range fault system to another, and that key technical uncertainty addressees the temporal and spatial variability that exist in the basin and range that Bob Wallace identified probably 10 years ago or so now.

MR. STEINDLER: The designation of whether you have a Type IV or a Type V is done by consensus among your staff?

MR. McCONNELL: Yes. It is developed by consensus. It is then reviewed by management, and it is approved by management. Only at that time is it identified as a KTU or a Type IV or a Type V.

MR. HINZE: I see. Remind me. Would you go over, please, what a Type IV is. What will that lead to? Type V is specifying that there will be research or activities. What does Type IV mean?

MR. McCONNELL: Type IV is a detailed review with analyses. It can use existing codes or existing data. There is not a direct requirement for an independent analysis by the Division of Waste Management or the Office of Research. So we don't necessarily need to develop an entirely new code to address that uncertainty in our review.

The Type V review says the uncertainty is so large and there are so many unknowns, and perhaps there aren't any codes out there that address that uncertainty, that we have to do our own independent analyses or code development.

MR. GARRICK: Is the uncertainty ranking totally driven by uncertainty as opposed to impact or consequence? In other words, I am not too concerned if the uncertainty is six or seven orders of magnitude, if it is between 10 to the minus 20 per year and 10 to the minus 14 when it may not be important unless it is down to 10 to the minus 6 or minus 7. It just seems to me that doing it strictly on the basis of uncertainty may be quite irrelevant in many cases. Can you help me?

MR. McCONNELL: Yes. There are many technical uncertainties, and their magnitude could be quite large, but it is only those uncertainties that do have a consequences to repository performance that are identified as key technical uncertainties. So there is a criterion, the identification of key technical uncertainties that says there has to be a high risk of non-compliance with the performance objectives before you can identify that key technical uncertainty.

Now, to date, that judgment has largely been qualitative, and it is the concept that IPA efforts will -- and Dr. Pomeroy mentioned this earlier -- will help focus and, perhaps, eliminate some key technical uncertainties based on the fact that the quantitative evaluation doesn't match the qualitative evaluation of repository performance when these are considered.

MR. HINZE: Is timeliness also a factor there in terms of fitting the logic of these together or in terms of DOE's program in trying to come to some type of conclusion regarding various aspects?

MR. McCONNELL: It is a factor, but this task, in particular, is basically guidance to the staff in the evaluation of a license application. Therefore, the timeliness is such that we will need these at the time of licensing, this input, but there are other activities that relate to the review of various documents, where timeliness does become more important.

In this pre-licensing consultative phase, we rely on research and technical assistance to help us in that area.

MR. HINZE: These several KTUs, then, are leading to the identification of research activities that might be carried on through research, right?

MR. McCONNELL: That is correct.

MR. HINZE: Okay.

MR. POMEROY: Just to follow that up, Keith, this is a plan for the future then? There aren't necessarily research projects in place to address any of these key technical uncertainties at this point in time? Rather, are they addressing the user needs that already exist?

MR. McCONNELL: At this time, the user needs were the primary weapon or method of developing the search plan to date.

Now we are hoping to develop the framework where the key technical uncertainties drive the user needs which will drive research. So there is going to be a little period of time where we are going to have to reorganize or integrate to make sure there is this one-to-one correlation between the key technical uncertainties and the user needs and the research work that is being conducted, research and technical assistance.

MR. POMEROY: Thank you.

MR. McCONNELL: I would like to make it clear, that is not to say we are doing things now that we don't think will feed into the key technical uncertainties eventually. We do have a concept of what the licensing needs are, and we think the research and technical assistance activities are addressing those needs.

MR. POMEROY: To carry it one step further, let me pick one that I am interested in; namely, the correlation of earthquakes with tectonic features. Is there a research program that specifically addresses that at this point in time?

MR. McCONNELL: There is, and it is basically a literature review to show what exists, and you will see some more of this when Larry and Steve Young talk that there are activities directly focussed on that issue, and I think we will address that issue.

MR. POMEROY: Fine.

MR. McCONNELL: To go from the key technical uncertainties to the user needs, the user needs address the presence of the potentially adverse conditions related to seismicity and structural deformation, but they do not address the likelihood of future events and possible consequences, and that is not completely true with respect to seismicity because some of the seismicity potentially adverse conditions actually do refer to the likelihood of future events. So there are aspects of this that do address a future of seismic events, but not structural deformation, and again, it all relates to how the rule is worded and the effort to systems engineer, a rule that wasn't derived systematically.

The user needs were developed prior to the identification of KTUs and following the identification of all the KTUs that will be revised. We feel that they do address issues in the existing KTUs, and I will put up the existing user needs.

These numbers to the left here are the numbers that were used in the transmittal letter to Research to itemize the basic user needs statements.

MR. HINZE: What would be the date on that letter, roughly?

MR. McCONNELL: I think it was about four years ago now, so in 1990.

MR. HATCHER: I have a quick question. How are you going to know when you have all the KTUs identified?

MR. McCONNELL: Once we have all the CTSs developed, we should have an idea about what all the KTUs are. However, it is kind of an iterative process in that the results of research activities may in themselves define other key technical uncertainties. So we have yearly program meetings in tectonics and volcanism where the Research staff, the Center staff, and NMSS staff get together and discuss the KTUs and user need statements, and that is the mechanism where we try to create a loop, an iterative loop.

MR. POMEROY: Keith, can you tell us what the position? Go back a minute to the question of not addressing future events. Why is it necessary to move around in defining what we are doing here in the way of a technical program because of the way the rule is written? Wouldn't it make more sense to rewrite the rule or modify the rule to take this into account?

MR. McCONNELL: I think that was a policy decision that was made years ago. We are just the implementers at this stage.

MR. POMEROY: But it is not subject to review?

MR. McCONNELL: There has been consideration of that, particularly with the upcoming revision to the EPA standard. That provides an opportunity to, perhaps, look at these other areas where there is regulatory uncertainty, but then, particularly at this stage in the process, you have the potential of opening Pandora's Box.

DOE has been working in Part 60 now for a number of years. The change of the ground rules would mean you change just about everything in the program, potentially, the study plans, the site characterization plan. There is a mass of documents that relate to Part 60 as it exists now.

MR. HINZE: Is there any prioritization to that list that you provide? When you provided this to Research, did you provide a prioritization list?

MR. McCONNELL: No. I think when we provided this, they were all of equal priority.

MR. HINZE: How did you arrive at those? The SEP evaluation?

MR. McCONNELL: It was the results of our reviews of the SEP, our on-site visits, and other activities. Again, it was a qualitative look at what we thought were the key areas that both had large uncertainties associated with them and the potential to affect repository performance.

One of the desires of the SRA effort and the development of key technical uncertainties is to get away from two geologists sitting in a room coming up with ideas of what might be and get closer to a more quantitative look at what really matters with respect to the repository, and that is why the framework is in place. We haven't fully implemented it yet, but we are getting there.

MR. HINZE: Going back to the priorities aspect, there is a limited amount of resources within NRC for research. You provide this group of seven or eight user needs and uncertainties to Research, to implement a research program. Was there further interaction with Research in trying to decide which ones of these would be implemented with the resources available, and thus, was there an implicit prioritization?

MR. McCONNELL: There was some discussion in those areas, and it involved the Center, and since people aren't fungible and disciplines aren't fungible, there was some discussion of that, too, what was the Center capable of doing at that particular time.

MR. HINZE: Which ones of these were implemented or are implemented at the present time?

MR. McCONNELL: I think that, to varying degrees, all of them are being implemented. There are literature reviews in place which you will hear about that address most of the issues.

I think one thing we have to do is go back and look at will these address fully the key technical uncertainties, and that is an evaluation that we have to make in the future, and it may be, again, related to the integration of the user needs with the key technical uncertainties. It is how well do the activities identified in the statement of work address the key technical uncertainties.

Prior to that, we are trying to get our framework in place, so that we know the full scope of activities that are needed.

MR. HINZE: Meanwhile, the research isa going on and has been doing on?

MR. McCONNELL: That is true, but again, we do believe and we have sufficient control to know that what they are doing is providing us with the assistance we need. It might not be the complete scope or all that we need, but what they are doing does support what we need, the licensing needs.

I won't read through those, unless somebody objects.

I want to speak briefly about the technical assistance activities that the Center is providing to the Division of Waste Management. I have split them out into reactive and proactive. I won't spend much time on the reactive because it is not really the focus of today's work.

The Center does, as you are probably well aware, assist us in our review of DOE study plans and topical reports. You are familiar with the review of the volcanism status report and also the review of the erosion topical report that is in process now.

They also support us at NRC DOE site visits, technical exchanges, TRB meetings, and meetings such as this.

What I have termed as "proactive activities" in technical assistance are, basically, again, the SEISM 1 code development and the tectonics modeling and data analysis that is ongoing.

In the SEISM 1 code development work, Larry will be talking a little bit more about this in his presentation. The SEISM 1 code is a Lawrence Livermore code that was developed for siting nuclear power stations in the eastern U.S. The CNWRA is modifying that code for use in the western U.S. and, in particular, Yucca Mountain. To this point, attenuation functions for the western U.S. have been added to the code, and it has been run on the Center's computers, and we expect an interim report on the Center code development work at the end of August of this year.

The Center is basically doing in three areas. There is the geometric modeling, the cross-section balancing that we briefed you on, I think, about a year or so ago now. That is continuing at a very low level and only is done in response to the development of site characterization data. It is a mechanism for testing DOE's models for their validity.

The Center is also working on the computer simulation of faulting within the repository block and the coupling of processes, faulting and volcanism, and this is a specific attempt to take the structural deformation technical assistance activities and relate it to the iterative performance assessment. In other words, we are trying to develop quantitative models of what happens in the repository should displacement on something like the Bou Ridge Fault occur, and there is subsidiary deformation in that hanging wall in the repository block. So this is an input, we hope, into the iterative performance assessment activities.

Finally, there is an effort to develop a 3-D graphical visualization of tectonics processes at the Center, and this is to help permit the analyst or the reviewer to conceptualize what is going on in the repository block when he is conducting his review.

So, finally, what I would like to do is go back to this vugraph. It tries to relate all of the activities, both technical assistance and research activities, being conducted at the Center and how they relate to the key technical uncertainties.

I have divided them up into two categories: research and technical assistance. This is an old vugraph, and it used to be called analysis methods. So this is technical assistance, and this is research.

Again, we would develop the compliance determination strategy for structural deformation, potentially adverse condition. Under that, we have identified the three key technical uncertainties. We would then identify the research and technical assistance activities that are needed to support those key technical uncertainties, and in the area of research, we would identify the user needs statements that would then be transmitted to the Office of Research for action.

MR. STEINDLER: I am a little confused as to where this process starts. Does it start in the top, does it start in the middle or start in the bottom?

MR. McCONNELL: Unfortunately, because of the timing of where we had user needs identified prior to the development of the key technical uncertainties, it is kind of starting at both ends and meeting at the middle at this time, but we hope this fiscal year to get to the point where it starts at the top and proceeds down.

That is my presentation.

MR. HINZE: Questions?

[No response.]

MR. HINZE: Keith, one of the motherhood bullets at the beginning of your discussion was regarding integration, and you have just discussed an example of integration regarding the Bou Ridge Fault, et cetera.

Can you give us any examples of how your group is involved in the integration process and how you are monitoring this? Give me a little better feeling on how the integration act vity really works out in terms of communication links, for one.

MR. McCONNELL: Integration with the Center?

MR. HINZE: What you are doing is you are integrating in terms of the subject matter, and that is what I was concerned about.

For example, one of your bullets relates to the high-gradient area, and that is obviously very much of a coupled process with hydrology and with other concerns. How are you effecting the communication? How is communication taking place to effect the integration?

MR. McCONNELL: What Bill is talking about is this Type IV key technical uncertainty that relates to the large hydrologic gradient, and the integration occurs at two levels and across two levels.

In the development of the compliance determination strategy from which this KTU was derived, it was a mixed group of hydrologists and geologists. So there was integration at the staff level.

MR. HINZE: To define it, but how about in terms of solving the problem? How is that integration being worked out?

MR. McCONNELL: I think Larry will talk to that in more detail, but at the Center, there is a specific task that relates to the integration of these efforts across disciplines and into performance assessment. What happens is the performance assessment program element is the primary integrator. It is responsible for making sure these activities occur and that they are integrated across disciplines, and then the element managers back at NMSS in the Division of Waste Management are responsible for making sure that the Center is doing a good job on their integration. So it is occurring both at the center, and it is being overviewed and managed by the Division of Waste Management, to make sure that it does occur.

For example, in the IPA Phase III process, the performance assessment element manager is requesting a proposal from all of the other elements, like geologic setting, to integrate into the performance assessment activities next year, and that will be a coordinated effort between geologists, hydrologists, and seismologists.

MR. HINZE: Incorporating both Center and NMSS staff?

MR. McCONNELL: Right.

MR. HINZE: Let me ask you this. In terms of the communication with DOE, when we discussed volcanism, one of the topics was the lack of resolution of SCA comments and questions between NRC and DOE and the possible impact on the whole process of this lack of resolution.

Can you give us some insight into what is a parallel situation in tectonics?

MR. HINZE: Yes. Because of the time frames, I didn't go through the open items that exist with respect to structural deformation and seismicity, but there is, perhaps, a similar but less focal or less intense situation in that we do have a number of open items that relate to structural deformation and how it is characterized at the site and also how seismic hazard is characterized at the site, including the use by DOE of a 10,000-year cumulative slip earthquake, which they now, I think, abandoned.

Buck, have we formally resolved that comment?

We haven't resolved that comment, but DOE has indicated in their topical report that they are abandoning this methodology. So there are a number of open items related to that, and in every letter that we send to DOE on structural deformation or volcanism, we encourage them to attempt to have early resolution of these concerns and not let them go to licensing.

One of the things that the development of the LARP is doing is it is clearly laying out on paper the st 's concepts of what is needed to address specific issues. Extreme erosion is an example. We hope to have this year the compliance determination method for extreme erosion completed. That will finalize what we consider as necessary to address that issue, and with that at hand, DOE, I think, will have a firmer idea of exactly what the staff wants.

A lot of times, we don't speak to each other. We kind of speak around each other or hear around each other, and it is not clear what the staff needs and what the DOE is giving us. Sometimes the twain doesn't meet.

MR. HINZE: Does the lack of resolution of these items lead to expenditure of further resources on your part?

MR. McCONNELL: Yes. Part of the equation is a recognition that, perhaps, we have to develop our own independent or confirmatory analysis activity, and that relates to whether we think DOE is going in the right direction in a certain area. The example is the development of the probability calculations related to igneous activity.

MR. HINZE: Bill?

MR. HATCHER: Why the emphasis on determination of fault mechanisms and alluvium? Does that mean that you understand the faulting mechanisms in Bedrock where the repository is going to be located or is this just simply an area about which you know nothing and you would like to know something because of support facilities and that sort of thing?

MR. McCONNELL: The key tool that DOE is using to evaluate faulting mechanism in general is the examination of the quaternary record, and our regulations specify that they look at the quaternary record, and most of that involves trenching, and that is in the alluvium.

They haven't been successful in their Bedrock activities as far as dating faults, dating the timing of faults. There is some work where they are able to develop the mechanisms, the strike slip versus dip slip.

Since most of the work is being conducted in the alluvium, in the quaternary alluvium, we felt that that was where the focus of our user needs should rest because that is where the large uncertainty exists.

MR. HINZE: John Trapp?

MR. TRAPP: John Trapp with the NRC.

One of the reasons that that came out as a key technical uncertainty in addition to what Keith has brought out there is there are several articles in the literature, such as the ones by Banella, which are talking about how these faults propagate through alluvium and the fact that many of the faults that you see in Bedrock, et cetera, which you know have moved do not show any type of displacement in the alluvium. So you are getting a false representation of the amount and severity of fault. This, like I said, was one of the key reasons that this thing came to the front.

MR. HINZE: Thank you, John.

Marty?

MR. STEINDLER: Can I go back to that last diagram? I continue to be confused.

If your compliance determination strategy sets the framework for the definition of KTUs, which in turn defines both technical assistance and research, why do you need user needs?

MR. McCONNELL: User needs are developed to transmit. They are more specific. They are derived from the key technical uncertainties, and so they are more specific than the key technical uncertainties. They address specific issues in the key technical uncertainty itself, and we needed a mechanism to transmit that information to the Office of Research, so that they can then develop their statement of work.

MR. STEINDLER: If that is what you expect of them, I guess my naive approach would be to find them between your KTU box and the research box.

MR. McCONNELL: Yes. Yes, I agree. I see what you mean. The box is confusing. It should be up here. Yes.

MR. HINZE: Paul?

MR. POMEROY: Keith, I was wondering a little bit about one of the things that we are concerned about which is timeliness of the research activities. To use a specific example, you have a user need No. 606 which is evaluation of the appropriateness precision and accuracy of probablistic seismic hazard analysis for long-term predictions.

As we have talked about, it is possible that the DOE may come in to you with a technical or topical report on seismic hazard analysis in the foreseeable and, perhaps, near future, and will you have the tools that you feel are necessary in hand as a result of the research that has gone on under user need 606 to evaluate that probablistic -- presumably probablistic approach that DOE will propose?

MR. McCONNELL: That user need is one that we haven't specifically implemented with the Office of Research, primarily, because we do have technical assistance activities that, at least in part, address that, and that is the development of the expert panel by the Center that involved a number of well-known experts to assist us in the development of a staff technical position on fault displacement and seismic hazard and the user of probablistic versus deterministic techniques. So there were things in place as far as technical assistance that said we didn't necessarily need to implement that user need at the Office of Research.

So, to answer your question, I think we have the mechanism in place and the people on board to help us in that review.

MR. POMEROY: Would you anticipate that there would be a technical position generated by NMSS with regard to the analysis?

MR. McCONNELL: The budget for FY '95 identifies that position as one that will be initiated in fiscal year '95 and hopefully completed in fiscal year '96, and that has been concurred on by management of the division.

MR. POMEROY: Thank you.

MR. HINZE: Are you the person to ask what is the relative percentage of TA and research work going on at the Center?

MR. McCONNELL: With respect to this particular --

MR. HINZE: Tectonics.

MR. McCONNELL: I am the person to ask, and I would probably say that it would be, if you include the reviews of various documents, perhaps, equal or a little bi tin the favor of research in the area of tectonics.

MR. HINZE: In the area of tectonics, what percentage of your technical assistance and related work is done by the Center versus your own staff? How much of your technical assistance types of activities are done by the Center and how much are done by your own staff?

MR. McCONNELL: At the present time, most of the reviews of study plans and the primary review of topical reports is done by the staff. If there is an area where we don't have expertise, we rely in a much greater detail with the Center. We did that for extreme erosion. We didn't have the expertise on staff to address that particular issue.

The modeling activities in the area of tectonics have been done largely at the Center. The computer resources and the expertise in computer balancing and computer activities rests at the Center.

MR. HINZE: We heard yesterday in the high-level waste performance assessment working group meeting about the excellent computer facilities and Earth Vision and the various codes that are going to be available. Do you have now in your own group the ability to balance sections? Do you have programs for handling this, using this hardware? What are your abilities in this area?

MR. McCONNELL: These are being developed, but at the present time, we have the hardware in place to work with Earth Vision. We don't have the cross-section balancing work that Steve Young has done. Again, that is being done at a very low level. So we have, basically, the 3-D visualization effort.

Eventually, we will probably have all of that on the NMSS hardware, but the NMSS hardware effort and software development is behind Center development at this stage, I would say.

For the geographic information systems, we have plans to make sure that the Center in their development of the data base supplies the NMSS staff with an equal data base.

MR. HINZE: That was my follow-on question, really, leading to that in terms of the success for your people. Is that now available?

MR. McCONNELL: Only through the Center.

MR. HINZE: Only through the Center.

MR. McCONNELL: There are parts of it that have been transferred up to the division's computer but I think that will be done mostly in FY '95, if I am not mistaken.

MR. HINZE: If there are no further questions, we are 26 seconds ahead of schedule. With that, you have set a record, and we appreciate the extra time that you have given us.

Bill, before you start your discussion, would you explain what you are going to present and what kinds of sequence and so forth?

MR. OTT: What I am going to try and do is provide a transition from what Keith has described in terms of the NMSS program to the research presentations that you will get following.

In terms of order, I am going to try and give you a diagram at the front to stimulate a little bit of discussion about how this all fits together.

If you look at the research program from the point of view of the budget structure, we have an area that we call geologic systems research. Under geologic systems research, we have three areas. We have hydrology, we have geochemistry, and then we have geology research. Within geology research, we have the tectonics and the volcanism programs.

We have briefed you on the volcanism programs earlier this year. Today, we are going into the tectonics side.

In the first vugraph, after the obligatory announcement of who I am and also the obligatory apology, I noticed this morning that when I was doing this, I put the arrow in the wrong box.

In the final analysis, we want to come down with something that helps us analyze the repository site in terms of assessing the contribution to release to the environment from geologic processes, such as volcanism and seismic events, which are all tied up in the tectonics setting of that Yucca Mountain site.

We previously, two years ago, presented to you separately flow diagrams for projects which we were planning in volcanism and in tectonics, an we never put them together on a single chart. They both contain this program which has not yet started, which is called the modeling of mantle dynamics, where we hope to pull everything together and integrate it all.

There is actually some integration between this project, which is the primary Center project in tectonics, and this one which is the first project in volcanism in the basin and range. I will get into that in a second because it shows up in the task structure where the first three tasks of the two projects are, essentially, identical, with one project focussing on the volcanic features and the other one focussing on tectonics features.

This gives you an idea of the timing of these projects, and I will relate this back to something that Keith said and the question that you have asked before in terms of the user need. Keith said that the user need is about four years old, and he is correct because that is when it was originated. However, when we were preparing the plan to go to ACNW a couple of years ago, we asked NMSS to do a revisiting of the user needs statement. So the user need was revisited as recently as two years ago, and the version that you have in the draft NUREG-1406 was actually revised and reissued to us by NMSS in '92. So it is not really that those things are four years old. The initial identification might be four years old, but as of two years ago, NMSS and Research still agreed that those were the operative things that we needed to be working on.

You will notice, also, that around '92 is when most of the work that is going on now finally started. The

Volcanism and basin and range project began then. Around that time, we had two proposals submitted to us as grant proposals, one on seismic pumping by Jim Wood at Michigan Technological University and one by Brian Wernicke. At that time, he was at Harvard.

I have listed it here as "Regional Strain Geoticy" because the title is too long to put in the little box, something like contemporaneous strain rates in the basin and range. Brian can give you more detail on that when we get around to it.

They were both submitted to us at the same time, and the decision was that since they were actually of very real interest to what had to be done -- in terms of Brian's, the strain rate, extremely critical interpreting what is going on tectonically. The seismic pumping very strongly related to the Szymanski report which had come out in the same time frame.

It was determined that we couldn't fund them as grants. Grants have to be more farther away from the real -- if it is that important, you ought to be funding as a contract. So we went through a rather lengthy process of converting these things into contracts, placed both of them.

Unfortunately, Jim Wood's project has just ended. He was in, actually, last week to do a final briefing, provide us a draft of his final report, which we will give to you. I will go very briefly into a little of what Jim would describe to us.

Ed O'Donnell and Linda Covack are here and were at the briefing and can give a little more detail if you have questions on it. We probably ought to defer that to getting you a copy of it.

I do apologize. George Birchard should be giving this talk. He just isn't available to us today.

MR. HINZE: Bill, if I might ask a question regarding that overhead, does this mean that all of the research that is going on at the Center is done under one statement of work that falls under regional extensional tectonics?

MR. OTT: At the present time, yes.

When we do start this modeling in mantle dynamics, there will be three operative statements. This is also a Center project. These two are Center projects. This is a Center project. This is the only one in tectonics that is a Center project at the present time.

MR. HINZE: Is the modeling of mantle dynamics authorized?

MR. OTT: We have not put the SOW on that together on that yet.

I will say that when we originally described the tectonics program to you, we had a separate project described, which was one on geochronology, to look at the techniques available to date all these various structures and events.

In the final analysis, we put a task into the regional project on geochronology and will probably wind up putting the funding that was set aside for geochronology into this project next to make this a larger project and take care of it under a single heading.

MR. STEINDLER: Before you take that off, I guess that is a fairly interesting diagram. The implication is that the modeling of mantle dynamics is the focus result of all of your activities, and I assume that past the year 2000, there is a customer at the end of that line who will find it is necessary and sufficient to have the data that you have assembled into this mantle dynamic model.

Is that a correct interpretation?

MR. OTT: It is a quasi-correct interpretation.

If you refer back to what Keith said, there are FACs and PACs that just deal with the features and with the investigation of those features. So there are products out of these three projects that are directly feeding into NMSS continual review of what DOE is doing.

In terms of the system assessment of the repository and the disruptive scenarios that involve either tectonics events, seismic events or volcanic events, that is where this project is aimed in the final analysis. This is a direct feed into the PA program, and I would hope would be feeding into IPA all along here. It is a question of when you get to the point where you have done enough. I don't know where the proper end of this is right now. I don't think we are far enough along to find that out.

MR. STEINDLER: Does it trouble you that that program, in effect, comes to a conclusion as late as the year 2000? Maybe that is not late in the way the DOE program seems to be going, but adhering to a schedule not too long ago --

MR. OTT: What I would say is that here in regional tectonics and in volcanism, these projects are supposed to be identifying and defining models that can be used in the PA process.

If at some point along the execution of this project we come to the point where we feel that we have adequate means to address this problem, then I would say that the project will die of its own weight. I am not confident. I can't say it with confidence that that will happen, and it may take longer.

MR. STEINDLER: So you are telling me that aligns to the customer extend not only from the mantle dynamic modeling effort, but also from the two or, perhaps, even three boxes surrounding it?

MR. OTT: Definitely, yes.

MR. STEINDLER: Thank you.

MR. HINZE: Keith?

MR. McCONNELL: If I could just add, we don't have to wait until the end of that box to get the results necessarily. There are intermediate milestones that occur in all of these activities where we do get products, we do implement those in our review plans and our reviews of DOE documents.

MR. OTT: A diagram of this is inherently simple because it does not display intermediate milestones.

MR. HINZE: Shouldn't there be some lines between the tectonics and at least the volcanism of the basin and range and, perhaps, even the field volcanism if there is proper integration?

MR. OTT: The way the projects are set up, the tasks are -- the first three tasks are almost identical with different focusses in two projects, one looking at volcanic systems and one in tectonics. Yes, there should be, and there is overlap. It is diagrammatically simpler to show it all feeding into the mantle dynamics.

The staff involved here are going to be the staff that are involved in these two projects.

The statement of work, I am going to go through this in a slightly evolutionary way to sort of show you how the projects evolved.

In terms of Brian's project and Jim Wood's, there was no process. They made submittals to us. We made a determination that the information was a value when we funded the projects, but this is fairly typical of what we would do for a Center project.

We transmitted an SOW to the Center in October of '92, and it referenced all six of those user needs that were listed that Keith mentioned. It specifically referred to the Brian Wernicke and Jim Wood projects in terms of integrating the data from those projects. It specifically assigned an integrating role to the Center to pull all that work together, and as a specific objective, it said we need to develop performance assessment capability. So we need to keep an eye in the evolution of this project as the provision of techniques and capability to IPA.

After this, we provided a proposed task structure to the Center, and we, essentially, proposed the first three tasks that were identical to that, which were proposed to the volcanism project, except that tasks three in the critical data review.

The assumption when both of these projects were begun was that there is a tremendous amount of data out there on the basin and range which has not been compiled and that we really need to know what has been done before we try and do something new. So that was the motive for the literature review and data compilation: let's get all this data together and take a look at it. Then there is how good is this data. So the third task was critical review of data.

For this project, there was additional amplification which said your critical review should have emphasis on integrating models of seismicity with models of structure, geological structure, modeling of faulting and deformation, and modeling of seismic hazards in regional tectonic processes. So here is where we started to part from the volcanism project in terms of specifying the focus for the critical review of the tectonic data.

What I am providing you here is the structure that we gave the Center in terms of the SOW. When Steve Young gets up and Dave Ferrill, they are going to talk to you about structure of the actual project which is underway right now, and you will be able to judge for yourself how faithfully what is being done reflects back on the process.

MR. STEINDLER: Is the implication of that previous vugraph that DOE has not done this or that you don't have access to what DOE has done in that area?

MR. OTT: The implication was that we had -- how do I say that?

Do you want to make a statement about what you feel DOE has done in terms of that area? I don't want to prejudge something.

MR. McCONNELL: That means getting the data?

MR. STEINDLER: Literature and data compilation and, perhaps, critical review of data strikes me as a precursor to anybody's research program, and DOE surely must have done that. No?

MR. McCONNELL: They have. They did that primarily in their site characterization plan several years ago.

t is getting all of that information into a format that is usable and manipulatable that the Center is working on; in other words, putting it into a GIS type of data base, so that people can manipulate it.

There are activities or actions between the staff and the DOE to try to make this smoother, too, to where DOE will just transmit us an electronic copy of the report or of a data package to where it then can be entered in without having to go through the process of digitization or something like that, but their program isn't fully implemented and neither is ours.

MR. OTT: To a certain extent, we had a perception also that DOE was not looking as far afield as we would in terms of understanding the structure and the basin and range.

Task four was designed to develop field studies, to establish cenozoic strain in the basin and range as they relate to Yucca Mountain, and to test and confirm models of tectonic evolution of the basin and range.

Task five, as I mentioned before, was the geochronology task, a literature review of methods, and this also contained the requirement for a study plan to assess the reliability of radiometric and other age determination techniques, and specifically here, I have made a reference to the Black Mountains field site because we have had several questions in the volcanism review about work being done at Black Mountains and why is it being done in their tectonics as opposed to being done under volcanism since this, essentially, is a volcanic system, but it is being looked at as an analog that can provide data in a number of areas; in particular, in the geochronology area, these age-dating techniques, also in terms of a deep structural analog. So there are several reasons that it appears here in task five. Steve can give you more detail on that later if you have further questions.

The last task six is assessment of data and development of alternative conceptual models of tectonic processes, and these alternative conceptual models would then be fed into the modeling and mantle dynamics project to be coupled with the same types of output from the volcanic program to help us get a fairly good hand on how to represent these processes in the PA process.

The seismic pumping project I mentioned, it is primarily funded because of a great deal of attention that occurred around the time of the Szymanski report. The project as a grant -- both Brian's project and Jim Wood's project were submitted as grants, which meant they actually asked for very little money. Both of these projects were funded at a rate of about $50,000 a year, which is currently our limit. The office tries to fund grants at that level or lower.

He proposed to look at two sites in California, one at Elk Hills, which is an area where there is a large petroleum reserve, and the Salton Sea site, which is a geothermal power generation location. Here, he was looking at formations at about 4,000 feet. Here, he is actually looking at the evolution of calcite deposits in the equipment in the piping to see how these calcite formations form as a result of a release of over-pressure. Sc here he is looking at process, and here, he is looking at some actual natural formations to see if he can make some judgments with regard to whether these were seismically induced features.

MR. HINZE: How will the results of that work be brought to the attention of DOE and the public?

MR. OTT: The final report has been submitted. I presume we will publish it as a NUREG. If NMSS feels it should be brought specifically to the attention of DOE, they will mention it.

Some of this here might have some impact on --

MR. HINZE: Is this the kind of thing that you would compare a research summary, trying to point out its relevancy to licensing problems?

MR. OTT: That is also a possibility, yes.

The results of the project were to develop an approach for assessing the origin of veins in cements, specifically calcite and opal veins, to examine the use of carbon and isotope ratios in the cements and the fluid inclusion. This is part of the methodology that he has developed.

They concluded with regard to the Elk Hills veins that they were formed as a result of seismic events from a narrow window in time. Basically, what that means is that Jim doesn't know whether this was a single seismic event or a series of seismic events. He does feel that these veins were formed over a fairly small window in geologic time, and he does feel that they have a seismic origin.

He was asked by George to take a look at his methodology with regard to the data that has been examined at Yucca Mountain with regard to the Szymanski report in terms of the calcite veins in those trench deposits. Taken along, specifically with regard to the carbon and isotope ratio techniques, people in the oil industry would consider that those veins were probably thermogenic in origin, but taken alone, they are insufficient at the Yucca Mountain area, and I guess there is significantly more information available in those Yucca Mountain deposits than just the carbon and oxygen isotopes.

What he was saying, you can't put all your eggs in the carbon and oxygen isotope ratio basket because they alone are insufficient to make a determination.

MR. HATCHER: I thought a lot of the evidence from Yucca Mountain indicated these things were meteoric in origin and not hydrothermal or thermogenic, as you say here.

MR. OTT: Right, that is correct. What he is saying if you only look at the carbon and oxygen isotope date --

MR. HATCHER: Okay. Right.

MR. OTT: -- people in the oil industry would conclude that they were of thermogenic origin, but they are inconclusive.

MR. POMEROY: Bill, I think I missed something there. The conclusion regarding being formed as a result of seismic events, what was the approximate date of formation, and how did he conclude that?

MR. OTT: I couldn't tell you. We have the report, but I don't know that I can give you that information off the top of my head.

MR. POMEROY: Okay. Fine. Can we eventually get a copy?

MR. OTT: We will get you a copy of the report as soon as it is made final.

MR. POMEROY: Great.

MR. OTT: Again, I don't think I have been faithful to the actual title of the project, but this is Brian Wernicke's project. It was submitted when he was at Harvard University. He has since moved to Caltech. That gave us a little difficulty in the timing on the starting of the project.

It has a limited scope. It is very discrete, primarily involved in making GPS measurements. It is directly responsive to the user need on strain rates. It was a very close correlation in terms of something that we saw that we needed and something that somebody proposed to do for us, and we said let's go for it.

He has involved the Center and NRC staff on field trips. These field campaigns apparently involve a fair number of staff, and George has been out, I believe, on two of them, and some of the Center staff have been out there and involved as well.

I would also point out that Brian either is or has been consultant to the center. So he is also making his expertise available.

It was actually fortuitous for us. When he first came on board, we right away pulled him into the workshop and natural analogs that we had down in San Antonio a couple of years ago.

I am going to stop right there. The two last slides in that package, the conclusion slides, are what I will go into at the end when we do the wrap-up, okay?

MR. HINZE: All right. Very good.

MR. OTT: If you have no questions, I will turn it over to Brian.

MR. HINZE: Questions? Further questions for Bill? We will have another chance at Bill when he summarizes.

MR. POMEROY: Bill, do you have the same kind of problems that Keith does as far as the strain rates concern? I notice the user need is rather specific in saying evaluation of quaternary strain rate estimates, and you are measuring today's strain rate measurements. Do you have any problem about the quaternary versus the future?

MR. OTT: I don't know whether I should say it, but we have a little less problem than Keith does.

Keith is trying to provide a structure within the regulation. The SRA is built on looking at all the requirements that NMSS has to fulfill and doing it in a very specific fashion. They need to make certain that they have complete coverage.

On our side of it, we can look beyond what the specific requirement is that generates a given user need to what the contribution of that user need may be to other parts of the review.

If you will notice, when I gave the original task description for the Center project, I said we put an objective for performance assessment. The performance assessment KTUs in this area are -- I guess the best of you would say is poorly defined right now? Okay. But performance assessment needs to deal with potential disruptions of the repository that may be caused by either volcanic or tectonic activity, and I don't feel that we could ignore that in developing a research program.

MR. POMEROY: I don't think you can either.

When you decided to fund this program, were you aware of DOE's program which also involves GPS measurements of structural deformation in the Yucca Mountain vicinity?

MR. OTT: You mean specifically Brian's project or all of these projects?

MR. POMEROY: No. I mean the specific DOE project.

MR. OTT: We said when we started this project. Are you talking about Brian's project --

MR. POMEROY: Yes.

MR. OTT: -- or are you talking about everything?

MR. POMEROY: Yes.

MR. WERNICKE: If I may, there were no GPS measurements on Yucca Mountain prior to the submission of my proposal.

MR. POMEROY: Right, but I am asking whether they were aware of the site characterization plan statements with regard to that.

MR. OTT: Yes. We have been involved in the site characterization plan reviews. We feel it is necessary for us in developing a research program to be aware of what DOE is doing. We participate within NMSS on technical exchanges with the Department of Energy. We organize some of our own. We try to keep as closely abreast of what is developing there as possible.

MR. POMEROY: And I presume the logic was that this is a regional study as contrasted to a site-specific study, except for the fact that there is some overlap?

MR. OTT: [illegible] only that, there is a confirmatory aspect to some of our research. There are times when we feel that even if DOE is doing something, we would like some confirmatory work of our own and give this an independent basis for evaluating it.

In this particular case, we felt that the strain rates were so important to getting an overall picture of what the current and future status of the region was that that was one that was appropriate for confirmatory work as well as independent work.

MR. POMEROY: Great. Thank you.

MR. HINZE: Are there further questions?

[No response.]

MR. HINZE: If not, we will take a 15-minute break, and at that time, we will get Brian Wernicke's projector set up and his overheads prepared.

[Recess.]

MR. HINZE: In the second portion of this morning's meeting, we will be hearing Brian Wernicke. Brian is going to tell us about the research project he has been carrying on for NRC.

Brian, you will also be open to any questions about tectonic models or related problems of the southwest, right?

MR. WERNICKE: Sure.

MR. HINZE: Very good.

MR. WERNICKE: What I am going to try to do here this morning is explain a little bit of the rationale, both from a practical point of view and from a scientific point of view, of why we are doing this project, which is to look at the contemporary deformation of the southwester United States.

I can say right at the beginning, we are very far at this point away from a solid refinement of the displacement field on the major faults that are adjacent to Yucca Mountain as well as characterizing Yucca Mountain itself, although I will present some preliminary results of some baselines, in particular, a baseline known as Wahomie Mile, which runs from the repository eastward into Area 25 for which we have a lot of data spanning a 10-year period when we combine the results from our project with the results from the Yucca Mountain project, funded by the DOE, and work carried out by the United States Geological Survey.

If I could have the lights, I just have a few slides to start with, and then we will go to the overheads that you have in your package.

Yucca Mountain sits in the basin and range physiographic province, which is a series of north-trending basins and ranges. It sits basically right there. It is one of these ranges in the basin and range. It is part of what I would call a diffusely deforming plate boundary zone.

Now, there are a lot of spectacular mountain ranges and quaternary faults over this entire map area. The major plate boundary fault, the San Andreas Fault here, carries most of the relative plate motion between the Pacific plate and the North American plate. The vast majority of it and the most rapid strain accumulation and the largest and most frequent earthquakes all occur on the San Andreas Fault, and this is, of course, a very intensively studied structure from the point of view of geoticy, over a century's worth of geoticy, seismology, quaternary tectonics and the like.

It is separate from what appears to be a relatively stable block here, which I will call the Great Valley/Sierra, Nevada block from the actively deforming basin and range province. From the point of view of geoticy and quaternary faulting and seismicity, we know orders of magnitude less about how this area works than we do about how the major plate boundary fault works.

The dominating influence, to give you a bit of an historic perspective on the evolution of the plate boundary, this shows a series of frames here. In light gray, the Pacific plate; and in dark gray, the Ancient plate; and then uncolored is the North American plate, with north to the left of the diagram. This just shows in broad scale the evolution from 30 million years ago up to the present of this plate boundary.

The story, as many of you know, is that the Pacific plate impinged against North America about 30 million years ago. When it did so, it created two migrating triple junctions which slowly expand with time getting particularly significant in length by about 10 million years ago, and of course, now it is well over a thousand kilometers long.

The zone of diffuse deformation inboard from this plate boundary predates the impingement of the plate boundary, the Pacific plate against North America, by a substantial degree.

This shows a tectonic map of western North America with the major tectonic provinces, the basin and range province here which contains Yucca Mountain at about the end and central, which largely lies to the east of a zone of cretaceous shown here in pink.

The onset of extensional deformation within the basin and range ranges back to about 35- to 55 million years ago. There is possibly also diffuse extension and compression, certainly compression, accommodated in the cretaceous. So this zone of diffuse deformation between the various Pacific plates and North America is long-lived. It is not a new phenomenon.

The area of interest shown here, this is Death Valley, the Funeral Mountains, and the area of interest ended up on the ceiling in this slide. It is right here, Yucca Mountain. What we have been trying to do is characterize not only contemporary strain accumulation across Yucca Mountain, but also strain accumulation of faults like the northern Death Valley Fault, the central Death Valley Fault, and the southern Death Valley Fault.

This fault zone with a right step forming the half graven of Death Valley and continuing northward another hundred or so kilometers is long enough to generate a magnitude of 8 to 8.5 earthquake, and essentially, nothing is known about its contemporary deformation.

On to the overheads. To give you a general neotectonic picture -- and this is the first that you have in your handout -- this sort of busy thing shows the zone of seismicity associated with the right lateral San Andreas Fault, and then a broad zone of seismicity that exists inboard of that, both seismicity and strain accumulation.

The major seismicity is actually rather clustered. The inter-mountain seismic belt runs down the eastern margin of the basin and range, the central Nevada seismic belt in the west central part, and then a broad zone of seismicity and quaternary faulting that essentially branches up off of the San Andreas Fault and runs along the west side of the basin and range, just to the east of the Sierra, Nevada/Grape Valley block.

The total amount of strain accumulation that occurs across the San Andreas Fault is about 35 millimeters per year. The total plate motion, on the other hand, Sixteenth Street about 48 millimeters per year. This is a figure from a popular article in Scientific American by Minster and Jordan. This is the total Pacific plate motion according to their reconstruction as of about '91.

The San Andreas slip doesn't account for all of that, and they subdivided the discrepancy here, the so-called San Andreas discrepancy, into a basin and range extensional component here and a shortening component parallel to the coast ranges.

It has since been shown by refinement of the plate motion models that this vector is probably considerably smaller than this estimate, but the 9 to 13 millimeters per year of relative strain shown in the directions of the arrows here and here, largely tensional in central Nevada and the Wasach inter-mountain seismic belt area, predominantly right lateral strike slip faulting, plus some extension in what has recently been termed the eastern California sheer zone, also known as the Walker Lane Belt, which I have abbreviated here as WLB.

So Yucca Mountain, then, the major challenge is to try to understand how this 9 to 13 millimeters per year of deformation is how this amount of strain accumulation is distributed across this zone inboard from the Sierra, Nevada/Grape Valley block. Yucca Mountain lies within, sort of, the join between the belt of seismicity and the inter-mountain seismic belt and the zone of seismicity that we might call the eastern California sheer zone.

Over the last 15 years a program sponsored by NASA called the Crustal Dynamics Project, has emphasized a technique called very long baseline interferometry. This is basically using astronomical objects, the radiation from astronomical objects as interferometers to gauge tectonic deformation.

The early Minster and Jordan articles were sort of skimming the cream of this data for Western North America as it came out. A 54-paper set of volumes was recently published by AGU in 1993 summarizing the results of the Crustal Dynamic Project. The result of this project is that the global plate motion models, such as Nuvel-1 or Nuvel-1 no net rotation, agree within about 95 to 99 percent of what is observed in the contemporary deformation of various monuments set on the Earth's tectonic plates.

In other words, plate tectonics works but more importantly, there is to a 95 percent level of agreement, the rates over the last 15 years between the Earth's tectonic plates agree with those over the last 2 to 3 million years measured by reconstructing magnetic anomalies.

For our current problem was have a fixed North American plate and a number of VLBI monuments, also so-called SLR or Satellite Laser Ranging monuments. Yucca Mountain is about here. Sites that rest on the eastern boundary of the Great Basin, according to this -- this is from paper by Dickson, et al, which unfortunately I did not attribute on this slide, unless it's on the top there. No, it isn't.

This is from Dickson, et al, AGU, Geodynamic Series, Volume 24, I believe.

Basically, this confirms or shows to a high degree of accuracy that the western side of the Sierra Nevada -- western side of the Great Basin, that is, the Sierra Nevada block, is moving at 8.6, 10, 13.9, 8.9, 8.9 millimeters per year, pretty much north or northwestward relative to the interior of North America. The site at Ely is moving about 5 millimeters per year in a more easterly direction.

This agrees relatively well with the direction of seismic moment release in the inter-mountain seismic belt, which has an easterly component, so Ely is moving east. And then the strong right shear in the eastern California sheer zone, plus the oblique tension in the Central Nevada seismic belt all add up to give us about a centimeter a year motion of that particular block.

Where is the motion and how much of it is accommodated across Yucca Mountain? If all of it is across Yucca Mourtain, we have a lot to worry about. We don't know where it is. The purpose of this project was to figure that out.

This is a tectonic map showing the area between the Sierra Nevada Mountains and the Yucca Mountain site. Geomorphologically, there is a broad triangular zone here, sort of a tall triangle, coincident with the eastern California shear zone that is far more active in terms of quaternary deformation than regions to the east.

The northern Death Valley Furnace Creek fault is along essentially continuous fault zone here, which is basically over 200 kilometers long, bounds this sort of triangular zone with a relatively -- what I would call relatively inactive zone where Yucca Mountain is currently located. Then, another large structure to the west of that, the Hunter Mountain Panamint Valley fault zone. And then, finally, two major structures, the Owens Valley fault right here and the Independence fault right here are respectively a major strike slip in normal fault.

The 1872 magnitude, somewhere between 7-1/2 and 8. Owens Valley earthquake occurred right here.

The blue dots, which unfortunately came out black on your copies, show our monuments. We have a permanent GPS station at Ovro, one on the Sierra Nevada block. We have near-field and far-field stations straddling the Hunter Mountain fault and its central portion. Near-field and far-field geodetic monuments straddling the Death Valley fault zone, plus two down here in the south.

And then a five-station network, subnet, going across Bare Mountain. The Crater Flat area, Mile is right here. Monument Mile is right here. A monument called TJ67S, and finally Wahomie is right here. And we'll be looking at the Wahomie mile results in a couple of minutes.

MR. POMEROY: Can you give us an idea on that slide where the DOE GPS stations are located?

MR. WERNICKE: Yes. The current -- we'll look at that in just a second, --

MR. POMEROY: Okay.

MR. WERNICKE: -- but you reference Wahomie and Mile. Then I'll show their grid in just a minute.

MR. POMEROY: Surely.

MR. HINZE: Could you also point out where the Little Skull earthquake occurred in reference --

MR. WERNICKE: Yes. Little Skull Mountain earthquake was basically right about there. The epicentral region was right about there.

MR. HINZE: Okay.

MR. WERNICKE: The Yucca Mountain project has been surveying a network funded by the USGS, Jim Savage and colleagues, and this shows from a paper of theirs in press in JGR, or very nearly in press as I understand it. This shows their monumentation.

Wahomie is right here. Mile is right here. Our TJ67S is in between and we have two more monuments that don't correspond exactly with their monuments off to the west.

The Little Skull Mountain earthquake epicentral region is right about here, depending on which focal mechanism you choose. And there is no real basis at this time to select one, because our locations of aftershocks are not good enough. It could project to the surface about right there or about right there. It's a moderately dipping fault plain -- 55 or 35, depending on which plain you pick.

The easterly dipping plain, which is the one Savage, et al, preferred -- pardon me. The westerly dipping plain, northwesterly dipping plane, would dip about 54 degrees. If it was easterly dipping it would dip about 36 degrees and project up somewhere near the monument Wahomie.

Okay. They collected data in 1983, 1984 and then, using an geodylite technique that is a conventional essentially line-of-sight geodetic technique. They re-measured this entire network in 1992 and using both GPS and geodylite so they could compare the two techniques to look for any systematic variation in baseline using the two techniques.

And here's what it looks like when you do that, just taking all of the baseline links. If you measure them using GPS, this is the geodylite link minus the GPS link. So if they agree, the data would plot on this blue line.

As you can see, the data seems to be systematically shifted above that line. And this is for the same occupation at the same time.

So they use -- depending on how you want to do it, you can regress lines through this to correct the geodylite measurements back to agree with the GPS measurements. But basically, the geodylite baselines were on average about 5 millimeters longer than the GPS baselines.

MR. POMEROY: Brian, at some point can you tell us something about the accuracy of an individual measurement in GPS that you're using?

MR. WERNICKE: Yes, we will. I'll address that.

The results of Savage, et al, are plotted here as vectors with one sigma uncertainties. Actually, I think there are two sigma uncertainties.

This shows the network. As you can see, the vectors are quite tiny with respect to the error ellipses at 95 percent confidence. So the upshot of what has been done so far by combining -- by the Yucca Mountain project -- by combining GPS and geodylite work over a 10 to 11 year period, is basically summarized right here.

The only substantial displacement you can see is that Station Rock is displaced from its 1983 position from outside of its error ellipse. And this is almost certainly due to the Little Skull Mountain earthquake.

Wahomie is perhaps -- it plots right on the edge of its error ellipse and also perhaps shows a small displacement relative to the Little Skull Mountain earthquake.

But notice the scale here. The scale is 50 millimeters of total displacement over approximately a decade. So the size of these ellipses are basically 20 to 50 millimeters, depending on the ellipse. And I believe that should be at two sigma. You may want to correct that.

And what this means is that the rates are constrained to be less than -- in general, less than 2 to 5 millimeters per year between any of the sites.

Now that's perhaps not a very robust result. We probably could have told you a priori that these things were not being displaced 2 to 5 millimeters. Maybe we couldn't. But it would have been a bit of a surprise if that were true.

The Savage, et al, study in terms of strain would, if we took the whole network, the total strain integrated across the network would be less than .02 micro-strains per year. That is, 2 parts in 10 to the 8th of an overall shear strain, say, that could be superimposed on the repository site.

For comparison, in the San Andreas fault there's an order of magnitude greater amount of strain accumulation going on adjacent to the San Andreas fault. So the upper bound here is an order of magnitude less than we would observe next to a fault like the San Andreas.

When we absorb roughly 200 micro-strains, that's a large earthquake. So, it works out just about right that if we multiply by 10 to the 4th, that upper bound is enough actually for there to be some kind of large earthquake or large shear strain release accommodated somehow across Yucca Mountain.

So the bottom line is we don't know I think how dangerous the area is. At least if you look at the geodetic data itself it shows, not surprisingly, that the strain accumulation is at least an order of magnitude less than what we would expect next to a major plate boundary fault, although that's not a big surprise. And the question is, can we do any better.

Now, what I want to show you is our combined -- and I should say, all of this work, I'm a dunce when it comes to space geodesy. I am the chief cook and bottle washer on this project. The GPS data reduction is being done by Jim Davis of the Harvard-Smithsonian Astrophysical Observatory.

Okay. What this shows is the Wahomie Mile baseline. Notice here we have length on this axis and we have year coming out here on this axis, 1983 through 1994. So that's a centimeter in each of the two tic marks represents 2 millimeters.

These are the two with the little star pattern are the three Yucca Mountain project measurements that at least show the uncertainty in Wahomie Mile and give that size error ellipse that we saw typical of Savage's final results.

In circles are the -- so far, the two campaigns that we've conducted across the baseline Wahomie Mile. That is, the NRC-CalTech-Harvard-Smithsonian. This was the baseline in which geodylite and GPS were used.

These stations have been corrected for the difference between geodylite and GPS. That is, the regression line that you saw through that systematic difference or systematically longer geodylite line. These have been corrected back down. In fact, when we first compared the uncorrected geodylite data with our first point, we had an enormous contraction between our first occupation and the geodylite data. And we thought, gee, Yucca Mountain is squeezing shut at some 5 millimeters a year.

But the Savage work shows that this comes down and that brought this measurement back to here.

Our next measurement plotted way up here, but if you correct using an elastic strain model for the earthquake, that is, on the northeast dipping plain as Savage did, this datapoint here has been corrected for the Little Skull Mountain earthquake. The earthquake itself occurred between these two. It occurred roughly in the middle of 1992.

So our point, we got in just before the Little Skull Mountain earthquake and the USGS got out just after it to conduct their campaign.

So, this gives you a pretty good idea of what the uncertainties are like with conventional GPS data.

Okay. The slope of this line gives a rate. That is, if we regress all five points that we have right here, we get a rate of .3 plus or minus .6 millimeters per year. That is at one sigma. That is, we have a sort of a 1 millimeter per year window here, that 1.2 millimeter per year window, basically centered on zero.

So I think what we've been able to do is by adding these two datapoints -- again, the statistics of it are that the more points you have, there's a really rapid contraction in terms of the regression that occurs between N equals 1 point and N equals 7 points.

Beyond that, adding more and more data doesn't really affect the mean nearly as strongly -- or, pardon me -

- the confidence limit is not affected as strongly as we get these first few points here.

So over the duration of our project, we will have two more occupations, one in 1994 and one in 1995, of this important baseline. And my guess is we will get this number quite a bit smaller than this.

That is, we've been able, I think, over and above what the Yucca Mountain project has done, adding our data to their data has contracted the upper bound in the amount of strain accumulation on Wahomie Mile. And I think as we get more data, rather than say plus or minus 1 to 2 millimeters a year, we'll probably be down at plus or minus a half or less millimeters per year.

MR. POMEROY: Let me interrupt you there, Brian, just a second.

MR. WERNICKE: Sure.

MR. POMEROY: And I just am asking you to help me out here. The points that you've identified there, the 1992 and the 1994 points represent a single GPS measurement at a single --

MR. WERNICKE: Yes. They represent the base -- the measure length of a baseline between Wahomie and Mile with two receivers differenced between Wahomie and Mile.

MR. POMEROY: Okay. And so you're using -- are you using differential GPS as well?

MR. WERNICKE: Yes.

MR. POMEROY: And so what's the accuracy of one of those measurements at Wahomie, say, versus the one at - I mean any?

MR. WERNICKE: You mean in an absolute frame? The accuracy in that?

MR. POMEROY: Yes.

MR. WERNICKE: It's much less. It's probably plus or minus a centimeter or more.

If you want to establish -- it depends on what absolute frame you want to establish. But these are -- when you compare one point relative to another, that's a much more accurate measurement than if you try to establish an absolute geodetic frame to refer all the points.

Say if you pick some frame like three sites on the North American Plate and call that an absolute frame and then say, okay, how far is everything moving, that's much less precise.

So these are just relative differences.

MR. POMEROY: Right. I guess I'm thinking in terms of the absolute accuracy of GPS being somewhere like 10 feet or -- I mean differential GPS without selective accuracy.

MR. WERNICKE: No. It's much -- you mean rather than differences, finding absolute points as a function of time.

MR. POMEROY: Talking about individual points.

MR. WERNICKE: Yes.

MR. POMEROY: Are you telling me -- what is the --

MR. WERNICKE: About a centimeter.

MR. POMEROY: It's about a centimeter versus a number that I had like 10 feet.

MR. WERNICKE: A millimeter.

MR. POMEROY: Yes. So, --

MR. WERNICKE: It depends on how you do it. See, what's going on here is that there's a difference between what you might call real time GPS where you have a receiver listening to satellites trying to basically guess where the satellite is and then determine it's position. Okay?

MR. POMEROY: Right. Yes.

MR. WERNICKE: What goes on in this process is there's a very detailed process that goes on that involves determining the ephemeris of the satellites. There's a whole -- there's a subnet of stations on the ground which GPS is constantly beaming its position to. So in order to get this level of accuracy, what you need to do is reduce those ephemerides in order to get precise satellite positions.

This can't be done in real time. It takes months to process the data to get this level of accuracy, which is exactly how the Defense Department would like it.

MR. HINZE: What is that line, the near horizontal line that is just beneath --

MR. WERNICKE: That's this .3 plus or minus .6 millimeters. That's this regression.

MR. HINZE: Okay. Is that the regression on what values? Is that a -- what is that line? Where is that coming from? Where is that slope coming from? What determines the position of that line?

MR. WERNICKE: Basically, a least squares regression of these points.

MR. HINZE: On all of the points?

MR. WERNICKE: Yes. On all of them.

MR. HINZE: Okay.

MR. WERNICKE: Yes. Both the corrected geodylite measurements and the GPS.

MR. HINZE: Are you placing any significance --

MR. WERNICKE: I might add if we took the GPS alone just for this interval here we would have 6.7, a much bigger number.

MR. HINZE: Okay. Is that -- are you placing any significance on the difference between those slopes? If you just used your GPS over the Wahomie line, are you placing any strain significance on your GPS measurements in comparison to the totality of the values?

MR. WERNICKE: No.

MR. HINZE: Okay. So, this is just part of the dispersion?

MR. WERNICKE: Yes.

MR. HINZE: Okay.

MR. WERNICKE: That is trying to get in with GPS with basically 24 hours of data on an annual basis or a bi-annual basis leaves a rather large -- an uncertainty of a number of millimeters, 2, 3, 4, 6 millimeters.

MR. HINZE: Yes.

MR. GARRICK: Brian, you made the comment earlier about the motion in the vicinity of Yucca Mountain and you indicated that if all the motion is at Yucca Mountain we have a lot to worry about.

MR. WERNICKE: Right.

MR. GARRICK: Can you elaborate on that a little bit with respect to what -- I live on the San Andreas Fault and I want to understand this a little.

MR. WERNICKE: Okay. Well, --

MR. GARRICK: What I'm really trying to find out is what results are you forming your opinion that there's a lot to worry about?

MR. WERNICKE: Okay. The single most important result that I'm forming my opinion about is the VLBI. Okay?

In other words, it's a fact that the Sierra Nevada Mountains are moving 9 to 13 millimeters a year northwestward relative to the interior of North America. It's fact that there's a broad zone of quaternary faulting and seismicity in between the Sierra Nevada in North America. Yucca Mountain sits within that.

Now, the question is, how much of 9 -- how is that 9 to 13 partitioned across that zone?

MR. GARRICK: Yes.

MR. WERNICKE: Okay. We don't know whether it is evenly distributed or whether it's very slow in some places and faster in others or distributed in several discrete zones. So part of our goal is to say if we have 9 to 13 millimeters, is most of it on the Independent Fault, say 8 on the Independent and Lone Pine Faults, maybe with 2 or 3 total across Death Valley and Hunter Mountain to the east and some insignificant fraction in Yucca Mountain. That's one possibility.

Another possibility. All the strain is accumulating right now across Yucca Mountain. There's no data now that really allows me to rule that out.

MR. GARRICK: I guess what I'm getting at is whether or not your worry is not only based on what's happening tectonically or seismically -- and I'm not a geologist, but what would happen to the general integrity and transport capability of the repository; whether or not that entered into your conclusion.

MR. WERNICKE: Okay. It's not -- it isn't my area of expertise to decide how exactly this affects the performance assessment of the repository.

MR. GARRICK: Okay. That's the reason for the question because from the standpoint of the bottom line of our interest here, when you make a comment like that -- of course, it gets our attention. But when you make a comment like that you want to know with respect to what. With respect to some feedback from the performance assessment that this would have a major impact on the consequences or is it strictly --

MR. WERNICKE: I think if -- yes. I'm taking it maybe as too much of a presumption in my presentation here that let's say a magnitude 7-1/2 under the repository is important for performance assessment. Okay?

MR. GARRICK: Yes. Okay.

MR. WERNICKE: But that's what I'm talking about. I'm talking about could there be a major earthquake. Could there be an 8 on the Furnace Creek? What is the likelihood? How much strain is going to accumulate in 10,000 years and where is it going to accumulate?

MR. GARRICK: So the connection really hasn't been made as far as the performance of the repository is concerned?

MR. WERNICKE: I might refer that to Bill or somebody over there.

MR. OTT: I would say that what we need to do is to see what Steve and Dave are going to come up with later on about integrating this work into the broader context.

MR. WERNICKE: Yes. Okay.

MR. HATCHER: I think there's another possibly relevant point that could be brought in here. Following the Landers earthquake year there was a bit of speculation that came up that maybe what we're seeing here with the Landers events is the shift of the main plate boundary from the San Andreas over to the Landers area and then on into Owens Valley or Death Valley or somewhere like that.

MR. WERNICKE: Uh-huh.

MR. HATCHER: This would have a very definite - if it happens rapidly enough. If this is truly happening and it happens rapidly enough, this would have a very definite effect on the performance of the repository. I think this is perhaps what John might have been getting at by asking that question.

And I think this is something that you would be capable of addressing in terms of what your experience is and what you know about the area.

MR. WERNICKE: Yes. I've spent a fair amount of time mapping the Landers break and at CalTech, of course, you hear every day about what the latest thing in Landers is.

I'm a co-author on the near-field investigation paper that CalTech put out on Landers.

MR. HATCHER: Not so much about Landers itself, but the effects on up into the east side of the Sierras, on into Death Valley and on into the area that you've also worked in.

MR. WERNICKE: It's going to be difficult to judge that one. There are pre-Landers strain measurements across the southern side of the southern part of the eastern California shear zone, a paper published by Saub and others about seven or eight years ago. And they get about 8 plus or minus 2 millimeters of right shear across the zone that ultimately was where the Landers break occurred.

I think it will be difficult to impossible for us to assess if there is a secular change from strain accumulation along the San Andreas system shifting eastward into the eastern California shear zone because we don't have a long enough time series to really be able to assess that variation.

I don't think we will be able to do that. It could well be true. It's certainly possible that there is on the 10,000 year time scale or even the 100 year time scale, secular changes in strain accumulation that shift back and forth between the San Andreas Fault and the east California shear zone. But this is absolute -- that's just the cutting edge of people even beginning to think about these problems.

MR. HATCHER: Right. I forget whether it was before or after the Landers earthquake. In May of last year there was a magnitude 6 just east of Owens Valley also and -- what's the valley east of Owens there?

MR. WERNICKE: Eureka Valley.

MR. HATCHER: Eureka Valley.

MR. WERNICKE: Yes.

MR. HATCHER: And that may just be another event in a long series of widely spaced events in time or it could be something else related to this too. Like you say, there's no basis for connecting these at this point.

MR. WERNICKE: Yes. There are historical precedents, the most obvious of which is a series of Anatolian earthquakes over the last summer where the North Anatolian Fault fired in succession all along its length. You could view the Joshua Tree-Landers events as the first two of a string of much larger events that we could expect running up the eastern California shear zone.

But there we're talking about strain release, what we expect the strain release to be. And what I'm focused on here is what the strain accumulation is. Okay.

But I have no -- I don't think we have any way of predicting that other than to sit back and watch the earthquakes happen. But I think you've pointed out an area of major concern.

I have one more viewgraph to show, and this is also from Jim Davis' research group at the Harvard-Smithsonian. They are currently involved -- one of their main focuses is the operation -- they are co-investigators in operating what we call a continuous GPS network.

Our current modus operandi and the one that is mainly used over the last six years by GPS projects is to take a GPS receiver on a tripod, set it up above a monument and allow it to record data for 24 hours. Now, it turns out that if you just leave the machine there, continuously record and reduce data, you get nearly an order of magnitude better accuracy on your position.

This is brand new. This has only been done basically for the last year and a half or so. And Jim prepared a plot here showing what one sigma uncertainty is as a comparison between a 24 hour to 48 hour annual occupation of a GPS site versus essentially continuous recording and reduction. That is, every day of the year with time.

So on this scale we have the standard deviation in millimeters per year. This is one millimeter per year, 10 and 100. It's a logarithmic scale, .1 and .001, and then this is time across the bottom up to five years.

Now, with the horizontal resolution you see it's running right about through here. That is, it's in the 1 to 3 millimeter range. After out 2 years -- okay -- we're about 1 to 3 millimeters. That's basically the type of data we're acquiring at Yucca Mountain.

The verticals are about a factor of 3 to 5 worse in terms of accuracy. And, of course, the more we have annual occupations the better the resolution gets. So, for example, with Yucca Mountain, if we pile up say four years of data, we will be at the fraction of a millimeter level in our horizontal resolution. That is, .7 millimeters.

Now, if you install a continuous GPS, this lower line here is the horizontal and the blue dashed line is the vertical. After five years of recording you can get down to .07 millimeters per year in resolving the average velocity over that five-year period.

In other words, 700th of a millimeter in rate, we could measure that. Now, whether we want to spend the money and whether it's relevant to performance or not, I have no idea. But if it were the judgment of the powers that be that it would be worth an order of magnitude better resolution on strain accumulation either in the faults around Yucca Mountain or across the repository or even around the repository itself, it is -- with current technology it would be able to get sub-10th of a millimeter resolution a year in terms of velocity.

The main reason for that is atmospheric corrections. A lot of the -- well, there's two main reasons. One is atmospheric corrections. They introduce systematic error that the annual measurements for a short period of time are not able to average out. The other error is just setting up the tripod costs you half a millimeter or a millimeter, maybe more. Because it's a different, different mounting -- if the thing just sits there and you don't touch it, then you know you don't have that particular error.

And a lot of our scatter on our points may well be due -- in Wahomie Mile -- may well be due to just that. It's a very difficult error to quantify.

And that's pretty much all I have to say, unless there are more questions.

MR. HINZE: Questions?

MR. POMEROY: Could you tell me just offhand when you make a measurement over 24 hours what the order of magnitude of the change is? Do you see a maximum amplitude of the change over 24 hours?

MR. WERNICKE: Well, when you make the measurement over 24 hours you basically reduce all of the data at one and pick an average. Okay?

MR. POMEROY: Yeah.

MR. WERNICKE: It's basically an averaging over 24 hours, so it's -- you could divide into bins of shorter duration of time and say -- so as the smaller and smaller the bins gets the worse and worse the data gets. But right now our bin is 24 hours.

MR. POMEROY: And what are the limits at the maximum amplitude excursion over that 24 hour period?

MR. WERNICKE: Well, I think if you take a given epic, basically there's way of recording. You pick up 30 seconds of data then you rest for 30 secs, then you get another 30 seconds. On the 30 second time scale they vary by more than a centimeter if you just had the 30 seconds to process. So you're looking at an averaging process over what looks like a very noisy signal, but because you have so much statistics on the measurement, the mean gives you about an order of magnitude better confidence limit on what the mean of that measurement is.

MR. POMEROY: Yes. I'm not denying that at all. And over the 30 seconds, you see the order of magnitude you just talked about.

MR. WERNICKE: Yes.

MR. POMEROY: How about between 30-second epics over the 24-hour period?

MR. WERNICKE: That's what I mean. You'll get a number that might be a centimeter. If you just processed one 30 second epic and then you processed another, they might be --

MR. POMEROY: And the maximum is about --

MR. WERNICKE: A centimeter or two.

MR. POMEROY: It's in the range of a centimeter or two. Okay.

MR. WERNICKE: Yes.

MR. HINZE: Are there any strain meter measurements in the area on which to check these results?

MR. WERNICKE: Not that I am aware of. That doesn't mean they don't exist, but I don't know of any strain meter program that's been set up on Yucca Mountain. Maybe somebody else does.

MR. HINZE: One has been proposed but it hasn't been set up.

MR. WERNICKE: Yes. There's a lot of things that have been proposed.

MR. HINZE: Right. But are there any other strain meters within Jim Savage's network, the DOE network?

MR. WERNICKE: There was -- I heard some word of mouth that small GPS sort of quadrilaterals were being set up on individual faults, but I don't know if that -- that's within the USGS. It hasn't been published. And I don't know what's become of it.

MR. HINZE: Buck, you had a question, Buck Ibrahim.

MR. IBRAHIM: Buck Ibrahim, NRC. In the figure before that one you indicated that you took the effect of the Skull Mountain earthquake in your solution.

MR. WERNICKE: Yes.

MR. IBRAHIM: There was another earthquake after that in the Rock Creek, about 20 magnitude, 3.5 plus. Were you able to take that also in your consideration?

MR. WERNICKE: If it was magnitude -- sorry, what was the magnitude?

MR. IBRAHIM: 3.5 plus.

MR. WERNICKE: Yes. If it was 3.5 the deformation at the field distance away where the monuments are would be less than a millimeter, far less than a millimeter.

MR. IBRAHIM: And you cannot measure that order of magnitude.

MR. WERNICKE: Yes. The earthquake, the slip on that kind of fault is two orders of magnitude less than Little Skull Mountain or sort of almost -- we're barely seeing Little Skull Mountain, so we'd be roughly seeing in effect two orders of magnitude smaller. And I don't think we would ever be able to see that.

I mean, you could look in the data and find it if you like, but I don't think a 3.5 would be resolvable.

MR. IBRAHIM: Because, as you know, all the activity at Yucca Mountain approximately was in that range. So my contribution on that may be the long run would have some effect on the capability of the site to advise us.

MR. WERNICKE: Yes. To make that sort of judgment on whether those earthquakes are -- how they're releasing strain would require continuous monitoring for some 5 or 10 years and then maybe you could see it. But I just think the displacements would be way too small.

MR. HINZE: Well, with that, we'll thank you, Brian. Very interesting discussion. And it's a good geophysical discussion, which always calls for more measurements.

MR. WERNICKE: Right.

MR. HINZE: That's a classic geophysical presentation.

MR. WERNICKE: Classical, not classic.

MR. HINZE: With that, we'll ask Larry McKague of the Center to introduce the research program that is going on at the Center.

MR. McKAGUE: What I'm going to do is give an overview of the CNWRA efforts in tectonics and seismology. We get our guidance, as you know, from Keith and George

Bouchard.

The presentation today, I'm going to make introduction and talk about the NMSS technical assistant tasks. Steve and Dave Ferrill will talk about the research aspects. Dave is now the principal investigator for the Tectonics Research Project.

Other investigators that have participated are listed below there.

This is sort of a roadmap or guidance of where we're going. The GS element conducts research in tectonics, volcanic and seismic investigations for both NMS and the Office of Research.

Generally, I've listed three disciplines here and corresponding tasks --

MR. HINZE: Excuse me, Larry. Do we have a copy of this overhead? Okay.

MR. McKAGUE: There should be one in there.

MR. HINZE: Okay. Thank you.

MR. McKAGUE: Okay.

MR. HINZE: Could we have one for Bob Hatcher, please?

MR. McKAGUE: All right.

I'm going to talk about the NMSS area here briefly. You've already heard about the volcanic area, research over here. And then Steve and David will talk about the tectonics.

Now the first slide I'm going to talk about, just very briefly about the magmatic modeling, simply because -- for sake of completeness.

The activity in technical assistance, the regulatory basis is given. The objective here is to develop a method of assessment of the uncertainty and the application of the statistical models to the probability of volcanic disruption.

In other words, we're worried about the uncertainties in the models themselves. We're not worried about what the probability is at Yucca Mountain. And this was a gap we recognized when we looked at the volcanic research projects and we weren't really concerned very much about the uncertainties in the probability models. And that's difficult to do with the data from Yucca Mountain because it's a small sample set.

So to do this we're going to look at method for developing -- method for estimating, establishing the limits of these uncertainties looking at data from volcanic fields, principally the Springville volcanic field, which has a large sample so we can look at the uncertainties in the models.

The key technical uncertainty associated with that is given below there. It's the uncertainties which exist because either many of the features we want to look at are buried or they've been removed by erosion. For example, what's the uncertainty on the volume of a volcanic cone when you've never seen the ash that was carried downwind. How do you take that into -- how to you factor that into your model.

Moving on to seismology, what we have done here is we have adapted SEIM 1 code. Now, SEIM 1 code was a code that was developed by Livermore for looking at the probablistic seismic hazards for the eastern United States. We acquired that code and modified it to look at the probability, fault displacement and probability analysis, seismic hazard analysis for the western United States.

It took us a number of months to modify the code to be able to be able to use it in the western United States. We've now accomplished that.

The objective here is to provide a tool which may be used by the NRC staff to evaluate seismic and fault probabilities and their uncertainties. They're provided or supplied by DOE or come up during the licensing process, the hearing process.

The key technical uncertainty of that modification falls under the general KTU's addressing the prediction of future states, system states, and the variability in the parametric values for the models.

Our accomplishments to date is that we've successfully modified the code and run a problem using Yucca Mountain data from the literature. We've recently -- very recently, in fact, within the last several weeks, have been successful in calculating the fault offset probability for the Solitario Canyon fault. And as Keith mentioned, we're in the process of preparing a report summarizing these results which should be out by the end of August, if not sooner.

MR. POMEROY: Larry, before we leave that, --

MR. McKAGUE: Sure.

MR. POMEROY: -- can you just comment briefly. These probablistic codes by and large have a basic input which is the determination of seismic source zones which contribute to the hazard. Normally, in these probablistic hazard analyses those seismic source zones are derived from some sort of expert elicitation for use. And usually those are a large number of representative experts.

MR. McKAGUE: Right.

MR. POMEROY: In the western U.S., have you done that?

MR. McKAGUE: No, we haven't. What we did for our -- this is essentially a test case to see if we could run the -- if we had modified the code successful so it gave us reasonable answers. And we took data out of the literature.

Renner can talk more about that.

And our basic assumption is that DOE will do an expert elicitation and we would probably use their data, look at it, rather than setting up our own elicitation, which can be very expensive. That's our basic philosophy.

MR. POMEROY: I see. So, for this test case, then, you just established some seismic zones?

MR. McKAGUE: Right. It was very difficult modifying the SEIM 1. It's a code that had lots of idiosyncracies that weren't documented. We had to go back to the people at Livermore and actually sit down with them for a day and have them tell us the little hidden tricks you needed to know.

So overall it was a rather long process and we just then wanted to verify that we'd made everything correct. So we took the values out of the literature, ran the code, and we got results which looked reasonable.

MR. POMEROY: Thank you.

MR. McKAGUE: The technical assistant work in the area of volcanics -- or excuse me, in tectonics. The regulatory basis is given here. The objective here, they're looking at finite elements, simulation of tectonic deformation at Yucca Mountain.

The goal here, the objectives here are to establish a credible mechanical basis for the discrimination between alternate models of faulting. The second objective is to establish the effects of the Ghost Dance Fault, effects on the Ghost Dance Fault of the seismic activity on the Paintbrush-Stagecoach-Bullridge system. The Ghost Dance Fault, as you may be aware, is in the Hanging Wall. Most of the deformation would be expected to take place there.

And finally, in the future we'd like to be able to do this, find that element of deformation in three dimensions so we can take into account the effects of larger variations in the azimuth of the faults and the effects they will have no the deformation.

The key uncertainties are given there, and I won't go into them. Basically, it resolves around exploration methods and uncertainties in interpreting and modeling the geologic structures.

The recent accomplishment is given there and that probably translates into we're still working on trying to set up the conditions of the calculation. We've gone through. We've run it a few times. We're learning how to run the code.

This is an area I just want to mention one thing and I'll talk more about integration. But in this particular task the fellow that runs the code for us is from RDCNO group and so the results may ultimately go to that group, the Repository Construction Group. But the fellow that's running this code using input from Steve -- and Steve looks at the calculations -- is from that RDCNO group. And so we're integrating that way.

By way of example, this is one of the preliminary calculations. What it does is show the redistribution of the in situ stresses after movement has taken place along this fault here. And that's the way it would be looked at. We may eventually like, for example, to put a fault which would model the Ghost Dance Fault in here, see what effects would be on it.

As I said, we're just getting into this right now.

The second area looking at models are three-dimensional structural stratigraphic model of Yucca Mountain. Basically, what we want to do is produce an integrated model of a structure stratigraphy and rock properties. And the idea here is it's a visual model. And I'll show you an example of it in a minute. But this would be like a base model.

As DOE produces additional information on location of faults, the distribution and stratigraphic units, these will go into that model and be recorded there so that it would act as a base.

This is an example of what it looks like. You can see the different -- these are the thermo-stratigraphic units from Sandia in it right now. You can see the topography on the top. We could easily substitute in the real stratigraphic units. We could substitute in hydrologic properties.

One use we've made to this recently -- maybe Bill saw that. We drew a cross-section along the line of the north portal entrance into -- excavation into Yucca Mountain and took it out on a field trip, the recent site exchange.

MR. HINZE: How well do you access DOE's information and put it into this model? How is that going?

MR. McKAGUE: How is that going? Mixed, I would say. We've requested a lot of information from them. Some of it we've gotten fairly quickly and most of the information we've gotten quickly has been geographic information like the road network, area boundaries, things like that.

Some of the geologic data has been a little longer in coming and it's an area we need to work on. Right now I think there are exchanges going back and forth on how the data should be transmitted. That sort of thing.

MR. HINZE: How do you know what to ask for? I mean, how do you know that the data are available? Are there menus that you could go to? Catalogues of --

MR. McKAGUE: There are catalogues of data. And we supplied them with a very large wish list about six months ago and they're slowly filling that in.

MR. HINZE: And eventually -- and I'd like to know when eventually is -- you'll have this on line? You'll have access to this on line?

MR. McKAGUE: We should have. One of the things -- one of the pieces of paper that came across my desk recently has been accessing the DOE database directly through Internet. Now, some of our experience has not been good on the -- for example, on the extreme erosion. We tried to use their database or get information out of their database and it came to us in a form which was very difficult to use and had errors in it. So we have to be very careful, at least initially, until we -- that data was prior to some of their quality assurance programs. I will say that in their defense.

Our goal is to use as much of their data as we can so that we don't have to generate our own data or digitize our own maps, things like that.

We have done that in the regional sense because it doesn't exist in their database. But on Yucca Mountain, we want to ultimately use their data.

MR. HINZE: At what stage do you enter the data into the repository? For example, we saw Ernie Major's seismic reflection work with his interpretation of faults. At what stage would you take that interpretation and put that into your database? Is there a qualification of your database in conjectural or the difference in the level of acceptance of the data?

MR. McKAGUE: I think Steve might be able to answer that a little bit better than I can, but I think it would be basically if feel the data is final form, completed. In other words, we don't want to have to reprocess the data, so if it's in final form, then we would enter it in.

MR. HINZE: Final form would be some kind of hard copy? DOE acceptance?

MR. McKAGUE: There would be some indication that it had been processed, reviewed, and was acceptable in the hard form. But them we would transfer it -- hopefully transfer it over electronically.

It's an area which is still unclear. Go ahead, Keith.

MR. McCONNELL: We don't anticipate the need, the tactical need of doing something immediately, so we get a periodic update in the form of a data catalogue from the DOE. When we see the data in that catalogue and it's of interest to any of the activities going on at the Center, then usually the Center will request it through the Yucca Mountain project manager, who will then request it from DOE.

The problems we've encountered is that it doesn't do us much good if we get a paper copy of whatever data that exists. We need the actual electronic media. And we're working no that.

MR. HINZE: Helpful. Thank you.

MR. McKAGUE: Okay.

I'm missing a slide that's in your handout there. It shows -- what I want to talk about is integration of several of the projects.

And what it shows are active ongoing integrations. The arrows indicate between the various projects what interactions are taking place. And there are -- I want to emphasize, these are not things we've sat around and said, well, we can interact with this group because the information is of interest. These are things where we're actually exchanging information, exchanging expertise, that sort of thing.

I've picked three out to speak about directly. The first is between the tectonics research project and the regional hydrology research project. The second one is between IPA and the tectonics project and task in the technical assistance area, and I'm going to talk about two things we're doing there.

And finally, between the tectonics research project and the volcanic research project and also between the tectonics technical assistance and the volcanic research project.

We'll look at the interactions with the regional hydrology project first. And we're doing three different things in there. The objective is basically to develop as good a model to improve the model for the regional groundwater flow, the hydrologic model. We want to improve that.

To do this, we're doing three things. To constrain the flow model we're looking at the distribution of the regional aquifers and aquitards. This is being developed from both surface and subsurface data.

This is what we have done to date. We've looked at the geologic maps in the area and we've selected -- identified whether they are an aquifer, an aquitard, and in the case of the aquifers, whether they're the upper or lower regional carbonate aquifer. It doesn't mean much down in here. It leans a little more over on the test site where the upper aquitard, the alliena, separates them.

Also included on here and indication of where we have not entered data, which is in gray. Drill holes are indicated by the circles. If they're green, they were drilled for gas or oil. If they're in blue, they're indicated -- looks like purple on here -- they're water well data.

This big collection of water well data in here is from Yucca Flat. Yucca Mountain is over here. Here's Bare

Mountain.

So we're developing this model, developing this data so that the hydrologists can use it in their regional model. It's being developed by geologists, people who have experience in interpretation of well logs, geologic maps, rather than letting a hydrologist get his hands on it.

The second area is we're collecting in situ stress data as input into the regional flow models, as well as the regional tectonic models.

This slide shows the regional groundwater flow and the maximum horizontal stresses and faults with quaternary offset on them, Steve? Yes.

The faults are the small black lines. The regional stress data are indicated by the symbols down here. That data is from Mary Lou Zoback from her database for the worldwide stress map.

The flow hours are from USGS data taken from various reports. And you can see that there's a general agreement between the direction of maximum compressor strengths and the horizontal flow -- or excuse me -- in the groundwater flow, which is flowing from the northern area of higher recharge towards the southern area, lower elevation area of discharge.

Again, this is data that is being collected and worked on by Dave Ferrill. He actively participates in the regional hydrology program. I believe it was he that suggested that this would be something -- and the basis of this is that if you have a highly fractured rock with many fracture orientations as you do in the basin and range, the directions perpendicular to the compressor stress will be closed and will not transmit fluids. Directions open to or parallel to the maximum horizontal stress may or may not transmit fluids. And certainly the recent -- any recent fracturing will be controlled by the current in situ stress pattern.

So again, this is to aid in the construction of the regional hydrologic model, as well as it will be used in the tectonic models.

Finally, we are just getting started constructing geologic cross-sections which will aid, again, in the development of the hydrologic flow model. The cross-section that was shown through the north ramp, the north portal ramp, was a start in that. We've also been in contact with the DOE environmental program which is constructing a number of cross-sections, geologic cross-sections, because they're also interested in regional groundwater flow and the restoration. That's the ground water restoration at the test site.

So, ultimately we'll construct some models but we intend to gather as many others from other sources as we can. Again, to aid in the regional hydrologic model.

Modeling experience are being developed in the technical assistance tasks. They're being transferred into the IPA, into the iterative performance assessment area.

One of the tasks we're performing there is to provide a simplified hydro-stratigraphic model of Yucca Mountain. And it's based on the 3D model that I had shown earlier.

It will be based on that model. And instead of having stratigraphic units, it would have hydrologic units, things like that.

This is a project that's just gotten underway since just before the beginning of the year. We've met with the IPA staff, discussed their needs. We've interacted with the hydrologists to identify key hydrologic parameters that would be needed in a hydro-stratigraphic model.

The three-dimensional model that I just showed is currently being modified for use in IPA by putting in faults, stratigraphy, porosity and the saturated hydrologic conductivity.

We just recently discussed a milestone where when the model was constructed about the end of this fiscal year, we'll get together with IPA and describe the model and see if it meets their needs, although we're talking with them on it on a nearly daily basis about it.

MR. HINZE: Are you going to be involved in the abstraction process?

MR. McKAGUE: In the what?

MR. HINZE: In the simplification of the models or --

MR. McKAGUE: Yes. We've had a lot of discussions about -- Steve is the one that's doing this work and we had a lot of talk about what will meet the IPA needs. In other words, we don't want to give them a model that's too complex for them to use in their calculations. And so we're interacting, making sure that what we produce is what they need.

Does that --

MR. HINZE: Yes. And are you doing statistical studies to try to look at grid intervals that are --

MR. McKAGUE: yes, yes.

MR. HINZE: -- acceptable? Will you be mentioning that?

MR. YOUNG: No. We hadn't planned to talk about that in detail, but we're experimenting with different interpolation methods and algorithms, creating and co-creating more simple approaches that amount to least square's nearest neighbor types of interpolations.

So up to a point, since we're putting a lot of the basic parametric data into the database, we have to make a lot of upfront decisions on how to grid it.

And so we talked to the IPA people, in particular the hydogeologists, about how they would handle it. It's pretty classic, sparse data kind of problem. Bore holes are widely spaced. How do you condition the data to get the most reliable interpretation.

So, yes, we have to make decisions like that right now.

MR. McKAGUE: One of the things in interaction or interworking with these, the closer the people sit the easier the interactions are, and over the years we've often dinged DOE for not integrating well. And now that we're having to do it, we're finding it's not as easy as we had anticipated. And certainly, Steve just being down two halls from IPA makes this a lot easier.

The second area we're working in is to implement a probablistic fault displacement model for utilization of IPA Phase III. Phase II did not have a probablistic fault model. It was one of the things they felt they needed. They came to us and asked us if we could provide this.

Gary Stirewalt is working on this. Recently he's reviewed the EPRI methodology for the preliminary risk and PA analysis of primary and secondary faulting and proposed a strategy to use existing Yucca Mountain data to predict the expected number of canister failures due to the fault displacement.

We use existing algorithms but put the data from Yucca Mountain into it. The strategies are just being developed. We've just, again, started working on this just before the beginning of the calendar year.

The volcanic research project from the volcanic and the tectonic project have several areas of mutual interest, as you might well expect. The objective is to develop a conceptual tectonic model or models, as the case may be, that accounts for both structural and volcanic phenomenology.

Data in the GIS database is applicable to both projects. By way of example, VOLC maps can be used to develop alternate conceptual models. It can be used to develop theories on the control of volcanism by structure.

One of the areas that we want to look into is in the San Francisco volcanic field. There are not many examples of -- definite, known examples of controlled volcanism by faults, but this is one we've identified recently.

There's a lava flow outlined by the blue-green dots here which seems to have originated in this area here which, there's a fault system here. There's another one just off the map up here, and there's this one, which comes down here and curves into here.

So, the lava flow apparently originated from this area, flowed to the east. North, if you'll notice, is to your right.

Subsequent to that there was faulting, which actually offset the flow. You can see the faults through here. This fault here was activated. Then, there was eruption of the small cinder cone here, which is transsected by this. It actually draped over the fault scarp produced by here.

This is area we want to go look at to see if we can learn more about the interaction of faults and volcanoes, or volcanism.

This would be looked at by both Steve -- or excuse me -- by Dave and one of the volcanologists.

Potential interaction of dikes and faults are of interest again to both, as I've sort of indicated above. The control of volcanism and the effects of probability on volcanism is of interest to the volcanologists. We went through that the last time in looking at the models.

The control of volcanism or the structural control of volcanism very much affects the probability.

Then intrusions along a fault is a potential a-seismic deformation mechanism.

Recent accomplishments in here, we've done two calculations. The first one was done in the technical assistance area. We used the code DYNA 3-D which we got from Livermore, and it's actually run by a company in California for us.

We looked at the interaction of dike like magma body at depths of a kilometer and 300 meters with an 80 degree dipping fault. And the preliminary result indicate -- again, under the conditions modeled -- that the faults can exert some control of dike emplacement at depths shallower than a kilometer.

Below a kilometer it may or may not, but above, shallower than a kilometer and again at steep dips, they can exert a control on the emplacement of the dike by a preexisting fault.

The volcanic systems, the basin range project, they did a simple 2D stress model that was used to calculate the interaction of an upward moving magma, its orientation controlled by the least principle in situ stress. And when it encountered a preexisting zone of weakness, a fault or a joint, results indicate under the conditions modeled, the magma can travel only along very steeply dipping preexisting structures of 10 kilometers, while at depths between 50 and 640 low angle zones can also be modeled.

What this basically at least kind of a broad brush first guess is that the deeper control of volcanism is pretty iffy. It depends a lot on the physical properties of rocks.

When you get to shallower depths less than a kilometer, maybe less than 2/3 of a kilometer, then the control by preexisting structures is a more important feature.

So what I've done here is basically talked about the NMS, the interaction of some of these projects. You've already heard about the volcanic field project. Dave and Steve will talk about the progress in the tectonics research progress.

Do I have any questions?

MR. HINZE: Questions?

(No response.)

What you're telling us is that there's a lot of integration between the various elements of the uncertainties and concern in KTU's and also that there is a good deal of relationship between the technical assistance and the research program.

MR. McKAGUE: That's right. Yes. We've made a determined effort to do this. And in part, it reflects on the staff itself and their ability to go out and talk to each other and their desire to get out and talk to each other and make this work.

MR. HINZE: As a result of your research, how much are you suggesting to research in your development of program plans? How much are you developing new ideas for research activities as a result of the work you're carrying out?

MR. McKAGUE: Some of the stuff I talked, for example, reflect Dave coming on board and having some new ideas about how to -- the in situ stress, for example -- how we should integrate that into it, too.

As new ideas develop, we talk to NRC Research about them. Some of them we can implement under existing project plans. Sometimes they may require modification of plans and it's something that we suggest and discuss with them, look at the significance of the relevance of it, and move on.

Right now the tectonic research project has only been ongoing for a little over a year now, so we're still kind of in the first third of it and moving it ahead. And we expect, as we move into these things, we'll see other areas that will need new research or new ideas.

MR. HINZE: You've spent a considerable amount of time working on concerns regarding literature reviews. Are we going to hear something about what that has led to? Where is that going?

MR. McKAGUE: Steve will talk about that. I think one of the things that was missing from that earlier discussion was that we've got very well qualified people, but most of them had not had experience in the basin range. So doing the literature review was a way for them also to gain experience. Plus, to update the literature review which DOE had done nearly 10 years ago in the site characterization.

So you will hear about that, yes.

MR. HINZE: Thank you very much, Larry.

Steve, are you going to be next, then?

MR. YOUNG: Yes.

My name is Steven Young. Dave Ferrill and I are going to present to you the current progress and results on the tectonics research project. Other principal investigators involved are Gary Stirewalt, Ron Martin, Brent Henderson and Kathy Spivy.

I don't want to spend a tremendous amount of time on here. Really all I want to point out with respect to the regulatory bases here is that we're doing work that really is focused on KTU's that are tied to these big regulatory area, or these regulatory topics here. And basically, we've got performance related regulatory bases and then we've got other issues.

These top three are performance related and then we have these other issues down here that are a little bit more qualitative and are really more closely related to siting criteria. So these are a set of these so-called potentially adverse conditions.

And you'll note here, I want you to be able to track this to a certain extent in your package of materials. There's a license application review plan number attached to a lot of these; structural deformation, structural deformation, for example. The section in the regulations.

This number might be kind of useful to you as you go through your package because the KTU's are defined in these LARP sections. So the key technical uncertainties tie back to their pertinent regulatory topic through the LARP. So that's why I wanted to put that up there and make sure everybody sees that.

I don't want to spend a lot of time on the KTU's. I think they've been discussed a fair bit here. But one thing to notice at this point is the way that the KTU's are structured under a particular regulatory requirement topic.

So, for example, you've heard that there's KTU on the poor resolution of critical exploration methods and uncertainty interpretation. Really has to do with our ability to investigate structural geologic features in the subsurface and the uncertainty that results from those investigations.

Evaluation of faulting mechanisms in alluvium. That's a very mainstream method or approach that's being used throughout the Great Basin, throughout the basin and range region, and in particular at Yucca Mountain, to be able to basically characterize the slip history of faults and thereby to try to develop the necessary database for input into both deterministic and probablistic fault displacement and seismic hazard analyses.

So, KTU's that we work on -- and this is not intended to be an exhaustive list of KTU's but rather a list of the key technical uncertainties that tectonics research is more specifically focused on.

MR. STEINDLER: Before you leave that slide, do you have in mind a picture of the repository and its contained waste, and therefore, the mode of interaction between structural deformations and the waste that could lead to some kind of consequence that is significant?

MR. YOUNG: Yes. I think the kinds of pictures that we have in mind are really pretty much that. They're very conceptual in nature. Ultimately those conceptual models of the interaction between geological structures and say the waste canisters in particular, those things will have to be encompassed in performance assessment scenarios.

Now there's been some preliminary description done for some of those scenarios. For example, potential interaction of both faults and fractures with canisters in situ. And so, for example, scenarios will include at least situations where fault offset causes point loads to be applied to the canisters or earthquake seismicity causes shaking to occur or bits and pieces from the annular wall to fall off and impact the canister.

So those are the kinds of scenarios and the kinds of conceptual models that I think most of us have in mind when we think about potential impact of tectonic processes.

There's another class of other processes that have to do with groundwater.

MR. STEINDLER: I understand that. To what extent do those pictures limit the scope of your tectonic research?

MR. YOUNG: I don't think those pictures are strongly constraining right now. I don't think they're strongly impactive right now because what needs to be done, probably in the performance assessment arena particularly, but maybe even in the combined performance assessment in the broader geologic arena, is that some assessment needs to be produced more strongly on the consequence side.

For example, what ultimately will be the effect of fault slip and earthquakes on those canisters? The tectonics research project currently is focused very strongly on the characterization side of the geological structures and in producing the necessary database to support a probablistic seismic hazard assessment, but again, on the geological side. So the kinds of data that would be produced ultimately by this project would be things that would feed directly into a hazard assessment, like fault length and slip rate and probability distributions of magnitude and things like that.

MR. STEINDLER: So you're not far enough advanced then in this business to be able to exclude those pheromenon under the label of tectonics that would lead to effectively no significant impact as far as the release or regulation violation is concerned. Is that right?

MR. YOUNG: I think as far as I can see, we're not far enough along to exclude any major class of tectonic process.

Keith?

MR. McCONNELL: That's correct. And I'd just expand it. Again, these are based on qualitative judgments at this stage in the identification of the key technical uncertainties and one of the recognized omissions from IPA Phase II was the potential effects of direct fault displacement on the repository.

And so it's going to be incorporated into Phase III, IPA Phase III so that we have a better quantitative evaluation of the effect of these features or potential effect.

MR. HINZE: Steve, to help me follow along what you're presenting here in terms of the tectonics research, Bill Ott presented as his second transparency this diagram illustrating the regional extensional tectonics from '94 to '96.

Do you have that broken down into elements and the goals on an annual basis?

MR. YOUNG: Yes.

MR. HINZE: Do you have that kind of a diagram to lead me through this?

MR. YOUNG: Yes, I do. I've got a viewgraph on each task actually that shows the objective of the task and what's being done in that task.

MR. HINZE: So we'll see that at each specific one?

MR. YOUNG: Right.

Okay. Again, the KTU's as they're classified under the major regulatory topic. You've sen this list of KTU's before. Some of these are expanded into a little bit more detail here to explain maybe more clearly exactly what the nature of the uncertainty is. But the overall objective, the overall purpose of the tectonics research project at this time is really to product an improved capability to do the whole range of study plan reviews and pre-licensing guidance and license review that ultimately will be needed.

We've seen just in the little bit of review work and literature review and data compilation that it's oftentimes hard to tell exactly what data you're going to need to address a particular problem. What we're trying to do is put together a database that is essential in character. In other words, it includes what we consider to be the essential elements to accomplish this.

And as you can see at this time we characterize focus of the tectonics research project to examine the sufficiency of mostly existing data and methods to determine compliance with the siting criteria. We think that that's a significant point because it isn't clear -- and I guess you can see that. It's kind of down there at the bottom.

We would maintain that it's not clear that the existing data are sufficient for either the qualitative compliance determination or in particular for perhaps the more quantitative performance assessment.

We think that the weaknesses that have shown up in the literature review and in the data compilation are primarily in those areas where you would produce correlations between fault length and earthquake magnitude and slip history and earthquake magnitude and things like the extent to which particular fault systems are either segmented or are characterized by more distributive slip. And in particular, in methods that would be used to date specific faulting events in the trenches and even in the geological methods or geological investigations at the trenches themselves that would be used to determine the slip history.

Now, our reviews of the literature and our data compilation have indicated that there's considerable uncertainty in virtually all of those methods and that at the very least the first thing that needs to be done is we need to pull together most of what's been done in that area and have a very clear idea of the types and the extents of the uncertainties in those areas.

So, we would characterize the primary goals of the current work here as again to improve capabilities to assess investigations of earthquake sources. And in particular, these would be sources that would be expressed at the surface or have a ground surface expression like a fault line or if you could characterize or identify a point source in a particular fault system.

And then, in addition to that, we are particularly concerned with the adequacy of investigations of sources that have no surface expression; specifically, the geometry and the distribution of these features. And in particular, -- I think this has been mentioned a couple of times today -- the Little Skull Mountain earthquakes is a relatively good example of that.

As far as we can tell, there's no preexisting surface expression of that. It was a 5.6 surface wave magnitude event. Didn't produce any ground rupture. How many of those occur?

We think that that particular event is triggered. What's the proportion of those events that are triggered versus those that would be characterized as a non-triggered event? And the investigations that would go toward or that would speak to this issue of buried sources or blind sources is a -- on the geological side, is a tremendous source of uncertainty.

Another particularly impactive example of a large earthquake on a blind source with anomalous amplification of accelerations, of course, was the recent North Ridge event. So blind sources are something we're very much concerned with.

MR. STEINDLER: Before you go forward, to back two viewgraphs, just to reiterate. You indicate the two premises in the objectives area. The bottom premise, in effect says that it's not clear that existing data are sufficient and so on.

But there's also another premise in there, and that is it is presumed that you can in fact obtain data in some reasonable frame of reference, both time and cost, so that you can do the quantitative performance assessment and qualitative compliance determinations.

How did you conclude that it's worth doing this research in the context of being able to accomplish something useful in the time necessary?

MR. YOUNG: Well, I think that -- how did we conclude that it was worth doing the research?

MR. STEINDLER: No. How do you know it's doable?

MR. YOUNG: Well, as this particular point says, we are focused pretty heavily on assessing whether the database is sufficient at this point. And as you pointed out, along with that goes some implicit thought on whether the data can actually be developed or not.

The sufficiency of the data, the answer to that question is attainable. This research project alone may not answer it, but this research project will go a long way towards establishing whether the data that are available now and the data that are anticipated to be produced by both site characterization and by NRC programs, whether that data are going to be -- whether those data are going to be enough.

So, can this project answer the question is it doable? In other words, can we solve all the compliance problems? This project alone can't answer that question, but it probably will go a long ways toward answering the question of do we have enough data to do it.

MR. STEINDLER: Let me ask the question

differently. I hear your answer and I think it's a reasonable answer. Are there any other sites, both in the U.S. or elsewhere where the same kind of issue has arisen in the sense of requiring what appears to be a large accumulation of new information where it can be reasonably shown that if you folks had planned a repository in that area you would have been able to get sufficient data to meet the two criteria that you have up there; determination some information on qualitative compliance, determination on the quantitative performance assessment?

MR. YOUNG: Gee, pull me back on track if I fly off in an odd direction trying to answer that. But I want to answer the first part of that. Is there another area where questions of this type have been asked or may be easier to answer? I think it's very safe to say that there's -- in my opinion there's no other place. There's no other situation where these types of questions or these types of problems are structured the way that they are here at Yucca Mountain.

In other words, what we're trying to do at Yucca Mountain is not precedented and so there really is no other place where you could go to and say, yes, this has been done before. The same kinds of questions have been asked and they've been successfully addressed.

And I think there's a part two back there that says can you think of a place where we could go and these things could be done? Is that --

MR. STEINDLER: No, no. Forget the part two. You've answered the fundamental issue that I was raising in your part one answer and we can just move on.

That's fine. Thank you.

MR. YOUNG: Okay. Now I'll go through a task by task listing of each of the tasks in the tectonic research project. And there was a question earlier about the literature review and the data compilation tasks and what was being accomplished there.

The literature review, basically we've done two fairly comprehensive literature reviews. One in connection with the volcanism research project which focused on tectonics and magmatism, and then we followed that up with a little bit more focused review that tried to hone in on the seismo-tectonic aspects of the region.

That literature review was done strictly to support the data compilation to build the geographic information system that we want to use as our analytical and review tool.

So this data, this literature review is done. It's accomplished. We've pulled together all the material. We're in the latter stages right now of pulling the quantitative data out of that literature and putting it into our geographic information system.

Something that I think is worth pointing out, though, at this point -- and I know that there've been questions raised now and again about user needs and KTU's and the extent to which those things mutually interact and what the basis has been for those up until the point where the research projects got going.

In our opinion, the literature review and the data compilation that we've done to date supports pretty well the development of the KTU's and the user needs up to this point. And I think in retrospect that that's not too surprising because the first order geological and tectonic problems are fairly easy to recognize and get started on in a work plan. And the literature reliably reflects those big uncertainties.

In other words, the uncertainties that we've identified also exist throughout the geological tectonic literature on the Great Basin.

MR. HATCHER: Could you give me an example of some of the quantitative data you're accumulating right now?

MR. YOUNG: Yes. In the compilation task, which is also ongoing right now, scheduled to end at the end of this fiscal year, I'll show you a specific example of this. But I want to show you the regions for which these things are being compiled and then I'll go through a list of exactly the data types that are going in there.

In particular, we are compiling data into the geographic information system for two broad regions; the Central Basin and Range region which you saw depicted on one of Brian's slides between the northern and southern basin and range region, and we have a relatively highly focused subset in there of the Yucca Mountain local region.

And the reason that we do that is because there are data that are available at various scales and resolutions, depending on the size of the region that you happen to be working on.

Now, we think that it's necessary to look at the tectonic setting of Yucca Mountain. And this region that you see here, which is picked out specifically to encompass what we would characterize as the tectonic sitting of Yucca Mountain. And I think Brian gave you an excellent idea of the structural geology and the deformation that essentially characterizes that area.

But what's important to recognize about the Yucca Mountain area is that it is situated in an area that genuinely has a mixed deformation style. It's adjacent to the Northern Basin and Range, which is characterized by a relatively simple east-west to north-west directed extension which forms these big mountain ranges and blocks. And then it's north -- and this is basically fairly strongly dominated by big normal slip systems. And then to the south, a strike slip dominated environment.

And here's Yucca Mountain sitting directly in between in the Walker Lane around the edges of the eastern California shear zone, and it genuinely has characteristics of both domains. It has nearly pure dips slip, normal faults, but it is bounded and those faults are kinematically linked to relatively large strike slip systems.

Now we've characterized the deformation in here and other people have characterized the deformation in the Yucca Mountain area as pull-apart. And those models, those conceptual models involve very close kinematic linking between both strike slip faults, normal slip faults, and in some instances faults that are genuinely oblique slip. So, with a strong component of both horizontal and normal slip.

So we're compiling data for a relatively large region that we think characterizes the regional tectonic model, the regional tectonic setting, but we also have relatively detailed data available for Yucca Mour.ain, so we're compiling at that scale, too.

Okay. Let me go on.

MR. POMEROY: Steve, let me just ask you a question in there.

MR. YOUNG: Okay.

MR. POMEROY: In terms of the age of faulting that you're mapping, are there any cutoffs in age or are you mapping any fault that's been described in the literature?

MR. YOUNG: Quaternary --

MR. POMEROY: Quaternary only?

MR. YOUNG: -- right now. As a matter of fact, and I'll --

MR. POMEROY: These are all quaternary faults that we're looking at?

MR. YOUNG: Yes. And that actually brings up a fairly interesting point.

You have this diagram in your package and I'm sure you'll have to look at that diagram to see this. But if you look in California and you see the distribution, all the faults on here are quaternary faults. These are faults that have some slip during the quaternary on them.

In all of the California part of this map, we have all of these faults flagged as to their age of latest slip. Now, most of that information comes from the various datase.s of Jennings, who put together the fault map of California.

Now go up into Nevada. Now you look at the northern part of this and you see that there are a lot of faults on the north part of the map. And then you come down and you notice that the fault spacing really drops off in here, so there's not nearly as many.

I don't have it marked on this particular map, but the reason for that is that the quaternary faults have not been well mapped in this area and so there are many, many more quaternary faults that are actually out there than even show up on this map.

Now this map is in progress and much of the data that's on this map -- in particular, the positions, the lengths and the types of these quaternary faults are coming from a series of maps that are being produced by John Dornwin and his co-workers at the U.S. Geological Survey.

Well, they simply haven't gotten down into a lot of these areas. And so, there are big blocks of territory where we should know where the quaternary faults are. We should know more about the slip history of those quaternary faults. And that work is in progress or in some instances not quite underway yet.

So it is a work in progress and it's bumping right up against the data that's actually available from the geological community.

MR. POMEROY: Let me ask one other question, Steve, that's sort of a more programmatic kind of question. And that is, is the GIS system and the database that you have it as set up now immediately accessible by the NRC staff here in the general Washington, D. C. area?

MR. YOUNG: Yes. The way it's set up right now is we've put -- we've got four licenses running and we've set aside a -- what we're considering to be a kind of an interim data catalogue. And that data catalogue is being built right now.

What we'll do is we'll set that data catalogue aside and essentially lock it in place so that work that's going on in modification will stop on that and we'll keep going in other area.

There is a working Internet link with NRC and we have experimented with running ARCHINFO over that network from the Center to NRC and we've actually run ARCHINFO from both directions using our database and stuff that we've transmitted up to them.

So, now that link is not as strong as it should be yet because that hasn't been our focus up to this point. But we've gone far enough to get the hardware in place, the communications software in place and to experiment with the link to make sure that it works.

I would say that probably over the next six to 12 months that something like more routine use will emerge.

MR. POMEROY: So at this point, Keith can't immediately call up this map, for example, but within six to 12 months he could call up that map. And he's going to answer the question, I guess, too.

MR. YOUNG: Okay.

MR. McCONNELL: Conceptually what we have planned -- ar[illegible] we haven't touched all the bases, is that since the research aspect, the R&D aspect of this activity is winding down. But we may want to consider int he future turning this over to a technical assistance type of activity where the Center would be responsible and it would be documented in their ops plan to periodically update this database and to maintain it and to make sure that the staff has access to it in Washington.

I know we've had some preliminary discussions to that fact and it may occur in FY95.

So that --

MR. POMEROY: If it --

MR. McCONNELL: Go ahead.

MR. POMEROY: I was just going to say if it does, I hope you include the ACNW as among the people who might use it.

MR. YOUNG: We are also working on other ways to make this data available in an easier sort of fashion by putting it on a subset of ARCINFO, called ARCVIEW, that we could then distribute on CD-ROM.

Now I will zero in to the Yucca Mountain region itself. This is basically a digital elevation model of Yucca Mountain and this is Yucca Ridge. Again, I want to point out that the reason that we've sort of divided the database into these two broad areas is that there is much more detailed higher resolution data and measurements available for the area directly around Yucca Mountain than there might be for the broader region.

So in order to take advantage of that, too, we have a focus at Yucca Mountain. I want to go through and just show you some examples. The ARCINFO database, the GEIS database that we're building is a very dynamic thing. I'm going to show you some examples or some snapshots out of it that don't really portray the real dynamic character of it, but will give you some idea of how very fast interactive kinds of analyses can be done with this database.

Here is a relatively small, but a conceptually kind of easy to understand very valuable exercise. Here we treat the digital elevation model like a synthetic low-sun angle photograph so that we can go in and we can illuminate the digital terrain model at very odd or unnatural sun angles.

Well, now, why would we want to do that? Well, when you go in and look at a normal low-sun angle photograph, you really can only get the sun either from the west or from the east, and you see that there's a particular geo-morphic fabric that is primarily or very strongly fault-controlled and you get some idea of what the fault and fracture orientations are from this.

To a large extent, it is these kinds of views that the knowledge or information and conceptual models of deformation at Yucca Mountain have been developed. However, when you go and illuminate the same image from odd angles that don't occur naturally, you see that there are other tectonic geo-morphic fabrics in there that are actually being expressed in the very fine detail and measurements at Yucca Mountain, but don't show up or are not nearly as visually obvious in a typical view.

So in a lot of cases, particularly in kind of an exploratory type exercise, you don't know what you don't know. So we try lots of different views to discover up to a point what is it that we don't know or that hasn't been discussed or discovered in previous investigations.

Now, again, as an example of the data sets in here -- and I'm going to answer Bob Hatcher's question in just a minute. I haven't forgotten about it. I'm getting to it. In this particular case, what we've done here is we've digitized the fault map from Frizzell and Shulters. Dr. Pomeroy asked early on are all the faults quaternary in here. Here is a particular example where some of the faults in this entire fault array, this is virtually all the faults mapped at Yucca Mountain. Not all of these faults are quaternary.

However, every fault in here that is quaternary is being flagged as quaternary. One of the values of a system like this GEIS is that we can take a myriad of mapped sources or machine-readable sources, get them all mutually co-registered into a single analytical or review environment, and query that environment as to which faults are quaternary, which ones aren't, and, to the extent we know the slip history, ask it which ones have a slip in a particular time range within the quaternary.

So we don't have to deal with maps of many different scales and many different projections. If you come across instances where you need to ask a question of the broader literature, oftentimes you find yourself up against a situation where you simply don't have the time or the ability or the resources to pull together all of the maps, reduce them on a xerox machine, overlay them on a light table and do all that stuff.

So we're trying to create a very fast environment for doing this. So in this particular instance, we've got all of the faults mapped at Yucca Mountain.

MR. HATCHER: Excuse me one second. On the previous diagram of all the faults that are there, do you have a means for distinguishing those that have been reactivated in the quaternary from those that are new faults, new breaks?

MR. YOUNG: Faults that have been inherited --

MR. HATCHER: Yes.

MR. YOUNG: -- have inherited slip in the quaternary. No. We don't do that right now. It's certainly possible to do it, but our current focus is on the quaternary slip history. Now, are some of those faults -- is some of that quaternary slip -- has that occurred on faults that had older slip? Yes. That is on there. We don't flag those right now because we're really very highly concerned with that quaternary slip history for now.

It's possible to do it, but we haven't done it. Now, with respect to the earlier map of the faults at Yucca Mountain, this then is the co-registered set of photo-geologic lineaments at Yucca Mountain. Many of these lineaments do mark quaternary fault traces. So this is an example of where we would take a couple of different data sets that exist on relatively course maps at other scales and in different projections that you couldn't ordinarily easily overlay and we can go in and match the -- of the total population of faults at Yucca Mountain, which ones are marked by these photo-geologic lineaments, which ones have been determined to be quaternary from trenching studies, etcetera. So those are just basically snapshots of the database.

Now, I think I will get to answering that question here. In our critical review task, also ongoing and ends at the end of this fiscal year, we're now going to go in and look at the key relationships between all of these data types. The data that are in the database now consist of terrain features in the form of digital elevation maps, earthquakes, in particular, the National Earthquake Information Center catalog, potential field geophysics, particularly the DNAG data sets, gravity and magnetics, and, in particular, higher resolution data sets, specifically the arrow mag data that's been acquired in the Yucca Mountain area and, most importantly for us right now, the quaternary faults and the data, the quantitative data that's being attached to those currently.

That data, in particular, consists of age estimates or dated fault slip events, fault link, slip magnitude, estimates of recurrence interval, and the correlation with modern earthquakes. So the quantitative -- probably the most important quantitative part in the typical sense of the data that's going in here consists of age dates and estimates of slip history. So dates and rate are the numbers that we're really mostly concerned with right now.

Our critical review phase is pretty much dominated by looking at correlations between the earthquake seismic record and the quaternary faults in that particular region. Now, this is a fairly complete earthquake catalog through -

- this particular one is through the end of 1992 or early 1993.

There are additional HIPL centers that exist here that have been acquired by the Southern Great Basin Seismic Network that are not in the database yet. We've got those on order. But as Brian pointed out previously, you can see that the earthquakes correspond pretty closely with a lot of slip on the San Andreas system and, to a somewhat lesser extent, are distributed through the eastern California shear zone, composed of the Mojave block, the greater Death Valley fault block region, and then continuing north into north central Nevada.

So probably most of the strain, most of the slip is occurring in an area over here. Most of the earthquakes are currently associated with that. But as you will see shortly, it is a reasonable assumption or supposition or conclusion that many of these big earthquakes out here have triggered earthquakes throughout this region.

Furthermore, as Keith mentioned earlier, Wallace and others, since his initial work, have pointed out that there's pretty good evidence that faulting and earthquake seismicity cluster in time and space. In other words, this may be the modern locus of earthquake seismicity, but we can't tell to what extent or what the probability is that earthquakes -- that the locus of these earthquakes may move to a particular different region.

There is ample evidence that there have been quaternary earthquakes throughout the fault systems in the Great Basin.

MR. POMEROY: Steve, did I understand you to say that you do not have any of the information that's been developed over the past several years in the local scale for the Yucca Mountain area by the Southern Great Basin Network?

MR. YOUNG: We don't have the complete Southern Great Basin Network catalog. However, many of the events that are in that catalog also exist -- are also held by the National Earthquake Information Center. What we want to find out right now is what the difference between the events in those two catalogs are.

We think from discussions with other people and we think that from just by looking at maps where other people have shown earthquake HIPL centers from that network, we think that there are events in that network that are not in the NEIC database. So we want to go look at that specifically and find out.

If there are events in there that we don't already have, then we need to have them. So that's an important data set that's not in there yet.

MR. POMEROY: Right. Particularly the low magnitude events that might be of some interest and importance in looking at the local Yucca Mountain area versus the broader scale picture that you're looking at, say, here.

MR. YOUNG: We're going to be really searching hard for methods that we can use to define these blind sources. That may be the strongest data set that will be available to do that. If more deeper reflection work is done, that is really going to help a lot. However, in addition to that or in lieu of it, the more detailed lower magnitude seismicity is going to be critical.

MR. HINZE: Steve, we want to leave Dave at least five minutes for his presentation.

MR. YOUNG: I'm glad you said that.

MR. HINZE: He only has 20 transparencies, I think. So he won't be able to do it in five minutes. Let's minimize the details and leave those to questions.

MR. YOUNG: I'll now turn it over to Dave Ferrill, who will talk about and describe the field work and modeling that's going to support these review tasks.

MR. FERRILL: Thanks, Steve. Task 4 has got a long title, but it's basically reconnaissance field work to support tectonic issues. This is both for this research project -- Task 6 is the regional tectonic modeling and the first three items listed under objectives here will directly support Task 6 of this project, which is the regional tectonic models task.

Tasks 3, 4 and 5 support NMSS work pretty directly. This work is ongoing and the bulk of it is expected to be completed by the end of the fiscal year, which is September 1994. Objective 1 is assess estimates of late neogene and quaternary rates and patterns of deformation. We're looking for confirming or evaluating published work. We're not -- this is, again, reconnaissance work and we're not actually out gathering large amounts of data.

Geodetic measurements, this is in collaboration with Brian Wernicke on his GPS project. This is basically field support for him to gain familiarity with the techniques so we can incorporate the data into our regional tectonic models.

Three, support development and assessment of alternative models of faulting and seismo-tectonic processes. Here we're looking for fault models to support the Task 6. But, also, this is the objective for evaluating the interplay of faulting and magnetism. We're looking for field analogues of types of fault and dike interactions, such as the one that Larry McKague showed earlier from San Francisco Volcanic Field.

Four, identify and describe areas which may be structural analogues for the proposed Yucca Mountain site.

We have a lot of information about the surface fault pattern at Yucca Mountain, but there's still a lot of controversy over the deep structural pattern -- how the faults link or whether they link at depth, are they plainer to some great depth or do they link up in a shallow listric fault system.

So by looking for structural analogues of the deeper parts of the fault systems, we can help to understand Yucca Mountain. Then, five, investigate the Landers surface rupture. Brian Wernicke talked about this quite a bit earlier.

Landers, being in the southern Mojave Desert, seems a little bit distant from Yucca Mountain. However, its recent earthquake had a large surface rupture extending along a length of 70 kilometers. It's right lateral strike slip, which is analogous to the pattern of deformation in the Furnace Creek-Death Valley fault system, and it also triggered fairly large earthquakes in the vicinity of the Landers quake, as well as triggered the Little Skull Mountain earthquake. So for those reasons, we're interested in pursuing that further.

MR. POMEROY: Dave, before you leave that too far, can you tell me -- I know you've thought a lot about the interrelationships of this reconnaissance work to the field mapping work that GS and other people are doing out in the area. Is reconnaissance the key word here that identifies the difference? How would you delineate or describe the difference?

MR. FERRILL: Referring to the work that the DOE is doing?

MR. POMEROY: Yes.

MR. FERRILL: Yes.

MR. POMEROY: Comparison with the DOE.

MR. FERRILL: The DOE work tends to be more localized right around Yucca Mountain and this is a more regional project, trying to understand the regional tectonic setting of Yucca Mountain. So it tends to be broader in scope than the DOE work. Yes, reconnaissance is a key word here. We're not going out and doing detailed mapping or any really detailed analyses right now.

Part of this is to go find areas where that sort of work might be beneficial to us and right now we're just trying to identify those sites.

MR. POMEROY: So that's the analog work in Item 4 here that we're looking at, basically.

MR. FERRILL: Right.

MR. POMEROY: Fine. Thank you.

MR. FERRILL: This is an excerpt from the digital elevation model that Steve's been showing. I just want to point out some of the work to date in this field reconnaissance. The geologic setting group has been involved in reconnaissance field work at Bear Mountain. This is Yucca Mountain. Bear Mountain is here. The Black Mountains and the Death Valley-Furnace Creek region.

So far, the results are encouraging. There seems to be evidence that we might be able to find a decent structural analog for the deep structure for Yucca Mountain in the Black Mountains area. The work at Bear Mountain we think is essential to understanding the local tectonic setting for Yucca Mountain. It's just actually a pull-apart in a strike slip system.

We think that by understanding what's going on at Bear Mountain and the uplift history, we might be able to learn more about the evolution of Yucca Mountain.

These circles with crosses through them are some of -- not all of them, but most of Wernicke's GPS stations, the geologic setting group. In particular, Gary Stirewalt was involved in the 1993 field campaign in this GPS survey.

Then we are also -- the third accomplishment to date for this task is involvement in the geological siting of America's field trip at the Cordiere and GSA meeting back in March to Landers. This was a good opportunity to interact with some of the people that had been working in the area; in particular, Earl Hart, who works for the State of California, has been mapping the surface rupture and this is for the purposes of zoning or setback for structures built near fault systems.

So we get to see some of his unpublished and preliminary maps based on field mapping and air photo interpretation. Also, we are fairly pleased to find that the surface rupture is not that badly degraded. The scarps are still well preserved with slip delineations. So this gives us encouragement and we plan on getting back out there in the next six months to spend a little more time looking at particularly the east side of this system. It would be the analogous position to Yucca Mountain with respect to the Death Valley-Furnace Creek fault system.

MR. POMEROY: Again, Dave, do you have plans or do you have in the database now the DOE/USGS positioning?

MR. FERRILL: No. We do not have those yet and we do plan to enter that data into the database whenever it's accessible for us. Task 5 is assessment of geo-chronological methods for dating and characterizing fault slip information. This task was completed in September of 1993.

Basically, the objective was to assess the utility and reliability of methods used for determine slip history. The outcome of this is that there is still tremendous uncertainty in both the analytical techniques used for these dating procedures, as well as field interpretation. And we saw this firsthand two weeks ago at the NRC/DOE site exchange. We saw trenches across the Bear Mountain fault.

It was generally agreed there was a meter-and-a-half of displacement that you could see in the trenches in the four faces of the two trenches we went to. But there was a lot of disagreement about over what period of time that slip occurred.

One interpretation was that it occurred between seven and 100,000 ago. The other interpretation was that it occurred between seven and 20,000 years ago. So we've got a great disparity here. At best, it's a factor of five difference. At worst, it's a factor of 14 difference between those two estimates. So the rate of slip is very uncertain for that fault.

Another example is along the Solitario Canyon fault, where Chuck Harrington has been using a preliminary or development technique using cosmogenic carbon-14 to date the fault scarp that's been observed and was interpreted previously as a holocene fault scarp, meaning deformation was in the last 10,000 years. The cosmogenic C-14 data suggests at least 20,000 years age for that fault scarp. So, again, at best, it's a factor of two difference between the previous interpretation and the new interpretation.

So these data techniques are a great source of uncertainty that remains for understanding the rate of slip, the recurrence interval, segmentation for these faults. So it's very important for the tectonic understanding.

Moving on to task six, this is a regional tectonic modeling task. We analyze the database and try to model tectonic setting and processes.

MR. HINZE: Is that ongoing? Dave, is that ongoing and how long will it be in existence?

MR. FERRILL: Task six is actually just beginning and I believe it goes through 1996, the end of 1996. So we're just in the initial stages right now.

The objective is to determine correlation between spacial and temporal patterns of late neogene and quaternary regional strain. This would include, also, faulting, earthquake seismicity and then tie this back to the Yucca Mountain setting.

Accomplishments to date. We've been visualizing in 3D earthquakes for the regional area, as well as for the Landers event, in particular. I will show you some of those results now.

This map shows all the earthquakes currently in the GEIS database. These are all from the NEIC database. As Steve mentioned earlier, we don't yet have all the details of the southern Great Basin seismic network. We also don't have all the earthquakes from the southern California net, but we're talking to Brian Wernicke today about that and we anticipate getting that very soon.

However, earthquakes from those two data sets are included in here. Basically, any earthquake of magnitude three or above from those networks is included in this data set. Again, the background is the regional digital elevation model. The Yucca Mountain area is highlighted by this box, California/Nevada border here.

You notice that it's a pretty measly pattern. It looks like California has a bad case of the mumps here. A lot of clustering or earthquakes along the first order structures, like the San Andreas fault system through here, the southern Sierra Nevada range has a lot of earthquake activity, Owens Valley, Long Valley, Caldera area. Brian pointed out earlier the central Nevada set of earthquake, the inner Montaigne Basin trend through here, the Walker Lane, roughly following the California/Nevada border.

We can also see the anthropogenic temporal cluster of the Cold War testing in the Nevada test site. This is unfiltered data. At some point, we plan on taking out those manmade earthquakes, so we'll just have the actual earthquakes.

So we see that there's a tendency for earthquake clustering along the major structures. We notice that the Death Valley-Furnace Creek fault system here does not have a large amount of earthquake activity. Does that mean that that is not an active fault system? No, it probably doesn't. Mara Threhies, at the Cordiere and GSA meeting in March, said that the Death Valley-Furnace Creek fault system is the most active fault system in the western Great Basin, that there are six to 12 millimeters of slip per year across that fault system, and this is based on trench studies.

In the last 5,000 years in the trenches, she sees seven major slip events. So a periodicity of -- a recurrence interval of somewhere at or under a thousand years probably for that fault system. So there may not be major events on the period of time covered by this display. We're looking at earthquakes from 1812 to 1994. A fault system that has a thousand-year recurrence interval may not show up in here.

To show you one of the temporal clusters, we look up in this region and we see a lot of large yellow and orange spheres. These are earthquakes that occurred during the mid-1930s to mid-1940s. Since then, not a lot of activity. We see a lot of little red spheres, small magnitude earthquakes, but not a lot of the large ones, like the Dixie Valley-Fairview Peak sequence from the 1930s and 1940s.

So that's an example of the temporal clustering. It could be that 200 years from now the Yucca Mountain area may have a cluster activity or the Death Valley-Furnace Creek system. So just the paucity of data does not mean that it's an inactive area or not a seismic area.

We're going to focus now on the Landers sequence. You see this pod of events right in here. That's the Landers sequence. This is a slightly smaller area. The San Andreas fault system through here, Garlock fault, Death Valley-Furnace Creek, Fish Lake Valley fault system, Yucca Mountain is there. Earthquakes here are colored, again, by the date of their occurrence.

This is a six-month period centered on the Landers events, starting in March of 1992. Landers was on June 28, 1992. Then the period of time ends in September of 1992.

The blue dots are precursors to or predated the Landers event. You can see there are very few blue dots on this map in the three months leading up to Landers.

There is, however, a cluster right here and this is the Joshua Tree sequence which occurred about two months before Landers. I should note for those of you who have black-and-white copies of these figures, these dates are all 1994. Of course, that slipped through. We've got it corrected on the color versions, however. So you might want to change that if you're looking at that.

The Joshua Tree sequence here was started by the Joshua Tree quake, which was a magnitude 6.3 quake. It had a series of aftershocks that tended to be shallower than the main shock. The main shock was at a depth of about 12 kilometers and the aftershocks all propagated upwards to the surface.

Then two months went by with the aftershock sequence for Joshua Tree trailing off and then the Landers main shock occurred on June 28, 1992. The aftershock sequence for that tended to be down and to the north. It triggered several events. The Pisga quake here, the Big Bear sequence in the San Bernadino Mountains or under the San Bernadino Mountains, then triggered the little -- apparently triggered the Little Skull Mountain event the following day at Little Skull Mountain, next to Yucca Mountain. That was a magnitude 5.4 quake.

If we just look at this pattern, even looking at the overall pattern, you can shift that up and compare it with the Death Valley-Furnace Creek system and the patter is similar. They're both right lateral strike slip systems. So by studying the Landers sequence, we particularly want to get on the ground and see what's going on in this position that would be analogous to the location of Yucca Mountain with respect to the Death Valley-Furnace Creek system, look and see what the surface deformation is like in that area.

Now we're going to go to a side view of this sequence. It's going to be a view looking towards the west.

MR. HINZE: Dave, I'm worried about time and I want you to have a few moments to summarize. We also have a report yet, a summary report from Bill, and we want to allow questions. So perhaps it would be left to questions and people using your slides here. If we could move to your summary word slides, I'd appreciate it.

MR. FERRILL: Sure. Some of the results to date. The GEIS database represents a basic reference of tectonic features. These can be used to test key assumptions, important assertions, reviewing study plans, site characterization plans, license application. This is a database of great utility.

The regional correlation of earthquakes with map fault traces, this is ongoing work. It's useful for review of study plans, pre-licensing guidance and license review of issues related to, of course, that, earthquake and tectonic features and their relationships.

Anticipated results, we've got five listed here. The first three all tie into probabalistic seismic hazard assessment under performance assessment, and these are probability distributions related to fault length and orientation, earthquake magnitude and recurrence, and fault rupture length, offset and slip rate.

The last two, alternative tectonic models, including potential earthquake sources with no surface expression. These are these blind sources; for example, like the recent activity in the Los Angeles area, as Steve mentioned. Then this is useful, again, for study plan review, site characterization guidance, license review, so forth.

An improved knowledge of temporal and spacial patterns of earthquake seismicity ties into -- it is useful for review of potentially adverse conditions related to the potential for increasing earthquake activity in the Yucca Mountain region.

To conclude, six conclusions here. The review of literature provides a firm basis for the KTUs. This has already been of benefit for us. The GEIS database is being developed for timely interactive access by the regulatory analysts. Steve already discussed that. Steve and Keith have already discussed the timeframe for getting that database accessible for the NRC.

Tectonics research contributes currently to regional hydro volcanism research and pre-licensing review. This is all becoming day-to-day activity for us. Critical review and analyses of the tectonics research database provides an assessment of adequacy of existing data for compliance determination. This is a task that will be finished up this year. This assessment, this critical review assessment will be finished by the end of the year.

Tectonics research database provides constraints on earthquake and fault rupture parameters for the review activities, as listed in the previous viewgraph. Then alternative conceptual models will provide a necessary basis for inclusion of these blind sources and, also, for the association between magnetism and faulting for performance assessment.

That concludes my presentation. I'll take questions.

MR. HINZE: Thank you very much. A lot of very interesting data and correlations. We could spend a great deal of time having fun with those. Are there questions? Please.

MR. HATCHER: One quick one. How do you intend to identify the blind sources, potential blind sources?

MR. FERRILL: By, first of all, identifying which earthquakes are linked or appear to be occurring along faults that have mapped fault traces along which they're occurring. So identify the non-blind earthquakes and then --

MR. HATCHER: Going back to some of the earlier issues, though, there's this lack of connectivity between earthquakes and surface faults, earthquakes and quaternary displacements, displacements of quaternary units. This brings on that question, I think. I think it's going to be very difficult to do.

MR. FERRILL: Yes. It's a tricky mess. By understanding the -- by coming up with three-dimensional models for the faults in our regional tectonic models, we can at least -- and also incorporating the GPS measurements and also the quaternary strain rate information, we can understand more about where the risk is high and where strain is accumulating and, without earthquakes, understand the blind -- you know, be able to look for signs of potential blind sources in that way.

MR. HINZE: I have a couple of questions, Dave, if I might. The second to the last transparency, these results, the anticipated results are useful for performance assessment. Are you investigating those results because DOE is not providing them or is this being done as confirmatory research?

MR. FERRILL: I think I might defer to Steve Young for that. He's spent more -- he's spent several years thinking about this.

MR. YOUNG: We're going to have, both NRC and CNWRA, the center together, have an independent or confirmatory performance assessment. So we see the data that we're producing at this time primarily feeding into that, into the probabilistic seismic hazard assessment program for a confirmatory independent performance assessment.

MR. HINZE: Do you anticipate that these data will become available from DOE within a reasonable period of time or do you anticipate, as a result of looking at the study plans, that these data will not be available?

MR. YOUNG: My opinion at this time is that the DOE does not have quite the regional focus that we have. So, therefore, we're likely to include events, faults, earthquakes in our database that perhaps are outside of a region that they would be more concerned with.

In other words, we probably will include stuff in our database that right now I don't see them producing.

MR. HINZE: I believe in the SAP they had a 100-kilometer radius, something of that magnitude.

MR. YOUNG: That's correct. We go out considerably farther than that.

MR. HINZE: And your radius is not necessarily a radius, but is more directed at specific analogues.

MR. YOUNG: It's defined by what we characterize as the tectonic setting of Yucca Mountain. That's how we determine which regions we're going to look at faulting and earthquakes in. Because of the complexity in the patterns that are emerging from the paleoseismological studies, we think that in order to do a reliable credible compliance determination, that we will need data from much of that region.

So we don't define it by a radius, no. Our region of operation is more geologically defined.

MR. HINZE: As I look at the various tasks, the six tasks that you've presented here this morning, two of them were completed basically a year ago and three are scheduled for completion within a few months. There is only one, the analysis of the database and modeling is the only one that has some continuity between now and 1996.

Can you give us some vision of what the research activities in tectonics are viewed in terms of 1995 or is everything going to be focused on database and modeling?

MR. YOUNG: I think the way we see it, it's going to be very heavy in modeling. We think we're pretty far along in data compilation. Data compilation will continue as a background or a support activity for modeling, because as paleoseismological studies at other major fault systems get completed, we're going to put that into the database.

But we're going to focus real heavily on putting these integrated models together.

MR. HINZE: So if I interpret you correctly, the single task that will be continued on through 9/96 will be the sixth one, the analysis of the database and modeling. You have no vision in terms of the results of the work that you've done on the first five tasks of additional research or the KTU analysis has not provided any view to new tectonics research that should be carried out.

MR. YOUNG: The modeling that's going to be carried out over, say, primarily the next two years or so, we expect that if there's anything -- if there's any new insight to be gained that is going to substantially impact KTUs, that it will come out of that modeling, because we intend for that step to create -- or to use that step to put everything that we've compiled into some sort of a set of alternative models.

So the coherent models or the viable alternatives have to emerge at this stage and we expect that it will be at this stage that if there are opportunities for new KTUs or for modification of existing KTUs or even for new research directions, that it's going to emerge potentially out of two tasks. It's going to emerge either out of the field work, the reconnaissance field work that we do this summer or through the fall, or it's going to emerge out of the modeling task.

The way that we look at it, the way that we view it right now is we look to those tasks to develop new directions, if a new direction is required.

MR. FERRILL: Part of the purpose of the reconnaissance field work was to identify field localities that deserve additional study as fault system analogues or fault and dike interactions, things like that, for additional work beyond the scope of this project, where it was intended to be reconnaissance work.

Another point is that part of the field work -- when we recently revised the project plan, we extended some of the field work beyond the end of the fiscal year into 1995. We've also added -- beyond just analysis of the database and regional tectonic modeling, we've also included in the recent revision some emphasis on analog modeling. We'll do sandbox or clay cake modeling in the lab to try to model structural fault systems at depth; be able to generate in a sandbox releasing bins, be able to slice through those and see what the deep fault system is like.

MR. HINZE: Will that be a new task, then?

MR. FERRILL: No, no. It's covered under task six. It was just a clarification of task six in the recent project plan review.

MR. HINZE: Steve, I want to make certain I understand. In terms of the objectives here, Steve, that you went over, I was struck by "at this time, the primary focus," and that's very emphatic, "the primary focus is to examine the sufficiency of data and methods to determine compliance."

At this time, does that mean through 9/94?

MR. YOUNG: Yes.

MR. HINZE: What would be the primary focus subsequent to that?

MR. YOUNG: Input to hazard assessment and input to performance assessment. We have a vehicle that's being established right now to move data that's produced by this project directly into performance assessment, and that's the auxiliary task that Gary Stirewalt is starting right now. He started that by looking at the EPRI methodology. We think that the EPRI methodology is probably okay as far as an algorithmic framework within which to use the available data.

What we expect to happen is at some point, we are going to begin to feed data into that and into probabalistic seismic hazard assessment and thereby into the fault and seismic models in performance assessment. So I would see that as being a logical change of emphasis at some point where we've satisfied ourselves that we've got enough to do reliable, credible modeling. Now, let's move the data in and start a series of models with it.

That, in my mind, would be a change in primary focus.

MR. HINZE: That's all I have.

MR. POMEROY: Anyone else?

MR. GARRICK: Can I just comment on one thing? In your first viewgraph, you anchored the tectonics research program pretty much to the regulations and were quite precise in terms of the document, another part that was relevant to the topic.

I guess what I'd like just to have a brief comment on is how did you decide on the scope? Is the program pretty much an interpretation of what the regulations are asking for, which are very general and, in many cases, non-specific? Can you give us a little insight as to the thought process that went on to resolve research scope?

MR. YOUNG: Yes. The important considerations for scope were very much a combination of the regulatory priorities and the resources available to go after it. So what we did is we went completely through the regulation and found -- made ourselves a catalog of all issues that were potentially related to tectonics and then went through and prioritized those.

It wasn't so much a prioritization exercise as it was of finding the important commonalities, and there are some very important conceptual threads that run through virtually all of the issues related to tectonics and they have very much to do with estimation of fault slip histories and estimation of earthquake magnitude and a few things that have to do with the characteristics of earthquake seismicity.

We found that the strong signal that came out of there is that we needed to know -- our biggest areas where we needed to have either a good understanding of the existing knowledge or we perhaps needed to advance our understanding some was in fault geometry and distribution; in other words, what types of faults were these, what are their shapes in the subsurface and what are the implications for earthquake seismicity, and then, furthermore, how far can we go to characterizing or discerning both the slip history of individual faults and the regional time and space patterns of seismicity.

So we knew that virtually all of what we had to do needed to impact on that right away. Further to that, we knew that we also stood a good chance of making good progress in that area in a relatively short period of time, because there's -- most of the geological work that's been done out there recently has been focused on tectonics and faulting and seismicity.

So we thought we stood a good chance at success in that area and that colored our decision, too.

MR. GARRICK: Has the feedback loop from performance assessment begun to have any effect?

MR. YOUNG: I have to say that not substantially. We're only now to the point where we can start and exercise this vehicle that Gary Stirewalt is setting up. Furthermore, I think that performance assessment is only now getting to the point where they're capable of assimilating this kind of data.

We've seen that in up through Phase 2 IPA that there hasn't been a good procedural mechanism in there yet to handle these type of data. However, that is now emerging in Phase 3. So our timing, somewhat serendipitously, but also somewhat from design, our timing is coming together about right on that.

MR. GARRICK: Thank you.

MR. HINZE: If there are no further questions, thank you, both of you, and Larry. Bill, we'll turn it back to you to summarize Research's overview of tectonics research.

MR. OTT: Before I go to that, I'm going to just throw up the -- make two points about this that we started off with this morning. The point I was going to make -- you recall that I started from user needs and I actually didn't address KTUs at all. I talked about the SOWs that were developed.

One comment I would have made when Steve was discussing how things were constrained is that he was very strongly constrained by the SOW that we sent down there. When we get back a project plan which doesn't respond to the SOW, it gets returned.

The other thing is that KTU development in terms of where we are today, there's been a very active period in this timeframe right here, right there of KTU development, LARP development, the whole process. You'll notice that both the regional extensional tectonics and the volcanism in the basin and range, we were collecting a tremendous amount of information during that time period. That goes into one other ~hing.

MR. HINZE: Bill, before you remove that, help me with what your thoughts are regarding the time period 1997 and 1998 on regional extensional tectonics. The tasks that we see here go through 1996. What do envision?

MR. OTT: Essentially, we've left -- well. My words took me too far, anyway. We've also left ourselves some flexibility. I understand that the center and George have had some discussions with regard to an expansion of some of the work, pulling in some of the work that was intended for geo-chronology. Those discussions haven't reached their conclusion yet.

The likelihood is that there will be some more resources put into the project. So there may be some expansion of some of the work that's been discussed here. Some of those tasks may last longer.

MR. STIREWALT: Excuse me. I'm Gary Stirewalt. I might comment on that, also, if I may.

MR. HINZE: Sure. Please do.

MR. STIREWALT: The way the SOW was structured was that that potential extension might well involve some additional field work. The stuff that David Ferrill described, that might be a continuation. Of course, I should also add that that doesn't happen automatically. That also would require assembly of a research plan. It would be approved by the NRC. But that's what that extended timeframe was partially meant to capture, as well.

MR. OTT: But the center is constrained by the resources and by the scope of work that we assign to them. They have come back and said that we could use some more resources to do some specific things. That's under discussion and we haven't made final decisions on whether we'll do that yet or not.

MR. HINZE: Are the resources available for tectonics research comparable to that for volcanism research?

MR. OTT: The expenditures at the present time are less on tectonics. The resources available if we put the total amount that was reserved for geo-chronology in there are about the same.

MR. HINZE: Do you foresee any increase in that in the succeeding years? Is that in the plans?

MR. OTT: Only at the expense of other programs.

MR. HINZE: Thank you.

MR. OTT: Essentially, the budget is flat-lined, except for minor variations, over the next four or five years or so.

MR. HINZE: Enough to give David a raise once in a while.

MR. CTT: San Antonio is so cheap to live, they don't need raises. After this morning, there are a couple of things that I wanted to make an observation on before I get to the actual final slides.

The Type 4 and Type 5 KTUs and user needs, Type 5s are quite often characterized as we've generally got to do research. Type 4 is we may use existing methods and things like that. Type 4s are things that we may do research on, as well. That's why they're included when we have these discussions. The Type 4s are maybe we will, maybe we won't. The Type 5s are we really need to do something.

As you pointed out in looking at one of Keith's slides, the overview slide that we usually bring with us to talk about the LARP process essentially has the CDSs flowing into KTUs, flowing into user needs, and then flowing into the research program. That was an accurate observation the way it works.

Marty came -- and Marty has disappeared, but Marty came up at the break and said I really ought to address, again, this question of NRC versus DOE, how do we choose what we do as opposed to what DOE does. Well, we don't really choose what DOE does. DOE is motivated by a lot of requirements of their own.

We sort of are on their back trying to help them make decisions that will get information that we need that we feel is necessary.

I wanted to point out an annual review of the NRC program. Every year we go through this as part of the LARP process. This comes back to this communication of new ideas for research. The center essentially participates very actively in the annual CDS/KTU reviews. What can be left for that review in terms of making long-term adjustments to the program are done at that time.

Something that comes up that's of overwhelming importance, the NMSS can communicate to us at any time in terms of trying to make a mid-term course adjustment in the program.

In terms of DOE, NMSS and the center are continuously in review of what's going on through technical exchanges and everything else. Research supports NMSS in those activities to the extent that we have staff available. Our operation is much smaller in terms of FTEs than NMSS' and we have to pick and choose at times. Otherwise, we don't get things like vouchers reviewed and contractors don't get paid.

Considerations in what we choose to do or how we choose to do it, they always come back to this question of independence in terms of licensing judgments. The NRC is an independent regulatory agency and we're charged with making this licensing decision to our best knowledge and our best degree of information.

What is our degree of certainty in what DOE has done? That's what it all boils down to. If we have a high degree of certainty that what DOE has done is going to give us the information that we need, then there's very little reason for us to do research. The source of this degree of certainty comes from the technical staff in the Office of Licensing, technical staff at the center and the technical staff in the Office of Research, and it comes through these annual reviews of our program and DOE's program.

In terms of why -- what we do to assert this independence, part of it is confirmation both of DOE's data and of a counter position. If somebody comes up with an alternative conceptual model which we don't necessarily have information supporting, DOE dismisses, but we feel it can't be dismissed, then we may have to do some work to either confirm or counter this position.

Assumptions are at the heart of much of the modeling. We have to probe around the edges of the assumptions. We may need to challenge these assumptions in order to make DOE do work to give a better basis for those assumptions.

Conceptual models, that's at the heart of everything that goes on. You don't start the performance assessment without a conceptual model of the system that you're trying to assess.

If there are alternative conceptual models in which your collection of data tends to confirm one or to not test another, then one has to worry about the other side of the coin and you may have to go out and collect data to allow you to test other conceptual models, such as the rather traditional example of fracture flow versus matrix flow.

Those are just some things that came out of the discussions this morning. The conclusions here are brief. Again, we tried to sit down after we had gone over the original proposed presentations by everybody and figure out what we wanted ACNW to come out of this review with, what we would hope we had convinced you of today.

One is that the tectonics program is strongly tied to KTUs and user needs. I think the focus of what we've done here today is tried to convey that to you. Both the user needs and the KTUs are developed after a lot of thought and a lot of canvassing of the available information that we feel they reflect what needs to be done and that our program is focused very closely on those aspects of the program.

The literature surveys have provided a firm technical basis for the KTUs. The diagram I just showed you minute ago gave you an idea of the timing. The first thing we did was go in there and try and get an assessment of this database and volcanism and tectonics -- what's out there in the basin and range. And KTU development, LARP development was going on at the same time with the same personnel. That information has been continuously fed back between those two operations.

So we feel that this particular aspect of the research program has made a significant contribution to the development of the current stage of the LARP.

Timeliness of the research efforts assist in preparation of the LARP. I've gone over that already again. And in pre-licensing and licensing reviews. These are going on all the time -- tech exchanges with the Department of Energy, site visits, the upcoming DOE meeting in which there will be presentations by center staff, as well as by DOE contractors.

Confirmatory databases and models are being established for state-of-the-art compliance reviews of DOE analyses and models. I leave that to your judgment. We have shown you what we're trying to accomplish with the GEIS and with the databases on both volcanism and tectonics. We feel they're going to be a significant tool in helping the agency do its job.

Well integrated alternative conceptual models are under development for evaluation of DOE models. This is perhaps not as evident from what we've seen today. It may be a lot more evident next year when we've done more work on the modeling.

I'd like you to come away saying it is a focus of our program, this is something we're going after. It's something that's even embodied in that overall diagram of the geology research that I started off with, modeling of mantle dynamics. That's the input that we really want to get to to feed into probabilities and consequences and the other things that they need to make PA work.

Tectonics research activities are well integrated with other research projects and technical assistance activities. This goes a lot to what Larry McKague did when he tried to describe what the PA program is and how it interacts with the research program.

I guess those are the things we'd like you to come away with. Do you have questions?

MR. HINZE: Let me ask a quick question, if I might. One of the things that's very much on the mind of the ACNW and others is the possibility that there is pervasive fracturing, if not faulting of the proposed repository site, the Sun Dance fault and other faults of a similar nature.

Is there any research that can be done to help to define or to ascertain whether multiplicity or faulting is a probability in this area, in this volume of rock, or what we can expect are one or two major faults, as has been the supposition and the way that the Yucca Mountain repository has been diagramed?

MR. OTT: I will ask any of the staff here if they'd like to answer that one, because I'm certainly not qualified.

MR. McKAGUE: Larry McKague. The problem, of course, is in the third dimension. About the only data that I know exists is data from the large diameter bore holes, particularly those on Yucca Mountain -- not Yucca Mountain -- on Pahoot Mason, north of Timber Mountain. In drilling, often -- well, in the last ten years, we've had down-hole movie cameras. It was not uncommon to see small faults in there.

So what you see at Yucca Mountain doesn't surprise me a whole lot. I expect there to be a lot of small faulting through there.

MR. HINZE: Are there mechanical models that you can put together that would suggest that there are intricate faults that might slice up the entire repository and would we expect those to have any particular orientation on the basis of our knowledge of the previous stress patterns?

MR. YOUNG: Yes. We have worked in the past on geometric and kinematic models of deformation there and we're working now on some mechanical models to simulate the deformation there. In fact, one of the assumptions in the whole major class of kinematic models is that a raise of small faults or fractures are the deformation mechanism for the hanging wall block.

So in one class of models that we have, distributed deformation is the assumed deformation mechanism. At different points during that modeling process, we have taken orientations of those small faults directly from either geological maps or cross-sections done by the USGS and we've useu those orientations specifically to constrain or set the geometry of the deformation mechanism in the hanging wall block.

So we do have models that include those and it dominates a whole class of those models.

MR. HINZE: Are there research summaries that focus in on that and that also clearly enunciate the assumptions that are in those models? Are those available to us at this time?

MR. YOUNG: Yes. I think that the work that we've done that addresses that issue is mostly in the reports on geometry of faulting that have been out for a while. Furthermore, the results of the mechanical deformation simulation, which will be out in about -- I think about another year or so.

MR. HINZE: This is sandbox.

MR. YOUNG: No. This will be the finite element work, although the sandbox models will address some of that, as well. Probably a point that should be made is that most of the work that addresses the issue that you're asking about right now we have had going on in technical assistance tasks as distinct from research. I think the reason that we put that in there is because it's a little more site-specific focus and a little bit less on the research side. So we put them in the technical assistance task work.

MR. STIREWALT: Bill, excuse me. Gary Stirewalt, again, if I might add one point to that. I think not just mechanical models suggest the possibility of more complex structures, but certainly mapping as early as what Bob Scott did in '84 I think convincingly shows that there are zones that lie along the Sun Dance and places other than where the Sun Dance occurs. That suggests that there could be a very complex fault pattern in the block itself.

I think there is good and reasonable field evidence for that kind of interpretation.

MR. HINZE: I think we've stood on the outcrops together.

MR. STIREWALT: We did.

MR. HATCHER: To the contrary, you might ask yourself why is Yucca Mountain there and why are the valleys in that area there. Just from a simple observational point of view, the valleys are where most of the faults are and that may indicate an intense -- a relatively lesser intensity of fracturing than the rocks or less intensity of faulting, except for very minor faults, which you're going to encounter anyway.

MR. STIREWALT: Yes. That's what I was going to say. Perhaps the valleys are areas of more major faulting, but, Bob, the concern is not just the amount of slip, but how, in fact, it may affect the hydrology. So if you have a continuous connected fracture system, whether there's a lot of displacement or not, it's still a potential concern, I think, and I know you agree with that.

MR. HATCHER: I agree totally, yes. Sure.

MR. HINZE: Well, it's past 12:00, even in Indiana time. Keith, please.

MR. McCONNELL: I'd just like to make one brief statement and that was in response to Dr. Garrick's question about the influence of performance assessment or IPA. I would say that at the technical assistance element manager level, it has had a dramatic effect in how we manage the center's activities in that it is -- everything we do is focused on key technical uncertainties that have some sort of performance implication.

There may not be complete agreement within the staff about that implication, but certainly there is a body of the staff that believes that it has a significant performance effect or it wouldn't be done at the center.

MR. STEINDLER: It may not be 12:00 in Indiana, but still. I notice that our -- I thought our agenda said 1:00. Did I read it wrong? So I still have a few minutes. I guess I've got a couple questions. You're about to rework the KTUs. And, I think, Keith, you indicated that you were going to try and get that job done by the end of the calendar year.

One of the concerns that the Committee has had in the past is that the KTUs were so broad that almost any user need would fall under them. My comment, rather than a question, is that I think that's an issue that we've raised in the past and I would urge you to maybe consider it and make sure that the KTUs are sufficiently sharply focused so that the relationship between the KTUs and, for example, performance assessment topics or needs is made fairly clear.

The other thing that I'm puzzled about, and it may be obvious to some, but in the absence of some clear indication of a model of how tectonics influence the performance of the repository, specifically how the either hydrology issues or impact on the waste engineered barrier system is done, it seems to me that the research program, database management aside, is not constrained enough or you have no mechanism of defining whether or not something is important to be investigated or not.

One, is that a reasonable picture? Secondly, if it is a reasonable picture, is there some mechanism that you folks could use or have available to you that identifies rational pictures of how tectonic events that you're looking at influence what happens in the repository as it relates to the either subsystems regulations or the EPA regulations, so that you can decide whether a particular avenue of research will uncover information that is important to that issue or, in fact, may be trivial.

MR. OTT: It's a long question. I'll try and answer it as best I can. Let me start out by saying that we're in a continually evolving process. When we began, we had no tools to assess the importance of one phenomenon over another.

Regulation was developed where there were a number of potentially adverse and favorable siting conditions specified through a process of use of professional judge, best professional judgment of the staff to determine what things would be of concern at any repository site, because you realize that Part 60 pre-dates Yucca Mountain significantly.

As the license program and the research programs evolved, we came to a point at which Yucca Mountain was selected and people started worrying about are there specific things about this location that we should worry about more than at other locations. There was fairly strong consensus that issues of the general geologic structure and the tectonic controls on seismicity and volcanism were things that needed to be evaluated as potential hazards to this particular repository site.

Now, we again are in a situation where I think the PA methodology is not yet far enough advanced to give you a good indication of how to prioritize within such a discipline as seismicity or volcanism. We're trying to move to that point, but those models in PA exist at the top of that pyramid of abstraction that we reviewed the last time when we were here when Norm Eisenberg made his presentation, and they lacked sensitivity to a lot of detail.

How much of what Steve Young presented today can get into that PA model is very little. He has to be responsible for abstracting that information and defining it in such a way that it's useable in the IPA format.

Again, in the volcanism presentation, Linda made brief reference to some very crude calculations that she did on the volcanism hazard. Could we have volcanic incidents that would cause us to release sufficient radionuclides to violate an EPA standard? Her conclusion, based on very crude calculations, was, yes, we could.

So in that instance, more than in the seismic area, we've done some rough calculations. The thing is that the tectonic picture is important to both the seismic evaluation and the volcanic evaluation in terms of both those hazards. The way that -- at least the way I understand it, and I'm not a geoscientist, my staff convinces me that an understanding of the basic structure is important to both seismic and volcanic hazard.

So if I had to say have we done anything to justify doing work on tectonics, I could say that we've done it in volcanism. We're a little bit farther along in terms of volcanic models being used in PA. I think we're moving in that direction in the seismic area, as well.

I think we're moving in the directions you want to. We may not be moving fast enough for you. I think we're all dissatisfied that we don't know enough now. Of course, if we knew enough now, we wouldn't be here at all.

So all I can say is I think your concern is inherent in the uncertainty of the problem that we're dealing with. That's the best answer I can give you right now.

MR. McCONNELL: I think I'd expand on that a little bit. We are fairly aware of the site characterization program that DOE is carrying out, including the conceptual designs of the repository and the potential for fault displacement to affect either the long-term isolation, the containment, or even pre-closure concerns. From that, we derive conceptual ideas of what was important.

In, as an example, extreme erosion, based on the knowledge of the site and the DOE work to date, I think everybody would agree probably it's not a major concern. There are no key technical uncertainties with respect to that aspect.

With respect to faulting, however, if there's a hot cell at the surface facilities during the pre-closure and they put it near a fault, as the Committee has prompted us to do, the staff has to be aware of the faulting in the area, has to be able to ask the right questions, to, I guess, paraphrase Commissioner Rogers, and be in a position to defend those questions when it comes up.

So all of that activity goes into our thought process as far as identifying key technical uncertainties and making sure that the research and technical assistance is constrained to those things that are important.

IPA is a part of that. It's one leg of that. But IPA is limited in the sense that there's a hazard to allowing the models to confirm the data, to a certain degree. We're using IPA and we intend to use it even more in constraining our concerns and our research.

MR. STEINDLER: Thank you.

MR. HINZE: Further questions?

[No response.]

MR. HINZE: If not, Bill, Keith, Larry, everyone, we do appreciate the excellent quality of the presentations, their comprehensiveness. The excellent diagrams tell a lot of stories and I'm sorry that we didn't have a chance to go into all the details of them. I'm sure that the Committee will give your presentation a lot of careful thought. If we have any further questions, we'll be back to you. With that, Martin?

MR. STEINDLER: Okay. Let me declare an hour lunch break and then we'll be back at 2:30 to talk about Yucca Mountain and the National Academy.

[Whereupon, at 1:27 p.m., the Committee was recessed, to reconvene this same day at 2:30 p.m.]

AFTERNOON SESSION

[2:34 p.m.]

MR. STEINDLER: Let's resume our meeting. In accord with the agenda, the afternoon session will start out with a report on the recent National Academy of Sciences panel meeting. John, I think you and Howard are going to share the reporting or whatever.

MR. GARRICK: Yes. Howard Larson of the staff and I went to Las Vegas on April 27th and 28th for the purpose of attending the open session part of the National Academy Committee on the Yucca Mountain Standard. We spent the first day being part of a tour. We toured the site, saw the hardware that had been delivered for the tunnel boring machine, and went into the tunnel and participated with some 11 others in the proceedings of that day, which was mainly a tour and a tutorial, so to speak, on what was going on at Yucca Mountain.

The second day was divided into two pieces as far as the Yucca Mountain Standards Committee was concerned. One was an open session that went from 8:30 until noon, approximately, and then the other, which we did not attend, was a closed session, a writing session, that took place in the afternoon and also the next day.

As most of you know, the National Academy's Yucca Mountain Standards Committee was formed in direct response to Title 8 of the Energy Policy Act of 1992, which directed the Administrator of EPA to contract directly with the National Academy of Sciences to conduct a study, to provide findings and recommendations on reasonable standards for protection of the public health and safety.

It might be worth noting that Congress had mandated that the study was to address three questions, primarily, and I'll just mention those. Number one, whether a health-based standard based upon doses to individual members of the public from releases to the accessible environment will provide a reasonable standard for protection of the health and safety of the public; number two, whether it is reasonable to assume that a system for post-closure oversight of the repository can be developed based upon active institutional controls that will prevent an unreasonable risk of breaching the repository barriers or increasing the exposure of individual members of the public to radiation beyond allowable limits; and, number three, whether it is possible to make scientifically supportable predictions of the probability that the repository's engineered or geologic barriers will be breached as a result of human intrusion over a period of 10,000 years.

So these were the principal questions being asked, but, of course, the mandate also made it clear that the Committee should not be bound by those questions and should feel free to make whatever other recommendations and observations that would seem appropriate to providing a basis for a new standard.

The short open meeting that we attended consisted of a series of presentations, although the presentations, for the most part, took the form of answering questions, because the Committee had adopted the format of not having formal presentations since they had received the exhibits from all of the presenters well in advance and were instructed to be there with questions, and the presenters would be, therefore, available to answer their questions. That was the approach.

People that were involved or institutions that were represented, rather, were the EPA, the county officials, Nye County officials, EPRI, the NRC, Margaret Federline, and there were also -- there was also the American Nuclear Society, and a few other people were involved.

The one thing that was clear from the session is that the Committee has made a very genuine effort to listen to everybody and to get input from whomever had anything to offer in the way of suggestions on what might be the standard or the basis for the standard. Of course, even from that small sample, it's obvious that the concepts vary widely.

One of the things that was kind of interesting, in my opinion, was that Bill Gunther of EPA sort of reminded the Committee that it was important for them to provide some sort of a rationale of the standard with the 40 CFR 191 as a baseline or as a reference. This precipitated a few questions and I guess the thought process here is that if we're going to have standards, even if they're different standards, at least from EPA's point of view, they ought to show some sort of connectivity. There ought to be some sort of consistent thread of logic from standard to standard.

Whether or not it's going to come out that way, I'm not sure. The Electric Power Research Institute was making a pitch for a two-part standard, one that would be for the period of time for which the engineered barriers or the engineered systems would be in place and then one for the times beyond that, the theory apparently being that for the engineered barrier portion, they would be able to develop a case of containment with high confidence as it was something that was manmade and, therefore, its details in the fine structure were known, where in the case of the long-term and the geological formations, the same may not be true.

I, after the meeting, was encouraged by a couple of Committee members to write a letter on my thoughts. I chose to do this as an individual rather than as a representative of either the Advisory Committee on Nuclear Waste or the National Academy's Board on Radioactive Waste Management, both of which I am a member. So in the context of a citizen, I did make a few brief comments and I wrote the letter to the Chairman of the Committee.

My impression, based on this short snapshot, is that the Committee is headed towards supporting what have become loosely called in the trade a speed limit on public health, accompanied by guidance on implementation of such a goal or a standard.

It also looked to me like they were going to rely quite heavily on the ICRP as somewhat of a model and I suspect they will try to make some sort of connection with the current EPA standard, 40 CFR 191, although there is still discussion and debate on that.

I'm sure it's not going to inhibit finally coming to closure on what they're going to present. Now, the Chairman -- namely, Bob Frye -- reminded everybody there that it was not their goal or charter to develop a standard. It was more a matter of getting a background, source material, guidance that could be helpful in inspiring or developing a standard.

Now, my own personal comments, I'll just highlight a few of them. I think that the Committee has a very difficult task, and I will be looking at my letter as I make these comments. My own feeling about this is that it's made difficult by the fact that they're being asked to answer a question that, from the perspective of an old risk analyst, may not be the right or even the important question to be answered.

The important question to be answered is what do we need to do to give ourselves and the public, including workers and stakeholders, confidence in the safety of the Yucca Mountain repository. The follow-on question is what performance measurement or measurements are important in this regard.

We should probably not be arguing about what performance measure to calculate and regulate, because I think most people know what indicators are necessary in order to develop confidence that you know how the repository is going to perform. So the point is that you should calculate them all, because it turns out when you've calculated one or two of them, calculating the others generally is reasonable straightforward. So that was a personal observation.

I, in making that point, drew on the experience, which I find in the waste field is not always a good idea, but I drew on the experience from the nuclear power field and, in particular, the safety goal approach and the problems of trying to regulate or trying to measure safety on the basis of a single attribute.

As a matter of fact, it wasn't until we started calculating multiple risk and safety parameters and doing it probabalistically that we began to really understand nuclear plant safety and the means for effective risk management.

So my point here was simply a lesson learned point in relation to the experience base that I had.

Another point -- well, having said that we are probably -- you're probably being asked to answer the wrong question, then I asked myself, well, how can I be constructive, what can I offer constructively to the standard question, even if it is the wrong one. My thought on this is that if -- my thought on it was that I believe the answer here is in the guidance part of the standard and guidance issue that they're heading towards. For example, if the Committee pushes for a broad-based analysis using, for example, risk assessment techniques as a way to get the standard, then perhaps a logical performance assessment will prevail even if we are talking about a single attribute.

If, on the other hand, compliance with the standard provides an excuse to not answer the more basic questions about risk and safety, then, in my judgment, we will not have served the public's interest.

So that's the point about the question and how to respond to their question in as an effective a way as possible.

Now, the other thing that got my attention was that there seemed to be a lot of ways of characterizing a standard. People talked about a standard that was technology based, release based, dose based, and all of that would be fine, but they also talked about another one which they referred to as risk based, where the latter evidently was to mean health based, which I found very confusing given that all of the others could be risk based, as well.

Yet, I think we were complicating, by using that kind of language, the whole issue of risk communication, safety communication, regulatory communication, something we certainly don't need to do. These are not mutually exclusive concepts. Risk assessment is not a consequence. It's a thought process. It's scenarios, likelihoods and consequences, where we can be completely free on what we choose as consequences. There's no where that says that it's a health effect, that it's any other single thing.

So I think there was a lot of discussion and debate that was unnecessary relative to trying to bend these concepts into specific categories.

The other thing that I commented on, and I'm not going to mention all of them, was there was a little bit of a belaboring exercise that took place with respect to the modeling of human intrusion scenarios. A Committee member was attempting, in my judgment, to micro-model a specific scenario and was challenging the presenter on how to do it.

I suspect -- and neither the Committee member nor the presenter got a heck of a lot out of the discussion. I know none of the rest of us did. But the point is that when we model things like this, experience at least has told us that we really have to be careful about not trying to model every detail or we will never get the job done.

I think, again, the nuclear power example makes the point. We do not attempt to model all leak sizes at all locations, for example, in the primary system. We tend to categorize leaks as small, medium and large and we tend to talk about a whole system where the thermodynamic conditions are consistent throughout that system, more or less.

I think that they were a little off track on that. On the other hand, I was impressed with the database, the information base that they have pulled together. I have very high confidence that the Committee will make a very sound recommendation. My suspicion is that it will certainly be a health-based recommendation and my hope is that it will be risk-based, as well.

And there's no question about the competence of the Committee. If they had any weakness, my judgment would be that it would only be in the area of an engineering-based risk assessor. As most of you know, in this business, there are two very distinct cultures. That is to say in this risk business. There is that culture that kind of emanates from the health sciences, including the EPA, and there's that culture that emanates from the nuclear power industry and the engineering community.

I kind of characterize these as engineering culture and the health science culture as it relates to risk assessment. The Committee is relatively weak on the engineering culture, in my judgment, but I think with the presenters and the consultants they have, that probably will not translate into a real problem.

I have high confidence that they're going to come up with something that does, indeed, serve most of our best interests.

Now, Howard Larson was there and he can probably correct all my mis-observations and certainly add depth to the description of the meeting. Howard?

MR. LARSON: Thank you. I gave you all a report on it and I could summarize a few points that maybe John, in covering a different perspective, didn't elaborate on. As I said, on our tour the first day, it was interesting. Of course, it was President Nixon's funeral. So it wasn't very crowded. There were only a dozen of us on the tour. We got to see a lot of things, got to spend a lot of time, were told that the last pieces of the TBM would be there or should be there by now, and that on August 8th they were going to put it in the tunnel and get it ready to run.

As far as the meeting itself, the National Academy of Sciences, as Dr. Garrick pointed out, Mr. Gunther from EPA indicated that their general counsel felt that whatever recommendations the Academy Committee came up with, it ought to be consistent with current laws, including things like the Safe Drinking Water Act.

As John said, that raised some interesting questions and comments, without resolution. It was a fact-gathering meeting, as Dr. Garrick pointed out. So there weren't really very many, if any decisions. It was more or less a discussion and a question.

As Chris Weppel, you called the substantially complete containment phrasing a technology-based dinosaur. He didn't understand that or reasonable assurance. There were even comments made on such things as the differences between groundwater and drinking water, that groundwater was not necessarily drinking water, and that led to some other questions, too.

They were asked whether EPA had decided whether the Yucca Mountain standard should be similar to the 191 standard that was issued for WIPP, and EPA hasn't decided what they want to do on that.

As John said, EPRI talked about two terms -- one, the near term, a thousand years or less, where they thought the containment should -- or the container should be -- the container integrity should really be the true licensing test and that anything beyond that, out to hundreds of thousands of years, should rely on PRA, and that there should be varying degrees of rigorousness for each of the time periods involved.

They also volunteered, in discussions with them later, to come in and discuss that in greater detail with the ACNW, should the Committee desire to hear more from EPRI on that.

There were some questions to the NRC, Margaret Federline, as to what did they assume insofar as future societies and the assumption, as you saw in her paper, was that future societies will be the same as today. As you can imagine, there were discussions on both sides of that, whether that was a rational or irrational decision.

MR. POMEROY: Howard, in here you say -- there's sort of a statement that says "should try to focus on what can be litigated," under Margaret's comments.

MR. LARSON: The feeling was that at least you knew what the current state of society was, whereas in the -- and you could state --

MR. POMEROY: You could argue about that.

MR. LARSON: You could argue about it, whereas it was difficult to argue about anything in the future. The NRC also -- or Margaret stated that the NRC believed that passive controls can be effective in the future, but that active controls, while they should be as good as possible, you couldn't really consider them for any credit for any period of time.

Nevada indicated that water economics in the future, and they sort of termed that as the next 50 years or so, they believed were such in Nevada that mining the Amergosa aquifer will probably be feasible and that the cost of water was such that that would be feasible, and the way the population was growing, but that this could change the current hydrologic gradient and that that should be considered as people analyze the site.

There was discussion on carbon-14 calculations, where Van Konenberg's calculations were challenged by a fellow, Mortenson. I think I've got part of his paper in there. Van Konenberg couldn't respond in a lot of depth. So the Committee requested that Mortenson send to Van Konenberg his calculat o.s so that he could check them and get back as to what ..e magnitude of the differences were between the two.

I guess the only agreement was that they agreed that EPA's calculations were wrong.

The Nuclear Energy Institute made the position that they felt that the National Academy of Sciences Committee's recommendations should be very strong recommendations, both to EPA and the NRC, and that the National Academy should feel free to propose regulations if they felt that more than generic guidance was required. These were statements from the floor. There maybe was some discussion, but there wasn't any necessary acceptance.

The basis for the EPA standards that the Committee has been asking for for years was raised. It was asked that they be redone and that perhaps the true level of protection that's required would fall out if they were done again or were ever really done properly. Some discussion on that, but the general feeling was that many had asked, but no answers had been chosen or given.

As Margaret Federline said yesterday, there will no further open meetings of the National Academy of Sciences Committee. They were going to continue with their executive sessions. They were going to have their blind peer review and the report would be out hopefully by the end of the year.

They did say that after the report had come out in the draft, they would intend to hold another meeting in the Las Vegas area open to the public so that people could ask them questions as to how they arrived at their questions.

In the package that I gave you, it indicated that there were 17 groups or so. Probably 70 percent of them or so were asked direct questions by the National Academy people. The others were -- each was asked whether there was anything they wanted to say. And so everybody did say something, whether they were asked a question or not.

So that all people that had provided written comments did get the opportunity to speak at the meeting. The meeting ran right on time, was over right at noon.

MR. STEINDLER: Anything else? Any questions?

[No response.]

MR. STEINDLER: Is it clear that this is going to turn out to produce a useful product, John?

MR. GARRICK: Well, fortunately, I have a colleague here that's also on the Board on Radioactive Waste Management and we've been in on some of the discussions that led to the formation of the Committee. I think there is a very spirited interest on that Committee to generate something that's useful.

MR. STEINDLER: The way the law is written, at least my interpretation, is that even if the National Academy Committee does, in fact, turn out something that we all might think is useful, that is no assurance that the EPA has to or needs to follow it.

MR. GARRICK: That's right. And I think the warning sign that came at our meeting was Bill Gunther's comment about tying it, if only loosely, to 40 CFR 191. So you're absolutely right. They really can do as they wish here.

MR. HATCHER: I would agree with you that they may be addressing the wrong question. But the quality of the group may produce an evolution so that they do, in turn, educate themselves to what the question really is about whether or not this -- they do want an acceptable standard, but how to ensure the safety of the site and the long-term safety of it. I think this is something they will end up with probably.

MR. GARRICK: Yes.

MR. POMEROY: Could I ask either of you whether or not there was any indication or whether you know of any indication -- under this item three that Congress specified, when we were commenting about it, we said not only is the question whether or not you can make scientifically supportable predictions of the probability that the repository will be breached as a result of human intrusion, but can you make scientifically supportable predictions regarding natural processes that may occur in the next 10,000 years.

Is there any indication that the Committee is looking in that direction at all?

MR. GARRICK: I think the Committee and the

Academy, in general, has been a frequent pusher for more definitive information on the effectiveness of engineered barriers. I think that this has been not only with respect to Yucca Mountain, it's been with respect to WIPP and other proposed facilities.

I think the thought here is that while you may not be able to guarantee that it will survive for thousands and thousands of years, you can arrive at designs most likely where there's high confidence that it will survive for up to thousands of years. I think that to a probabalist, he or she has to think that way.

It's like I remember being involved in a press conference on the Seabrook risk assessment for the Seabrook Nuclear Power Plant and presenting our results about the core damage frequency, etcetera, etcetera. And that evening, one of the TV anchor ladies accurately represented what we said, on the one hand, but, on the other hand, she said, also, correctly, but the message was wrong, that that doesn't mean it couldn't happen tomorrow. And that's the way it is. It's just not likely.

MR. STEINDLER: But the notion of the engineered barriers is, in a sense, actively discouraged by the current NRC approach to holding tight to the requirements of subsystem criteria.

MR. GARRICK: It's very discouraging, especially if you believe the analyses that have been performed in terms of the gains you get in going from a ten to 20-centimeter outer steel barrier to something like a 30 to 50-centimeter outer barrier. The gains are tremendous.

I think a lot of it will come down to what seems to end up being as the time interval for which we have to be accountable.

MR. HINZE: But, John, in answer to Paul's question, do they have anyone looking at this problem? I know that Bob Budnitz has said that the question has been raised. Were there any scientific groups that addressed this issue in presentations to the National Academy Committee?

MR. GARRICK: The issue of the integrity of an engineered waste package?

MR. HINZE: No. The question is is it feasible to predict the natural potentially adverse conditions on a repository for 10,000 years? This is a question that we wrote up in one of our letters to the Commission. So there are other questions -- other times that this question has been raised.

The question that I think Paul was asking and that I would like to know about is were there any comments from the scientific community on this point.

MR. GARRICK: Not at the meeting that we were at, in particular, but I think there have been a number of studies that have looked at what kind of containment extension might be achieved as a function of increased outer barrier size or increased outer barrier dimensions.

So I think that there does seem to be quite a bit of indication that it's not out of the question being able to design a waste package and a waste package containment system that will survive for thousands of years. To say any particular number is probably not a reasonable answer.

But I think there is increasing evidence that you can engineer a waste package containment system that will last for thousands of years.

MR. STEINDLER: But, Bill, the focus of your question is normally set aside when we address -- when we are addressed by the representatives of what I call the geologic community, there's always the presumption in all of their work that they are, in fact, able to provide adequate, whatever that means, predictions of future events over the time period that the repository is of interest; namely, 10,000 years.

It's always been assumed that you can do that in a sufficiently precise or accurate fashion. Whether or not that is true, of course, is difficult to demonstrate. The only flap that we've heard is the future state of society.

MR. HINZE: I think the point was that this was an occasion upon which a National Academy of Sciences Committee could make that kind of remark and fortify previous Academy discussions on this point.

It would have a lot more prestige, a lot more importance placed upon it, because there has been an attempt to widdle away at the possibility of the geosciences as being unable to predict over the 10,000-year period. As we know, this is a great opportunity to have an impartial group look at that.

MR. GARRICK: Now, whether or not this Committee will do that, I don't know. But I do know that the Academy is thinking that way. The Academy is thinking increasingly aggressively about alternatives to waste containment, alternatives to geologic isolation, for example, and in different time increments.

One simple strategy is build a 100-year facility, which we know we can do, and in the course of time, figure out a better solution for long-term containment. That's certainly one strategy that is available to us. That may not be a strategy that's compatible with the current Waste Policy Act, but we're in a society where such acts can be changed, fortunately.

But I do think that if we continue to struggle with the question of containment, then we have to begin to separate the solving of the radioactive waste management problem from the problem of guaranteeing geologic integrity, because they are separate problems, in fact.

We don't have to use geology to solve the problem.

MR. HINZE: I don't agree with that, John. I think there's enough concern about the engineering integrity of these canisters over a long time period and that's why the defense-in-depth was initiated to begin with. I have yet to hear any engineer that is willing to guarantee me that they will build a canister with zero defects, however many canisters, over a 10,000-year period of time.

MR. GARRICK: Well, you're hung up on a number.

MR. HINZE: I don't care. Make it whatever number you want.

MR. GARRICK: No. The issue -- the question could be answered a different way entirely. The question could be answered how do we manage radioactive waste, rather than having the question being how do we contain radioactive waste. And if the question is asked that way, there are alternatives available to us such that we don't have to lead the public to believe that the solving of the radioactive waste management problem is synonymous with perfect containment from a geologic formation.

We may, as an industry, have made a serious error in doing that. That's the only point. They are not the same. They are only the same because we've regulated them to be the same. And I think as scientists and engineers, we have to keep reminding ourselves of the obligation we have of being able to cope with the fundamental issue, and the issue is more fundamental than geologic isolation.

MR. STEINDLER: I would expect that the National Academy charter is a little more narrow than that because it is constrained by the Energy Policy Act.

MR. GARRICK: This Committee's charter is certainly more narrow than that, but the Board on Radioactive Waste Management's charter is not more narrow than that.

MR. HATCHER: Regarding the questions that come up related to the long-term containment, when you look at the site in which the repository is located, the phenomena there operate not on a scale of 10,000 year increments so much as hundreds of thousands to millions of years. That is one of the things that I think many of us, including geologists, have difficulty in reconciling.

We are talking about something that has to be contained for a relatively short period of time geologically, and yet we are looking for a single event or a series of events that might breach the repository during that time. This is a question of probabilities too, whether we can say that within that time we are not going to have a disastrous event, a volcanic event, a change in the hydrology, a series or a single large earthquake that might breach the repository.

I think that we have to look at it not in terms of the way we look at most geologic processes over a long period of time but in terms of small, catastrophic events and to evaluate it that way. This is why it becomes a question of defining the system as closely as possible and then looking at the probabilistic effects on it.

MR. GARRICK: Bill, I'm certainly a supporter of the defense in depth concept. It's a sound concept and it needs to be a part of our thinking and planning.

MR. HINZE: Let me also say that I'm very much a supporter of enhancing the engineered barrier. From word one, I think that is going to be an important thing in terms of the public perception of what is going on.

MR. STEINDLER: Let me recommend the following approach to our as yet unstructured agenda. I think it would be useful with the recorder functioning to comment on what we heard this morning, as is, I think, our somewhat usual procedure; to comment on what we heard this morning from the tectonic folks.

After that, my reading of the agenda is that we don't need to have our discussions recorded. Then we can declare a short recess and pick up basically the rest of the agenda, move into letter writing and plan out what is going to happen in June, if we could only figure out where we are going to meet.

I realize I caught you short on the issue of tectonics. Would you want to make a few comments on what you heard this morning?

MR. HINZE: I gather you are looking at me.

MR. STEINDLER: Why not?

MR. POMEROY: From my perspective, I would like to at least think about what my notes say overnight.

MR. STEINDLER: You want to do that tomorrow. Okay.

MR. HINZE: I would prefer that, because I am trying to reflect upon everything that we heard. I certainly have some feelings about what we heard. The problem here is that Bob will not be here tomorrow. Bob is our consultant in this area. I've asked Bob to give us some written comments, not over ten single-spaced pages. Perhaps Bob could give us a few of his reflections in terms of the constraints that we put upon the presentations.

MR. HATCHER: I could be here if you need me. I'll be in town. I will be happy to give you some of my comments from this morning now.

MR. STEINDLER: Sure.

MR. HATCHER: First of all, I think there may be some inconsistencies -- not incorrect things -- in the way the KTUs have been identified and listed. The things that enter into that statement are this lack of correlation between earthquakes and surface or prehistoric but yet fairly recent faulting.

Also, as I said in a comment this morning, I think that the study of faulting in alluvium is likely to yield less than trying to understand fault mechanisms, displacements, or whatever in bedrock, because that is where the repository is to be located; that's where the energy is to be expended if there is a major earthquake in the area.

On the other hand, the study of faulting in alluvium will provide information on timing probably better than anything else. That's what Keith said in response, and he is correct about that.

Another concern related to what I've just said is this business of identification of blind earthquake sources. This is a major problem, I think. I commented on that earlier.

The earthquake they had this year in north LA was on a blind source, but yet that was imaged with seismic reflection data. They knew the faults were there; they knew the shape of the faults; they knew where they were; they just didn't know that particular one was active. We knew a lot about those faults already. We can pinpoint them. Once they had the earthquake, they knew exactly what fault it was on. There are situations where that might not be the case in the Yucca Mountain area.

Again, this is not to raise a flag but simply to raise a question and to raise a point about the difficulty in defining or characterizing some of these things, particularly if you are trying to, for example, image shallow potential earthquake sources using something like seismic reflections through some of the alluvium there. That is a very difficult thing to do.

MR. HINZE: The difficulty made me grimace, because you and I have gone through that before.

MR. HATCHER: A second comment relates to the question I asked Brian Wernicke about the speculation that has occurred since the Landers earthquake sequence, about the potential for the movement off the plate boundary inland. This is something that a number of seismologists have argued since the earthquake. Again, it is something that is out there; it's an idea; it's a hypothesis yet unproved. Brian answered that correctly by saying, well, all we can do at this point is wait and see where the next earthquakes occur.

There is something else that should be occurring, though, in my opinion. If the plate boundary is going to move, there should be orders of magnitude increase in micro-seismicity inland, orders of magnitude decrease in micro-seismicity and other larger events on the San Andreas system. Of course, within hundreds of years we still won't know the answer to that probably. It will take thousands, perhaps even longer, longer than the life of the repository to figure that out.

MR. HINZE: A good place to put a strain meter.

MR. HATCHER: Right.

There was a third comment that I didn't get to make this morning. I had a really interesting question for Brian because of his knowledge and ideas regarding the structure of the basin and range. He has talked before about a major step in the base of the crust across the Las Vegas shear zone, across the Walker lane. The crust gets thicker south of there, as I recall, thinner to the north because the amount of extension is greater to the north than to the south.

My question was, what is the potential relationship between that and the cessation of volcanic activity in the Yucca Mountain area over Crater Flat? Hundreds of thousands of years ago apparently Crater Flat volcanic activity decreased and stopped. What would be the relationship if there were additional extension to the south along the major detachment system in there and the re-initiation of volcanic activity? That was a question I wanted to ask him and he escaped before I could do that.

Those are my main comments from this morning that I have thought of so far. Some of these things would relate to the integrity and life of the repository, I think.

MR. STEINDLER: That's fine. We will reserve the rest of the comments until tomorrow and call on Bill and Paul and John then.

My recommendation is that we close the recorded part of the meeting. I don't see any reason to continue recording. We will take a three minute break and then continue on the agenda.

[Whereupon at 3:25 p.m. the recorded portion of the meeting was concluded.]

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: 64th ACNW Meeting

DOCKET NUMBER:

PLACE OF PROCEEDING: Bethesda, 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.

Michael Paulus

Official Reporter
Ann Riley & Associates, Ltd.

PRESENTATION TO THE ADVISORY COMMITTEE ON NUCLEAR WASTE

UNITED STATES NUCLEAR REGULATORY COMMISSION

DIVISION OF WASTE MANAGEMENT ACTIVITIES IN THE TOPICAL AREA OF TECTONICS

PRESENTER INFORMATION

DWM Activities Related to Tectonics	Keith I. McConnell, Section Leader Geosciences and Geotechnical Engineering Section Engineering and Geosciences Branch, DWM (415-7289)

OBJECTIVES OF PRESENTATION

- Demonstrate that a framework exists for licensing needs to drive technical assistance and research.
- Demonstrate that there is a method of prioritization of technical assistance and research.
- Demonstrate that technical assistance and research activities provide timely and valuable information to address licensing needs and issues.
- Demonstrate that tectonics technical assistance and research is integrated with other disciplines and performance assessment.

OUTLINE OF PRESENTATION

- License Application Review Plan Activities
  Status of LARP Development in Tectonics
  Identification of Key Technical Uncertainties (KTUs)

- User Needs

- CNWRA Technical Assistance for DWM

  Reactive Activities:

  Proactive Activites:
  SEISM1 Code
  Tectonic Modelling and Data Analysis

LICENSE APPLICATION REVIEW PLAN

STATUS OF LARP DEVELOPMENT

- Compliance Determination Strategies for the Potentially Adverse Conditions (PAC) related to structural deformation and seismicity completed in LARP Rev. 0

- Compliance Determination Methods for PACs scheduled to be developed in FY95 - FY98.

- Existing CDSs do not address probability of structural deformation in the future or consequences of an event. This will be the subject of other review plans.

LICENSE APPLICATION REVIEW PLANS
STATUS OF DEVELOPMENT (CONT.)

- Structural deformation and seismicity and the projection of those processes will be components of many review plans including the Geologic System Description, other PAC and FAC review plans, design and performance review plans.

- Additional Key Technical Uncertainties related to structural deformation and seismicity will be developed under these additional review plans. Many of these uncertainties may require the development of independent review capabilities including research.

LICENSE APPLICATION REVIEW PLAN
IDENTIFICATION OF KTUs

- Evaluation of faulting mechanisms in alluvium (Type V)
- Development and use of conceptual tectonic models as related to structural deformation (Type V)
- The inability to predict the likelihood of earthquake occurrence during the next 10,000 years (Type IV)
- Correlation of earthquakes with tectonic features (Type V)
- The cause of the large hydraulic gradient located north of Yucca Mountain, and the potential for tectonic disruption... (Type IV)

LICENSE APPLICATION REVIEW PLAN
IDENTIFICATION OF KTUs (cont.)

- Poor resolution of critical exploration methods and uncertainty in interpretation and modelling of techniques available to detect and investigate structural features in the subsurface (Type IV)
- Paleofaulting data indicates that seismic activity has migrated randomly from one major range front fault system to another (Type V)

CNWRA TECHNICAL ASSISTANCE
FOR DWM (Reactive)

- Reviews of DOE study plans and topical reports.
- Support at NRC/DOE site visits and technical exchanges, NWTRB meetings, and ACNW meetings.

User Needs
Seismicity and Structural Deformation

- Address the presence of PACs related to seismicity and structural deformation, but do not address the likelihood of future events, and possible consequences.
- Were developed prior to identification of KTUs
- Address issues in existing KTUs
- Will be modified following identification of all KTUs related to seismicity and structural deformation.

User Needs
Seismicity and Structural Deformation

606 - Evaluation of the appropriateness, precision, and accuracy of probabilistic seismic hazard analysis for long term predictions.

607 - Evaluation of distributive faulting characteristics of the Basin and Range.

608 - Evaluation of fault segmentation characteristics in the Basin and Range.

609 - Evaluation of fault displacement and basaltic volcanism as contemporary events.

610 - Evaluation of fault mechanisms in alluvium.

611 - Evaluation of Quaternary strain rate estimates.

612 - Modelling of fault activity using computer-aided techniques.

ACNW 05/17/94

CNWRA TECHNICAL ASSISTANCE
FOR DWM (Proactive)

- SEISM1 Code

LLNL code developed for siting Nuclear Power Stations in the eastern U.S.

CNWRA modifying code for use in the western U.S. and in particular the Yucca Mountain site.

Attenuation functions for western U.S. have been added to the code and it has been run on CNWRA computers.

CNWRA will provide the results of a test run of SEISM1 to the staff on 8/31/94

CNWRA TECHNICAL ASSISTANCE FOR DWM (Non-Reactive) cont.

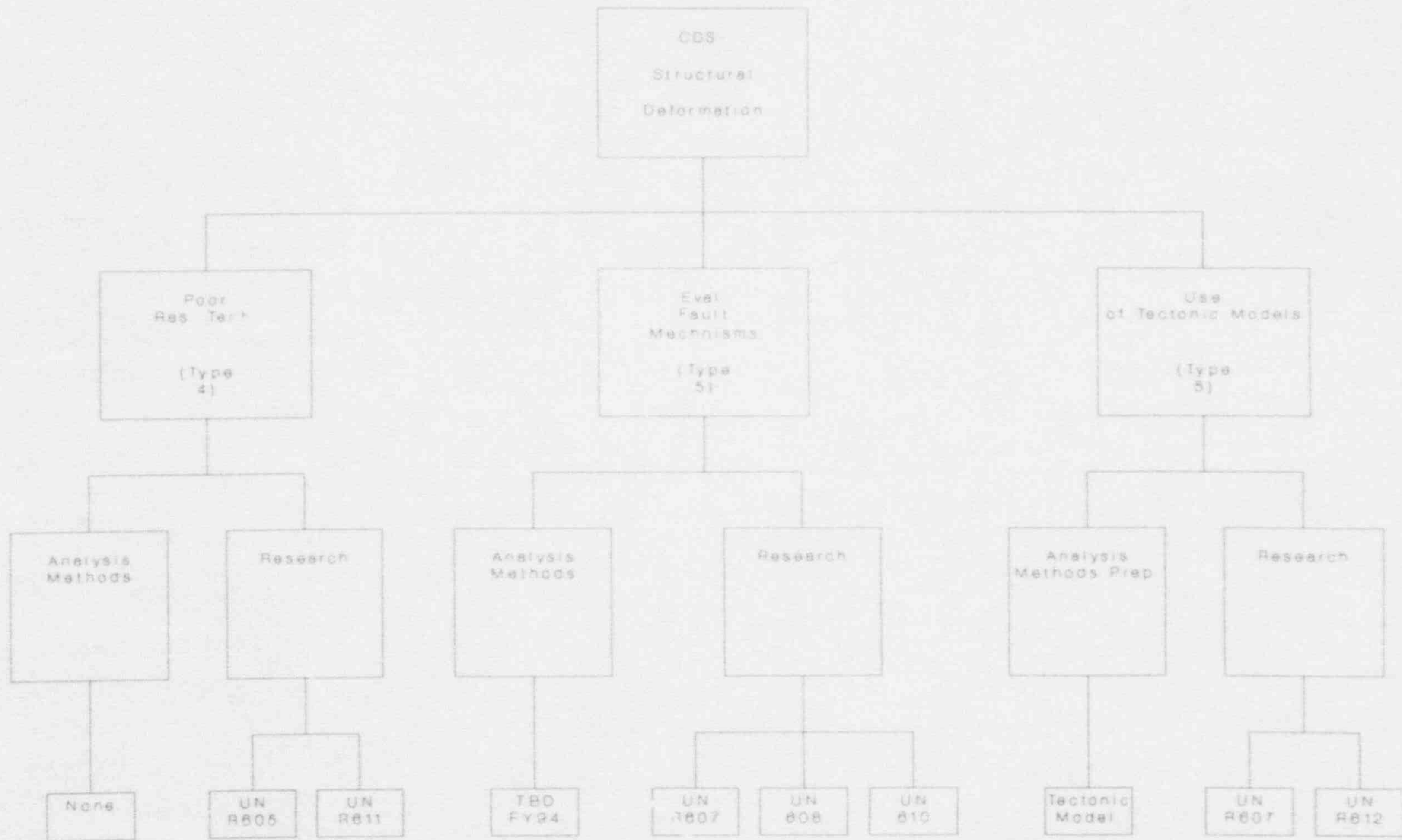
- Tectonic Modelling and Data Analysis:

  Geometric modelling to continue in response to DOE data generation.

  Computer simulation of faulting within the repository block and coupling of processes (e.g., faulting volcanism).

  3D graphical visualization of tectonic processes to permit a better conceptual understanding of tectonic processes to be used in PA.

Flowdown Related to Structural Def. PAC DWM/RES/CNWRA Activities

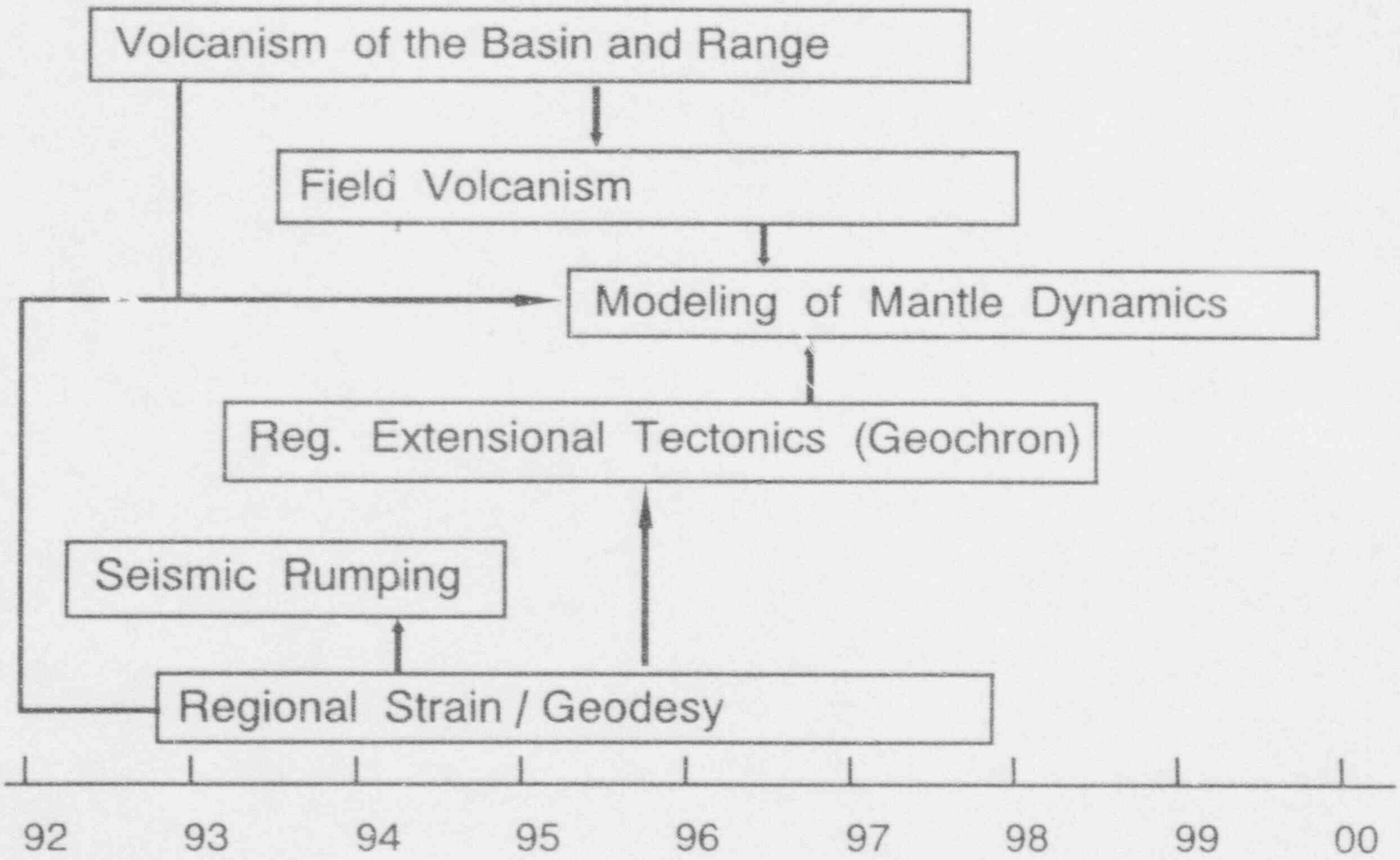


NRC RESEARCH PROGRAM ON TECTONIC PROCESSES

Presented to the ACNW on May 17, 1994

BY William R. Ott (301-492-3882)
Waste Management Branch
Office of Research
US Nuclear Regulatory Commission

GEOLOGY RESEARCH



Statement of Work for Regional Tectonics

SOW for Regional Tectonics transmitted to CNWRA 10/19/92

- Reference to all 6 User Needs
- Refers to Wood and Wernicke projects as providing data
- Assigned integrating role to CNWRA
- Specifies P.A. capability as an objective

Task Structure

Task 1, 2, and 3 Provide tectonic portion of:

Literature Review,
Data Compilation,
Critical Review of Data

Critical Review - emphasis on:

Integrating models of seismicity with models of geological structure.

Modeling of faulting and deformation

Modeling seismic hazard and regional tectonic processes

Task Structure

Task 4: Field Studies

Establish Cenozoic strain rates in the Basin and Range as they relate to Yucca Mountain

Test and confirm models of Cenozoic tectonic evolution of the Basin and Range Province

Task 5: Geochronology

Literature Review of methods

Study Plan to assess reliability of radiometric and other age determination techniques (Black Mountains Field Site)

Task Structure

Task 6:

Assessment of Data

Development of alternative conceptual models of tectonic processes

Seismic Pumping

Proposal Submitted by J. Wood, Michigan Technological University (FY 92)

Submitted around time of "Szymanski Report"

Limited scope to examine evidence of seismically induced movement of water

- at Elk Hills, California
- at Salton Sea site in California

Seismic Pumping

Results

Developed approach for assessing origin of veins and cements (Calcite and Opal veins)

Use of C and O isotope ratios in cements and fluid inclusions

Concluded veins (Elk Hills) formed as result of seismic event(s) from a narrow window in time

Applied to Yucca Mountain - Isotopes would be considered thermogenic - taken alone are insufficient evidence

Contemporaneous Deformation in Death Valley Region

Submitted by B. Wernicke, Harvard University/Cal Tech

Limited scope to make GPS measurements

- Directly responsive to User Need on strain rates
- Has involved CNWRA and NRC staff on field trips
- Wernicke is a consultant to the CNWRA

CONCLUSIONS

1. Tectonics Program is strongly tied to KTU's and User Needs.

2. State of the art literature surveys provide firm technical basis for KTU's.

3. Timeliness of research efforts assist in preparation of the LARP and in pre-licensing and licensing reviews

4. Confirmatory databases and models are being established for state of the art compliance reviews of DOE analyses and models.

5. Well-integrated alternative conceptual models (coupled tectonic-seismic-volcanic) are under development for evaluation of DOE models.

6. Tectonic research activities are well integrated with other research projects and technical assistance activities.

OVERVIEW OF CNWRA EFFORT IN TECTONICS AND SEISMOLOGY

Keith McConnell (NMSS)
George Birchard (RES)

Presented by:

H. Lawrence McKague
Stephen R. Young
David A. Ferrill

Center for Nuclear Waste Regulatory Analyses
6220 Culebra Road
San Antonio, Texas 78238-5166

Investigators:

Stephen R. Young, David A. Ferrill, Charles B. Connor
Ronald H. Martin, Renner B. Hofmann, and Gerry L. Stirewalt

CNWRA CONDUCTS TECTONIC, VOLCANIC, AND SEISMIC INVESTIGATIONS FOR BOTH NMSS AND RESEARCH OFFICES

DISCIPLINE	NMSS	RESEARCH
	Technical Assistance: Investigative Issues Related to Geology/ Geophysics	Specific Research Projects
Volcanology	Magmatic Modeling & Data Analysis	Volcanic Systems of the Basin & Range Field Volcanism
Seismology	Seismic Modeling & Data Analysis	—
Tectonics	Tectonic Modeling & Data Analysis	Tectonic Processes in the Central Basin & Range

NMSS TECHNICAL ASSISTANCE WORK IN VOLCANISM

UNCERTAINTY IN THE USE OF PROBABILISTIC MODELS FOR VOLCANIC DISRUPTION

REGULATORY BASIS

- Evidence of Igneous Activity in the Quaternary — 10 CFR 60.122(c)(15) [LARP 3.2.1.9]

OBJECTIVE

Development of methods for the assessment of uncertainty in the application of statistical models to the probability of volcanic disruption of the candidate repository. This will include:

- Development of methods for establishing the limits and uncertainty of application of probability models to volcanism in the Yucca Mountain Region.
- Development of methods for testing of probability models through application in other regions.

KEY TECHNICAL UNCERTAINTY

- 3.2.1.9 — Evidence of Igneous Activity
  - Large uncertainties exist in probability models of volcanic disruption because of the inability to sample igneous features as a result of depth of burial or removal by erosion.

NMSS TECHNICAL ASSISTANCE WORK IN SEISMOLOGY

ADAPTATION OF THE SEISM 1 CODE FOR USE IN THE WESTERN U.S. FOR PROBABILISTIC SEISMIC AND FAULT OFFSET HAZARD ANALYSIS

REGULATORY BASIS

Performance of the Geologic Repository Operations Area Through Permanent Closure 10 CFR 60.111 [LARP 4.5.1]

General Design Criteria for the Geologic Repository Operations Area — 10 CFR 60.13 [LARP 4.2]

OBJECTIVES

Provide a tool (computer program) which may be used by NRC staff to evaluate seismic and fault offset probabilities, and their uncertainties, provided by DOE or proposed during the hearing process.

NMSS TECHNICAL ASSISTANCE WORK IN SEISMOLOGY

ADAPTATION OF THE SEISM 1 CODE FOR USE IN THE WESTERN U.S. FOR PROBABILISTIC SEISMIC AND FAULT OFFSET HAZARD ANALYSIS

KEY TECHNICAL UNCERTAINTY

Modification of the SEISM 1 code for application to the Yucca Mountain area falls under the general KTUs addressing the prediction of future system states and variability in model parametric values [LARP 6.1, 6.2].

RECENT ACCOMPLISHMENTS

- A successful seismic hazard computation using data published for the Yucca Mountain area.
- Preparation of a report summarizing progress to date.
- Success in calculating fault offset probability for the Solitario Canyon Fault.

NMSS TECHNICAL ASSISTANCE WORK IN TECTONICS

FINITE ELEMENT SIMULATION OF TECTONIC DEFORMATION AT YUCCA MOUNTAIN

REGULATORY BASIS

Structural Deformation — 10 CFR 60.122(c)(11) [LARP 3.2.1.5]

Correlation of Earthquakes with Tectonic Processes — 10 CFR 60.122(c)(13) [LARP 3.2.1.7]

OBJECTIVES

- Establish a credible mechanical basis for discrimination between alternative models of faulting.
- Estimate the effects on the Ghost Dance fault of primary coseismic slip on main bounding faults (Paintbrush-Stagecoach and Bow Ridge).
- Produce 3-dimensional models of faults at Yucca Mountain — required to better estimate magnitude and direction of fault slip.

NMSS TECHNICAL ASSISTANCE WORK IN TECTONICS

FINITE ELEMENT SIMULATION OF TECTONIC DEFORMATION AT YUCCA MOUNTAIN

KEY TECHNICAL UNCERTAINTIES

Poor resolution of critical exploration methods and uncertainty in interpretation and modeling techniques available to detect and investigate structural geologic features in the subsurface. [LARP 3.2.1.5]

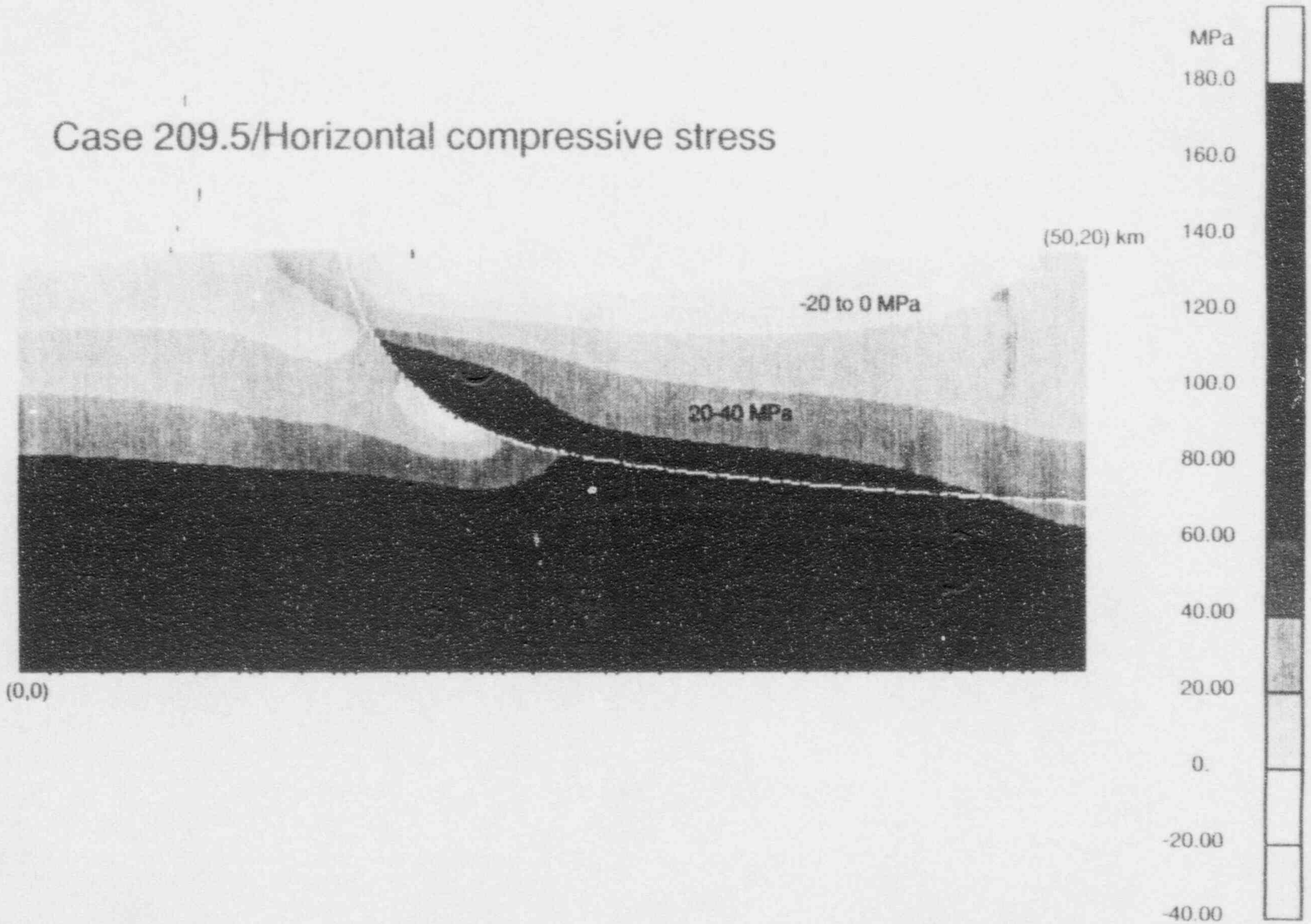
The relationship of conceptual tectonic models to related structural deformation. [LARP 3.2.1.5]

Correlation of earthquakes with tectonic processes and features. [LARP 3.2.1.7, 3.2.1.8]

RECENT ACCOMPLISHMENTS

- Initial and boundary conditions have been estimated and a simple set of geometries have been run. Results indicate additional adjustments in boundary parameters must be made.

Case 209.5/Horizontal compressive stress



NMSS TECHNICAL ASSISTANCE WORK IN TECTONICS

3-DIMENSIONAL STRUCTURAL/STRATIGRAPHIC MODEL OF YUCCA MOUNTAIN

REGULATORY BASIS

Overall System Performance Objective for Geologic Repository After Permanent Closure — 10 CFR 60.112 [LARP 6.0]

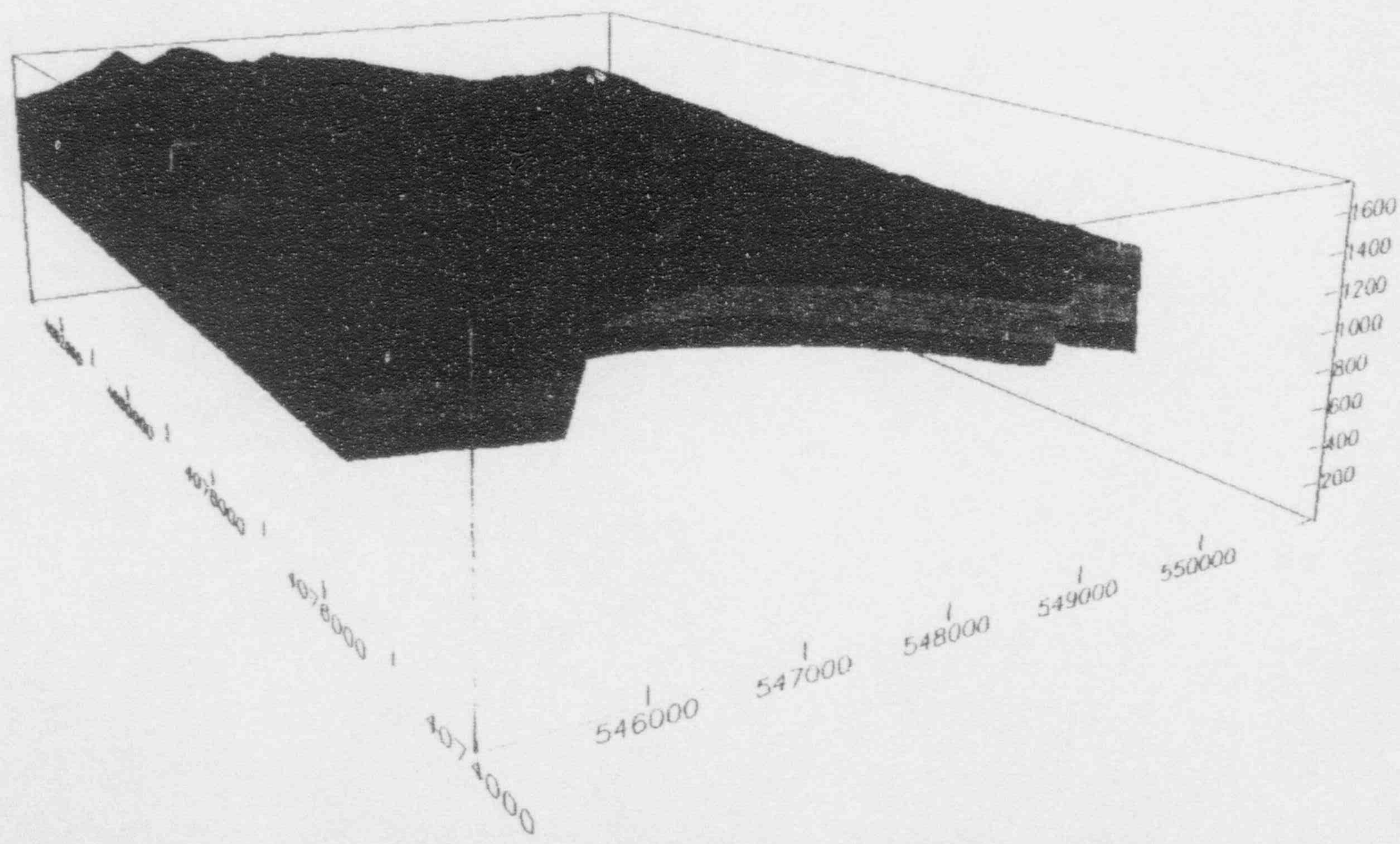
OBJECTIVES

Produce an integrated model of structure, stratigraphy, and rock properties

KEY TECHNICAL UNCERTAINTIES

Development and use tectonic models to represent future structural deformation [LARP 3.2.1.5]

Development and use of tectonic models as related to igneous activity [LARP 3.2.1.9]



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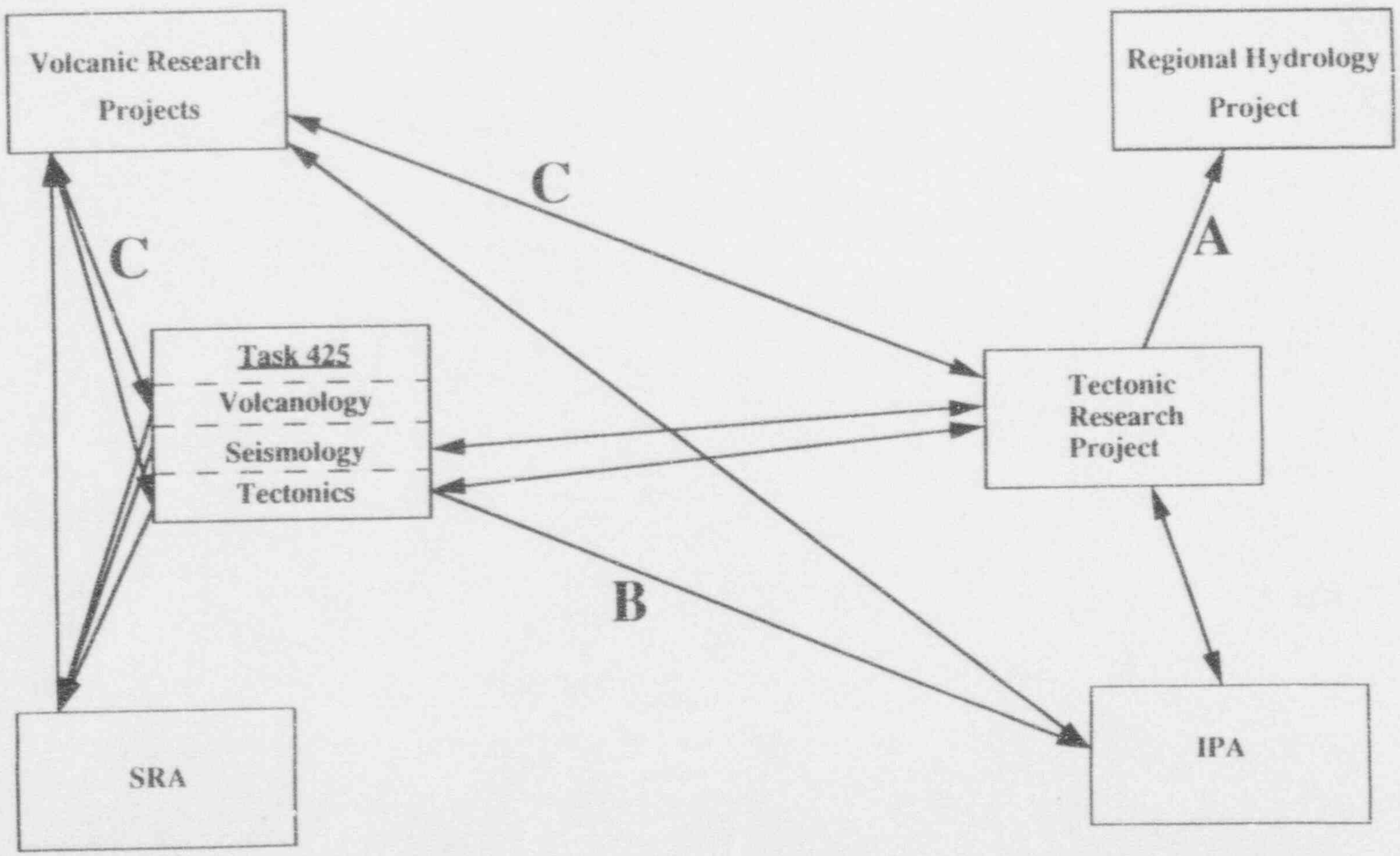
GEOLOGIC SETTING ACTIVITIES ARE INTEGRATED AND INTERACT WITH SEVERAL RESEARCH AND TECHNICAL ASSISTANCE TASKS



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INTEGRATION OF THE TECTONIC AND REGIONAL HYDROLOGY PROJECTS OCCURS IN THREE AREAS

OBJECTIVE

To support the regional hydrology project in the development of a better regional hydrologic flow model.

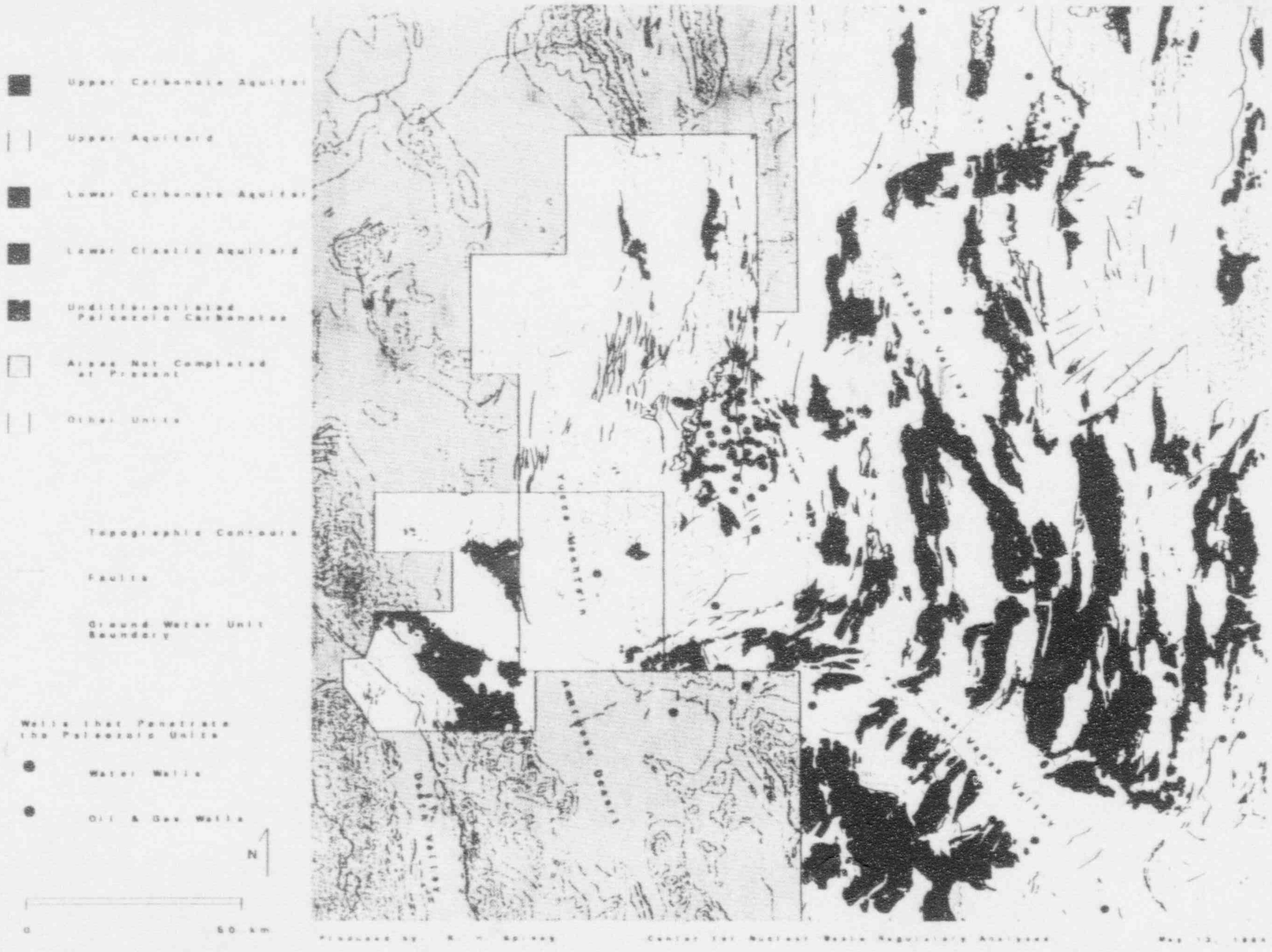
RECENT ACCOMPLISHMENTS

- In order to constrain a regional 3-dimensional hydrologic flow model the distribution of the regional aquifers and aquitards is being developed from surface and subsurface geologic data.

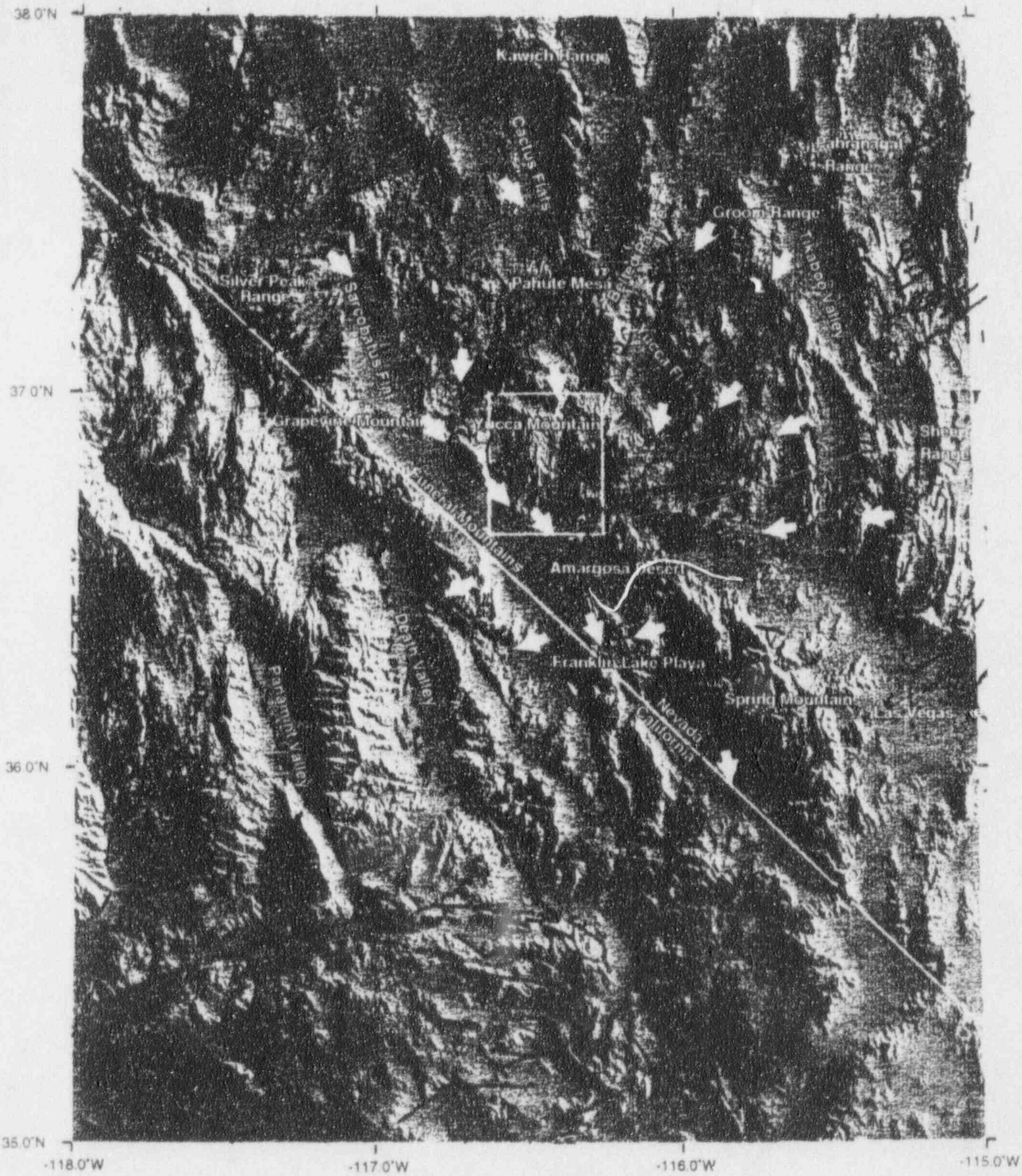
- *In Situ* stress data is being collected as input to the regional flow models, as well as regional tectonic models

- Regional geologic cross sections are being constructed which will aid in the development of a regional hydrologic flow model.

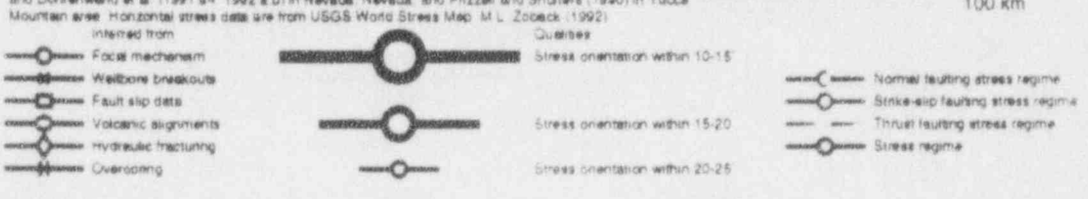
Hydrogeologic Map of Regional Aquifer System



REGIONAL GROUND WATER FLOW and MAXIMUM HORIZONTAL STRESS



Produced by Southwest Research Institute: D. Ferrill, G. Wittmeyer, S. Young, B. Henderson, R. Martin, and R. Klar (5/12/94). Faults traces are from Dohrenwend (1982), Dohrenwend and Moring (1991 a,b,c) and Dohrenwend et al. (1991 a-f, 1992 a,b) in Nevada, Nevada, and Frizzell and Shulters (1990) in Yucca Mountain area. Horizontal stress data are from USGS World Stress Map, M.L. Zoback (1992).



MODELS AND EXPERIENCE DEVELOPED IN TECHNICAL ASSISTANCE TASKS ARE BEING TRANSFERRED TO IPA

OBJECTIVE

- To provide a simplified hydrostratigraphic model of Yucca Mountain for Iterative Performance Assessment (IPA).

RECENT ACCOMPLISHMENTS

- Met with IPA staff to discuss needs.
- Interacted with hydrologist to identify key parameters needed in hydrostratigraphic model.
- The 3-dimensional structural/stratigraphic model of Yucca Mountain is being modified for use by IPA.
- Have started to construct model with faults, key stratigraphic units, porosity, and saturated hydraulic conductivity.

MODELS AND EXPERIENCE DEVELOPED IN TECHNICAL ASSISTANCE TASKS ARE BEING TRANSFERRED TO IPA

OBJECTIVE

- To implement a probabilistic fault displacement model for utilization in IPA Phase 3.

RECENT ACCOMPLISHMENTS

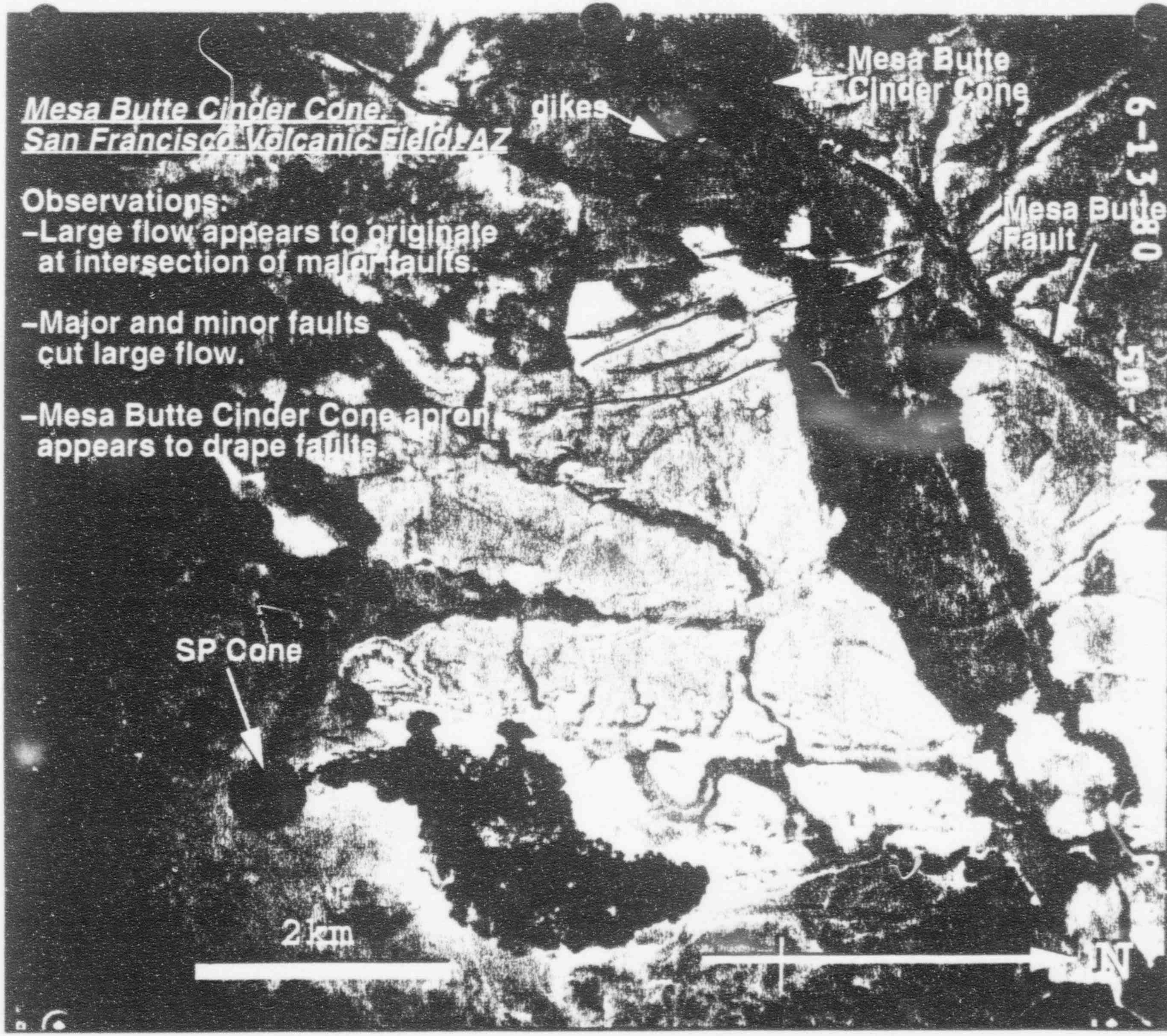
- Completed a review of an EPRI methodology for preliminary Risk/PA Analysis of primary and secondary faulting at Yucca Mountain.

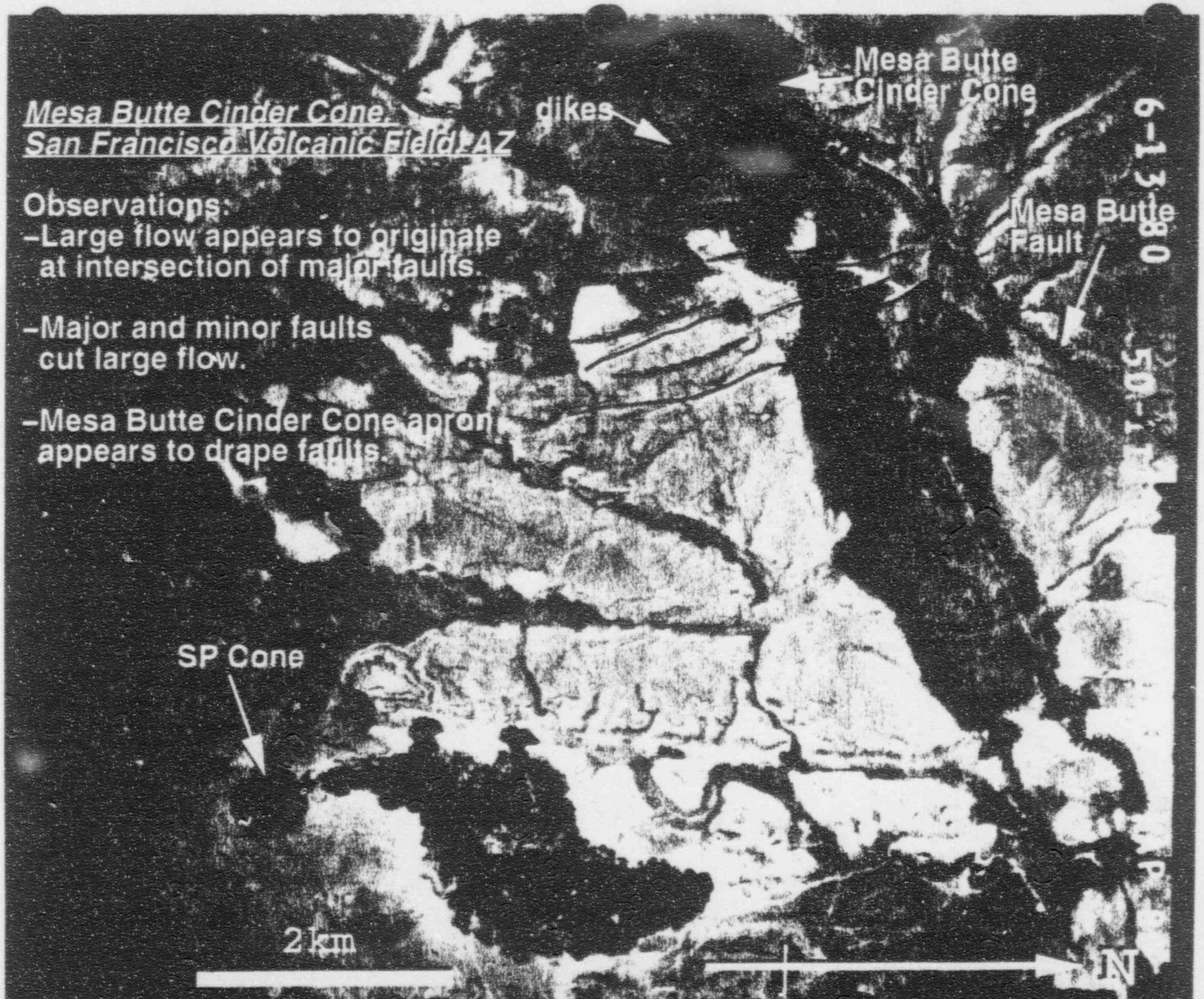
- Proposed a strategy which will use existing Yucca Mountain field data to predict the expected number of canister failures due to fault displacement.

THE TECTONICS RESEARCH PROJECT AND THE VOLCANIC RESEARCH PROJECTS HAVE SEVERAL AREAS OF MUTUAL INTEREST

OBJECTIVE

- **To develop a conceptual tectonic model(s) that accounts for both structural and volcanic phenomenology**
- **Data in the GIS database is applicable to problems in both projects**
  - **Fault Maps**
    - **Development of conceptual structural models**
    - **Control of volcanism**
- **Potential interaction of dikes and faults are of interest to both research projects**
  - **Control of volcanism and effects on probability of volcanism is of interest to volcanologists**
  - **Intrusion of magma along faults is a potential aseismic deformation mechanism**


Mesa Butte Cinder Cone:
San Francisco Volcanic Field, AZ
Observations:
–Large flow appears to originate at intersection of major faults.
–Major and minor faults cut large flow.
–Mesa Butte Cinder Cone apron appears to drape faults.
dikes
Mesa Butte Cinder Cone
Mesa Butte Fault
6-13-80
SP Cone
2 km
N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dikes
Mesa Butte Cinder Cone
Mesa Butte Fault
6-13-80
SP Cone
2 km
N

THE TECTONICS RESEARCH PROJECT AND THE VOLCANIC RESEARCH PROJECTS HAVE SEVERAL AREAS OF MUTUAL INTEREST

RECENT ACCOMPLISHMENTS

- The technical assistant project used DYNA 3-D to model the interaction of a dike-like magma body at depths of 1000 m and 300 m, with a 80° dipping fault

  — Preliminary results indicate, under the conditions modeled, faults can exert some control of dike emplacement at depths shallower than 1 km and at steep dips

- In the Volcanic Systems of the Basin and Range Research Project a simple 2-D stress model was used to calculate the interaction of an upward moving magma, controlled by the least principal *in situ* stress and a preexisting zone of weakness (fault or joint). [McDuffie et al. (1994), Spring AGU Meeting]

  — Results indicate, under the conditions modeled, magma can travel along only very steeply dipping pre-existing zones at 10 km, while at depths of between 50 m and 640 m low angle zones also can be exploited.

TECTONIC PROCESSES OF THE CENTRAL BASIN AND RANGE RESEARCH PROJECT

NRC Project Manager: George Birchard

Presented by:
Stephen R. Young
David A. Ferrill

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San Antonio, Texas 78238-5166
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May 17, 1994

Principal Investigators:

Stephen R. Young, David A. Ferrill, Gerry L. Stirewalt
Ronald H. Martin, Brent Henderson, Kathy Spivey

CNWRA Project Manager: H. Lawrence McKague

TECTONICS RESEARCH

REGULATORY BASIS

PERFORMANCE OF THE GEOLOGIC REPOSITORY OPERATIONS AREA THROUGH PERMANENT CLOSURE - 10 CFR 60.111 [LARP 4.5.1]

OVERALL SYSTEM PERFORMANCE OBJECTIVE FOR GEOLOGIC REPOSITORY AFTER PERMANENT CLOSURE - 10 CFR 60.112 [LARP 6.0]

PERFORMANCE OF PARTICULAR BARRIERS AFTER CLOSURE - 10 CFR 60.113 [LARP 3.3-1]

STRUCTURAL DEFORMATION AND GROUND WATER - 10 CFR 60.122 (c) (4) [LARP 3.2.2.8]

STRUCTURAL DEFORMATION - 10 CFR 60.122 (c) (11) [LARP 3.2.1.5]

HISTORIC EARTHQUAKES - 10 CFR 60.122 (c) (12) [LARP 3.2.1.6]

CORRELATION OF EARTHQUAKES WITH TECTONIC PROCESSES - 10 CFR 60.122 (c) (13) [LARP 3.2.1.7]

INCREASING EARTHQUAKE FREQUENCY/MAGNITUDE - 10 CFR 60.122 (c) (14) [LARP 3.2.1.8]

EVIDENCE OF IGNEOUS ACTIVITY - 10 CFR 60.122 (c) (15) [LARP 3.2.1.9]

TECTONICS RESEARCH

KEY TECHNICAL UNCERTAINTY TOPICS

3.2.1.5 STRUCTURAL DEFORMATION

Poor resolution of critical exploration methods and uncertainty in interpretation and modeling techniques available to detect and investigate structural geologic features in the subsurface (Type IV).

Evaluation of faulting mechanisms in alluvium (Type V) - ***complex propagation of bedrock faults through overlying Quaternary alluvium; uncertainty in dating fault offset and determining fault geometry.***

Development and use of conceptual tectonic models as related to structural deformation (Type V) - ***i.e. for Probabilistic Seismic / Fault Rupture Hazard Assessment - description and abstraction of fault segmentation, distributive faulting, alternative fault shapes, and associated earthquake seismicity is inherently underconstrained in site-specific models.***

TECTONICS RESEARCH

KEY TECHNICAL UNCERTAINTY TOPICS (continued)

3.2.1.7 CORRELATION OF EARTHQUAKES WITH TECTONIC FEATURES

Poor correlation of earthquakes with surface expression of tectonic features (Type V).

3.2.1.8 INCREASING EARTHQUAKE FREQUENCY/MAGNITUDE

Inability to predict the likelihood of earthquake occurrence during the next 10,000 years (Type IV).

Paleofaulting data indicates earthquakes have migrated from one major fault system to another in the Basin and Range tectonic province (Type V) - *there is considerable uncertainty that the relatively low seismicity at Yucca Mountain will continue over a 10,000 year period.*

3.2.1.9 EVIDENCE OF IGNEOUS ACTIVITY

Difficulty in development and assessment of alternative conceptual tectonic models for Volcanic Hazard Assessment. Models of coupled faulting and magmatism are under-constrained - considerable uncertainty on role of faults and in-situ stress in magma transport and eruption at Yucca Mountain.

TECTONICS RESEARCH

OBJECTIVES

The overall purpose is to improve the capability of NRC to produce prelicensing guidance, and to review licensing and performance assessment issues related to tectonics.

The important premise here is that the NRC will need ready access to a broad body of knowledge, methods, and data.

At this time, the primary focus is to examine the sufficiency of data and methods to determine compliance with the siting criteria, and with the quantitative performance objectives.

The premise here is that it is not clear that existing data are sufficient for either qualitative compliance determination or quantitative performance assessment.

TECTONICS RESEARCH

OBJECTIVES (continued)

Specifically, the primary goals of the current work are to:

Improve NRC capabilities to assess investigations of earthquake (fault line or point) sources (location, type, and slip history of faults).

Improve NRC capabilities to determine adequacy of investigations of sources with no surface expression (geometry and distribution of buried, or blind, faults).

Determine adequacy of data used to estimate earthquake magnitude and recurrence at Yucca Mountain.

Support development of models that include coupled faulting and magmatism.

TECTONICS RESEARCH

TECHNICAL ACTIVITIES

Project timeframe: **January '93 through September '96**

TASK 1 - Review of Literature on Late Neogene and Quaternary Tectonism (completed 9/93)

Objective: Determine the type and extent of existing data related to Late Neogene and Quaternary tectonism in the central Basin and Range region.

Accomplishments: Review completed. Results reported in research semi-annual CNWRA 93-01S - ***supports basis for initial development of KTUs.***

TECHNICAL ACTIVITIES (continued)

TASK 2 - Compilation of Tectonic Data (ongoing - task ends 9/94)

Objective: Compile data on tectonics, faulting, and seismicity associated with recognized faults and actively deforming fault zones into a Geographic Information System.

Accomplishments: The Arc/Info software system is installed. Data on faulting, earthquakes and geophysical potential fields are being compiled for: i) the central Basin and Range region; and ii) the Yucca Mountain local region.

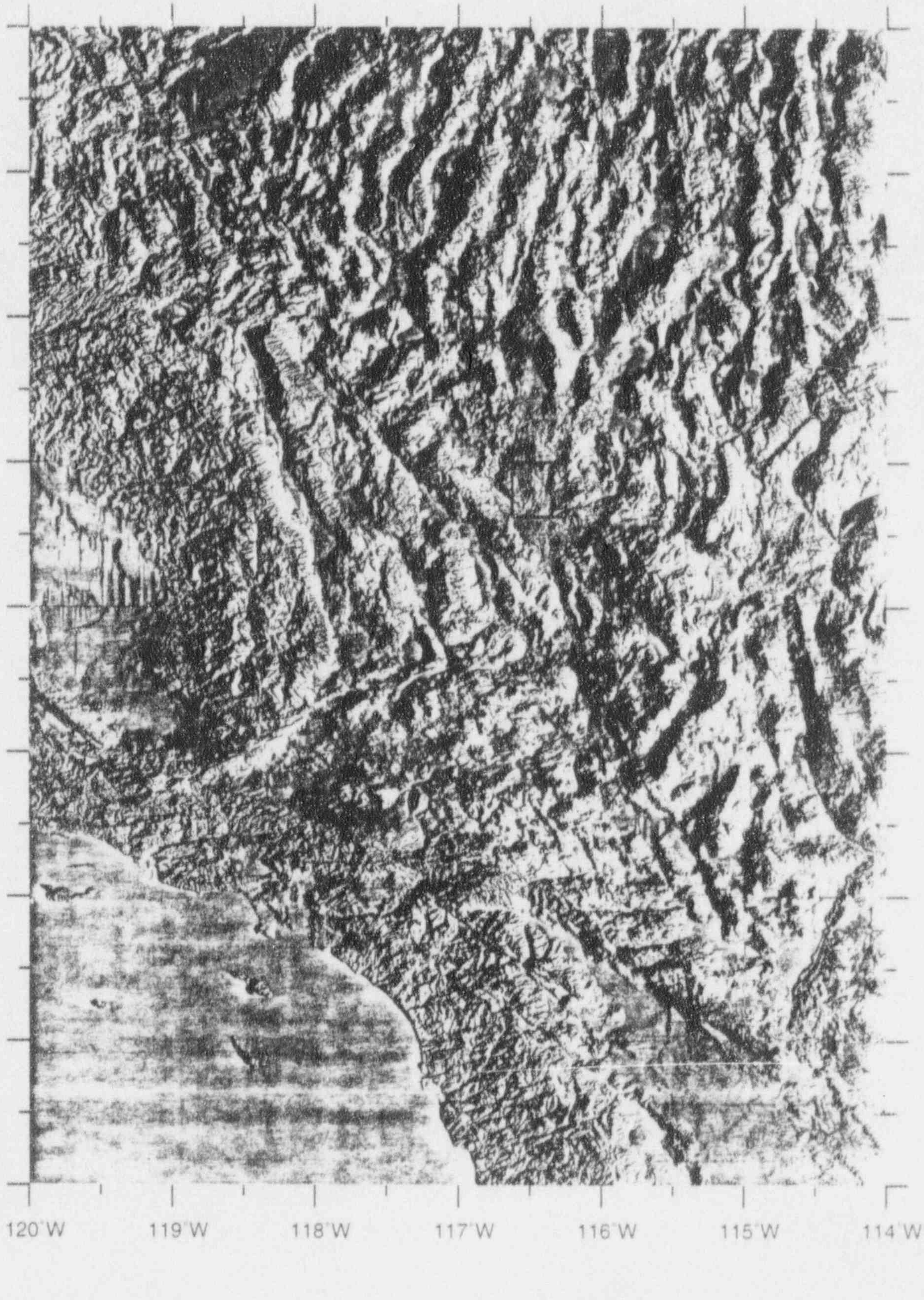
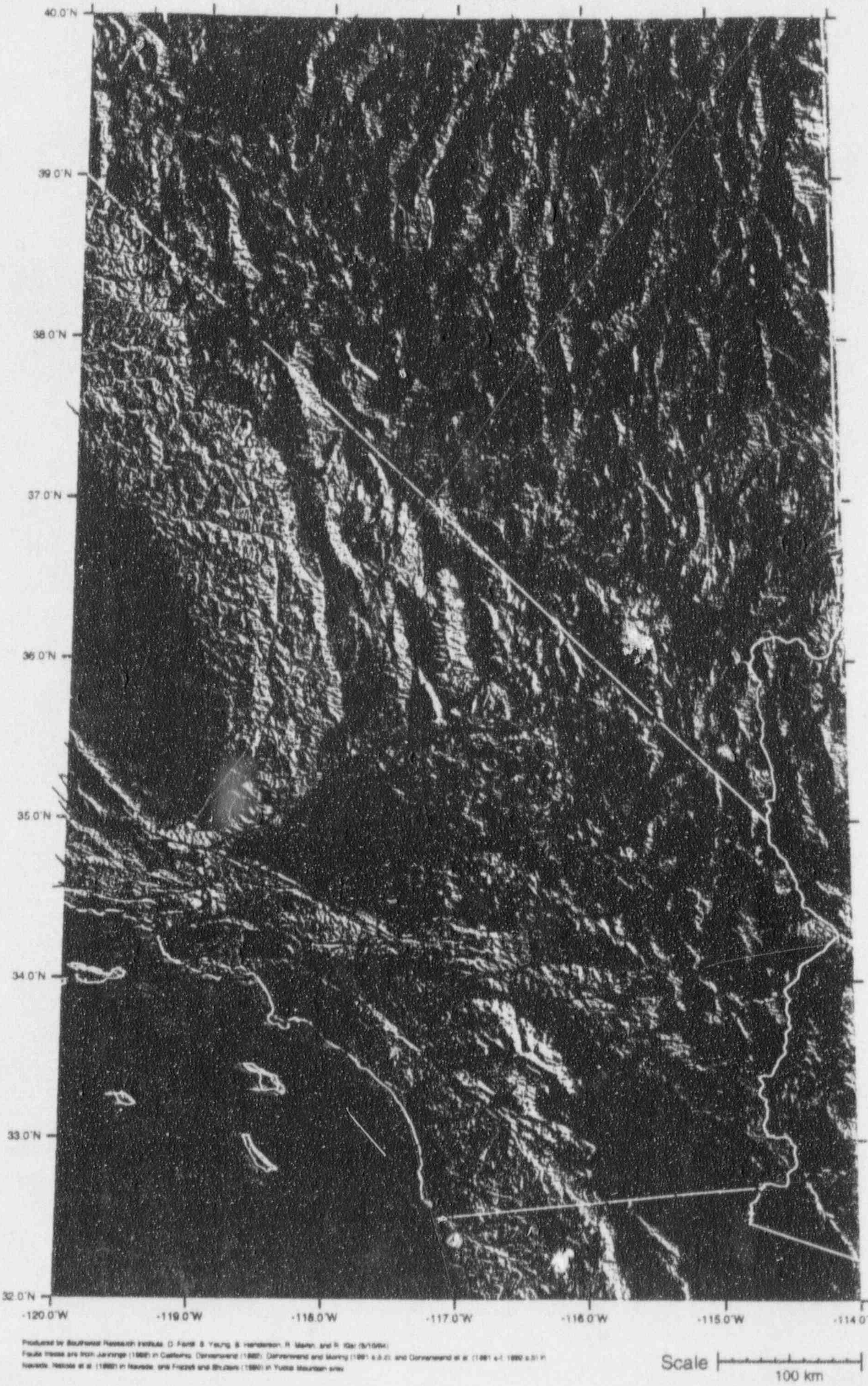


Figure 11-2. Digital Shaded-Relief Terrain Model (DTM) of the area covered by the central Basin and Range Regional Tectonic Database (RTDB). The DTM image of the RTDB area is produced from digital elevation data with a spacing of 3 arc-seconds between elevation points. Yucca Mountain is located in the center of the black square near the middle of the map. North is toward the top of the image. Distance and location in this projection is measured in latitude and longitude.

FAULT TRACES



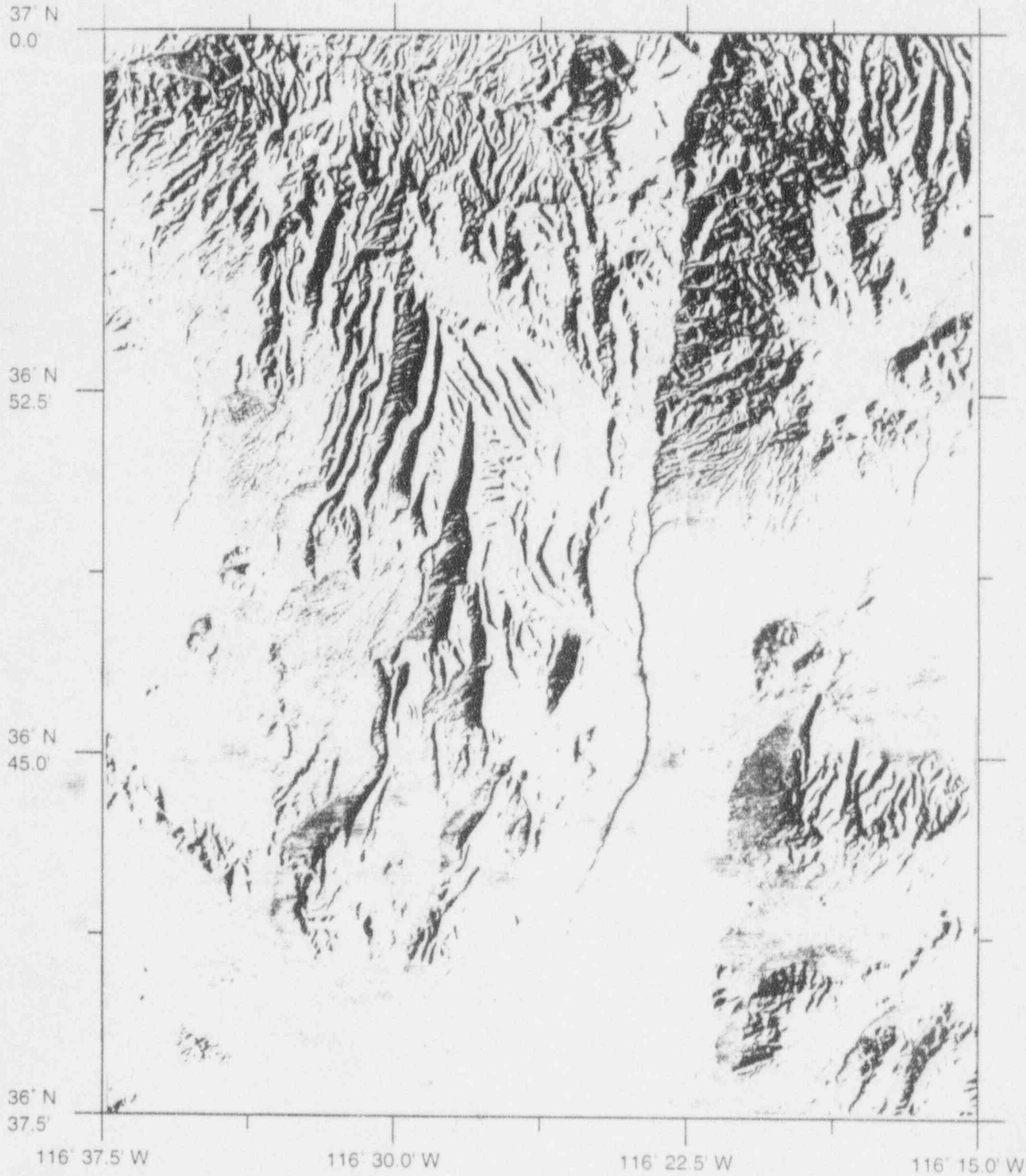


Figure 11-5. Digital Shaded-Relief Terrain Model (DTM) of the area covered by the Yucca Mountain Tectonic Database (YMTDB). The location of this area is indicated by the solid black square near the middle of Figures 11-1B and 11-2, and by the white square grids near the middle of Figures 11-3 and 11-4. The DTM image for the YMTDB area is produced from digital elevation data with a spacing of 30 meters between elevation points. The model is illuminated from an azimuth of 105° (east-southeast) and 35° above the horizon. Yucca Ridge is the prominent north-south ridge in the center-left of the image. Projection is Universal Transverse Mercator. North is toward the top of the map. 1 inch = 3.3 miles. 1 cm = 2.06 km.

(a)

(b)

(c)

(d)

Figure 11-9. Shaded-relief digital terrain model shown in Figure 11-5 illuminated from west (a), north (b), south (c), and east (d). The computer generated terrain images may thus be treated as a synthetic alternative to low sun-angle aerial photographs. For instance, illumination from north (b) and south (c) enhances northeast trending structural/geomorphic fabric that is not as distinct in the images illuminated from west (a) and east (d).

Figure 11-6. Map of Neogene and Quaternary faults (Frizzell and Shulters, 1990) from the Yucca Mountain Tectonic Data Base plotted onto the digital terrain model shown in Figure 11-5.

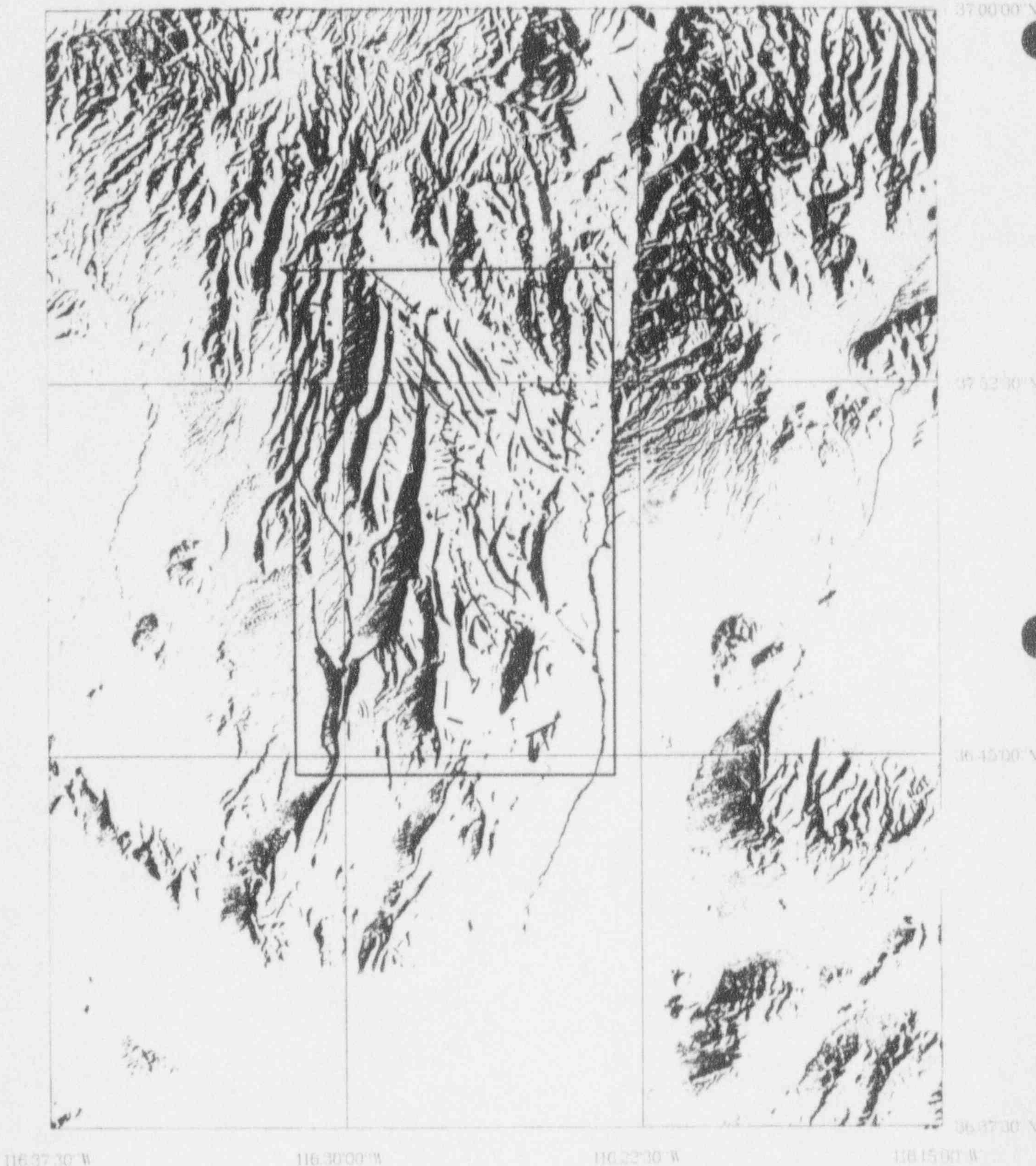


Figure 11-7. Map of photogeologic lineaments (O'Neill, 1993) from the Yucca Mountain Tectonic Data Base plotted onto the digital terrain model show in figure 11-5.

TECTONICS RESEARCH

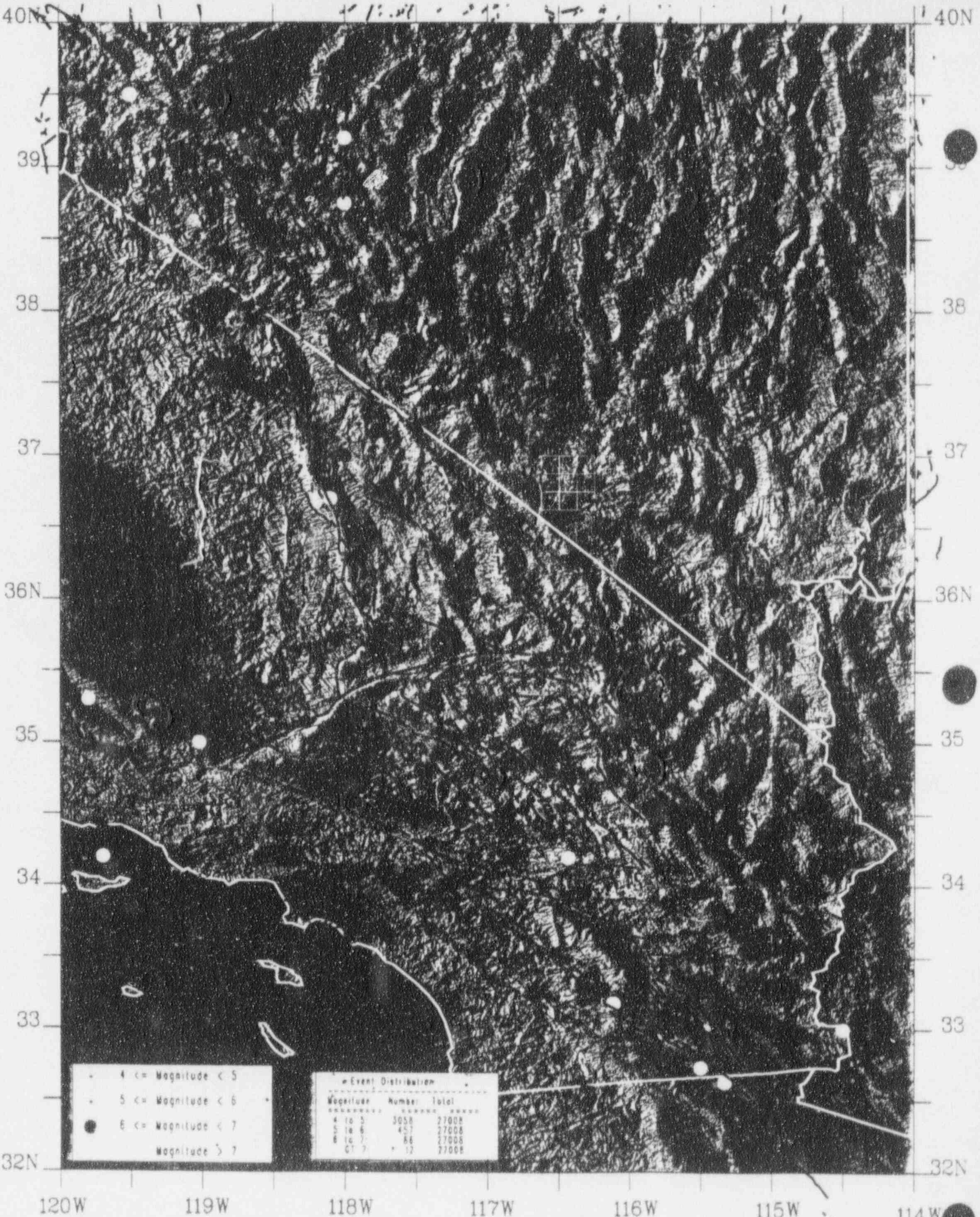
TECHNICAL ACTIVITIES (continued)

TASK 3 - Critical Review of Compiled Tectonic Data (ongoing - task ends 9/94).

Objective: Identify key relationships between contemporary crustal-scale strain and resultant seismic and aseismic slip on known fault systems.

Accomplishments: Terrain features, earthquakes, geophysics, and Quaternary faults have been coregistered and correlated within the central Basin and Range region. Terrain features, faults, drainage patterns, and boreholes have been correlated within the Yucca Mountain local region.

These data may be adequate to partially resolve uncertainty in regional correlation of earthquakes with first-order tectonic features (3.2.1.7). However, local-scale problems persist at Yucca Mountain.



Map of Quaternary fault traces (Nakata et al., 1982) and earthquake epicenters (USGS/NEIC 1992b) from the Regional Tectonic Data Base plotted onto the regional digital terrain model. Quaternary fault traces are depicted as solid black lines. Earthquakes are indicated by small blue and green squares (M4.0-M5.0 and M5.0-M6.0); round red and yellow dots indicated larger magnitude earthquakes (M6.0-M7.0 and M7.0+). Nevada and California state lines are in white. Yucca Mountain is at the center of the white square grid near the middle of the map. The white square grid indicates the nine 7.5 minute USGS topographic quadrangles that comprise the area covered by the more detailed Yucca Mountain Tectonic Data Base (figure 11-5). Earthquake dataset valid from: 08-Dec-1812 to 02-Jun-1993. Projection is Geographic.

TECTONICS RESEARCH

TECHNICAL ACTIVITIES (cont.)

TASK 4 - Field Investigations to Assess Estimates of Late Neogene and Quaternary Strain and to Support Development and Assessment of Alternative Models of Late Neogene through Quaternary, and Contemporary Tectonic Development of the Central Basin and Range Region (ongoing - task ends 9/94)

Objectives: Utilize field investigations to:

(i) assess estimates of late Neogene and Quaternary rates and patterns of distributed crustal-scale extensional deformation;

(ii) use geodetic measurements to assess existing estimates of contemporary rates and patterns of distributed crustal deformation;

(iii) support development and assessment of alternative models of faulting and seismo-tectonic processes;

(iv) identify and describe areas which may be useful as structural/tectonic analogs of the proposed Yucca Mountain site;

(v) investigate the type and extent of tectonic deformation associated with the 1992 Landers (M7.5) earthquake, and implications for Yucca Mountain.

TECHNICAL ACTIVITIES (continued)

Task 4 (continued):

Accomplishments: Reconnaissance survey conducted in the Black Mountains (Death Valley) to assess usefulness as a deep structural analog - indicates additional focused work will improve fault-geometry models.

Participated in Global Positioning Satellite survey - initial phases of a survey intended to independently test estimates of strain accumulation.

Participated in Geological Society of America field trip to the Landers earthquake region - familiarization with the region for subsequent focused work.

TECHNICAL ACTIVITIES (continued)

TASK 5 - Assessment of Geochronological Methods for Dating and Characterizing Fault Slip and Seismic Events (completed 9/93).

Objective: Assess the utility and reliability of methods used to determine slip history of faulting and to estimate ages of seismic (earthquake) slip events.

Accomplishments: Review completed. Results reported in research semi-annual CNWRA 93-02S. Considerable uncertainty remains in both analytical methods and field geological interpretation used to estimate ages of slip and paleoseismological history of Quaternary faults in the central Basin and Range region. These uncertainties need to be explicitly expressed in alternative tectonic models, and methods are required to include uncertainties in Performance Assessment modules (e.g. SEISMO).

TECHNICAL ACTIVITIES (continued)

TASK 6 - Analyses of Database and Modeling of Tectonic Processes and Geologic Deformation

Objective: Determine correlations between spatial and temporal patterns of late Neogene and Quaternary regional strain, faulting, and earthquake seismicity, and to identify patterns of fault rupture and seismicity which may be used to assess faulting and seismicity at Yucca Mountain.

Accomplishments: 3-Dimensional visualization of the Landers earthquake sequence shows both upward and downward propagation of aftershock patterns, and close association of the Little Skull Mountain earthquake. Implication: triggering may strongly influence the rate of elastic strain accumulation between 1st-order faults.

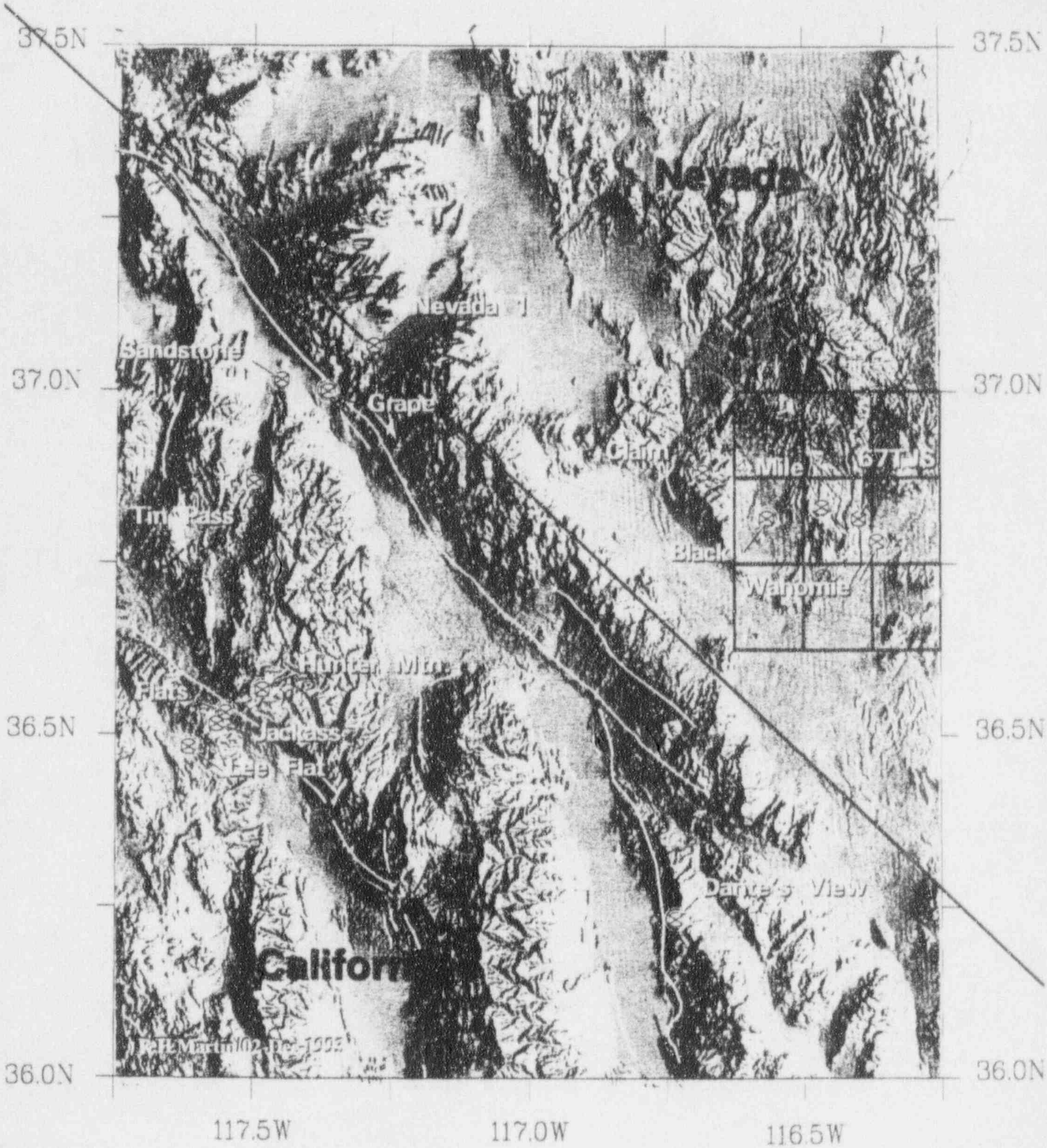
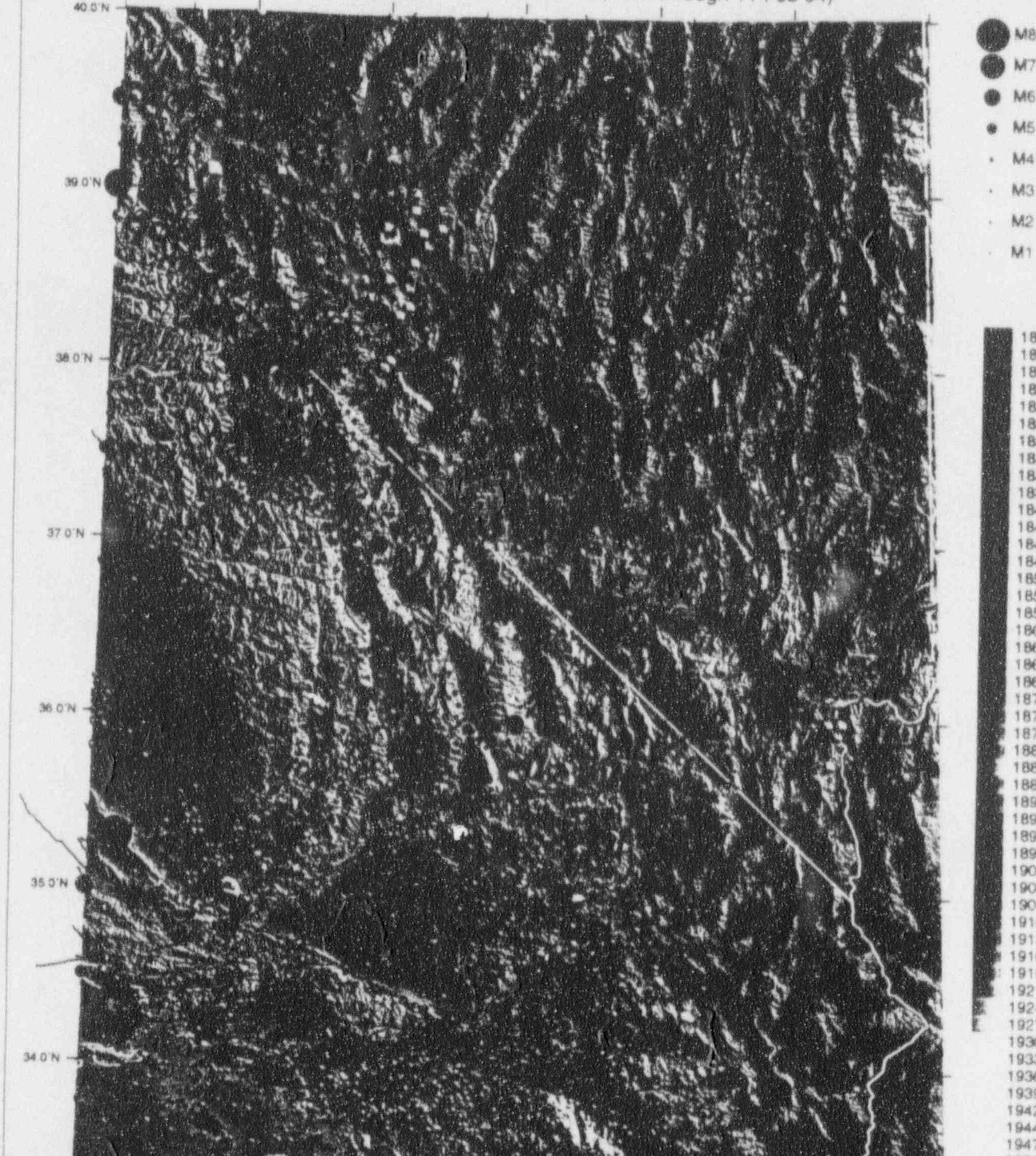


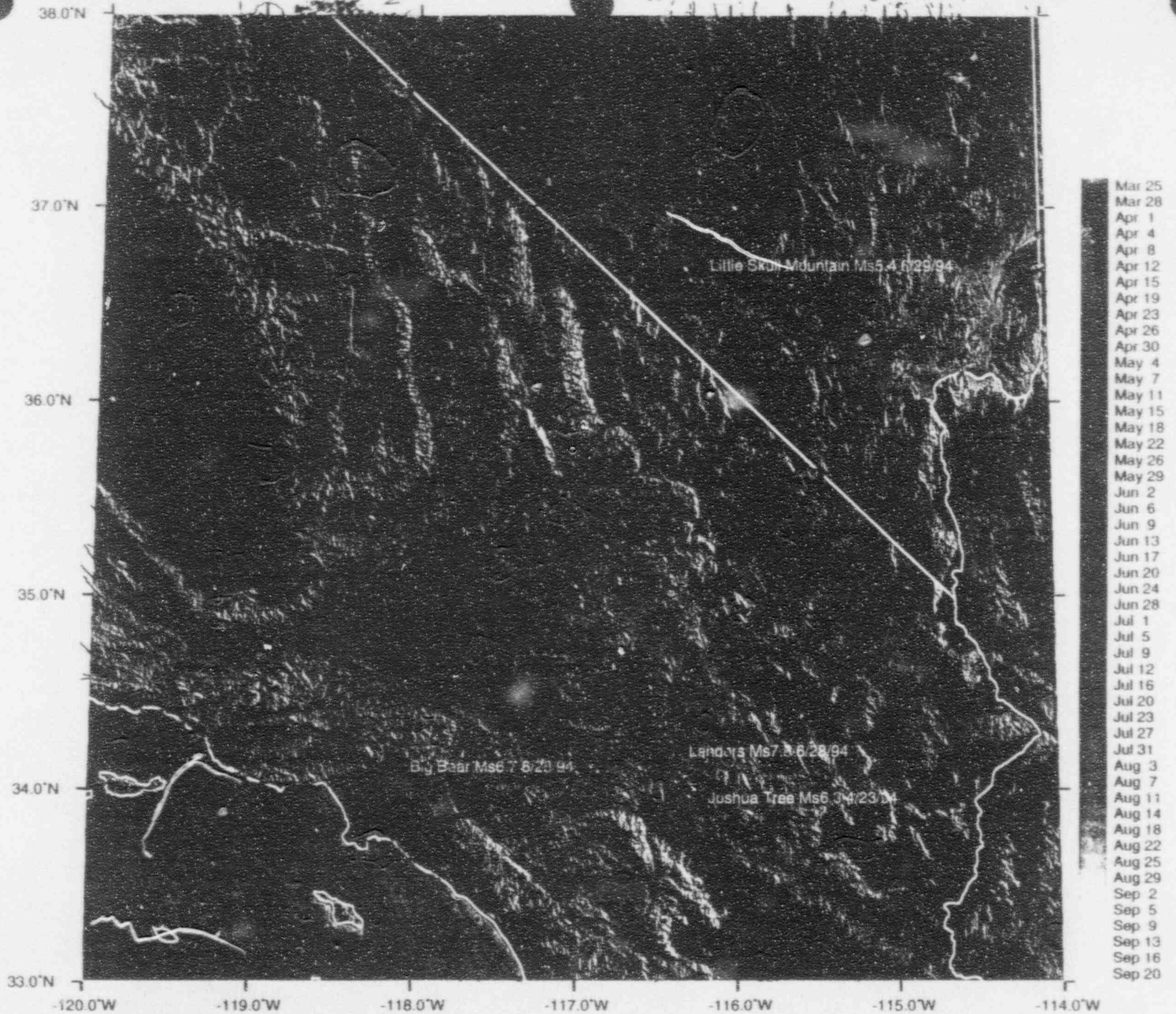
Figure 9-2. Global positioning satellite (GPS) stations. Faults are from sources noted in Figure 9-1. Yucca Mountain is located at the center of the nine square grid. Map projection is UTM.

EARTHQUAKE HYPOCENTERS (1812 through 11 Feb 94)



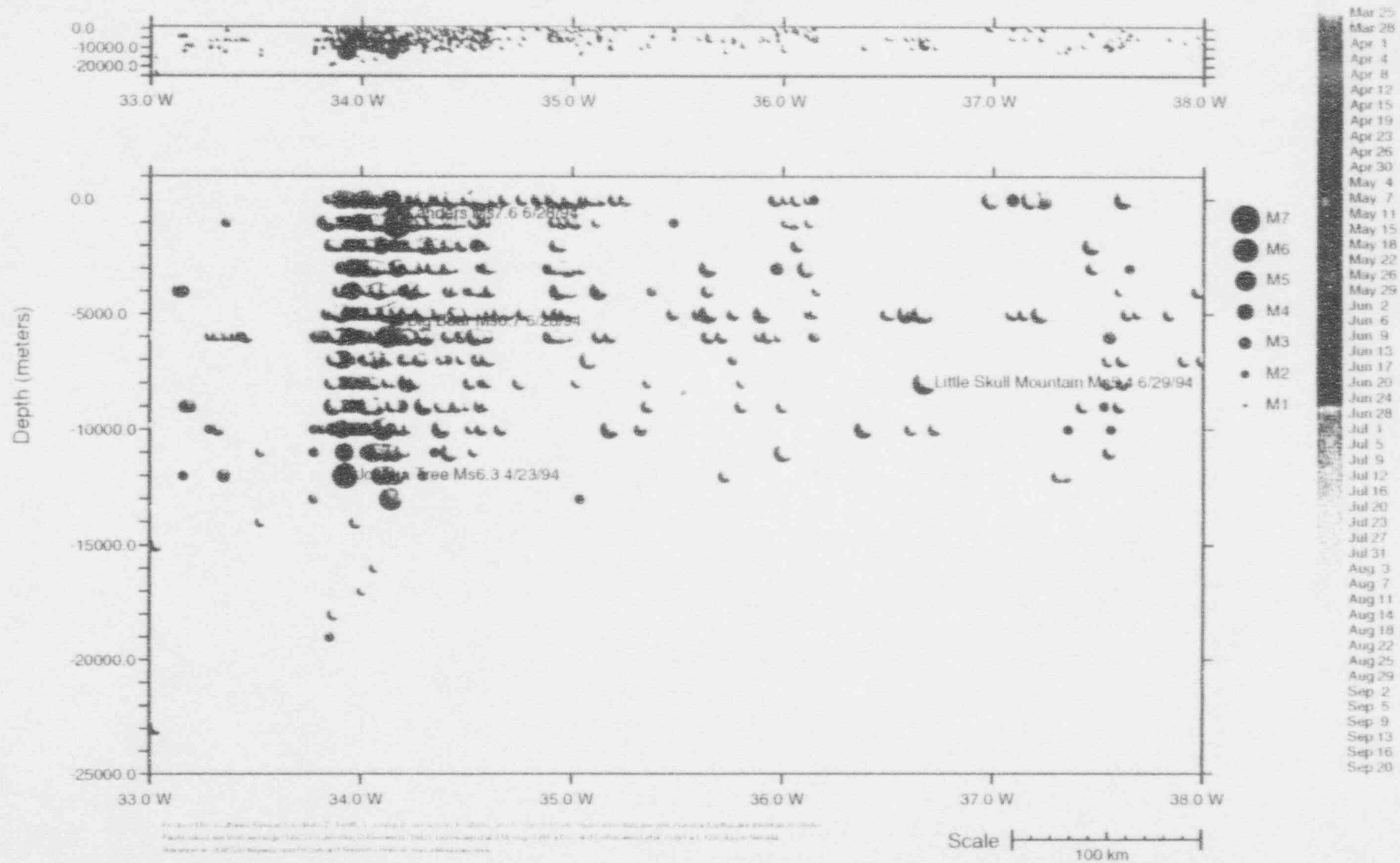
Produced by Southwest Research Institute: D. Ferrill, S. Young, B. Henderson, R. Martin, and R. Xiao (3/10/94). Hypocenter data are from PDE Catalog/National Earthquake Information Center. DNAG hypocenter data is used when there is no corresponding entry in the PDE Catalog for the same location and date. Magnitudes are assigned a value from one of the following fields in order of preference: Ms (average surface-wave magnitude), mb (average body-wave magnitude), contributed magnitude 1, or contributed magnitude 2. Faults traces are from Jennings (1992) in California; Dohrenwend (1982), Dohrenwend and Moring (1991 a,b,c), and Dohrenwend et al. (1991 a-f, 1992 a,b) in Nevada; Nakata et al. (1982) in Nevada; and Frizzell and Shulters (1990) in Yucca Mountain area.

LANDERS EARTHQUAKE SEQUENCE (Earthquake Hypocenters 3/25/92 through 9/28/92)



Produced by Southwest Research Institute: D. Ferrill, S. Young, [illegible] Henderson, R. Martin, and [illegible] (9/1[illegible]/94). Hypocenter data are from National Earthquake Information Center. Faults traces are from Jennings ([illegible]) in California; Dohrenwend (1992), Dohrenwend and Moring (1991 a,b,c), and Dohrenwend et al. (1991 a-f, 1992 a,b) in Nevada; [illegible] et al. (1992) in Nevada; and Frizzell and Shulters (1990) in Yucca Mountain area.

LANDERS EARTHQUAKE HYPOCENTERS SEQUENCE - View is from East towards West (3/25/92 through 9/28/92)



TECTONICS RESEARCH

Results to date useful for Performance Assessment, Pre-licensing Guidance, and License Review:

Result:	Use:
Established a reference, or confirmatory, database of important tectonic features.	Test key assumptions and important assertions presented in Study Plans, the Site Characterization Plan, and in a License Application (e.g. locations of fault-line sources, focal-mechanism type, fault-length, orientation within in-situ stress field).
Regional correlation of earthquakes with mapped fault traces.	Review of Study Plans, Pre-licensing Guidance, and License Review of issues related to correlation of earthquakes with tectonic processes.

TECTONICS RESEARCH

Anticipated results useful for Performance Assessment, Pre-licensing Guidance, and License Review:

Result:	Use:
Probability distributions of fault length and orientation.	Performance Assessment - Probabilistic Seismic Hazard Assessment
Probability distributions of earthquake magnitude and recurrence.	Performance Assessment - Probabilistic Seismic Hazard Assessment
Probability distributions of fault rupture length, offset, and slip rate. GPS will be an especially strong test of slip rate estimates.	Performance Assessment - Probabilistic Seismic Hazard Assessment
Alternative tectonic models including potential earthquake sources with no surface expression.	Study Plan Review, Site Characterization Guidance, and License Review of potentially adverse conditions related to Structural Deformation - extent to which features may be present and undetected.
Improved knowledge of temporal and spatial patterns of earthquake seismicity.	Review of potentially adverse conditions related to potential for increasing earthquake frequency and magnitude.

TECTONICS RESEARCH

CONCLUSIONS

i) Review of the literature provides a firm basis for initial development of Key Technical Uncertainties.

ii) TecRes GIS database is being developed for timely, interactive access by the regulatory analyst.

iii) TecRes currently contributes significantly to Regional Hydrology Research, Volcanism Research, and to pre-licensing review.

iv) Critical review and analyses of the TecRes database will provide an assessment of the adequacy of existing data for compliance determination.

v) The TecRes database will provide important constraints on earthquake and fault rupture parameters for review activities, independent confirmation and performance assessment.

vi) Alternative conceptual models will provide necessary basis for inclusion of blind sources and associate: magmatism in Performance Assessment.

Ma, for an average spreading rate of about 17 mm/a. Comparing VLBI geodetic data with contemporary plate motions (e.g. Minster and Jordan, 1987; Ward, 1990) requires

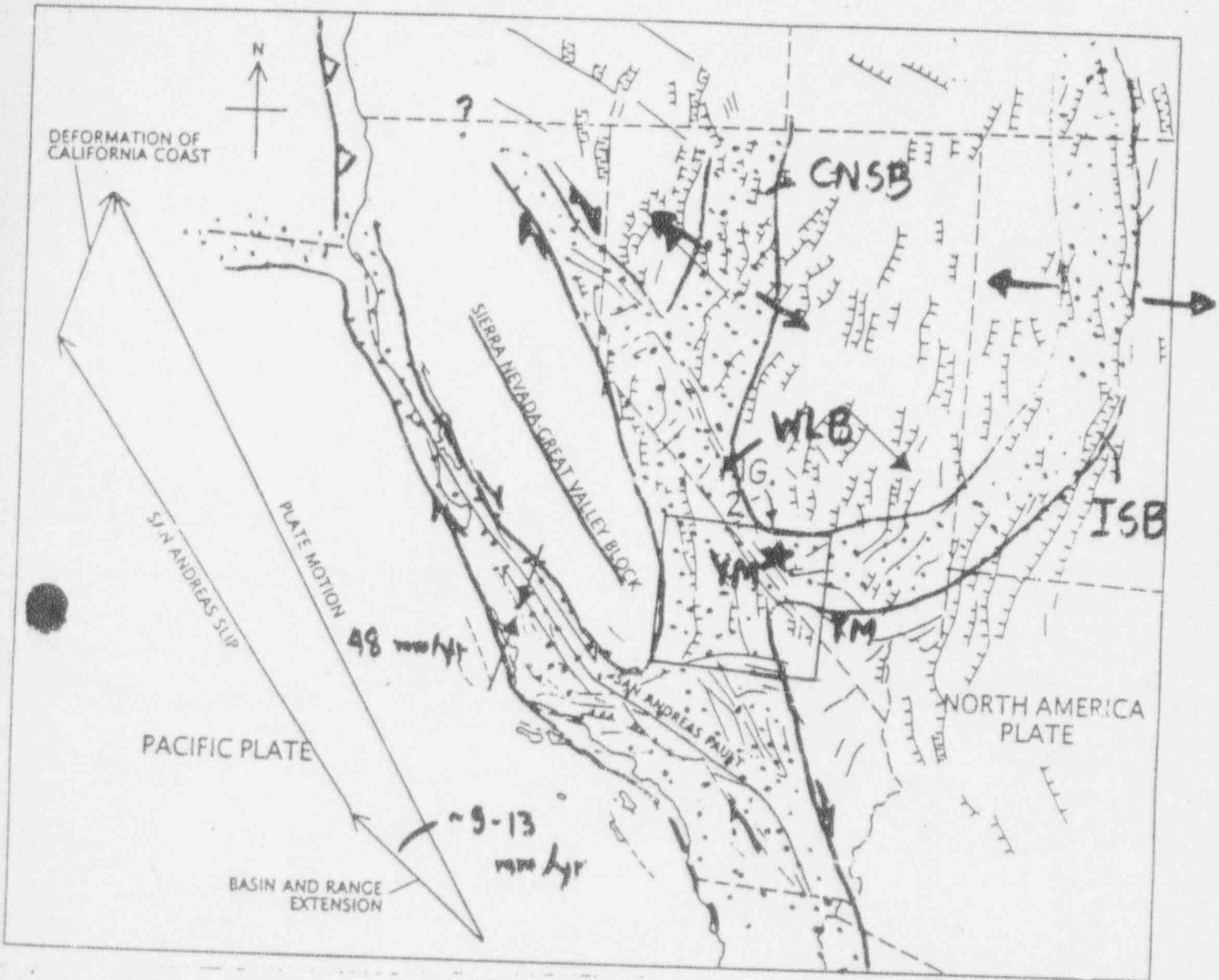


Fig. 1. Partitioning of total Pacific–North America plate motion among domains of deformation in the western U.S., from Minster and Jordan (1988). The vector diagram shows the relative rate and direction of plate motion, extension in the Basin and Range, slip on the San Andreas, and deformation in coastal California.

approximately 9 mm/a of spreading in the Basin and Range, accounting for as much as 20% of total Pacific–North America motion (Figs. 1 and 2). Some interpretations of recent GPS results suggest that nearly all of the San Andreas discrepancy may be accommodated in the Basin and Range (Agnew et al., 1990). However, relatively little effort has been expended to test this notion directly using GPS networks.

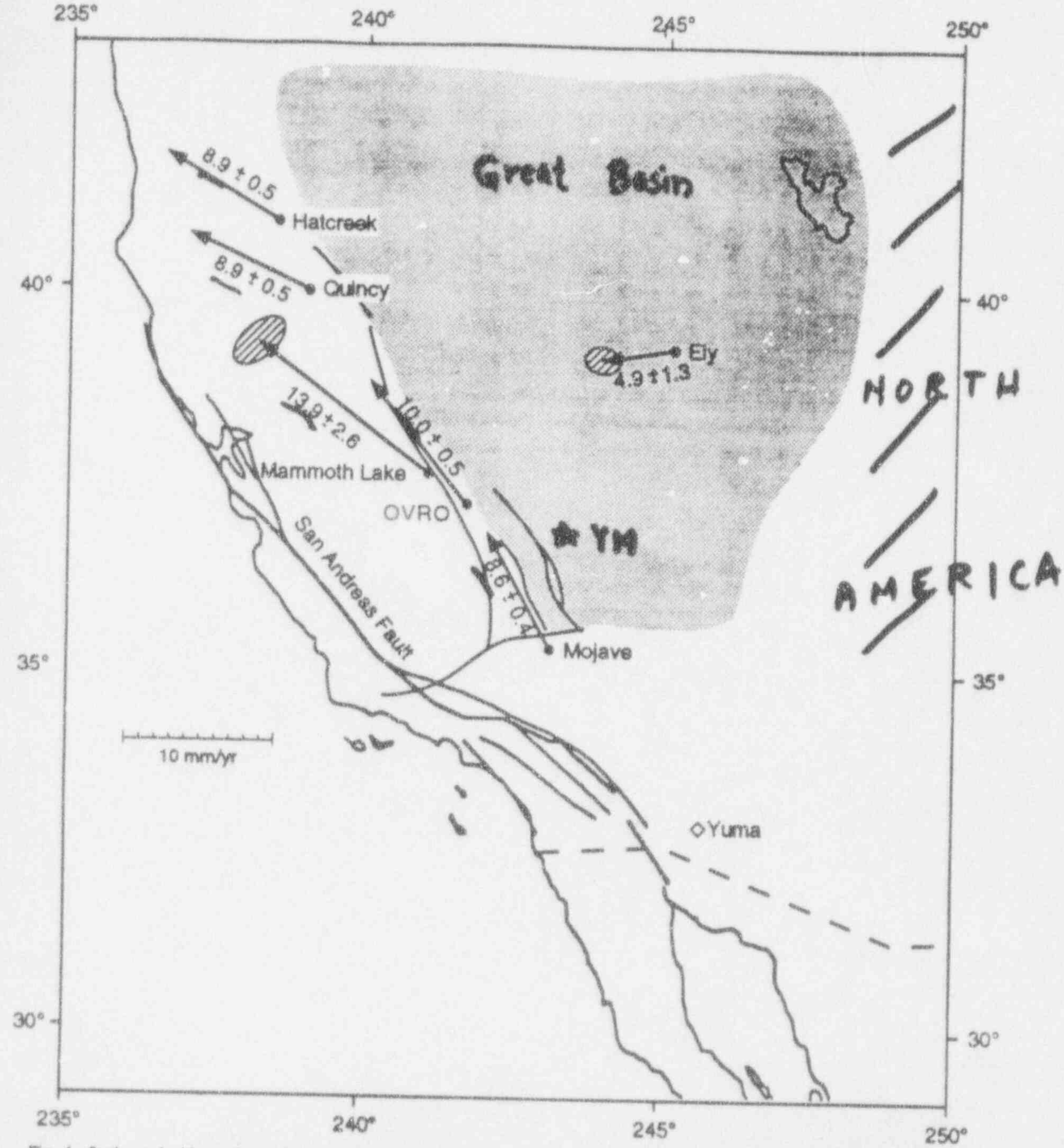


Fig. 4. Station velocities and one sigma errors in rate for SLR and VLBI sites in the western U.S. that are east of the San Andreas fault and in or near the Basin and Range province (stipple). Sites with open diamonds are thought to be located on stable North America. One sigma error ellipses (Table 3) are smaller than dimensions of arrowheads for all stations except Ely and Mammoth and are omitted from figure. High northwest velocities of OVRO, Mammoth, Quincy and Hatcreek suggest that these stations all lie on the Sierra Nevada block, west of the actively deforming Basin and Range and west of the eastern California shear zone.

have a significant effect on the velocity estimates. In general the 1988, 1989 and 1992 data were collected under similar conditions; the 1990 data and all pre-1988 data suffer from various inconsistencies. We used all available data from the four experiments conducted between 1988 and 1992 for which both CASA and OVRO had at least four hours of simultaneous observations. This criterion eliminated one day in the 1989 experiment. In contrast to this generally rosy picture, data from

As has been observed at both short and long timescales, extensional strain in the Basin and Range province is partitioned between areas of low and high strain (e.g. Greensfelder et al., 1980; Wallace, 1984; Wernicke et al., 1988). In the Death Valley region, the Northern Death Valley fault zone appears to be the east limit of rapidly extending crust based on geological observations (e.g., Hamilton, 1988; Wernicke et al., 1988). A triangular region in the western part of the Basin and Range between the Sierra Nevada, Garlock fault and Northern Death Valley faults (Fig. 2) appears to have

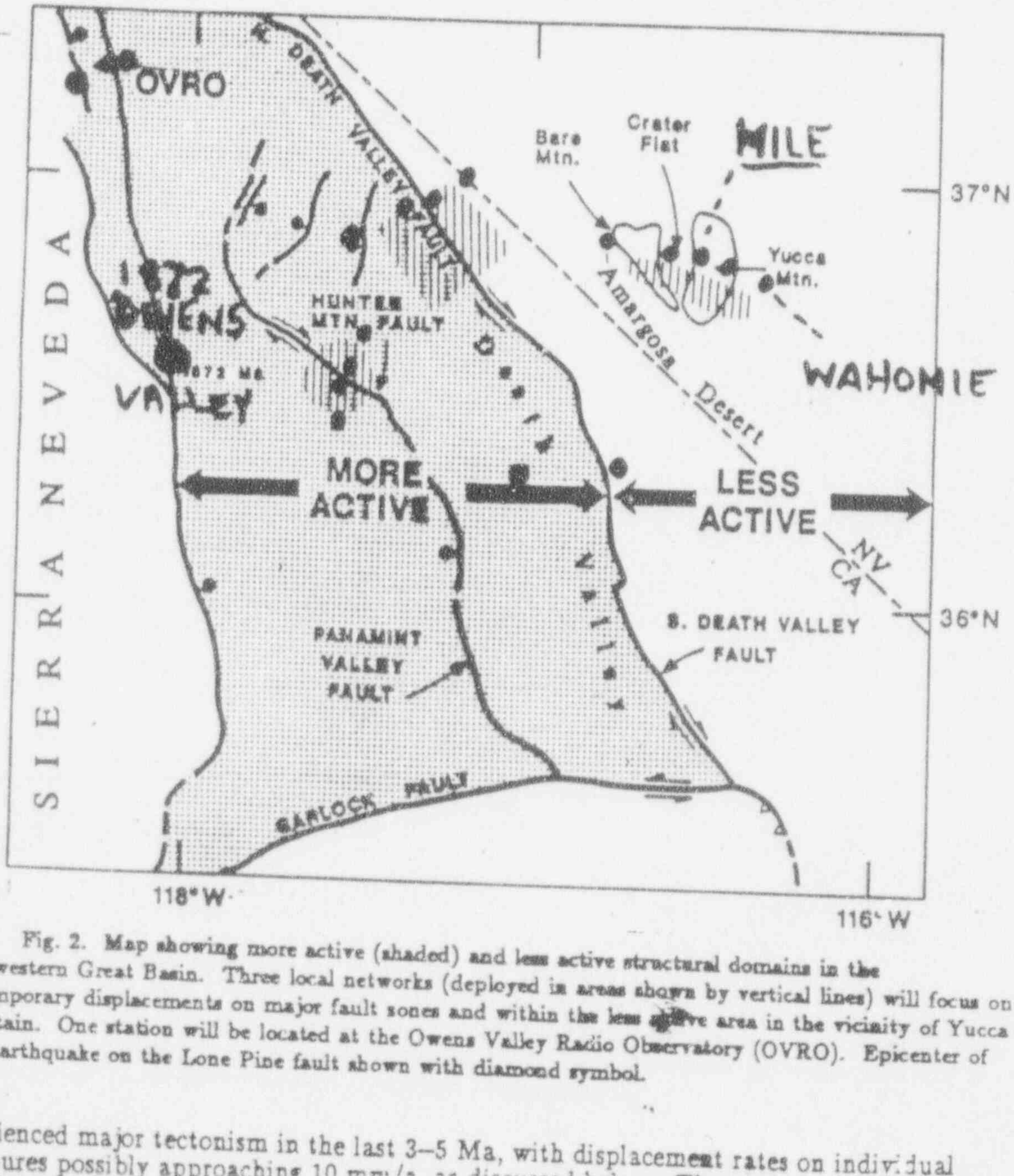
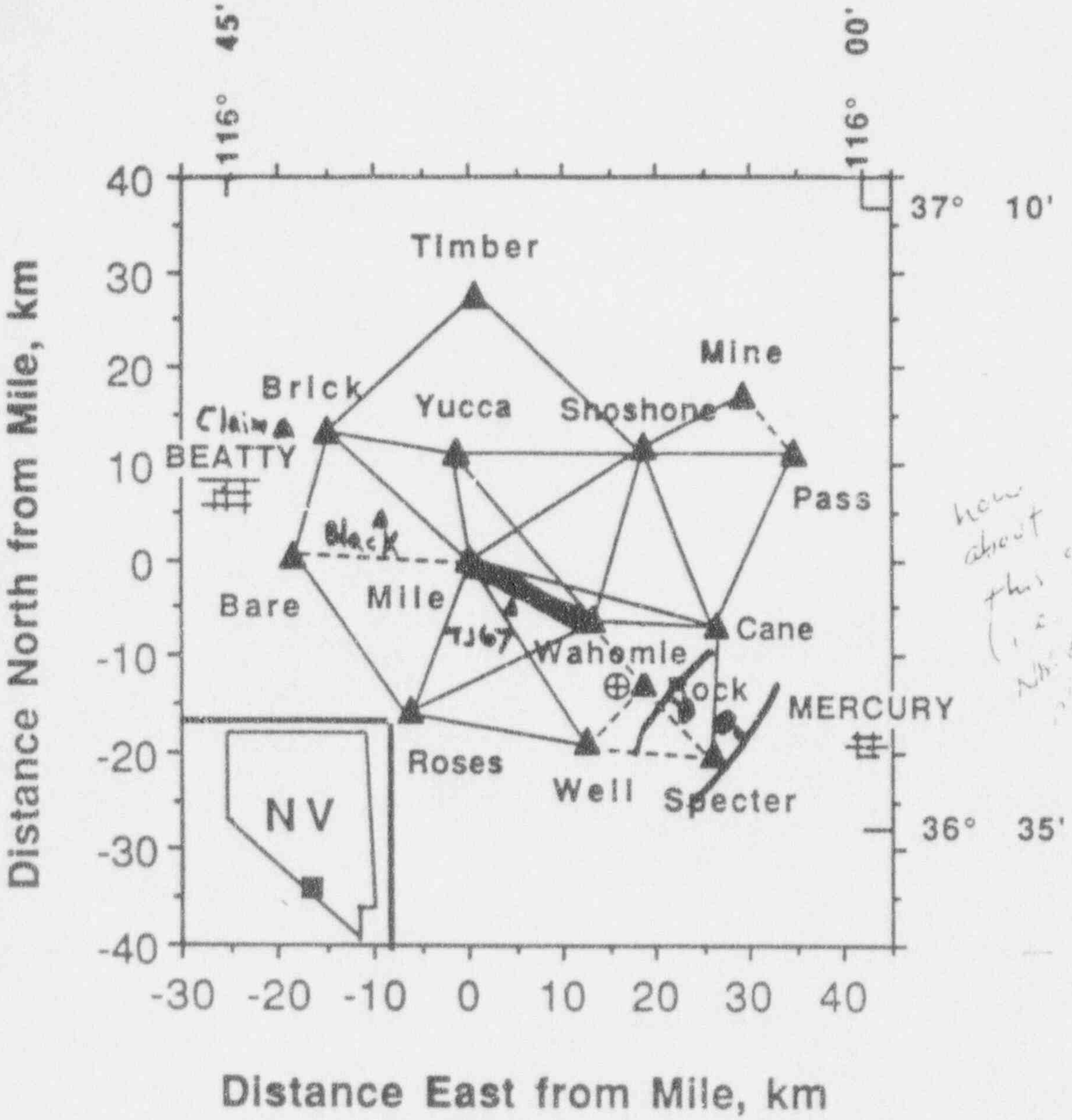


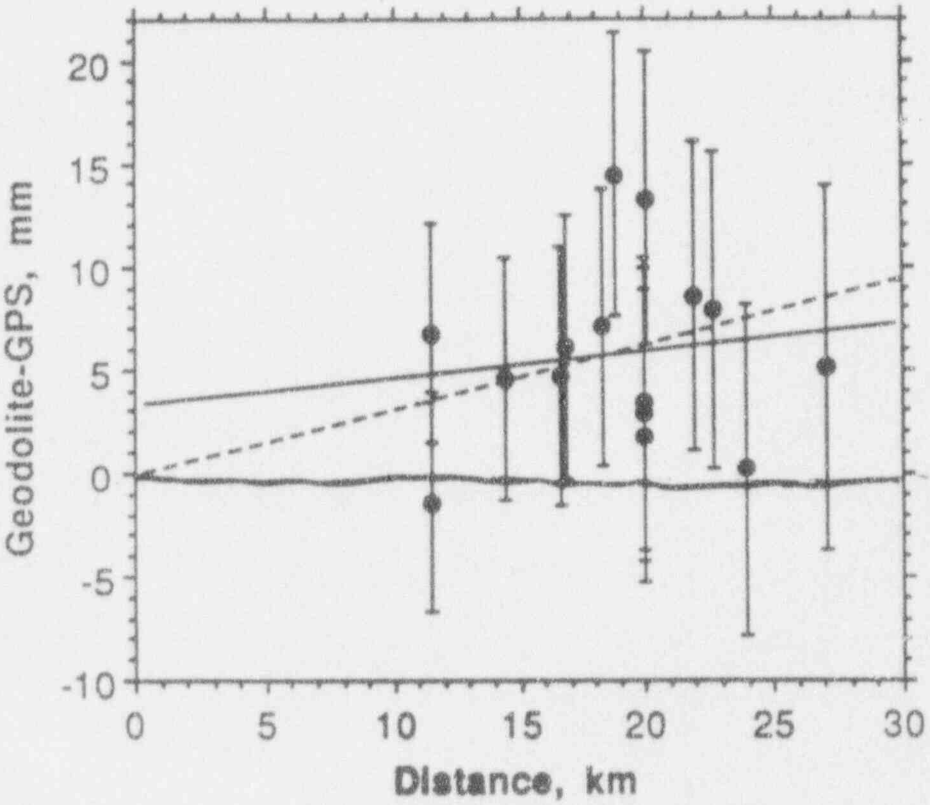
Fig. 2. Map showing more active (shaded) and less active structural domains in the southwestern Great Basin. Three local networks (deployed in areas shown by vertical lines) will focus on contemporary displacements on major fault zones and within the less active area in the vicinity of Yucca Mountain. One station will be located at the Owens Valley Radio Observatory (OVRO). Epicenter of 1872 earthquake on the Lone Pine fault shown with diamond symbol.

experienced major tectonism in the last 3–5 Ma, with displacement rates on individual structures possibly approaching 10 mm/a, as discussed below. The area to the east, which includes the northern Amargosa Desert and Yucca Mountain, appears to be substantially less active (Fig. 2). Somewhat paradoxically, major structures in the Death Valley region are relatively aseismic (with the exception of the Lone Pine fault adjacent to the Sierra



how about this one

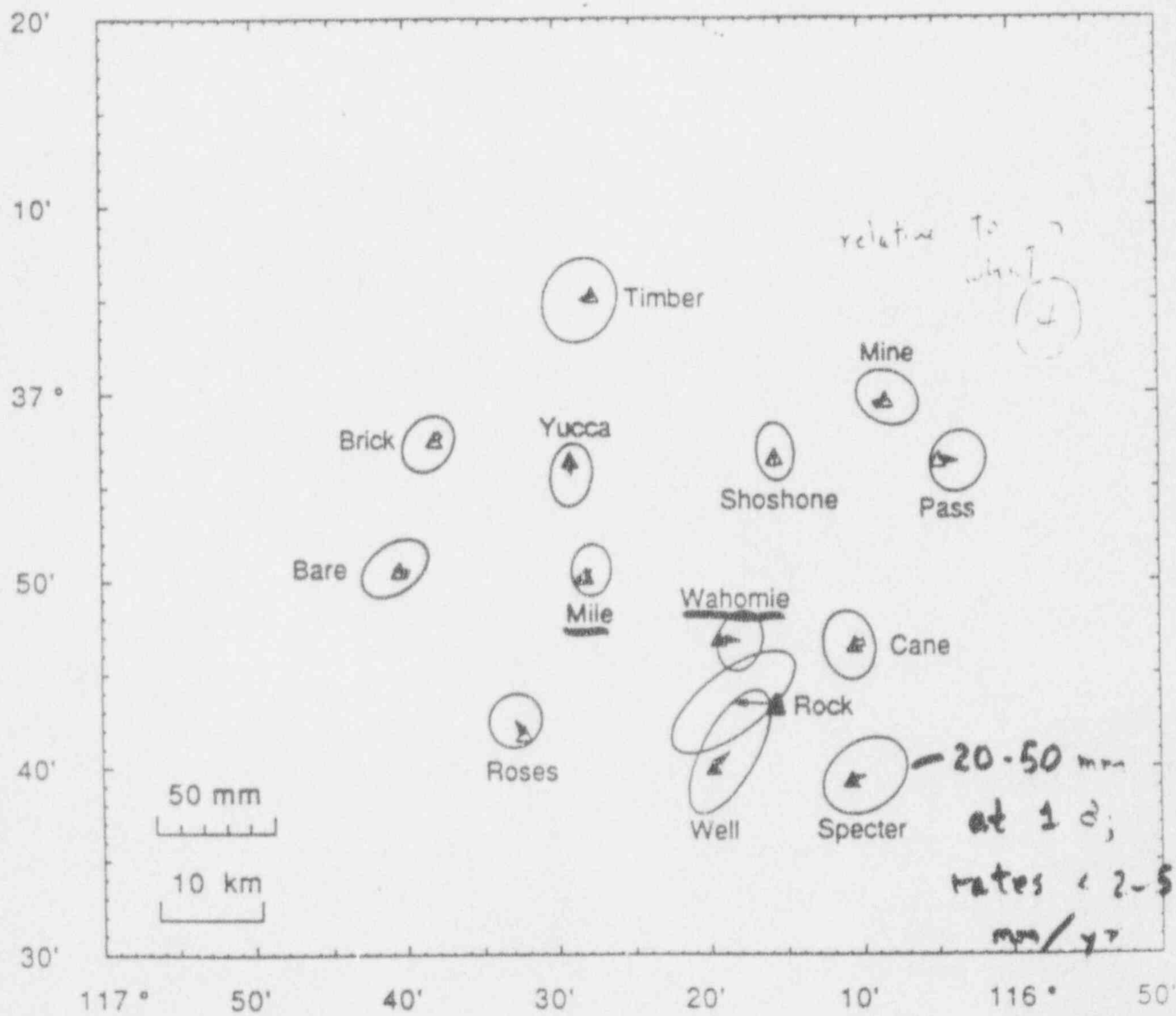
Savage et al., in press (JGR?)

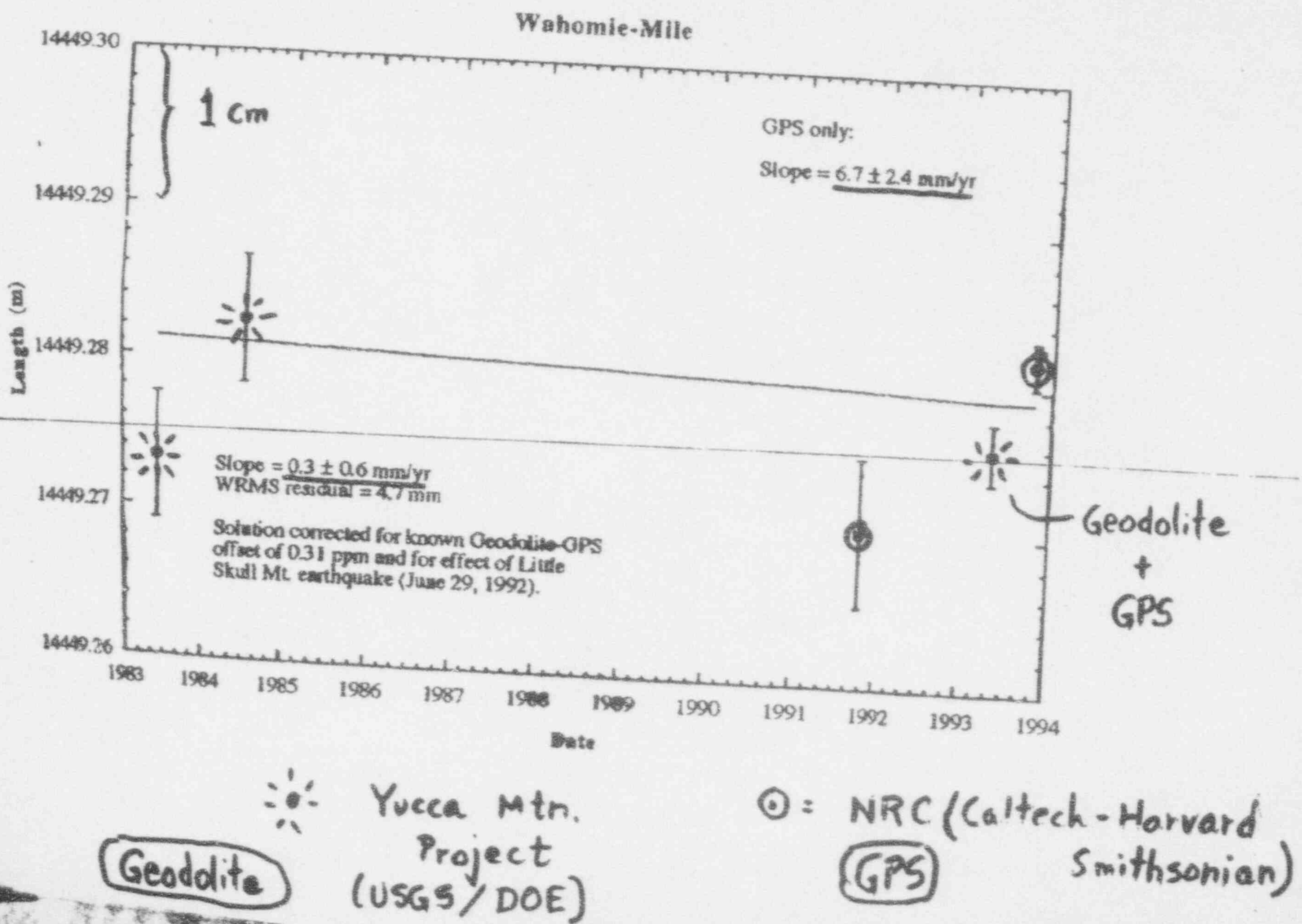


Geodolite baseline ~5 mm > GPS baseline

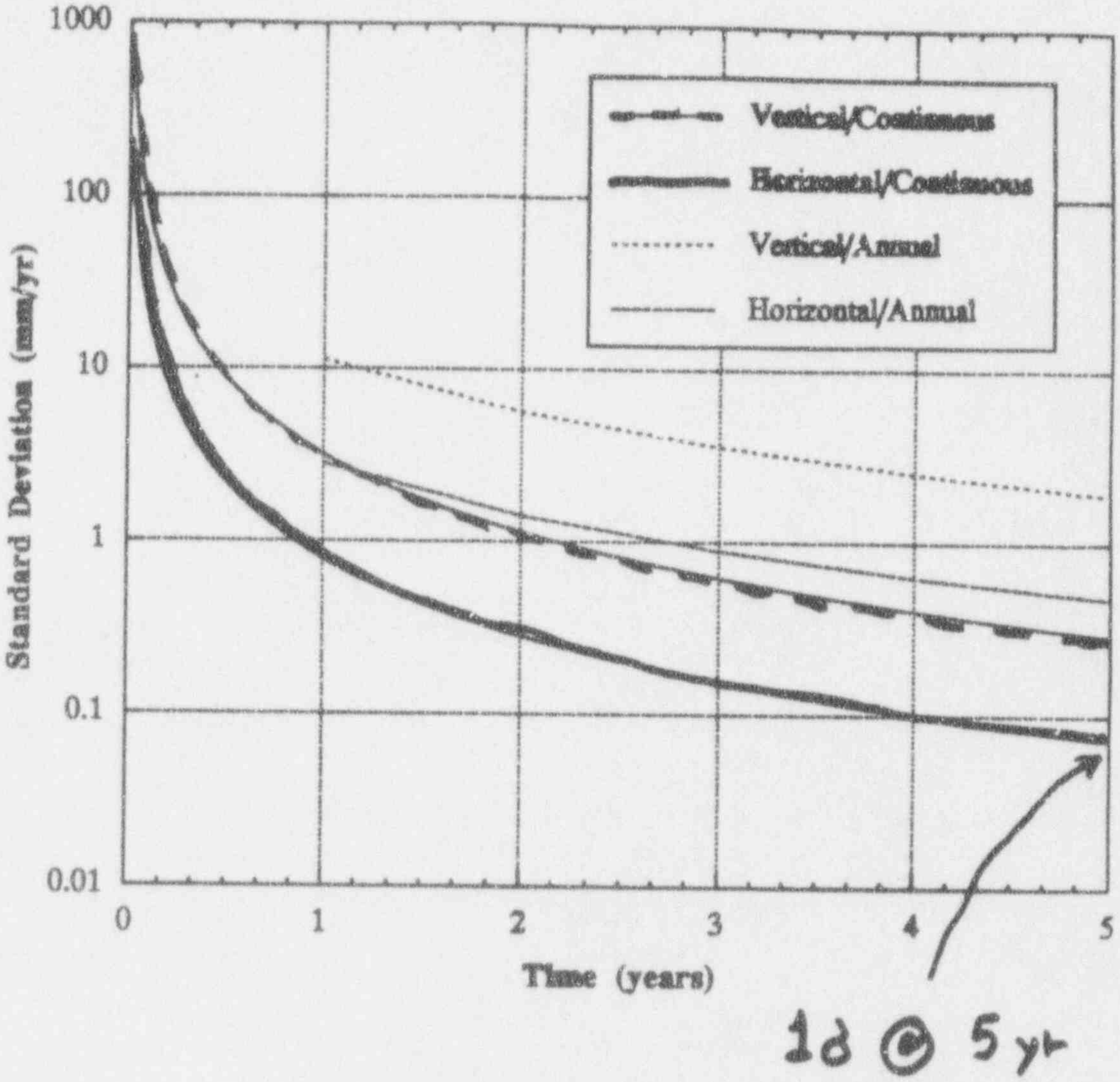
Savage et al., in press JGR.

Savage et al., in press
JGR





Wahomie-Mile
14449.30
14449.29
14449.28
14449.27
14449.26
Length (m)
1 cm
GPS only:
Slope = 6.7 ± 2.4 mm/yr
Slope = 0.3 ± 0.6 mm/yr
WRMS residual = 4.7 mm
Solution corrected for known Geodolite-GPS offset of 0.31 ppm and for effect of Little Skull Mt. earthquake (June 29, 1992).
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
Date
Geodolite + GPS
Yucca Mtn. Project (USGS/DOE)
Geodolite
NRC (Caltech-Harvard Smithsonian)
GPS



From J.L. Davis, Harvard/Smithsonian based on Fennoscandia results 1992-1993