NUCLEAR REGULATORY COMMISSION

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In the Matter of:

SOUTHERN CALIFORNIA EDISON COMPANY, ET AL.)
) DOCKET NO's
(San Onofre Nuclear Generating Station,) 50-361/362-OL
Units 2 and 3)

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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SOUTHERN CALIFORNIA EDISON COMPANY, ET AL.	:	Docket Nos. 50-361 OL 50-362 OL
(San Onofre Nuclear Generation Station, Units 2 and 3)	:	

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Stardust Room
Stardust Hotel & Country Club
950 Hotel Circle North
San Diego, California

Tuesday, June 24, 198?

Evidentiary hearing in the above-entitled matter was reconvened, pursuant to adjournment, at 9:10 a.m.

BEFORE:

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Atomic Safety and Licensing Board

DR. CADET H. HAND, JR., Member

MRS. ELIZABETH B. JOHNSON, Member

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C O N T E N T S

PRESENTATION OF:	PAGE NO.
Dr. Robert Mc Neil	1155
Dr. Stewart Smith	1179

WITNESS:	CROSS
Edward George Heath	
By Mr. Wharton	1255
By Mr. Brune	1298

EXHIBITS:

(None)

P R O C E E D I N G S

JUDGE KELLEY: Good morning. We are ready to reconvene the hearing.

Mr. Chandler, you said you had one housekeeping matter. Let me ask, on the first day, we had introductions right to left or left to right, of everybody who was here, and I have seen a few new people arrive since then, and I think as a matter of practice, so we will know who is up on the front tables, if you have a new person come in, you might introduce them at that time, and perhaps left to right I could get whatever additional -- the gentleman in the middle, I think --

MR. CHANDLER: I will make the introductions, Mr. Chairman. In addition to Counsel with me at Counsel table is Mr. Harry Rood, who is the NRC Staff's project manager for the San Onofre Units 2 and 3. In addition, Mr. A. Thomas Cardone, who is a staff geologist and responsible for the geology review of the San Onofre Units 2 and 3 facility.

JUDGE KELLEY: Mr. Wharton?

MR. WHARTON: Yes, in addition, at our table is Dr. James M. Brune. Dr. Brune is a professor of geophysics at University of California, San Diego.

JUDGE KELLEY: You have the same team this morning, I think, less one.

MR. PIGOTT: Same people here, that there has been with me at previous -- during the evidentiary portion of the hearing, Mr. Gene Hawkins, the distinguished white-haired gentleman who has been sitting to my right, who is a geologist with the Edison company.

JUDGE KELLEY: Mr. Chandler, you had --

MR. CHANDLER: Yes, Mr. Chairman. As I indicated yesterday, I have now received a document entitled NRC Staff Views with respect to Question Posed by the Atomic Safety and Licensing Board in the area of Emergency planning," which represents the Staff's comments on the questions raised by the Board at the April 29 pre-hearing conference regarding emergency planning.

I will serve that upon the Board and parties. It is noted on the certificate of service, that as indicated by double asterisks, service is being accomplished by special delivery service, which as I mentioned yesterday, means service mailed to me, and I will make personal service on the Board parties.

In addition, as I mentioned on Monday, the Staff will be offering one additional Exhibit as part of its direct case. That document is entitled "A Safety Evaluation of the Geologic Features at the Site of San Onofre Nuclear Generating Station." It is in docket numbers 50-206, 50-361, 50-362, and it is date July 8, 1975. For your information, docket 50-206 is the docket number assigned to San Onofre Nuclear Generating

Station Unit 1, and I would like now to provide the Board and parties with copies of each of these documents.

JUDGE KELLEY: Fine.

MR. CHANDLER: I am not offering it or asking that it be identified at this time. I would like to note, Mr. Chairman, that with respect to the Staff's views on the Board questions, references made to two affidavits, an affidavit by Brian Grimes, which is indeed attached as indicated, because of some complications in transmission, the affidavit, the second affidavit that is referenced in that document, affidavit of Robert Jaske of FEMA, is not attached. I anticipate receiving that today, and I will provide that to the Board and parties as soon as possible after receipt.

JUDGE KELLEY: Thank you. Prior to the beginning of this hearing, and after, however, the Board's receipt of testimony and Exhibits in the case, we were reinforced in our initial impression as to the highly technical nature of this litigation, particularly with respect to some issues, and particularly with respect to seismic issues, and we had a discussion with Counsel last week as to whether there might be some means whereby the -- well, the Board frankly, in our self-interest, could become better educated, so that we would have a better understanding of the testimony and the record as it develops.

And Counsel for the Applicants suggested that they would be willing to give a presentation of I don't know how to characterize it, the elementary seismology. I will leave it to Mr. Pigott to spell out more clearly just what he has in mind this morning, and then the understanding would be Dr. Brune is the expert here this morning for the Carstens Intervenors. He may wish to comment on certain aspects, and we will see he will have an opportunity to do that after the presentation has been made by the Applicants, and similarly with the Staff, if they wish to make comments or ask questions, they will have an opportunity to do so. But this is for the education of all of us, if you will, certainly for the Board.

It will be transcribed. It will be in the record. We will not, however, swear the witnesses. This is not being offered as substantive evidence. This is just being offered as an aid to understanding to us in this technical case. So, with those comments, let me turn it over to Mr. Pigott, and he can spell out perhaps in somewhat greater detail what he plans to do this morning.

MR. PIGOTT: Thank you. We have prepared three -- or requested three of our experts to prepare an introductory -- some introductory remarks to the subject matters covered by their testimony. We are attempting to keep it very academic, and it will be away from -- not directed to the precise issues in this hearing, or any of the geologic features that we have been talking about.

Obviously, this is a broad field, and the discussion will center on the areas that are of concern to this hearing,but it will be a very general type of a discussion.

We will be hearing from Dr. Robert McNeill, who will be talking about -- I hate to generalize it as the engineering aspects, but certainly more than pure seismology. And Dr. Stewart Smith, who will be talking about the seismology generally, and Dr. David Moore, who will be talking about some of the techniques and the procedures used in offshore profiling, which is a large part of this case.

So, with that, if we are ready, I would ask Dr. McNeill to proceed.

MR. WHARTON: What is the purpose of presentation of engineering? We don't have any issues regarding engineering.

MR. PIGOTT: We don't have an engineering issue. It has more to do with the -- let me put it this way. The design spectrum, getting to a discussion of how you get to the design spectrum, the thing that we are trying to determine whether or not it is conservative. You are correct, we are not going into structures. And with that, Dr. McNeill?

Whereupon,

ROBERT McNEILL

was called to address the proceedings, and spoke and was questioned as follows:

MR. McNEILL: Good Morning. I have prepared this little tutorial in a rather simplified form. I am going to go rather slowly. It will take about 40 minutes.

I would encourage you to interrupt me at any time to ask questions. I think that is probably more efficient in the learning process than to do it afterwards.

We will be talking about earthquake vibrations, but before I do, I would like to talk just about simple vibrations for a while, and define some terms that we will be using, and I might just use this as an example, and note that this takes a certain period of time to complete one oscillation, and we call that a period. We give it the dimension of seconds, although really it is seconds per cycle of complete motion. We say seconds, but it is seconds per cycle.

If I were to pass a piece of paper across the top of this, and if this were an ink pen, it would mark for me the time history of the displacements it is undergoing, and in that time history, I would define the period, which I have already describe to you, and also the amplitude of the motion.

Now, it is important to recognize that the amplitude of the motion can be describe in several ways, but fortunately those different ways can be related in quite an explicit form, and I will depict that in just a moment.

But for example, noting this vibration, what you see with your eyes is the amplitude measured in terms of displacement. It is going so many inches back and forth.

But you also recognize that right now, the velocity is zero, but when I let it go, it picks up velocity, gets a maximum velocity here, then commences to slow down, and it goes back to zero velocity and reverses that process, and so I can also describe that motion in terms of velocity, displacement and velocity.

Also, when it is at this particular point, it is being pulled back by the rod, that is, it is feeling an acceleration, and so I could also describe it, although you can't see it, in terms of acceleration. So I will use almost interchangeably these terms, "displacement velocity" and "acceleration," and I will show you how to relate these to each other in just a moment.

Notice also that if I let this vibrate and talk to you for a while, that the vibrations are tending to damp or to die. That is, nothing goes on forever, except perhaps a hearing.

(Laughter)

MR. McNEILL: So, we describe -- we describe the tendency for the motions to die out or to damp as damping, and we express that as a percentage, a percentage of what? If the damping were zero percent, the motions would go on forever.

If the damping were a hundred percent, for example, this were in a bath of very viscous oil, then if I pull it back and let it go, it would just return to the same position and not overshoot, and not vibrate any more. So when I talk about vibrations that are for example two percent, five percent, seven percent, it is of that critical very high damping, and numbers of two and five and seven percent are in fact very low dampings.

JUDGE KELLEY: Is damping the same as or related to attenuation?

MR. MCNEILL: Not the same as, but related to. It has to do with the same phenomenon, that is, energy is being converted to other forms. For example, if I were to move this fast enough and let it move long enough, then clearly it would become warm down here, because the energy is being converted to another form, heat, but it is being lost to the form which is the vibrating motion.

Now, I have to apologize. In engineering there are certain dogmas, just as for example there is in law. You use Latin --

JUDGE KELLEY: Unfortunately that is true.

MR. McNEILL: Yes. In Germany, you worry about the articles and how you decline the nouns, and there is rhyme or reason. It is just done that way.

Well, in engineering, we have a little feeling of our own. That is, we talk sometimes in terms of period, which you can see very easily there, and at other times, and often in the same sentence and interchangeably, we will talk about frequency, and those a.e related, quite simply, in that the period is the reciprocal of the frequency and vice-versa, so I can talk in seconds per cycle as the period, or in cycles per second as the frequency.

So, for example, when I speak to you of a period of one second, then obviously I am talking about a frequency of one cycle. If I talk to you about a period of a half second, then I am speaking of a frequency of two cycles per second, and so on. And one has to acquire the ability to flip those around in your mind. I have been doing it for 30 years, and I haven't acquired that ability yet.

Now, what I have been discussing with you are rather simple vibrations of a discrete particle, but obviously what we are leading to are the vibrations and the wave mo ns of an earthquake, and as the earthquake happens, it creates waves which vibrate through the ground, so instead of talking about this motion in terms of time, as we have been doing, it is often appropriate to talk of the motions in terms of space.

That is to say, you might imagine that I could just take a snapshot of that wave as it is going by on the ground, it is a lovely pointer. Do we have a better one?

And, you might imagine that wave travelling at some velocity, and let me clarify now that that velocity depends on two things, the type of wave, and the properties of the soil or rock through which it is propagated. Thank you, Gene.

So the wave is moving at some velocity, which is a definable calculatable term, and the wave has a certain portion of space that it occupies, and that is referred to as the wavelength, and that wavelength, for example, might be much larger than a building, it might be much smaller than a building, and we can quantify that by combining these quantities with the period that we have already discussed, and knowing that the wavelength can be calculated from the relationship that it is the product of the wave velocity times the period of the particular motion.

We will return to this in just a moment, and extract some of the properties of that very simple equation, but before we do, let me point out that I have discussed with you without defining them two velocities.

One velocity was the one that we developed for this little particle going back and forth, and so we will distinguish between that particle velocity and this wave velocity, and if I don't distinguish between them, please interrupt and make sure that I have made that point clear.

As we look at this simple equation, either in the form of period or in the form of frequency, you notice that for a given rock or soil, the wave velocity for a particular wave is sensibly constant, and therefore that the length of the wave varies as the period or inversely as the frequency. In other words, if I have very long periods, I am going to have long waves. If I have very short periods, or high frequencies, then I will have very short waves, and it is often possible for those waves to be small, compared to the characteristic dimension of a structure.

In the early description, I emphasized the point that you can describe a motion either in terms of displacement, or velocity or acceleration. I also indicated that those can be related. In general, the relationship is not simple, but for the purpose of the maximum of those motions, that is, the maximum velocity ones right here, or the maximum displacement ones clear over there, the relationship for a given period of vibration is in fact quite simple.

That is, I can relate displacement, velocity and acceleration by noting that the velocity, maximum velocity, is equal to 2 pi, divided by the period, times the displacement, and the maximum acceleration is 2 pi divided by the period, times the velocity.

Now, as you notice that progression, from displacement, velocity, acceleration, it is clear that if you wish to do so, if I give you any two of the four quantities, period, displacement, velocity, acceleration, you could very readily compute the other two, and if you wished to do that, that would be fine. You do not, however, have to do that, because if you will notice these, the form of these equations are power functions.

Power functions plot as straight lines on log log paper, and therefore, it is very simple to plot on what appears to be a very complex plot, and I am going to simplify it very fast, and John, would you -- since these zeroxes don't really do the job they should, I am giving you an original, and it is blank, of that paper, so that if you wish to follow this more closely, it would be convenient to do so.

This paper, which is called harmonic or tripartite or spectrum paper is a display of period across the bottom, displacement moving from the lower left to the upper right, velocity from the bottom to the top, and acceleration from the lower right to the upper left, and to read any one point, for example this one here, we read the period off the bottom, this is one second, we read the displacement off this axis, and that is two inches per second, and the velocity off this one -- I am sorry, that is two inches -- the velocity off this one, that is 12 inches per second, and the acceleration off this one, and that is two-tenths of a G. It is a simple way of relating these four fundamental quantities, period, displacement, velocity, and acceleration, without having to go through the process of making that calculation, which even though it is quite simple, you usually make a mistake about one every six calculations, so this is just a simple way of doing that.

Okay. So far, then, we have discussed the fundamental quantities. We have discussed the relationship. We have discussed this very useful nomographic display of those quantities. How do we relate those things to earthquake engineering?

Let me show you a rather typical earthquake record. Dr. Smith in a very short time will discuss these in more detail with you. It is obvious, I am sure, as you look at this, that this -- something is happening here that is different from something that is happening there. As you look at it, you could get a feel for the periods or the frequencies involved, but not a very satisfactory feel, and you could also note that it would appear that the maximum acceleration on this particular record is about a quarter G, and upon just an inspection of that record, that is about all you could determine from it.

There are ways of determining a great deal more from it, and those involve using this record to generate an unique spectrum which represents properties of that record. Now, there are many different kinds of spectra, the Fourier, response, all I am going to talk about is response spectra. It is the particular one that is used by seismologists and engineers to study ground motions, and in somewhat altered form, by engineers to design and to analyze structures.

Tape 2

I would like to demonstrate for you bu using -- by this little device. I can vibrate this in such a way that these little elements will respond quite differently. For example, if I move this back and forth slowly, then the ones which have natural periods which are very short -- or very long, will tend to respond more than the ones which are stiff and have short natural periods.

On the other hand, and by the way, I could now draw, for the motions I have just given this, its spectrum. Its spectrum would be almost no motion here, and very large motions for these. If I then vibrate it at somewhat of a higher frequency, then the spectrum would be almost none here, very high there, lower, and lower, annd lower, for the others.

So the spectrum, then is a way of displaying in a convenient form how structures of various natural periods will respond to certain input motions. The motions that I have shown you are ones that are nice and regular, like the ones that I had in the earlier sketches, but I could also do the same thing mathematically for some sort of a very irregular motion, and draw the spectrum for that particular irregular motion, going in to these series of different structures, with different natural periods.

That calculation is ve., simple mathematically, and when it is done, you have a result that has certain properties:

Here, as the jagged line, is the response spectrum for that particular earthquake record that you saw just a little while ago, and that response spectrum has upon it a great deal of information. Let us try to walk through and see what it tells us.

First of all, those structures which have very short periods, that is very high natural frequencies, for example, one like this. If I subject that to motions that are low, you notice it is hardly moving, except to respond almost rigidly to what I am doing to the base, and that is true also for earthquakes, that is, the very short period motions do not amplify and rather faithfully reproduce what is going on in the ground around it. We call that, because it is short periods, the "zero period acceleration," which corresponds to the peak ground accelerations.

So we will be using two terms: the "zero period acceleration," in the referring to the spectrum, or the "peak ground acceleration," when you are referring to the time history that we had on earlier, two terms, sometimes synonymous.

You will also notice that we could probably gain a great deal more information, if you would eliminate, for purposes of discussion the jagged nature of the spectrum, and instead smooth it in some way that we could mutually agree upon, and perhaps talk about it in that simpler form.

For purposes of this discussion, I have done that as show here, and when you do that, you find a characteristic shape that you find in virtually all earthquake spectra. That is, you will notice there is a plateau which is almost constant velocity, here 10 inches per second. You will notice there is also a plateau which is almost constant acceleration, and one which is almost constant displacement.

And then, in transition between the short period ground motion, and the acceleration plateau there is a distinct rim. We call that the "acceleration rim." And the ratio between the acceleration plateau and the zero period acceleration is called the "dynamic amplification ratio," that is, it is the amount by which that structure would amplify what I put in down at the bottom.

I am putting in a very small motion here, and it is being amplified to a large one here. So that is what the dynamic amplification ratio is.

Okay, we have gone from a rather complicated earthquake record to a somewhat less complicated spectrum and then to a very simple spectrum.

Now, how do we go from that, which represents the earthquake to something that represents the motions of a structure, so that we can design or analyze that structure?

In order to do that, we have to understand a few of the physical principles which govern the behavior of structures when they are subjected to dynamic loads.

These principles all speak to the response of a structure being equal to or less than the amplified response spectrum that we were just discussing, and I am going to go through with you the reasons for that:

At short periods, several things affect the response of structures, compared to the response of the free field: The plan dimensions of the building, the depth of the structure, certain non-linearities in the structure performance, and also the mass of the mass of the structure.

With respect to plan dimensions, there are probably two things that are important: One is the wave length of the incoming waves, compared to the size of the structure itself, and you might put into your mind's eye the difference in response between an ocean liner and a rowboat when subjected to water waves.

If the structure is large, with respect to the wave lengths of the incoming waves; if the structure is rigid then it will not respond exactly to those waves, but instead to some kind of an average of what those waves might be.

MR. WHARTON: May I interrupt a second, Your Honor?

I had not anticipated getting into this area at all. This is one of the things that was litigated -- this question, at Diablo Canyon, it is the tau effect. I don't think that it is proper, because it is seemingly part of Mr. McNeill's, and I just think this is a controversial area as to whether it applies or not. This is not general. This is not the kind of thing that I was talking about or thinking about, when I agreed to a general overview of seismology.

JUDGE KELLEY: Any comment?

MR. PIGOTT: Yes, this is not related to any particular point of the testimony, but the testimony does reflect these various principles. I think it is essential that the Board understand them. What is being put in now is not being put in for the purpose of being relied on in the decision. It is being put in for the purpose of general education. If it is never used by the Board, chalk it up to extra knowledge, but I do not believe it goes beyond the scope of the contentions, in that it is part of the testimony, and this is explaining how you get to it.

I see nothing controversial about pointing out, for instance, that a rowboat responds differently than an ocean liner to the waves around it. And we are not saying how high the rowboat is going to bob, and how still the ocean liner is going to be, but we are pointing out natural phenomena that should be considered by the Board, when they are looking at this testimony.

JUDGE KELLEY: Well, I think the presentation is generally helpful. It is very difficult to parse out minute segments and five-minute segments. It is not coming in as evidence, and on that basis, I am going to overrule your objection, Mr. Wharton.

If you will continue, Dr. Mc Neil.

MR. MC NEILL: Thank you.

So, in summary, with respect to that point, structures behave at something less than the ground motions for wavelengths which are short, compared to the size of the structure, provided the structure is rigid.

I should also point out to you that the structure is being excited by the ground around it, but the structure itself has a response, and it is therefore radiating energy back into the ground, as it goes through its vibrations. Some of that energy participates in the motion of the structure, but some of it, and in some cases, a great deal of it simply radiates away into the ground, and never returns to participate in those structural motions.

Fortunately, the mathematics of that type of radiation turn out to be a simple damping term, just as we had discussed for the little discreet particle.

So as that spatial damping varies as a function of the planned dimensions of a structure, the larger you make the structure, holding everything else constant, than the large is that spatial damping, and the more the damping, in the range of periods that you work with on structures such as nuclear reactors, the less is the response. So that due to the plane dimensions of the structure, the two effects: wavelength and spatial damping, both speak to a lessening of a motion, compared to that in the ground around the structure.

In addition, if the structure is burried, its depth has some effect in that the amplitudes vary with depth, so that again there is a sort of an averaging going on, and due to the presence of the boundary of the ground surface and also of the structure, there is a scattering of waves, which also probably leads to some sort of an averaging process.

In engineering, we try to keep the arithmetic simple, so we assume that structures are linearly elastic. In point of fact, they are not, and there is a great deal of recent research that indicate that that is not so.

If one addresses that particular situation, one becomes aware it is apparent that the non-linearities consume energy, as in damping, and also have the effect of slightly decreasing the inertial loads.

The effect of mass is generally to increase the spatial damping, because given a structure of a given size, if you increase the mass, you increase that spatial damping, and therefore tend to decrease the response.

Now, those are the aspects of structural response that apply to short periods. There are some aspects that also apply to all periods. For example, we analyze earthquake waves as if they were exactly plane and propagating an almost idealized sense, but in point of fact, that wavefront is probably very incoherent, because it is bounced around, it has gone through materials that are anything but homogenous and if there is incoherence in that wave, then there will again be some sort of an averaging effect. I don't know how to account for it, but as a physical principle, it must exist.

And then further, if one were to allow a little bit of springiness to the structure, then that ductility would also consume energy and decrease the inertial load, and I should tell you that in my understanding of contemporary design of nuclear reactors, ductility, in general, is not called upon in design, but I mention it just so that the list is reasonably complete for you.

Now, we can quantify some of these. There are ways of calculating the wavelength effect. There is a certain way of calculating a spatial damping effect. There are ways of estimating the scattering and varying amplitudes effects of burried structures, but in general it seems better, until these are quite secure, both theoretically, and from the standpoint of demonstration in the field, to use field data, and we can make estimates of these, as I will now do for you.

Before I do, however, I just wanted to show you in general what the difference between an instrumental spectrum and a design spectrum for a very large structure might look like, and this is calculated using the methods of NUREG 0098. This would be -- and this is just a casual example. It has nothing to do with Units 2 and 3.

This is the instrumental spectrum, and then following the methods of NUREG 0098, this would be a design spectrum for a very large structure for which a minor amount of yielding or ductility might be allowed.

So the differences in some cases can be appreciable. In other case, for small structures, not appreciable.

MR. WHARTON: I am going to have to raise an objection again. Mr. McNeill is arguing their case, at this point. I have to object, and I am very upset with putting Mr. McNeill on to essentially argue the case. This is not what I agreed to.

JUDGE KELLEY: Well, I must say that the transparency now up seems to me to be pretty far away from the issues here. We explicitly rejected some design issues in this case, and I think if you could foreshorten this portion -- I don't see how the discussion of that transparency will assist us in what we have before us, in the way of geological, seismological issues. When a plant will break, is just not in this case, at this point.

MR. PIGOTT: I don't think this goes to when a plant will break. Just to be clear about this, we are not getting into the structures. We are getting into some of the considerations that go into moving from this free field, as it has been described, to the design basis, your design spectrum, and the question is whether or not these design criteria are adequate or inadequate.

This shows some of the elements, without quantifying or discussing that allow you to say that the design is adequate. There is a difference, as has been pointed out, between the free field and the design spectrum. The design spectrum is what it is being built for. We are not going beyond the design spectrum, as to whether or not it has been built to that. That is a different question. But getting from the free field motion to that criteria is a part of this case, and it is a part of the case that we have done it, and that we have done it with margins of conservatism and some adequacy, and these are the things that go into it, and they just have to be discussed.

Now, if we come close to what Mr. Wharton may think is in issue, we are not here to talk about irrelevancies, we are here to talk about the theories that will be generally applied one way or another, and that is the attempt, to acquaint the Board with the general area.

JUDGE KELLEY: I didn't think we were getting into conservatism of design in nuclear power plants.

What issue would that come before?

MR. PIGOTT: Well, the issue that we have been talking about now: whether or not given a maximum MS 7 -- I can't remember the words now, exactly -- assignment of a MS 7 renders the design basis inadequate. The design basis is that design spectrum. Is that inadequate, given the activity of an MS 7 out there in the zone. You have got to somehow or other get it from the fault to the site, and that is what we are doing, and once you get it to the site: What is the shape of your design spectrum? What do you look at when you go into that design spectrum?

We are not quantifying anything. We are just going through the considerations that the Board should be aware of and have some familiarity with, and there is absolutely no attempt to try the case here.

As far as I am concerned, we filed our direct, and we have covered the case. We don't feel the need to argue further, and we are not doing that.

MR. CHANDLER: Mr. Chairman, if I may?

JUDGE KELLEY: Yes, Mr. Chandler

MR. CHANDLER: I think that we are at a point here where I think we probably have exceeded the bounds of what I understood we were going to be hearing this morning.

I think whether it is appropriate for the testimony or not, is irrelevant for purposes of this presentation right now. I understood the Board was desirous of acquiring some fundamental knowledge with respect to seismology. I think we have crossed those bounds and gotten into the engineering aspects of seismology, and without suggesting whether or not I consider that appropriate for the testimony, I think it goes beyond what I think the Board was requesting for its presentation this morning.

JUDGE KELLEY: Thank you, Mr. Chandler, I would essentially agree with your comment.

Mr. Pigott, I would suggest that we foreshorten the engineering portion of this, and move ahead into the what I will call the seismologial portion.

MR. PIGGOT: That is fine with me.

Let me ask Dr. McNeill if there are further subjects ahead that you would like to skip to?

MR. MC NEILL: Well, I am almost finished. I was going to cover two point that I was just getting into here, and that is what the true conservatisms are, and I can drop that, and then I was going to go over some criteria that I felt might be beneficial for the comparison and evaluation of spectra, and that was the end that I had.

MR. PIGOTT: Perhaps we could slip to the last.

I recognize Intervenors apparently don't want an education here, but if we could skip to that last point.

MR. MC NEILL: All right. It is the typed slide.

(Slide projected)

MR. MC NEILL: Whenever one has a spectrum that is being used for the design of the structure, there is quite naturally an apetite to compare that spectrum to actual data reported from earthquakes, and I heartily endorse that process and think it should be done.

If you do make such a comparison and find that the spectrum has exceeded a number of times by a number of earthquakes, then I think you have to be concerned that maybe the spectrum is maybe too low. On the other hand, if you make a number of comparisons, and it is not exceeded, then you probably should be concerned that maybe it is too high, and somebody's money is being wasted.

I think those comparisons are best made is one adheres to at least these seven criteria, that is the spectra certainly should be of the same type.

We have already spoken of response. Those are the only ones that I think engineers really use, and those are the only ones that I have prepared.

The spectra being compared really should be in the instrumental form, not in the design form, and you could make a comparison of a design to an instrumental spectra if you wished to do so. That is an incorrect, but nevertheless conservative process, and if the comparison shows the instrumental to lie below the design, then the design is probably all right. If it lies above, that certainly should be looked into more closely before conclusions are to be drawn.

The spectra, of course, should be for the same damping. The effect of damping, as I mentioned earlier, is generally to lower those spectral values, and so the comparison should be done on apples-for-apples basis.

They really should be from earthquakes of the same magnitude, but we don't really have all that many earthquake data, so we sometimes have to scale from different magnitudes, and the scaling should be done in a consistent way, but probably not over too broad a range. In my practice, I try to stay within the magnitude of what it is I am concerned with. Sometimes you don't have the data to do that.

The spectra being compared should be recorded standing at the same distance, or they should be scaled to represent the same distance, and the distance scale of whatever it is -- it doesn't really make much difference -- should be done in a consistent manner, and I know how to spell "measured," even though the typist may not.

They should also be for earthquakes of the same style of faulting, and since Dr. Smith is going to offer a tutorial on that, I will not dwell on that point; the same with the fact that they probably should be from earthquakes in the same tectonic setting, and again, since Dr. Smith is going to deal with that, I will leave that to him.

That is the end of the tutorial material that I had prepared. I would be happy to be available for questions.

JUDGE KELLEY: Thank you very much, Doctor.

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Tape 3

MR. PIGOTT: As Dr. Smith is preparing to start, it may or may not be appropriate to afford the Board a copy of a particular book, recommended reading for this course, I guess. It is "Earthquakes: A Primer," by Bruce A. Bolt. We can lodge copies with the Board and each of the parties, if that is of benefit. I leave that strictly to the Board.

JUDGE KELLEY: It is an excellent book. I would love another copy. It was the beginning of wisdom for me.

Fine, we would like to have a copy.

MR. PIGOTT: It will take just a second to rearrange.

JUDGE KELLEY: Mr. Pigott, are you ready?

MR. PIGOTT: Ready.

DR. STEWART SMITH: My purpose is to explain--

MR. WHARTON: Mr. Chairman, I wanted to see if Dr. Brune had any comments to what Dr. McNeill just presented. He has some comments regarding it, and I think it would be appropriate if he was able to just state a few of them at this point.

JUDGE KELLEY: Yes, it seems to me that if we have three different people presenting, then at the conclusion of each one, if you want, and the Staff, too, if you want to make comments.

If you have comments about the first presentation, Dr. Brune, why don't you go ahead.

DR. BRUNE: Well, on the point we were just discussing about the building response, I am not a structural engineer, so I am here as a seismologist, but it is my impression, from being at the Diablo Canyon hearings, and talking with engineers, and so forth, that the whole question about the building response that was presented, that is, how much the building foundation averages, how much the size of the building averages, exactly how the building responds, and wheter the stresses get amplified in accelerations, and so forth, is a question that is uncertain, and was litigated at Diablo Canyon.

One of the questions at Diablo Canyon was in fact why during the Imperial Valley 1979 earthquake, the foundation in the Imperial County Services Building had a higher acceleration than the ground outside, and there were a lot of arguments presented pro and con, because my understanding of it is that traditional engineering assumptions were that the base of the building would not respond as much as the ground on the outside, and it went the other way. And that question was argued pro and con.

MR. PIGOTT: I might point out to the Board that we do have a decision of which you can take notice: ALAB -- the number I can't remember, coming out of Diablo Canyon, and discussing and resolving a number of those issues, and I believe we will provide to the Board a copy of that, for whatever use they may desire to make of it. It is voluminous, and I don't think we have sufficient copies here right now, but we will make that available, inasmuch as it is an official record of the NRC, and I am sure if you were in Washington, you would have it in your offices.

MR. CHANDLER: Mr. Chairman, that is the document I referred to yesterday. It is ALAB 644, dated June 16, 1981.

JUDGE KELLEY: Well, I will be certainly interested in seeing that.

Anything else, Dr. Brune?

Dr. Smith?

DR. SMITH: My purpose is to explain something of the nature of earthquakes--

JUDGE KELLEY: I am sorry, you are Dr. Stewart Smith?

DR. SMITH: Dr. Stewart Smith.

JUDGE KELLEY: Thank you.

DR. SMITH: --the nature of earthquakes, where they occur, why they occur, and define some of the commonly used terms that we are going to be hearing in this proceeding.

The first thing I would point out is that we know a great deal about earthquake phenomenology now. We know a great deal more than we did in years past. Earthquakes are not mystical phenomena, although in the early days the Japanese believed that earthquake motion was the result of of a giant carp beneath the Japanese islands that would occasionally move and subject the ground to great shaking.

Earthquakes in fact occur on a worldwide basis, in a highly organized fashion.

(Slide shown)

This is a global view of earthquake occurrences, with each black dot on here represents an earthquake location and you can see the outlines of the major continents: North America, South America, Africa, Australia.

In this particular projection, we are looking somewhat from the South Pole.

We see that the vast majority of the world's earthquakes occur around the Pacific, where these black dots are highly concentrated, and we see an interesting pattern of earthquakes in the middle of oceans, such as in the Atlantic Ocean between Europe and North America. There is a string of earthquakes following right down what is called the Mid-Atlantic Ridge, and on closer inspection, we see that the entire Earth is divided into a mosaic of building blocks, what we call "paltes," and earthquakes occur at the margins of these plates.

JUDGE KELLEY: Excuse me, Doctor, is this tectonic plate theory, is that now universally accepted by seismologists and geologists?

DR. SMITH: Yes.

This shows in more detail some of the specific plates and the arrows indicate the direction of motion of the plates.

One of the plates that we are concerned with in Western North America is the Pacific Palte, which essentially encompasses the entire Pacific Ocean region. We are right now sitting on the North American Plate. The North American Continent rides upon this plate. The plate itself goes clear to the middle of the Atlantic Ocean.

Volcanoes and earthquakes are clearly related to the plate motion and I would point out that if a plate such as this is to move and produce earthquakes on its margins -- if the plate moves, obviously, you have to have -- if the plate is moving in this direction, that means that part of the plate has to disappear at this end, and some new part of the plate must be generated down here, because the Earth is, of course, of fixed size. And if the plates are moving with respect to each other, than some of the boundaries will be consumed and others will be generating new material for the plate.

This is a closer look at a simplified view of the major elements of plate tectonics, as they apply to seismology.

Here we have a perspective drawing, a representation of a plate that is moving in this direction. Material from the mantle of the Earth is being injected along what we call a spreading center, or a ridge. This would correspond to the Mid-Atlantic Ridge, for example, where new material is coming out of the interior of the Earth.

The plate moves away, and as I mentioned, at the other boundary, something has to happen. It has to be consumed or disappear in some fashion, and what happens is it dives down into what is called a subduction zone.

Since there are numerous plates and we are on a sphere, these plates must have edges, and an edge is represented in this fashion. So what we are looking at here are the three major elements of plate tectonics: spreading centers, subduction zones, and plate edges, which we call transform faults.

In general, we see small to moderate sized earthquakes on the ocean ridges, because there the material in what we call the Earth's lithosphere is hot, thin and weak, and they don't seem to be capable of generating great earthquakes.

The world's largest earthquakes appear to occur on subduction zones, where the lithosphere is -- it has progressed from here to here and it has been cooling along the way, and it has gotten thicker and stronger and there is a large surface area involved, so we appear to have very large earthquakes on subduction zones, such as in the coast of Chile, or the Aleutian Islands, or Japan.

Transform faults appear to have intermediate size earthquakes, although some of them, such as the San Andreas may have earthquakes comparable in size to the largest on subductions, although generally -- In a generalized sense, this is the kind of plate boundary we are dealing with in California.

Now, in order to go through a list of terms that we use, let me just mention briefly -- I have already implicitly used the concept of an epicenter. An epicenter is the location of an earthquake. It is the point on the Earth's surface above where the earthquake occurs. So the map I showed you with the black dots on it, those are in fact epicenters. Now, earthquakes are not points; as you might guess from this kind of figure, if a large section of this subduction zone were to slip suddenly, causing an earthquake, the earthquake should be described as a volume or an area source that might be quite large. But nonetheless, we represent that as a point on a map. The epicenter is generally viewed as the point of the initiation of the rupture that subsequently occurred.

The rupture might take many seconds, but when we plot a point and call it an epicenter, it is the first point of rupture.

Hypoce" .er is simply a three-dimensional description -- actually four-dimensiol al, including the space, spatial location of the earthquake, and the time.

Now, what does a seismologist measure?

JUDGE KELLEY: Did you say the epicenter is on the surface--

DR. SMITH: That is right.

JUDGE KELLEY: --where the rupture occurs?

DR. SMITH: It is the point on the surface above where the first point of rupture occurred.

JUDGE KELLEY: What if there is no rupture on the surface? Then there is no epicenter?

DR. SMITH: No, the rupture may be burried deep in the Earth, and the rupture might initiate at the point here. We would project that point to the surface, and plot that on a map. That is called the epicenter, projected vertically upward.

So, for example, in a case of a rupture like this that might break through to the surface, if the -- if the point of initiation were deep on the fault and the rupture eventually filled out this area, the epicenter would be here, vertically above that point of first rupture, but the actual fault might break the surface some distance away, depending on the orientation of the fault plane.

Now, let me say a word about P waves and S waves, because they are going to come up in a number of different contexts:

The first context will be in the measurement of magnitude. What I am showing you here is a representation of a seismogram. A seismogram is a wiggly line which describes how the ground moves. It is what Dr. McNeill was describing earlier. This is at a particular point. This is from one particular station and we are watching what happens as time increases. We are watching the shaking of the ground change, as time increases.

The first arriving wave we call the "P wave." It is a compressional wave. "Compressional wave" is like a sound wave in the air, where the particle motion associated with the wave motion, the wave motion with my voice travelling to you is going in that direction, and if you were to examine the air molecules, you would find they were vibrating back and forth in the direction between where I am speaking and where you are receiving. It is sometimes called a longitudinal wave, but we will refer to them as "P waves."

They have the fastest velocity in the Earth, and so they are always the first arriving wave. So before an earthquake, we have no ground motion whatsoever, and we can be confident that the very first motion that we see in a seismogram will be associated with a P wave.

Shear waves are--

JUDGE KELLEY: Excuse me, do P waves travel underground?

DR. SMITH: Yes, they travel underground. They travel a path of least time, so for example to travel between California and Europe, they would seek a deep path that might go through the core of the Earth.

Later on we will talk about surface waves, which would take a different route travelling along the curvature of the Earth between here and Europe.

Since the velocity of the Earth increases with depth, we often find that the fastest route that a wave will seek out will be to go to some depth, and then return back to the surface.

An S wave is a shear wave, is a transverse wave, and an easy way to visualize that is the motion you might see on a telephone wire between two poles, when a bird lands. You will see a distrubance where the bird lands, and you will watch that disturbance travel down the wire. Now, if you were to look carefully at the movement of the wire, you would find that the particles were not moving in the direction the wave was moving.

In the analogy of the telephone wire, you would find that the actual movement of the wire was up and down, after the bird landed, but nonetheless, the disturbance was travelling along the wire. So this is a transverse wave.

The direction of particle motion is perpendicular to the direction the wave disturbance is travelling. These waves always travel slower than compressional waves. So they always arrive later in the seismogram.

In a general way, we find that the shear waves are the largest contributor to horizontal shaking, and thus typically are the onse that are most crucial in considerations of ground motion for engineering purposes.

We find that often, under certain circumstances that may be discussed later in this proceeding, the vertical motion will be controlled by the compressional wave.

Now, in a moment I am going to describe one other type of wave, the surface wave, but right for now -- Yes, let me do this:

The slowest waves of all -- Most of the figures, by the way, are from the little primer by Bruce Bolt that you have on the desk.

Here is another example of a seismogram. Simply focus on this line here. This represents the motion in a very distant earthquake, and we see as time increases -- this is one minute from here to here -- first disturbances of P wave, or compressional wave, several minutes later, the shear wave arrives. Now, the further away the earthquake is, the greater the distance between the P and the S waves, because their velocities are different. If you are very close to an earthquake, the P and the S waves will arrive very close to each other.

Some time following the shear wave, we often see a very large and long period disturbance that is the surface wave. These waves will be important in our discussion of magnitude in a moment. These waves do not travel the most rapid path between the source and the receiver. They, of necessity, will follow the surface. The wave motion is of the type that is controlled by the boundary conditions at the surface of the Earth, and so they will always travel along the surface, and thus take considerably longer to get from the source to the receiver than the P or the S waves.

Well, we need to characterize the size of -- whenever we say "earthquake size" you might put qoutes around it, and we use the term "size" as a general way of reflecting the fact that earthquakes really do come in different sizes, but how you characterize it may depend upon your objective. Our objectives in a proceeding like this are ultimately to charcterize the earthquake in terms of the ground motion that is produced, but there are other reasons for characterizing earthquake sizes, so let me run through the types of magnitudes that are used to measure earthquakes:

The first and historically it was the first developed, by Richter, the so-called "local magnitude." It is designated: M_l and the "l" stands for "local magnitude."

It was developed in Southern California, and the procedure is a very simple one. Dr. Richter simply noticed that if he plotted the peak motion on a particular kind of seismograph recording, a Wood-Anderson Seismograph, if you plotted that as a function of distance, he found a consistent pattern that allowed him to introduce a perameter to describe the difference in sizes between earthquakes. He had no direct physical -- at the outset, there was no direct physical interpretation of this. It was simply a convenience of putting earthquakes in different size baskets, saying "these are big earthquakes, and these are small earthquakes." It was a way of getting a h lle on the statistical variation of earthquakes.

It is a logarithmic measure, and just for your interest, the equation by which one calculates magnitude from a seismogram can be graphically illustrated, and that is shown here. One would take the peak motion, in this case, 23 millimeters -- this represents 23 millimeters of motion. One enters that number here on this graphical equation solver. We put in the distance that this seismograph was recorded, connect them with a straight line, and that intercepts this scale, and leaves us a value of the local magnitude. This is essentially equivalent to plugging the numbers into an equation.

In passing, I would note that this scale is defined only for relatively close in distances to earthquakes, certainly wtihin 400 kilometers. One could not use the local magnitude to measure the size of an earthquake in South America, as recorded in California. It is simply outside the range of definition of this measure.

Because it is used locally and close in, the peak motions tend to be controlled by the shorter periods, the higher frequencies. There are some drawbacks to the local magnitude scale which is one of the reasons that so many other magnitude scales have developed.

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The appendix to the text that you have shows some sample calculations of other types of magnitudes. Referring back to the seismogram I mentioned earlier, there is a so-called body wave magnitude designated by m_b, which is valid in great distances beyond several thousand kilometers. Where one measures the ground motion associated with the P wave, calculates -- from a seismogram -- calculates what the actual ground motion would have been, in microns, and calculates the period of the P wave and enters a formula such as this to calculate the body wave magnitude.

This particular seismogram at this distance yields a body wave magnitude of 5.3, for example.

An alternative procedure, the surface wave magnitude -- designated by M_s -- is measured from the peak motion of the surface wave train at a period of 20 seconds. In this wave train there are various periods from longer to shorter in here and you seek the particular part of this wave train that has a period of 20 seconds -- that's the way this magnitude is defined -- measure that amplitude and enter this formula, logarithm of the amplitude, a distance correction, and for this seismogram that yields a magnitude of 5.0. So this illustrates that you can get different magnitude estimates for the same earthquake and they are both valid.

The primary difference between the body wave and the surface wave magnitude that I would point out here is that the body wave magnitude is typically measured at periods of about one second or between one second and five seconds. So it is a relatively short period. It is still long compared to the motions of interest for engineering, which would be a tenth of a second period, say, or 10 cycles per second.

Nonetheless, it is shorter than the longer periods that are present in surface waves, 20 second waves. A twenty-second oscillation is indeed a very slow oscillation.

There are several other types of magnitude measures based on energy and there is one in particular that I am going to come to based on seismic moment. But first let me say something about the origin of the physical process involved in earthquakes.

JUDGE KELLEY: Could I ask you a question? This morning's San Diego paper has a story about yesterday's testimony in which there was some testimony about maximum earthquake size, and I believe that the witnesses were talking about surface wave magnitude -- M_s 7, let's say. The paper speaks of 7 on the Richter scale. Now is the Richter scale of any precise meaning? I think most members of the public think of that as the way to measure earthquakes. And if so, what is it?

MR. SMITH: Well, the Richter scale would refer to M_l, the local magnitude. So that was strictly speaking an incorrect quote in the paper. Below about magnitude 6, it really doesn't matter. All of these scales are comparable kinds of numbers. But when we get to larger earthquakes there begin to be significant departures.

As I said at the outset, earthquakes are not a magical or a supernatural feature. They are related to plate movement. They are the subrelease of stress in the earth's crust or lower parts of the earth. This will lead us in a moment to another term that is used commonly by seismologists, stress drop. I am not going to go into great detail on this because I don't think it is appropriate right now. I simply want to point out that if it weren't for stresses in the earth we wouldn't have earthquakes. This figure illustrates some of the kinds of features one might see in response to compressional stresses. One might see folding like that, thrust faulting, where each of these boundaries here is a thrust fault. We might see a thickening of this kind.

In tension we would find rifting or pulling apart of blocks of the earth. If that pulls apart in that fashion it is likely. In some circumstances we would get downdropping. These would be called normal faults. We might also get thinning in response to the tension. The thing is not on this figure would be to illustrate the plate edges or transform faults or response to shear.

But basically, there are three types of faulting: thrusting, normal faulting, and shear faulting.

JUDGE KELLEY: We have heard the term "strike slip" quite a bit. Could you tell us exactly what that is?

MR. SMITH: Right. A shear fault would be a strike slip fault. A strike of a fault is basically the direction, the geographic direction that the fault -- that the intersection of the fault with the surface of the earth points in. So if we have a fault surface like this, it would intersect the surface along a line like that and that direction would be called the strike of the fault. A strike slip earthquake is one whose slip is in the direction of strike. And it can be either left lateral or right lateral, depending on the sense of motion.

JUDGE KELLEY: What is a dip slip fault? Maybe you are coming to that.

MR. SMITH: Yes. This would be a dip slip fault, I should say, is the geographic direction -- it is the angle that the fault makes with the surface of the earth measured from the horizontal downward and it includes both that angle and the direction of it. So we might refer to a fault that is striking north, for example -- I am disoriented. I don't know which way north is -- a fault is striking north and it is inclined in this fashion, the dip would be described as say 20 degrees to the east.

So a dip slip fault is one whose slip is in the direction of dip. And such a normal fault here would be a dip slip fault. Strictly speaking, one can refer to a thrust fault also as a dip slip fault, although that is typically not done.

Now if an earthquake is stress release, you must have a buildup of stress prior to the earthquake. Stress drop in simplest terms is basically the difference between the stress levels before and after an earthquake. To illustrate that I might stress this glass. There is a certain level of stress in here now, and an earthquake represents the point when the earth's crust reaches the point of failure and a crack or fault occurs. Let the record show that it was a plastic glass that I cracked.

After this crack has occurred, there is a different level of stress in there. The difference between those is what we call the stress drop. There are some fairly -- highly esoteric kinds of definitions of stresses involved in representing earthquake ruptures that I will not go into at this point.

JUDGE KELLEY: I have seen the term "bar".

MR. SMITH: A bar is a measure of stress. You can think of a bar as synonymous with one atmosphere of pressure. It is about 15 pounds per square inch. In terms of an atmospheric analogy, it is the pressure that the atmosphere is pushing down on the ground. We don't think of that -- that is not a shear stress, however, but the dimensions are the same.

JUDGE KELLEY: Is there some way to measure the amount of stress on a particular fault so as to predict when it is about to go?

MR. SMITH: That is the subject of a great deal of important and current research. There is presently no direct way to measure the stress level prior to an earthquake. We can, however, measure some of the properties of earthquake sources that occur as the rupture is going on and from which we can infer -- I stress the point -- infer what the level of stress is. But there is no direct -- you can measure strain in here but you cannot measure stress directly.

JUDGE KELLEY: What is the difference?

MR. SMITH: Strain is the deformation. For example, getting back to the glass, if you are looking at this glass and it is that shape, if you knew that I squeezed it you would know that it stressed. But suppose that I had prior to coming in here held this in a candle and heated it up until it had taken on this shape and then showed it to you. You wouldn't know whether it was stressed or not, and in fact it wouldnot be ready to break because that would be its normal shape. You can measure deformation as it proceeds in the earth, but you can't measure stress.

JUDGE JOHNSON: Before you go on, we heard yesterday that listric normal faults, the term was used fairly frequently.

MR. SMITH: I think it would be much clearer if we could just have a really short statement from Perry Ehlig about listric normal faults. They are a special kind of configuration of faults. But in general, they are dip slip faults. Would that be --

MR. EHLIG: Any fault that changes its dip with depth, that curves, can be said to be listric. In the case of a listric normal fault, it starts out rather steeply inclined at the surface and flattens down. That is the characteristic feature. So it becomes a very flatly inclined surface at depth.

MR. WHARTON: Could somebody draw that, what they look like? I think that is not very clear what that term is.

JUDGE KELLEY: Let me make a suggestion. It is just about coffee break time. We've got a big piece of paper up here and maybe somebody could take a grease pencil and try their hand at a listric fault. But why don't we take a 15-minute coffee break at this point. Is this a good enough point for you to break off? I don't want to disturb your train of thought.

MR. SMITH: This is fine.

JUDGE KELLEY: Okay. Let's do that.

(A brief recess)

JUDGE KELLEY: Could we resume? We broke at the point where Judge Johnson asked a question about a listric fault. Dr. Ehlig, is that your listric fault? Can people see it?

MR. EHLIG: Dave Moore actually drew it. The characteristic feature of a listric normal fault is that the fault plane flattens with depth. Here we show a fault coming down and flattening with depth. Now at depth the fault is following a more planar surface that is more gently dipping than the near surface trace. So that as it moves outward, it would open up a void space here. I will color red on either side to show that it would open up a potential void space if the rocks were strong enough to hold up.

What typically happens, if the rocks are fairly brittle they will break along secondary faults here and this will drop down to form a depressed zone, referred to as a graben -- I don't know whether that term will come up, but it is a German term that refers to a downdropped trench-like zone.

On a listric normal fault in sedimentary materials it is very common for the material to collapse backwards in the head area so that you will see the surface drop back in what is known as reverse drag. Now right next to the fault very commonly, because as it slips down it will drag back, you will see a little normal drag and then this collapse back whereby, if you project the surface over, it may not be offset significantly, but there will be a large offset right at the fault. In many listric normal faults there will be many breaks further out from the most headward part of the fault. But that is all it means. There are many examples of these. The Gulf Coast region has an active zone of faulting that occurs just inland from the coast. They are also referred to as growth faults because they are going on synchronous with sedimentation and the near surface strata show less deformation than deep strata.

There they pass beneath the Gulf of Mexico and have their toe down in the bottom of part of the area of the Sigby Deep, which is way out in the Gulf. So they are very, very flat planes beneath the Gulf of Mexico. They are active today but are not seismically active.

JUDGE KELLEY: Just one point of clarification. When you say active but not seismically active, what is the difference?

MR. EHLIG: They are moving. They disrupt the ground surface. If you go to Corpus Christi you can see where one of the highways has been very nicely deformed, a number of places where the ground is deformed and structure has been affected, but there is no seismicity, at least nothing that would attract attention as earthquakes.

JUDGE KELLEY: When you say no seismicity, you mean there is no significant stress buildup? Is that why one wouldn't expect an earthquake in connection with one of those faults?

MR. EHLIG: It is occurring more plasticly than as a stick slip type mechanism. Actually in landslides, if you start to make microrecordings of landslides, you will hear ground noise that is in essence microearthquakes. But the magnitude is so low that it is nothing that would attract anybody's attention.

JUDGE KELLEY: Thank you. Does that cover your question?

JUDGE JOHNSON: Yes. One more in pursuit of it. Is the fact that these move slowly related to their not being seismic?

MR. EHLIG: On listric normal faults you cannot conclude just looking at old ones whether it moves slowly or with earthquakes. It depends upon the type of rock along the base. It could stick slip and have earthquakes along it.

JUDGE JOHNSON: Thank you.

JUDGE KELLEY: Thank you. Dr. Smith, do you want to resume?

MR. SMITH: I guess the next topic is seismic moment. To address this question, I need to go back to some consideration of the faults which cause earthquakes. The general description given under the heading "Elastic Rebound

Theory" in the little text you have illustrates what happens generally on the surface of the earth during the build-up phase of stress and strain and then the sudden release in an earthquake. An easy way to visualize this is if we had a fault in the earth -- this is a plan view, now. we are looking at a map and this is a fault trace. That means there is a fault surface down beneath the ground. If we built a fence across the fault like that, some years later, going back, if this fault had been subjected to a shearing kind of strain like that, some years later we would find that the fence was deformed like this.

So this is a snapshot in time here. Later on in time here is another snapshot. We see the fence is deformed like that. Now we have an earthquake. There is sudden release. We find the next snapshot in time the fence has come back roughly to that position. So the offset on the fault is this amount here.

Now the amount of offset that occurs during a fault has a very large impact on the amount of ground motion that is recorded at distance. Some other factors are important also, however. For example, how rapidly the fault snaps back is important in determining how the high frequency vibrations occur. It turns out that the total offset here controls the amount of very long period vibrations. So if we were to be looking at the magnitudes that were produced by an event like this, if someone gave you this sequence of pictures and said what is the magnitude of the earthquake that produced that, first you would have to ask what kind of magnitude are you talking about. If you are asking about the local Richter magnitude, which is primarily a high frequency kind of phenomenon, then we would need more information. It would have to tell you how rapidly this fault motion took place in order to say something of what the Richter magnitude at high frequency would be.

On the other hand, you would get a pretty good handle on what the surface wave magnitude was from this offset. One other dimension enters into this -- it is not shown on this figure -- and that is the length of the fault rupture. Clearly, if now our fault is mapped like that -- again, this is a plan view map -- and a rupture initiates at this point and spreads out in this direction, involving this length of rupture, that is going to also influence the amount of long period waves that are generated.

So what is evolved is a measure of earthquake size which is called the seismic moment, which is the product of the displacement, that is, the slip on the fault, times the fault area. That is the way of characterizing the strength of the fault -- the strength of the earthquakes size.

JUDGE KELLEY: You said area?

MR. SMITH: Yes. It is a three-dimensional fault surface. One would extend this to depth and the moment is defined as the product of the strength of the materials, the elastic strength, the rigidity of the materials, times the average slip -- U bar -- times the area of the fault surface, which is just the length times the vertical dimension.

This seismic moment also pops out of the mathematical analysis of seismic waves and so it is something that we can measure from a seismogram. I showed you a seismogram a moment ago, schematically as a function of time, the ground motion might involve P waves, S waves, surface waves of varying periods, and the seismic moment is related to the very longest period waves that we see in the seismogram. Sometimes, as in the recent Imperial Valley earthquake, one can measure waves with periods of several hundred seconds or even longer. These waves whose wave length is very long compared to the fault length and source dimension, can be used to derive the seismic moment.

So seismic moment is an extremely important measure because it is the one link between geology and seismology. We can measure it from a seismogram from a distant earthquake, we can look at a seismogram and estimate what the seismic moment is. A geologist can go in the field and measure the amount of slip on the fault, average it over the fault trace, measure the length of the fault, and infer the depth of the fault. Thus it is a field measurement that a geologist can make. So this is an extremely important concept, seismic moment, because it links seismic data to geologic data.

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MR. SMITH: And the way to think about it in seismological terms, that its moment is like another magnitude scale, except it is applicable only at the very longest of periods, periods in excess of hundreds of seconds.

JUDGE HAND: Does that fault have to be exposed at the surface to get the length of it?

MR. SMITH: Not necessarily. There are other ways of inferring the length of the fault rupture. After a major earthquake occurs, there are often thousands of after-shocks that occur within hours and days, and those aftershocks typically define the plane of rupture, and so there are indirect ways of getting at the fault rupture dimensions, even if it doesn't break through the surface.

In order to put things on a consistent footing, a number of seismologists have formally adopted a moment magnitude scale, which is basically -- overlaps with the other definitions of moment at shorter period and smaller earth-quakes, so that you get about the same number, if it is seven or it is say six, on the surface wave magnitude scale, it will also be six on the moment magnitude scale, and then for very large earthquakes, there start to be departures, which brings me to the point of magnitude saturation, which was the next item I was going to discuss, if I had answered your question.

JUDGE KELLEY: Does an earthquake's moment tell you very much about horizontal ground-shaking?

MR. SMITH: Not necessarily. It is more a measure of the fault characteristics. It averages out any short period jerkiness of the fault, and only tells you about the net effect that occurred during the fault process. The fault process might take tens or even hundreds of seconds, and the moment tells you about the integrated effect of all of the things that went on during that fault rupture process.

JUDGE KELLEY: So it is not necessarily of great significance in a proceeding like this?

MR. SMITH: No, it is because of the way a proceeding like this is structured, namely going from a fault to a magnitude to ground motion, it can be a very important concept. If you ask the other question, is moment magnitude a good number to use to assess ground motion, I would have to say no, but in the context of the discussion we will be in here, it is relevant.

Now, if we were to plot for a number of earthquakes their determination, their MS surface wave magnitude determination on this axis, say we had a 6.0 on the MS scale here, and on this axis we were to plot the local Richter magnitude, 6.0 for example, we would find a collection of points -- there is a scatter, of course. My first illustration from the Earthquake Primer showed an example of an MS 5.3 -- 5.0 corresponding to an ML of 5.3, and so there is a certain scatter here, but in general, the trend is a straight line in the lower magnitudes, followed by curvature in some fashion like this, or saturation such that above some certain MS value, as the earthquake gets larger in dimensions, that is, longer fault rupture, longer duration and so forth, MS increases, but there is not a corresponding increase in ML, so there is some kind of upper limit on how big an ML measurement you can make, irrespective of the size, quote unquote, of the earthquake.

The exact point of saturation is not terribly critical at this point. There are some examples; recent reworking of the San Francisco 1906 earthquake shows that the ML was probably around 6.9, whereas the magnitude for that earthquake, that has been published, is roughly equivalent to a surface wave magnitude, is thought to be about eight and a quarter, so there can be very large differences in these magnitude measures for large earthquakes.

Now, the same kind of saturation effect takes place for MS for very large earthquakes, if you compare it to the moment magnitude, and that was one of the reasons the moment magnitude was developed, so as to get a scale that would not saturate. If you get a longer and longer fault, the moment magnitude will continue to increase. It doesn't necessarily mean the ground motion is any different, but it is a -- it is simply a different measure of earthquake size.

Another term that will undoubtedly be discussed,

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and I will just speak very briefly in very simple terms about, is focusing. One of the early observations from earthquakes is that the ground motion is not uniform all around the fault, and as early as 1952, after the Kern County earthquakes, it was recognized that some kind of dynamic interaction between a fault rupture and the wave motion was occurring.

In simplest terms, a moment ago, I considered a fault, which the point of initial rupture was here, and that the rupture progressed in this direction. Of course, faults don't behave quite that simply, but for our purposes here, let us just simply say it started there, and it progressed smoothly in this direction. You can imagine that if you had a piece of glass in a laboratory setting, and you put a little flaw at one point so as to ensure that that is where the fracture would start, you sheared it until it reached the breaking point for that particular flaw, and took high-speed motion pictures of it, you would see that the crack actually initiated and travelled in some fashion, in this direction.

Now, so since 1952, a number of seismologists have been endeavoring to model this type of dynamic fault process to calculate what the ground motion effects would be, and there is a wide collection of models; you are going to hear about a number of them at this proceeding.

The general -- the general conclusion is that focusing is clearly important, in that if a rupture progresses

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in this direction, you are very likely to have larger ground motion at a site up here than you are down here. Practically any model that you construct will yield that result.

The problem is that simple models of uniform rupture or simultaneous rupture can produce amplification factors of tens to hundreds, comparing sites downstream versus upstream of a rupture, and so seismologists have been struggling with how these models correspond with actual data.

My conclusion on that is, focusing is important, along with a number of other effects, and that rather than being factors of ten and a hundred, it is probably more likely to be factors between one and two.

MR. WHARTON: Mr. Chairman, this is opinion that he is giving you with regard to --

MR. SMITH: Yes, that is my opinion.

MR. WHARTON: -- focusing, and we want just general. This is clearly an opinion that he would testify to subject to cross-examination.

MR. PIGOTT: Mr. Chairman, it is a general opinion of the general phenomena. I would suggest that if Applicants have a different range or different feeling on it, that they be allowed to indicate that this is perhaps one of the controversial aspects, but still, the purpose here I think is to acquaint you with that with which you will be dealing.

There are a lot of things we could talk about that

6 are without any controversy, but they wouldn't be very useful to you either.

JUDGE KELLEY: I think the comment was sufficiently general and would look to Dr. Brune to offer a different opinion if he has one when Dr. Smith is finished.

MR. WHARTON: Mr. Chairman, just one more word on this. It was my understanding that we would get into general areas so that the Board could understand what the testimony was going to be, and comprehend as it went along and have an understanding as it went along, and not getting into areas that basically elicit the opinion of this particular expert witness, and I must say that it appears we are getting into the opinion of this particular expert witness that should be subject to cross-examination. I understand what the Board has said. I just wanted to make the point.

JUDGE KELLEY: Well, I think generality is a band, rather than a point, and that people are going to have different assessments of where we are on the band, but it seems to me that up to this point, it has been useful. We can get so general it will be useless to us, and we would like to have some idea, I think, of just what areas are controversial, and so with those observations, why don't you proceed?

MR. WHARTON: Well, I guess I have succeeded in doing that, anyway, letting you know which ones we think are controversial.

7 JUDGE HAND: Focusing occurs in the direction of propagation of this action?

MR. SMITH: Yes.

JUDGE HAND: Do the faults ever go both ways?

MR. SMITH: Yes, they do.

JUDGE HAND: So you could have focusing in two directions.

MR. SMITH: Yeah. Or in fact, since these are three-dimensional phenomena, imagine a rupture initiated on a plane, the rupture can proceed in a very complex kind of direction anywhere in that plane, and there will be dynamic effects, interaction effects between the propagating rupture and the waves that are excited. It is an indisputable physical phenomenon.

JUDGE HAND: You purposely drew the location of that focusing effect on the upper part of the paper away from the actual track of the fault?

MR. SMITH: Well, yes. I didn't want to get into great detail on this, but the focusing effects on different types of waves, compressional waves, shear waves, and surface waves, and so forth, have different kinds of patterns, and so I wanted to avoid any singular kinds of positions like right at the end here. For certain kinds of waves, clearly the maximum effect might be at the end there.

For other types, the maximum effect could be at some other angle. My purpose was simply to say that focusing is an important physical phenomenon.

JUDGE HAND: But it is not quite like focusing a light through a condensing lens?

MR. SMITH: That is a good point. This is an entirely different type of focusing phenomenon. There -- the earth does act as a lens, and do the other type of focusing, but that is not what we are talking about here. We are talking about a dynamic interaction between a moving source and the radiation emitted, so this is not a geometrical optics kind of a phenomenon.

JUDGE HAND: Too bad you had to choose the same word that had other meanings.

MR. SMITH: Yes, that is unfortunate. Directivity is perhaps -- that is a good point. Maybe I will try to use that term more, but in the common literature, it has been referred to sometimes as focusing.

JUDGE HAND: That is why it is difficult for lay people. They know one meaning of a word and not another.

MR. SMITH: Right. In this context, there are other important considerations that control ground motion. They are the distance from the fault, from the earthquake, and I think it probably will develop later in the proceeding that even the concept of distance measurement is controversial.

As an example, I mentioned the epicenter, that is

9 the point on the earth's surface above the point of first rupture, so the epicenter would be at this point. Suppose our station is here, and we are collecting data on peak ground acceleration, for example, what distance would we use to measure, if we are going to make some kind of correlation of distance with acceleration, what distance would we use to categorize the data from this earthquake? Would we use the closest distance to the rupture? Would we use the distance to the epicenter? Would we perhaps use the distance to the closest point of the projection of the fault?

These different distance definitions can have a very profound effect on any kind of statistical correlation.

Now, Chairman Kelly asked at the outset whether damping was the same as attenuation, and attenuation has a very specialized meaning in this context. Attenuation generally refers to the decrease in ground motion with distance, so -- and that is of course in part due to damping of the waves as they go through the medium, but one says attenuation curve, what they mean is some kind of plot of some parameter of ground motion, say, peak ground acceleration versus distance, and one generally finds that the shorter the distance, the larger the acceleration, so there is some kind of shape to this curve; tried to draw a noncontroversial shape.

But the data points on here for the one earthquake I just referred to might have had a peak motion, say, of a

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half a G, would be this point here, and the distance we used might control whether the point was plotted here, or here, and so you can see if these data points have some kind of shifting that is permitted by the definition of distance, this can become a very sticky issue. In the line of --

JUDGE KELLEY: Are you going to comment further on peak ground acceleration?

MR. SMITH: No, I am not.

JUDGE KELLEY: Can I then ask you a question or two about that?

MR. SMITH: Yes.

JUDGE KELLEY: That is one of the basic points toward which we are headed here, you know, how high can that be expected to be. I think it was established in the first proceeding at .67 G's, and Dr. McNeill, when he began with his -- oh, whatever you call those things --

MR. SMITH: Pea dinger-swinger.

JUDGE KELLEY: What?

MR. SMITH: Never mind.

JUDGE KELLEY: In any event, he referred among other things to acceleration, and I took that to mean the rate of increased speed of the wave or the ball on the top as it came across. Now, is peak ground acceleration, is that the highest rate of increase of speed, of what, the surface waves, or just what is it? Could you spell that out for us?

MR. SMITH: Well, it is very simple, when -- if you were to view an accelerogram, that is, a plot of the ground shaking, your instrument is an accelerometer, that is sensing ground motion, and we are measuring it in a fraction of G. We are talking about vertical accelerations. When they got to one G, our instrument would begin to lift off the earth, unless it was tied down in some fashion.

So, we might have some kind of time history like this, of the variations in acceleration with increasing time, and the peak ground acceleration is simply go through and find the maximum acceleration. Now, relating that to Dr. McNeill's experiment here, in terms of the spectrum, he was pointing out that if you move this thing very rapidly, it is the shortest period here that reflects exactly what the -- you find that a short enough period, the maximum acceleration of this highest frequency little oscillator here will be exactly the peak motion that is encountered, so that is the tie between the spectrum and the time history, but the peak ground acceleration turns out to be the -- what the spectrum is at its highest possible frequency.

If Dr. McNeill is here, did I adequately -- it is okay? Apparently. Do you have a comment on that, to answer the question? Well, let me ask, does that answer your question, or would you like some further amplification?

JUDGE KELLEY: I think I -- I am not quite sure I am there yet, and --

MR. PIGOTT: Well, it is an important concept.

JUDGE KELLEY: Yes, it is.

MR. PIGOTT: Bob, perhaps you could come up and if the two of you would go through it again, what is being asked is an explanation of exactly what are we talking about, when you are talking about peak ground accelerations? I get to cross-examine my own people here.

JUDGE KELLEY: One of the things I wondered about, and perhaps you heard, I asked about the relationship if there was one, between your earlier comments when you were shaking the things back and forth, you referred, among other things, to the acceleration of, oh, the tall one on the left, and I could see it picking up speed and stopping, and I just wondered, does that have anything to do with the peak ground acceleration, or was that -- and if so, what?

MR. McNEILL: Yes, you have correctly defined acceleration as being the rate of change of velocity. It also represents the thing that causes forces to be felt, that is, you may recall elementary physics, that force is mass times acceleration, so that there is an equation between the two, and if for example, I have a small instrument sitting on the ground surface, and the ground commences to vibrate, then the instrument responds to the force or acceleration applied to it by the ground, and that is what it senses and measures.

In the same way, then, a structure would do the same thing. It would feel the force which is due to that acceleration. You may remember in the days before the fuel shortage when our feet were a little bit heavier, that when you would accelerate in an automobile, you would feel a force against the back of the seat. It is the same thing.

JUDGE KELLEY: I understand the concept of acceleration. I am wondering how we are using it exactly here. For example, did you indicate that it was the short high-frequency waves that would register highest on the -- on the seismograph?

MR. SMITH: In general, that is true. Let us try -- let us try the following kind of experiment. Let us imagine that this is an actual earthquake recording of the ground motion. Let us take that and through some type of mechanical device, and people have built such devices, a shake table, let us shake this spectrum analyzer exactly the way that the ground motion is varying, so I will simplify it a bit.

It might for example start off fairly slowly. We are shaking like this. And then there will be a -- the peak motion will be the largest excursion here. Now, if you look at -- if you look at each of these little pendulums here, you will find that they have a dynamic response that can be either more or less than the -- than the actual movement of the base here, but the shortest one, the stiffest one, the

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highest frequency one, will -- its excursion will exactly match the highest value here.

JUDGE KELLEY: So are those the waves of interest from the standpoint of peak ground acceleration and amount of excitation of the ground, say of the site?

MR. SMITH: Well, that is basically an engineering question. You are asking which part of the spectrum is most important, and that depends on whether you are worried about the Golden Gate Bridge, which would be a very long period, or about some very stiff kind of structure, so that is why we use a spectrum to describe the ground mot[illegible].

JUDGE KELLEY: Thank you, that is helpful.

MR. SMITH: I was going over kind of a shopping list of things that are important in controlling ground motion and I had mentioned focusing. I had mentioned distance. The geologic structure through which the waves propagate can be very important. We have learned a great deal about that in recent years. The site conditions can be very important.

There are a lot of parameters which control just exactly what the level of ground shaking will be at one point. So, what I -- let me just recap here. I have said that earthquakes occur in very highly organized fashion on the earth along plate boundaries. I should for completeness point out that there are some earthquakes that occur in the interiors of plates. We don't fully understand these. As a matter of fact, there are lots of things in seismology that are not fully understood. Why earthquakes occur, they are a sudden release of stress. You can think about it, if you like, as something like brittle failure, as the experiment I did with the plastic cup.

There are lots of parameters that we use to describe the rupture process and the earthquakes that result and there are at least four different magnitudes that can be used to describe earthquake size. There are at least a half a dozen parameters that control ground motion.

And I think that is probably as far as I should go, and would like to respond to any questions that you might have.

JUDGE KELLEY: Could I just ask you a question? Right at the end you were talking about different mediums around the site in question. Just as extreme parameters -- if I am concerned about an earthquake, would I prefer that my building sat on dirt or granite, or something else? And that may be a bad question, but I am just -- I think you see what I am driving at.

MR. SMITH: Well, the answer is a complex one, and it would depend upon what frequencies you were dealing with, what kind of structures, for example, but in a general kind of way, there are non-controversial physical processes that take place. One of them is the concept of acoustic

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impedance. If you go from a medium in which the wave is travelling at high velocity to a medium where the wave is travelling at low velocity, physical principles, conservation of energy and momentum in the wave, tell you that the amplitude of the wave will increase, so for that -- and you said rock, dirt, dirt in my context would have a low velocity, and therefore you would expect an increase in the amplitude of the waves when they encounter the dirt.

That is not the end of the story, though. There are other physical phenomena that occur, nonlinearities in the elastic or non-elastic response of materials would tend to mitigate those effects, and so it is a question of what frequency, what level of loading one is talking about. I guess I should point out that a lot of interest in what different site conditions do to ground motion, and this has been the subject of recent statistical analyses, some of which you will hear about in this proceeding.

JUDGE KELLEY: Dr. Smith, thank you very much.

MR. PIGOTT: I have one other presentation, Dr. David Moore.

JUDGE KELLEY: Oh, excuse me just a moment. Excuse me just a moment. At this point, with reference to Dr. Smith's presentation, any comment?

MR. WHARTON: Nothing.

JUDGE KELLEY: Staff?

MR. CHANDLER: I haven't finished reading Mr. Bolt's book yet, sir.

MR. PIGOTT: I didn't think so. Dr. David Moore, he will talk primarily about offshore profiling, and that special area of the technique.

JUDGE KELLEY: Fine.

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MR. MOORE: One of the issues before the Board concerns the structure beneath the floor offshore. In our present state of knowledge, the best way we know to determine the structure offshore is by means of what we call seismic reflection profiling. And so I will briefly describe what seismic reflection profiling is and what some of the difficulties are in using that technique and interpreting it and some of the advantages that it has.

I have a few 35mm slides here.

This is just a photograph of an advertisement in the AAPG Bulletin or something like that but it will give us the idea. Don't pay any attention to the name; that's somebody's patented name for their system. People tend to name the system after the sound source that they used. I'll explain that a bit later.

But basically seismic reflection profiling is the same principle as echo ranging. It's the same as echo sounding. For example, when a ship has an echo sounder, except that generally they use lower frequencies.

Basically the components that are utilized are sound source of some type, and I'll go into that a bit more later, and hydrophone streamer, which is just a linear hydrophone array.

Of course, there are different types of these things. Some use more than one streamer and some use very long streamers and some use short ones. But, for our purposes today, we'll just assume that we have a single linear hydrophone array and a sound source. And this sound source goes off at intervals of anywhere from several times a second to once every ten or twelve seconds or so, depending on the frequency and the scale that you want to use.

The ship is towing this along. The ship is underway, and, as it moves along, it fires let's say every half second it fires its sound source. The sound travels down and reflects from the sea floor back up to the receiving array, but it also, because it is low frequency sound, relatively low, penetrates through the sea floor and reflects off of layers beneath the sea floor. The reflections are a result of differences in acoustic impedance, which simply is changes in velocity and density of the materials. So that the reflections we look at are not always necessarily changes in lithology or changes in the formation, for example. It doesn't mean that you're going from formation A to formation B. It simply means that the sound waves have encountered a difference in acoustic impedance which would cause a reflection.

Because the ship is moving and because we're firing, you can develop a continuous display because, after these signals are received in the hydrophone array, they are then transmitted up to the ship where they are filtered to get rid of unwanted frequencies and they are amplified and fed into a graphic recorder.

Now there are many different ways to do digital manipulations with this kind of thing, but most of the records that we will be concerned with in these proceedings are what we call analog records, so we don't have to worry about the digital for now. It's much easier to understand the analog.

If I can just make a little drawing here to show -- if we assume that this is our recorder and this is time 0 and this is time 1 second, there is a stylus on the recorder and each time our sound source fires we have an outgoing signal pulse. The stylus will make a little mark for each time the thing fires and it will get another mark. Now this is reflection time; it's the time it takes the sound to travel down to a reflection horizon and back up to the receiving array.

For example, if we have a structure that looks like this -- I'll make just a small drawing down here. Here is the sea floor and here is a -- there is sediment over the top of the sea floor and then there is bedrock that's dipping below.

If we traveled along with our ship above that, towing our array and firing, we'd have the outgoing pulse, we'd have our first mark when the echo comes back from the sea flow. The stylus would mark again when it got the echo back from the bedrock interface. And, by the time we reached this position here, it would also get a mark back from the interface between this type of rock and that type of rock. So we would have a mark that looked like this.

As we continued along, each time the stylus makes one sweep, the paper in the recorder moves slightly. In other words, I will be moving the stylus along, but, in actuality, the paper is moving through the recorder. So we will end up making another mark at the next shot and another mark at the next shot and so on. Because these are lined up one next to the other, they will draw a cross-section which is comparable to the horizons of acoustic impedance that we have encountered down here. These are happening once every second.

So, if this is a horizontal line, this will end up by being a horizontal line. And, similarly with the bedrock interface. And the dipping reflector will come in as a vertical line like that.

So, in principle, it's simply a matter of continually one after another firing a sound source and having the reflected signals come back and be amplified and filtered to the right frequencies and then printed out on the graphic recorder.

Now probably the single most important variable that is involved in seismic profiling is the different frequencies, the use of different frequencies. We use frequencies that vary from 20 to 1200 hertz, hertz being one cycle per second. Generally, the low frequencies are not attenuated as easily as high frequencies are within the medium of their propagation. Therefore, if you want to look at some structure that is deep beneath the sea floor, you generally have to use fairly low frequency, some kind of a sound source that gives you low frequency signals.

But the problem with low frequency is that it does not give you a great deal of resolution because both penetration and resolution are a function of frequency.

I might just say, before I get too far along, that some of the different kinds of sound sources that are used are discharging a high-intensity discharge of spark into the water or arc; that's called a sparker record. What they do is just charge up a capacitor bank and, at intervals, discharge that through an electrode into the water and it forms a big plasma bubble. And, when that collapses, it makes a good signal for propagating sound through the sea floor and back.

So, generally, those kinds of records are called sparker records.

Another sound source that is commonly used is what we call an air gun and it's simply charging up high-pressure air into a container and then letting it go out rp6

explosively so that you release an explosive release of high-pressure air to make a big bang.

A modification of that is what we call a water gun and that simply is the use of high-pressure air to force a cylinder at very high velocity out of a gun into the water and that displaces a slug of water which causes a cavitation bubble and then collapses.

When we get into the higher frequencies, also transducers are used, such as in echo centers. It's magneto-striction or a crystal transducer which pulses as you put a pulse of electrical energy through it.

Depending on the sound source and the resultant frequency and the rapidity with which you sweep the recorder, we can look at the details in the upper few meters of sediment beneath the sea floor with a high frequency system like -- for example, we call it a 3.5 kHz system. That's a very common frequency used in looking at some detail in the upper

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few tens of meters.

From there you can go all the way to using a big array of very low frequency air guns and sweeping the recorder at, say, a ten-second sweep. At a high frequency, you might sweep it at a fraction of a second. In the deep penetration, low frequency systems, you might use a ten-second sweep.

So by modifying the sweep rate and the frequency of the system, you can look at details in the upper part of the section or you can look for structure deep in the section.

Unfortunately, because of the physics of the sea floor and of sound, it's not possible to look at all of these things with one system, so we commonly make surveys wherein we utilize not just one system but several systems. Like we might travel along over the sea floor firing a big air gun system to look deep down in the section and, at the same time, we might be using a hull-mounted transducer which would be looking at the details just in the upper part of the section here.

Sometimes you may have to go back over the area again, using an intermediate frequency and sweep rate, which would give you somewhat more detail in the upper 100 meters or so.

Basically, the data that has been utilized by all parties and examined by all of us in the area of San Onofre have involved all of these kinds of systems.

I think I have a couple of examples of some of the different kinds of data here.

This, for example, is a 3.5 kHz record and that is a high-frequency record to look at details in the upper few meters below the sea floor. This happens to be down in the Gulf of California in the Cuyamas Basin for those of you who are interested.

If you look at the vertical scale -- the scales on these are always registered in terms of travel time, two-way travel time or reflection time.

Now, if you want to put that in terms of absolute depth below the sea floor, you have to think in terms of what the propagation velocity is through the different media, through the sediments and the rock below because sediments have a much lower propagation velocity than do the rock. And, therefore, you get some distortion in the vertical scales on these reflection records because they normally are looked at just in terms of reflection time. So, you have to keep in mind, when you are looking at reflection records, that the vertical scale is a time scale only.

There are methods whereby you can print out using digital methods and, on computers, you can print out what are known as depth sections rather than time sections. But, to do that, you must know periodically -- you must have a knowledge of the velocity in these different sediment and rock units.

All of the data that were used in our analyses by all parties are expressed in time sections, in seconds or fractions of seconds of reflection time.

This shows that you can see very small, thin layers offsetting here along a fault in Cuyamas Basin(ph) and we can see that we can resolve down to quite small thicknesses of sediment. In fact, in 3.5 kHz, you can resolve probably --

at the very best, what you could expect to resolve would be somewhere in the neighborhood of about a half a meter. And the resolution, of course, is the function of the frequency.

When you're dealing with frequencies of about 100 hertz, for example, which is typical of the frequencies used in sparker records, then the best you can expect to resolve is perhaps around four meters. That is, you could not resolve the thickness of a layer less than four meters.

The best resolution is between a quarter and three-quarters of a wave length, somewhere around a half a wave length. Since the wave length is a function of the velocity and the frequency, low frequencies have less resolution than high frequencies.

This is an example of a sparker record. The frequency that is used, rather than 3.5 kHz, as in the previous example, is probably a center frequency of somewhere around 100 to 200 Hertz, in that range.

I can use this also to demonstrate the fact that you do see geological structure on these records. Now this is 0 to 1 second in reflection time, down to 2 seconds here. And you'll note that, on the horizontal scale, we have 10X which expresses the vertical exaggeration.

I've mentioned that the vertical scales are a function of reflection time.

The horizontal scales, on the other hand, can vary quite a lot, depending on several different factors. It depends on, for example, the speed of the ship over the ground. If the ship is going very rapidly, the distance between shots fired will be much greater, and so it will tend to compress the horizontal scale and also the rate at which the paper moves through the recorder will affect the horizontal scale.

In most of these systems, I might add, there is built in some vertical exaggeration and there's an advantage to vertical exaggeration in that it allows you to more easily see the structures, to more easily see faults and folds in the section.

The disadvantage, on the other hand, is that, when dips become too great or when the inflections in folds, for example, become too steep, you may not be able to resolve them, so you lose them.

For example, at a vertical exaggeration of ten times horizontal, a slope over here, which looks like it's about 40 degrees, because it's a tangent function, is really about 5 degrees. So, in looking at these records, we must keep in mind that the features that we're looking at are highly compressed. The Great Pyramid at ten times the vertical exaggeration would look almost like a little needle, you see.

So there are both advantages and disadvantages to vertical exaggeration.

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But, in fact, in nearly all seismic profiling systems that have been used in these surveys. there is some vertical exaggerations and they range from about 3 up to over 20, depending on the system. Usually we try to express what the vertical exaggeration is.

The sampling density also is very important and that normally ties in very closely with the horizontal scale and vertical exaggeration. The sampling density, again, is the function of the ship's speed but it's also a function of how often you fire the sound source. If the sound source is being fired very rapidly, you might get a reflection back from the sea floor every five meters. If it's being fired every ten seconds and the ship is going along at five knots, well, obviously, there's going be quite a spread between the acoustic samples you get of the sea floor and the subsea floor structures. That's no great problem when things are horizontal or very gently dipping. But, in an area where you have complex folds and faults, such as in this region, which happens to be off of Pt. Conception, just around Pt. Conception, it's important that you have a fairly high sampling density and that means that you should fire your system as high a rate as possible and run the ship as slowly as possible and still keep the streamers running and the ship under control.

I might add that, while the ship is making these transsects, it is being positioned automatically by radio-ranging positioning systems. That's the way they do it now.

I'd just like to say a few words about planning surveys. Assuming that you have the proper equipment for finding the types of structures that you're looking for, it's important to plan a survey so that you can have the transsects run in the optimum direction.

If the geology of the region -- if this is the coastline and it's known from onshore that most of the main structures, anticlines, are trending like this and you would expect that they might be the same offshore, you would probably want to orient most of your lines to cross those offshore with a few tie lines in the other direction.

So, in general, before you go out and run a survey, you want to know as much as possible about the structure, the tectonic structure, the drain and orientation of onshore structures so that you can plan the traverse correctly.

It's usually an advantage if you are able to go in an area and do a reconnaisance survey first. That would be relatively wide-spaced lines designed just to get a quick look at what's there and then, at a later time, return to the area and concentrate on the more closely-spaced lines in areas of greatest interest.

Once you collect these records, then you must interpret them and there are some pitfalls to interpreting records. One of these is multiples and here we're showing a very simple multiple. The most common multiple is what we call the bottom multiple and that means that the sound reflects off the bottom and returns back up where it is received at the hydrophone. But it also reflects from the air-sea interface because the air-sea interface is a very strong reflecting mirror because of the acoustic impedance difference between the air and the sea water. So it acts as a mirror and the pulse of sound returns back down and reflects back up again. So the graphic recorder will see the bottom and it will see the bottom -- the second multiple of the bottom as well. If the bottom is sloping, the multiple will slope at twice the slope as the actual sea floor.

Bottom multiples are very troublesome but they are fairly obvious and people who work with these things soon get used to filtering them out visually.

Here we can see a bottom multiple of the sea floor and this structure here has another bottom multiple down here.

There are other kinds of multiples, internal multiples and so forth, which can be troublesome. But, in general, the bottom multiple, especially in shallow water, is the main one that causes problems.

Another problem that has to be faced in interpreting these records is the directivity. Now directivity is the function of the size of the -- let's assume that our sound source is omnidirectional and it sends signals out in all directions; therefore, to get directivity, you must attain the directivity in your hydrophone array, and that's one reason why they build streamers because it does give some directivity, particularly in the fore and aft direction.

These drawings here simply show the use of an echo sounder which is not trying to penetrate through the bottom but just look at the one reflector from the sea floor.

In deep water, because the directivity of the system would have an equivalent of a beam angle of -- this, I think, is a 12-kHz echo sounder transducer which has a beam angle -- double angle somewhere around 30 degrees, I believe -- as the ship is passing over it, it will begin to see -- if the ship is here, for example, it will see a reflection from there before it sees a reflection directly beneath it. As it approaches this side, it will be seeing the reflectors from here and here before it sees the reflector from there. So, when the ship is here and it sends out a beep, it will get an echo from there, from there and from the bottom. These are called crossovers and they're very common. You get different configurations of crossovers with different types of structures. But, for a simple

U-shaped or a V-shaped body, you can see that you can get rather complex crossovers which make interpretation a little difficult. This can be minimized by focusing the beam and making it narrower. A long array is helpful in that respect.

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Of course in a seismic profiling system we are not looking just at the bottom. We are looking at the reflectors beneath the bottom as well so that these kinds of crossovers will continue on down as you are looking at reflectors beneath the sea floor.

And another effect of the same phenomena, when shown on an actual record here, for example, this is down in the southern part of the continental borderland off Mexico, south of Punta Banda, this is a big fault scarp here and there are beds dipping this way and younger sediments that have been deposited later. You can see that these rocks have been folded up here and abut the fault here in something like Perry Ehlig's reverse dip. But the phenomenon we are talking about right now, you can see that the flat lying turbidity current deposits here that have been deposited in this little basin actually go up under the wall of the fault scarp. Of course they don't really go under the wall of the fault scarp. It is just a function of the crossover configuration that I explained earlier.

So when we look at records like this, we must keep in mind that we can sometimes have very strange looking phenomena, for example, of turbidite beds extending up under the fault scarp. We know that is not real and we don't interpret it in that way, but it is there and you have to take it into consideration.

Another problem that is common in shallow water when you are working on continental shelf areas with hydrophone streamers is that of side echo from the hydrophone array. The hydrophone array is a series of phones one after the other so that in a fore and aft direction sound that is reflecting from the surface over here -- here is your sound source -- and sound that reflects from here will come back and it travels along the hydrophone array and is cancelled out as it travels along.

Similarly, a reflection from back here would travel along the hydrophone array and become cancelled out. One that is from directly below will be received simultaneously along the length of the array and it will be reinforced. So we do have fore and aft directivity. But it does not have directivity from side to side, so that if we are looking at -- if there is a reflector out to one side or the other, it will reach the hydrophone array simultaneously so that it is reinforced.

So let me try to draw a picture here of what sometimes happens.

Now I have drawn a picture of a homoclinally dipping sequence of beds that have been planed off by wave erosion and then some sediment deposited on top of it. If we run the ship up dip or down dip, the system is able to resolve these irregularities because of the fore and aft directivity of the array. However, if the ship is traveling into or out of the board here, the hydrophone array which we are looking at now will receive echoes from the bottom and the sub-bottom here but it will also receive echoes from these strike ridges that we are looking at in crossection on either side. And as we travel along, because these strike ridges are not always the same height -- some are higher than others -- it will tend to cause a whole series of overlapping hyperbole on the record.

It is very typical in shallow water, in areas where you have beds that have been planed off, dipping beds, whether they are dipping seaward or landward, that when you try to operate a long strike you have difficulty in resolving the geology because you get so many side echoes that it causes the records to be of very poor quality. This slide is of very poor quality, too. But it shows an example of here the ship was going up dip and it turned and it is now running along the strike. This is very typical, all of these little side echoes, of both above -- this is the bottom here and this is the subbottom reflector. But we are also cluttered up with many, many side echoes that occur both above and below the bottom, which simply mean that they are at a greater distance. Some of them are right at the bottom, so they would be reflections close to the same distance here. The ones that are above would be out on either side of the reflector, the bottom reflector and ones below would be from irregularities in the geology down dip on either side.

I don't think I explained that very well, but the general idea is that it is difficult to interpret records that are taken along strike, in shallow water particularly.

Some of the other problems in the interpretation of records can be associated with erosional forms. If you are trying to locate faults, for example, there is one -- this is out in the San Diego Trough, which is just offshore from here. This is the Coronado Bank -- the San Diego Trough is filled with horizontally bedded turbidites. This is quite clearly a fault. It has been mapped. Everybody knows about it. But there are other complications in here and these turbidites are deposited by channelized flow and overflow of the channel. This is a turbidity current channel which exists at the surface here, but there are other buried channels, for example, in here and in here. If one is not careful, one can fall into the trap of looking at those channels and seeing that there is disruption in the bedding and think that perhaps we are looking at faulting.

And here I have just drawn some examples of other complications that can arise which make interpreting records sometimes difficult. If you have an anticline, for example, that is faulted -- and anticlines are not uncommonly faulted in rocks off California -- it would probably look something like this. If you have an anticline that was exposed during low sea level stand so that gullies were eroded into it, it could look like this. It is sometimes very difficult to decide when you are looking at these records whether you are looking at an actual faulted anticline or whether you are looking at one that has been eroded by shallow -- by subareal erosion during a low stand of sea level.

And the same problem can arise when you are looking at a fault zone out near the edge of the shelf break or when you are looking at an erosional terrace out near the shelf break edge that has some debris lying on it from collapse of an old sea cliff and the like.

This one is fairly common when you are working in shallow water. You have nice bedding running along and it suddenly stops. Now are we looking at a fault there or are we looking at a channel that has been cut, an old river valley, you see. If you can find the other side, it still doesn't solve the problem entirely, because this could be a zone of faulting. So that requires -- to differentiate these things, one must run several profiles along to see if this is a linear feature and whether it is linear in the right direction to be a river channel or whether it is linear in the right direction to be a fault.

When you have high vertical exaggerations it is sometimes very difficult to tell the difference between a tight asymmetrical fold and a fault scarp like that, for example. Here is a good example of that. This is a tight asymmetric fold and here is a fault scarp. But we have a 20 times vertical exaggeration here.

I am pointing these things out just to emphasize that there is a considerable amount of subjective judgment in making interpretations of seismic profile and one must keep in mind what all the alternatives are.

JUDGE KELLEY: Your last reference to the slide, where you say the first is a fold and the second is a fault scarp, is that something in some cases at least that you can say with a very high degree of certainty or is that just an overall sort of best judgment? It would vary from record to record, but --

MR. MOORE: It would vary from record to record and your decision will also vary, depending on what this same feature looks like in an adjacent line, if you have one. Sometimes it is a fairly easy decision; other times it is very subjective.

Sometimes faults are very easy to recognize, like this one. I show this for two reasons: one, to demonstrate that this is a major fault here. This is a transform fault down on the Gulf of California. We can see that there are unconformities in here, with beds dipping up and truncated, there are some small folds, and everything is turning up very sharply out here towards the edge, where the fault is down into the basin here. I think it is San Pedro Matir Basin.

In order to get the most use out of records like these, one wants to know not only the structure, but what are the ages of these rocks, so that we can get some idea of when these structures were generated, so that if we had, for example, a bore hole here, we could sample the age of this horizon here and get a pretty good idea of what the subsidance history of this margin was right there. For example, if we could take a dark core out here, we could see what the age of this -- these deep beds were that have been sharply upturned along the fault.

And therefore, to ideally utilize seismic reflection data, one must combine it with either bore hole data or dark core data. You have to use bore holes over here, but you could use the dark core here, perhaps, and maybe here, so that you can put biostratigraphy, in other words, time stratigraphy, incorporate the time stratigraphy in your seismic stratigraphy.

A technique that is commonly used and that I will show in the next slide is to make line drawings of these profiles. The line drawings are made primarily to show where major unconformities are and to simplify the structure so that it can be reduced in scale, such as has been done here. This last slide showed just about this much. If we tried to show as much on a regular record as we did on that line drawing, it would take up far too much room. So line drawings are very handy to show small scale, that is, reduced scale versions of the seismic records, and particularly if one makes line drawings that show critical horizons such as unconformity. One can then reduce them, greatly reduce them in scale, and stack one up next to the next so that you can safely make a ladder of these and you can see how these structures continue from one line to the next, do they have continuity or do they not.

I think that is all I had planned to say right now. Do you have any questions?

JUDGE JOHNSON: You said that shallow water can cause you difficulties on occasion. What is shallow?

MR. MOORE: Well, that is a very good question. Shallow in seismic profiling depends on the sweep, the scale of your recorder, of course. Shallow, if you were using a 10 second sweep, would be much deeper than if you were using a fraction of a second. But in general when I say shallow water I am referring to shelf depths, and particularly the inner part of the shelf. That would be say out to 50 meters or 100 meters, 0 to 100 meters. When you get beyond that you get out of the effects of the features that have been carved into the bottom by rivers during low stands of sea level.

The sea level was low during pleistocene and the shelves were exposed to subareal erosion. So there are many features that are relics from that time. But also you get in deep enough water when you are over the shelf so that you are no longer bothered with multiple reflections from the sea floor, for example, because it has gone out of the picture by then.

So I guess to answer your question, shallow in general means shelf depth.

JUDGE JOHNSON: It is not a constant.

MR. MOORE: No, no.

JUDGE JOHNSON: Also, you mentioned that bore holes can help you in interpreting data.

MR. MOORE: Right.

JUDGE JOHNSON: Can a sonic profile or can any of the profile -- means of obtaining profiles -- resolve the presence of bore holes?

MR. MOORE: Can they resolve the presence of the bore hole?

JUDGE JOHNSON: Yes.

MR. MOORE: Probably not, no. In general, one would want to make a seismic survey, certainly at least a reconnaissance survey before you did the dart sampling or the bore hole sampling, so that you could see what the nature of the structures were and you could more profitably place your dart cores or your boring.

JUDGE HAND: How far beneath the surface can you look with these wonderful gadgets?

MR. MOORE: Well, that of course is a function of the rock types. But in general, let's say with a 3.5 kHz system, a high resolution system, you are looking at the upper few tens of meters. With a sparker system where you are using the high intensity spark for a source and frequencies of somewhere around 100 Hz midrange, you could expect to penetrate down to several thousands of feet or a thousand meters or so. Using very large, powerful airgun systems and low frequencies, you can get down many thousands of feet, tens of thousands of feet.

JUDGE HAND: And I think the other day we heard the term "acoustic basement". Did we hear that word?

MR. MOORE: Yes. Acoustic basement is simply the deepest reflection that you can see that has any correlatable reflectors in it.

JUDGE HAND: And that depends very much on the frequency you started out using in the first place.

MR. MOORE: It would, yes.

JUDGE HAND: And somewhere in the testimony -- we may not have gotten to it yet -- the word "side scan sonar" shows up. Is that something you know anything about?

MR. MOORE: Yes. Side scan sonar is a different type of system in that it is not designed to penetrate the sea floor, but instead is designed to send out -- if the sea floor looked like this, where you had a series of humps along it, and here is the sea surface, and we towed the side scan sonar -- the ship is going into the paper here -- the side scan sonar sends out a signal that has a wide band like this and it gets reflections back. It would see a shadow behind this, for example, and behind this and behind this. So that as you traveled along, it would draw you a picture. You would see a ridge running like this on that one and a ridge here, perhaps a small one there, and a ridge out here. There would be acoustic shadows behind those things.

For example, it will show up ripple marks, large scale ripple marks or strike ridges or gullies and that sort of thing.

JUDGE HAND: How big is a ripple mark?

MR. MOORE: Well, it can -- ripple marks can be from a few millimeters to tens of meters. But I guess the simplest way to describe side scan sonar, it is like side-looking radar. It is designed to look at the topography of the sea floor to show up the relief of the sea floor, rather than to look at structure beneath the sea floor.

JUDGE HAND: Good. Thank you.

Mr. Wharton or Dr. Brune?

MR. WHARTON: We don't have anything in this area.

JUDGE KELLEY: Staff?

MR. CHANDLER: No, sir.

JUDGE KELLEY: And does that conclude the seminar, Mr. Pigott?

MR. PIGOTT: That is the end of this Course 501. At least if the Board does have further questions, obviously we would be happy to come back in this same kind of a format to explore particular areas that you may encounter where you want a little bit of the extra education, in effect.

JUDGE KELLEY: Thank you. I think this has been useful and we appreciate it.

JUDGE HAND: Do we get certificates now?

MR. PIGOTT: We'll see what the final exams look like.

(Laughter)

JUDGE KELLEY: We are at 12:25 and we broke off -- the next event I believe was Mr. Wharton's cross examination was coming up on yesterday's witness, Dr. Heath.

MR. WHARTON: Or whether or not there is going to be redirect of Dr. Ehlig.

JUDGE KELLEY: That's right. In any case. Why don't we break at this point, which is a convenient point, and reconvene at 1:30 here. Thank you.

(Thereupon, at 12:25 p.m., a recess was taken until 1:30 p.m., the same day.)

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

JUDGE KELLEY: We will reconvene at this point.

Mr. Pigott, are we at the point for cross-examination by Mr. Wharton?

MR. PIGOTT: We certainly are. Let me dispose first of the status of Dr. Ehlig. Over the evening recess and through this morning we did have an opportunity to examine his transcript of his cross-examination yesterday. We do not have any redirect for Dr. Enlig at this time. We would ask that he be excused from this portion of the hearing to reappear with respect to a later issue.

JUDGE KELLEY: Granted.

MR. PIGOTT: In which case, I believe we are now in a position to proceed with Mr. Heath, and I would ask that he take the witness chair. The only other preliminary thing I can think of that -- might think of, is the map that was identified yesterday, and I just leave that to the Board as to its disposition of that.

JUDGE KELLEY: I think at some point or another, it may become useful. I think when I was asking about maps, I didn't realize that you would have the visual aid and the transparencies that you have brought that I think are very helpful, and perhaps more than do service for that purpose, but go ahead, you were going to say?

MR. PIGOTT: I was going to say, it is our intent

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not to use transparencies over and above that which has been submitted as figures.

JUDGE KELLEY: Yes. My understanding has been that everything that has been put up there as a transparency is also in the testimony, and it is just a bigger version of the Exhibit.

MR. PIGOTT: With the exception of the tutorials, that is correct.

JUDGE KELLEY: Yes, right. Mr. Wharton, have you had a chance to look at the map? Do you have any --

MR. WHARTON: Yes, we have had a chance to look at the map. I note there are no offshore faults indicated on the map. That is -- Mr. Pigott, that is correct, and that is intentional, I take it, I mean, that we are not going to be referring to that map to determine where offshore faults are from that map?

MR. PIGOTT: That is an official fault map of the Division of Mines and Geology of the State of California, and I won't speak for their intent. That is just to give you a general overlay of supposedly a noncontroversial depiction of where the major and even some of the minor faults are in the State of California.

MR. WHARTON: Well, if the map is being offered to show all of the faults in the area, it certainly is deficient. I don't think it should be used, since it doesn't have anything about the Newport-Inglewood -- I mean, the offshore zone of deformation. There is no question involved that there is an offshore zone of deformation, and this map just conveniently doesn't have it on it.

MR. PIGOTT: First of all, I object to the characterization that this is -- that the Applicants had anything to do with the manner in which these faults are placed on there. I don't know whether there are offshore faults on that map. It just may be that there are. But whether there are or whether there aren't is certainly not within the purview of the Applicants. This is something that is put out as an official publication of the State of California?

MR. WHARTON: Well, we don't --

MR. PIGOTT: If you don't subscribe to the way the State of California maps its faults, take it up with them.

MR. WHARTON: We are not talking about anybody coming in here and authenticating the map. I mean, if we are talking about using a map to show locations, that is fine. If we are talking about using that map in any way to rely on the faulting in that map, absolutely not, because we don't have any authentication in the map, and it doesn't have the important faults on that map that we are discussing here, for use solely for where San Onofre is in relation to other places.

But if it is used for any purpose as far as faulting, absolutely not. We would submit that we have a map that -- Dr. Brune informs me that there is an official map from the Division of Mines and Geology which shows offshore faults, all of the faults.

This does not -- this map, according to Dr. Brune, does, if we have to have a map, I would suggest that that would be the map we would use if it does show the offshore faults.

JUDGE KELLEY: Well, I am not sure we really have to. Let me say I thought of this as a visual aid, another way to get a handle on the situation, not as a substantive evidence of matters in controversy. Let me just ask Mr. Chandler if he has looked at the map and what the Staff's views are on its use or not.

MR. CHANDLER: We have looked at the map, Mr. Chairman. I certainly have no objection to its use as a general reference point. I think its present status, having been marked for identification, is sufficient to attain that objective. I don't see any need, for example, to receive it in evidence, and I think just as the Board Chairman characterized it a moment ago, a visual aid is sufficient, and we have no objection to its use for that purpose.

JUDGE KELLEY: Thank you. Well, I think at this point, we will leave it where it sits. I appreciate your bringing it in. If at some point or points it seems useful to use it as a visual aid and a location device, we may do that, but I don't know that that is essential right now, so it is not -- it has merely been numbered as an Exhibit. It isn't in evidence, and it may get some use, but we can concern ourselves later with whether anyone objects to the use that it is being put to, and so is there anything else that needs to be raised at this point before we turn to the witness?

MR. PIGOTT: Nothing from Applicants. The witness is tendered for cross.

Whereupon

EDWARD HEATH

the witness on the stand at the time of recess, resumed the stand and, having been previously duly sworn by the Chairman, was examined and testified further as follows:

JUDGE KELLEY: Mr. Wharton, go ahead.

CROSS-EXAMINATION

BY MR. WHARTON:

Q Yes, Mr. Heath, I note in your deposition you have a Master of Arts degree in geology?

MR. PIGOTT: Is there a deposition?

MR. WHARTON: Correction from his prepared testimony.

THE WITNESS: That is correct.

BY MR. WHARTON:

Q Just for a little bit of clarification, why is it referred to as a Master of Arts degree instead of a Master of Science degree?

A Because at Pomona College, where I actually -- pardon me, Claremont Graduate School, which is associated with Pomona College, they don't offer science degrees. All of their Masters degrees are in arts.

Q Is the Masters of Arts degree that you received, would that be equivalent to a science degree in some other school just called differently, or is there a different curriculum?

A It would be very similar. All of my graduate work was in science.

Q Okay, do you have any degrees other than Master of Arts degrees in geology, and Bachelor of Arts degree in geology?

A No, I don't.

Q Do you have any special credentials or qualifications in the area of probabilities and statistics?

A No, I do not.

MR. PIGOTT: I would like a clarification of what special credentials means in this context.

MR. WHARTON: I would refer to it as special training that is, formal education, any extensive experience, that is, working in that area for an extended period of time, say, more than a year, or anything that you think would lead

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one believe that you have credentials in the area of giving opinions as to probabilities and statistics.

MR. PIGOTT: Objection. I would like to know where probabilities and statistics becomes a relevant issue for this witness. His direct testimony, I don't believe is in the area of probabilities and statistics.

MR. WHARTON: Mr. Chairman, when the witnesses who are testifying are saying likely, reasonable, conservative, more conservative, most conservative, less conservative, they are also -- they are basing this on some kind of form of a probability, of some sort. They are weighing a probability in their own mind.

Now, our point is, if they are in fact weighing probabilities, which they have to be doing to come up with these kinds [illegible] determinations, then I would think they would have to have some kind of credentials or something to show that this is something that they are competent to testify to.

JUDGE KELLEY: Objection is overruled. I think the question is proper and understandable. Qualifications beyond what one would normally get in the educational degrees that you have already referred to.

MR. WHARTON: That is correct.

THE WITNESS: In reference to numerical statistical analysis, I do not have any special qualifications.

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BY MR. WHARTON:

Q So in numerical statistics and probabilities, you don't have any special qualifications, then?

A No. I have only 27 years or so of practical experience in working in the geologic problems, many of which require decisions and analysis.

Q Okay, do you have what we would refer to as special qualifications and credentials as used in the last sentence, in the area of risk assessment or you may refer it as determining an acceptable level of risk to the public?

MR. PIGOTT: Objection. This witness is not here for purposes of risk assessment. He is here for -- to render a professional geologic judgment, and I think that this is a blatant attempt mischaracterize the purpose of this witness.

MR. WHARTON: Mr. Chairman, absent a statement on the prepared testimony that -- flat statement that no earthquake higher than this can occur, absent a statement such as that, whatever this witness is testifying to when he refers to reasonable, appropriate, most conservative, conservative, qualitative, all of these are decisions, values decisions that he is making, and the values decisions that he is making are based upon his understanding of what is an acceptable risk to the public, and I think I am entitled to get into his background. These decisions are made, and I want to find out what his basis is for making them.

JUDGE KELLEY: Objection overruled. I think that the witness's testimony can in at least some ways be fairly characterized as risk assessment.

THE WITNESS: Would you please repeat the question?

BY MR. WHARTON:

Q Yes. Do you have any special qualifications or credentials in the area of risk assessment or determining an acceptable level of risk to the public?

A Well, I have the nine years of -- correction, 13 years of experience as an engineering geologist. I am certified by the State of California as an engineering geologist, and over this time, we have made many assessments regarding public safety in relation to landslides, active faults, surface rupture, things like that.

Q Are there any criteria you follow when you are making these kind of assessments?

A Base it on sound geologic evidence, as we can obtain the facts, and make a decision based on that.

Q So are you saying, then, that you look at the geographic scenario of an area and decide on that basis only on the geographic scenario what you think an earthquake is going to be --

A Not at all. We look at a lot more than geographics.

Q In the process of coming up with these determinations that you say you have experience in doing, do you look at other social factors in making these determinations?

MR. PIGOTT: Could we have a definition of what you mean by social factors?

JUDGE KELLEY: Yes, would you elaborate, please?

MR. WHARTON: Yes.

BY MR. WHARTON:

Q I think you testified that in 13 years' experience, during that 13 years you have made decisions as far as risk assessment, and I take it from that, risk assessment means that there is a certain acceptable level of risk to the public that you are assuming in making that assessment, is that correct?

A No, that is not correct.

Q Okay. Do you ever look into what the acceptable level of risk to the public is in making the kind of decisions that you make?

A No, we very seldom look at what would be the acceptable risk to the public. We look at the scientific data and try to evaluate what the so-called geologic risk is, and what the chances of a geologic failure or chances of a certain level of earthquake, but some other public agency, or someone else has to determine what the acceptable risk to the public would be, knowing the basic geologic facts.

Q Okay, so that when you use the word "acceptable" in the context of your written testimony here, you are not taking into account any results of your decision, that is, any results of risk to the public in making that decision that this is acceptable?

A I think you would have to be more specific on where I used the terms.

JUDGE KELLEY: Could you tell us what you are referring to in the testimony?

MR. WHARTON: I misstated the word. The word should be, that we are referring to, is "appropriate."

MR. PIGOTT: Could we again still have a citation?

MR. WHARTON: Yes, okay. Page 5, line 21.

JUDGE KELLEY: The question was put by a hypothetical interrogator, was it not? The word "appropriate" --

MR. WHARTON: Yes, and he is responding.

BY MR. WHARTON:

Q The question is, would you please state your conclusion as to the appropriate value to be assigned for the maximum magnitude earthquake for the OZD. In my opinion, M six and a half is a reasonable maximum earthquake magnitude consistent with the geologic and seismological features of the NIZD. If there is a question as to whether he was responding to that, I can just ask now. In your answer there, were you determining at that point, that six and a half, by stating

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that it is a reasonable maximum earthquake, was an appropriate value?

A Not necessarily. I was answering the question as I understood it, on what I considered the maximum magnitude for the OZD to be. I did not use the word "appropriate."

Q Okay, I will be getting into some other words later on. I don't want to go into that right now. Moving on, the -- what have your positions, that is, your positions of employment been with Woodward and Clyde since 197??

A Well, I came to work for them from another engineering firm as a project geologist. Since that time I have worked on a number of different types of engineering geology projects. After approximately two years or so of learning the procedures of the corporation, I was advanced to a project manager status, and senior project geologist, and --

Q Excuse me for interrupting. Is that considered a management position?

MR. PIGOTT: Could we have the witness be allowed to complete his answers?

JUDGE KELLEY: Yes.

BY MR. WHARTON:

Q Complete your answer, excuse me.

A As a project manager, the position there is to take projects as they come into the company, and form depending on the size of the project, the project team, with the appropriate expertise, and develop a plan in order to evaluate the project, prepare a report. This is all done under the direction of the project manager. Sometimes the project manager is also one of the prime technical researchers or investigators in the project.

Q Okay. Now, the present position that you hold with Woodward and Clyde, is that a management position?

A It is a project management position, as I have just described.

Q Okay, in the strata of management of Woodward Clyde, which I don't know anything about, is that considered an upward management position, middle management, lower management, if there are such stratas, could you describe where that would fit in?

A I presume middle management would be appropriate.

Q Do you in this position make any business decisions for Woodward Clyde, that is, outside of your particular profession?

A Not that are outside of my profession.

Q Okay, what kind of business decisions do you make that would be inside your profession?

A Well, we prepare proposals for projects, and we scope the proposal and prepare the cost estimates, and so to that degree, you are doing some business management, some business decisions. We decide what level of effort we should be proposing on a particular project.

Q Did you prepare -- you prepared proposals for San Onofre?

A I assisted the project manager on that. I was not the project manager for Woodward Clyde on San Onofre.

Q Do you happen to know what percentage of Woodward Clyde business is with the nuclear industry in general?

A No, I really don't.

Q Would you say that it is -- is it more than 50 percent or less than 50 percent?

MR. PIGOTT: Objection. He has answered. He doesn't know.

MR. WHARTON: Mr. Chairman, I believe in cross-examination when there is an answer such as that, it is usually appropriate to try to ask a narrowing question just to see if they can make some kind of answer.

JUDGE KELLEY: Did I hear you say, sir, that you didn't know what percentage of the Woodward Clyde business was --

THE WITNESS: Yes, that was my --

JUDGE KELLEY: -- with the nuclear industry?

THE WITNESS: -- my answer.

JUDGE KELLEY: Objection sustained. Move on.

BY MR. WHARTON:

Q Would you say that Woodward and Clyde from your knowledge does a substantial amount of business with the nuclear industry?

MR. PIGOTT: What is substantial? What do you mean by substantial? It is a vague word.

MR. WHARTON: Since I can't get into percentage of business, I am trying to think of some way to ask the witness whether or not he knows if Woodward and Clyde does business with the nuclear industry, so I will simply ask it that way.

BY MR. WHARTON:

Q Does Woodward and Clyde do business with the nuclear industry besides San Onofre?

A Yes, we do.

Q What other projects have Woodward Clyde worked on?

A We have worked on some for PG & E up in central California, and for Oregon utilities and Washington utilities along the coast.

Q Any others?

A And some work in the Houston area.

Q Any others?

A I believe there is some work going on in the east, but I am not familiar with it.

Q Are there any others you can think of?

A Not offhand.

Q Okay, what is Woodward and Clyde's function, then, working for Southern California Edison on San Onofre? What has been their main job?

A Basically I think it is in two fields. One is the project that I have been working on directly, was to assign a maximum magnitude to the offshore zone. I also have been doing the earthquake response studies for ground response.

Q Did Woodward Clyde play any part in selecting the site for San Onofre Units 2 and 3?

A Not that I know of.

Q Would you say that Woodward Clyde Company has a strong interest in seeing that this plant is licensed?

MR. PIGOTT: Oh, objection. That is -- that calls for speculation. It is too broad. It just has no meaning to it.

JUDGE KELLEY: Sustained.

BY MR. WHARTON:

Q I will ask directly to you, do you personally have any strong feelings about the licensing of this particular plant?

MR. PIGOTT: Objection. I think it is irrelevant what his particular feelings may be as to the overall progress of the plant. He is here to testify concerning a professional geologic judgment.

MR. WHARTON: Mr. Chairman, the main considerations that you look at in bias, if a person has a very strong feeling about the plant, and is doing reports that are going to be relied on --

JUDGE KELLEY: Objection is overruled.

THE WITNESS: Would you please restate the question?

BY MR. WHARTON:

Q Yes. Do you have any personal feelings about whether or not this -- rephrase the question. Do you have any strong personal feelings about wanting this particular plant to be licensed?

A No, I do not have any strong personal feelings.

Q Do you have any feelings about regarding this plant being licensed or not?

A I am certainly not opposed to it. I am not opposed to nuclear energy, so I --

Q Thank you. On the -- did you help devise what was referred to and what I am going to refer to as the slip rate method?

A Did I help devise it, was that the question?

Q Yes, that is, formulate it or put together this particular method?

A Yes, I did.

Q And did you do that by yourself or in conjunction with others?

A I did it with -- in conjunction with several other people that are working on the project.

Q Was it your goal in putting together this particular slip rate method to come up with further justification for assigning an MS 6.5 earthquake or MS 7 magnitude quake?

A No, not directly. I didn't have a number in mind. When I came up and developed this method, it was after looking at some of the existing methods which have been used for some time, finding that they weren't completely adequate for assessing the maximum magnitude for the OZD, and in conjunction with that and the research we had done, we found that a lot of work had been laid for developing an evaluation based on the degree of activity of faults, comparing the faults, and the slip rate method was simply taking that one step further and trying to quantify this relationship by using a number such as slip rate to represent the degree of activity of the various faults.

Q Okay, has this method ever been used before?

A The degree of activity method is used, but the relationship that we developed on slip rate and magnitude, as far as I know, has not been used before. This is a new, essentially state-of-the-art addition to the general packet of methods that have been used. We have used existing methods, plus adding this one.

Q Okay, along those lines, you are testifying that you use that to supplement the existing methods?

A Yes.

Q Okay. In reviewing the existing methods, did you find what you thought were weaknesses or some insufficiency or something that was not quite as solid as it should be, regarding San Onofre, the site at San Onofre, regarding these other methods, that is that they were not as good a data base as you would like?

A It is a rather long question, but let me --

Q I will rephrase the question.

A Okay.

Q Okay. You referred to the other methods, and I am going to review them and see if I have them all down here. My understanding, another method is the maximum historic earthquake method, is that one of them that you are referring to?

A Yes.

Q Okay. With regards to San Onofre, does this particular method have any weaknesses in determining what the maximum magnitude earthquake would be?

A I don't know that it has any more weaknesses in regard to San Onofre than it does elsewhere. It is simply limited by the observational time of historic earthquakes.

MR. PIGOTT: Excuse me, Mr. Chairman. I don't object to this question or this line of questions. I do want to -- it is, however, substantive; in the last couple of witnesses, we have had Mr. Barlow doing the examination on the substance side.. I certainly do not intend to have my witnesses double-teamed by the Intervenors, so I assume that if Mr. Wharton is proceeding with substantive questions, that he is doing the substantive examination.

MR. WHARTON: Well, Mr. Chairman --

JUDGE KELLEY: I gather that is not their intention. If you would comment -- let me ask you, Mr. Pigott, perhaps this should be self-evident to me, but it is not.

When you say double-teamed, what exactly do you mean?

MR. PIGOTT: I mean, I don't want a lawyer coming in with a lot of questions on the substance of the -- it is one thing for him to examine on what he -- attempts on bias, and credentials and the more introductory approaches. However when he reaches what I would say the substantive, which he is now doing, I think, probing for weaknesses or gaps in the actual methodology used by Mr. Heath to assign the appropriate maximum magnitude to the offshore zone of deformation, I consider that substantive.

I feel that it is unfair to the witness to be subjected to that line of questioning once from an attorney and then have in effect a second team of supposed experts come in and ask the same type of questions, and I would say, I don't think -- I don't think that my objection is unusual. I think that in usual trial practice, certainly when there is more than one party cross-examining, or rather when a party is cross-examining a witness, they are usually allowed one person to do the cross-examination and not to have more than one attorney doing a cross-examination.

In this case, where we have an attorney plus potential use of experts, I again think that it would be unfair to subject the witness to in effect a double-teaming, and this is a clarification. I am not objecting to these questions. I just want to know what the procedure is going to be.

JUDGE KELLEY: Well, let me ask Mr. Chandler for any comments he may have.

MR. CHANDLER: I agree in principle with what Mr. Pigott said, but it is his witness, Mr. Chairman.

MR. WHARTON: Mr. Chairman, I don't want to get into technical parts or the substantive part. I am looking now for the reasons it was decided to come up with a slip rate method, rather than going into the details of the slip rate method. That is the motivation for determining slip rate method when there are many other ways of determining this.

JUDGE KELLEY: Well, we would certainly be concerned about his -- obviously about asking the same question twice and doubling the length of this cross-examination.

Subject to that, and maybe there is a somewhat greater hazard of overlap and redundancy when you have two people instead of one, but I would add, too, this seems to me to be fairly technical as opposed to bias and things of that sort, but having said all that, subject to the possibility that we do feel that you are getting into redundancy as a result of two questioners, I think I will allow you to proceed at this point.

MR. WHARTON: Okay.

BY MR. WHARTON:

Q Get my train of thought back here. Page 6, line 23, you state in referring to various methods of determining magnitude of earthquakes, use of either of these methodologies alone is not appropriate based upon the uncertainties in the data base available for the OZD. When you are referring to either, would you, in your testimony, clarify which method you are referring to?

A Yes, it is -- as stated in the sentence above, I also evaluated rupture length versus magnitude and displacement per event versus magnitude relationships.

Q Okay, so you are not then referring to the maximum historic earthquake method, fault rupture length total displacement method, degree of deformation method, and rupture length versus magnitude method?

MR. PIGOTT: Objection, compound, complex.

JUDGE KELLEY: Slow it down a little bit.

MR. WHARTON: Okay, I will slow it down.

BY MR. WHARTON:

Q Are you in this sentence referring to maximum historic earthquake method?

A No, I am not.

Q Okay. Are you referring to the fault rupture length method?

A Yes, I am.

Q Okay. Total displacement method?

A No.

Q Degree of deformation method?

A No.

Q Rupture length versus magnitude method?

A Yes.

Q And --

A I believe I quoted --

Q Okay, I just wanted to go through so we --

A The two are listed there on lines 21 and 22.

Q So would that lead you to conclude then that the other methods are, besides displacement per event, versus magnitude relationships, that besides these two, the other two are appropriate to use?

A I don't think I said that. I don't think it is appropriate to use any one of them by itself.

Q Okay, going on to the -- was there any review by independent geologists, that is, other than Woodward Clyde employees, of the methodology used in the slip rate method, prior to the presentation of that method and report to the NRC Staff?

A Yeah, it was reviewed by some of the other consultarts for the Applicant.

Q Who else was it reviewed by?

A I believe it was reviewed by Jay Smith and I also believe possibly Perry Ehlig. I know he was aware of it. I don't know how much he reviewed that.

Q Did you at any time prior to presentation to the NRC have the USGS review this method?

A No, we did not.

Q Did you have the California Division of Mines and Geology review this particular methodology?

A No, we did not, prior to submitting it?

Q Did you request any outside Woodward Clyde and consultants for Edis-- at that time opinions?

MR. PIGOTT: I am going to object on the grounds that it appears to be based on an assumption not in evidence, and that is that review of this procedure was a function of Woodward Clyde, in the context of being applied to this site.

MR. WHARTON: I am trying to get to the

independence of this particular method. That is, if it is something that Woodward Clyde did themselves, and then gave -- and presented to the NRC, or did they present it for -- call it peer review, if you will, before being presented to the NRC.

JUDGE KELLEY: Well, certainly we all understand the peer review concept, at least generally. I am not aware that a company such as Woodward Clyde, if they came up with a new technique, could get any kind of formal review from the USGS or the NRC or any other government agency, so to the extent that -- I may be wrong, but I am not familiar with that, other than informal peer review by people who work there. Now, am I right or wrong, or can you comment on that?

MR. CHANDLER: As a general rule, Mr. Chairman, you are correct. The Staff does not do anticipatory reviews. It would be reviewed in the context of the review of an application.

JUDGE KELLEY: But if you are directing your inquiry to the extent of peer review of this newly developed technique, and I gather you are --

MR. WHARTON: Yes.

JUDGE KELLEY: Right. Could you just answer that general question about to what extent was there peer review outside of Woodward Clyde and other consultants for the Applicant as to your technique?

THE WITNESS: Okay, as I recall, there was no additional outside peer review; the time period for gathering the data base developing this method and presenting it to the NRC was only several months, as I recall, so there was not a lot of time available for peer review, outside of the other consultants that I have mentioned, prior to submittal. We were trying to make a deadline.

MR. WHARTON: That answers the question, I think.

JUDGE KELLEY: Since then, has thir slip rate technique been written up in technical journals, say even by yourself or others?

THE WITNESS: No, it has not.

JUDGE KELLEY: Or has any kind of peer review, formal or informal, occurred since then?

THE WITNESS: That is correct.

JUDGE KELLEY: There has not, is your answer?

THE WITNESS: Oh, I am sorry, I didn't hear your question.

JUDGE KELLEY: I am wondering about the peer review subsequent to your submission to the NRC, which I gather was some time back?

THE WITNESS: Yes, it was originally presented in December, '79, I believe. It has been an ongoing study and there have been several revisions since then, and of course after it was submitted to the NRC it was put out, I believe, by them, for review by U.S. Geological Survey, the State

Division of Mines and Geology and the NRC consultants, which is Dr. Shlemon.

MR. PIGOTT: There is a -- I feel there is a bit of a misunderstanding, or maybe supplementary questions, but the questions are being asked, it seems, in the context of review of this application, at least the answers seem to be coming back in that -- could we make a distinguishing point between review of the slip rate magnitude procedure versus the slip rate magnitude procedure as used by Mr. Heath and Woodward Clyde in this proceeding, because I don't think that Woodward Clyde is the only person who has ever used this kind of an approach, or published this kind of an approach. In fact, I know it isn't.

MR. WHARTON: Would you like to testify?

MR. PIGOTT: Not now.

JUDGE KELLEY: Well, but that in part is what we -- I thought we were getting at. I thought the technique was invented by the witness and others fairly recently.

MR. PIGOTT: Yes, but what I detect is that the answers are coming back in a context different from what the questions are going to. That is -- there seems to be an ambiguity, that is all.

MR. WHARTON: I think that could be resolved on redirect, if Mr. Pigott thinks there is an ambiguity.

JUDGE KELLEY: In any event, why don't we proceed?

MR. WHARTON: Yes, I think you clarified the questions finally.

BY MR. WHARTON:

Q On page five of your written testimony, line 24, in my opinion, MS six and a half is a reasonable maximum earthquake magnitude consistent with the geologic and seismological features of the NIZD. Now, looking to this word "reasonable maximum earthquake magnitude," did you -- were you present for Dr. Ehlig's testimony?

A Portions of it, yes.

Q Had you read Dr. Ehlig's written testimony?

A Yes, I have.

Q Okay. Dr. Ehlig refers to as the maximum earthquake likely to occur along it -- along it, based on its features, geologic strain rate, and regional tectonic setting. Now, in your opinion -- are you saying here that assigning the reasonable maximum earthquake magnitude is the same as deciding what the maximum earthquake likely to occur is?

A I have not equated them. I am not really sure of Dr. Ehlig's exact clarification of that statement. I know you asked him that, but I mean, those are his words, they are not mine, and I can't say that my wording is equivalent to his.

Q So you would -- would you use words like "likely to occur" to establish reasonable maximum earthquake magnitude?

A No, I don't think I use words like "likely to occur."

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Q On page 5 -- strike that -- page 6, line 14, it says: My specific approach uses both a qualitative and quantitative comparison of features, such as maximum historic earthquake, fault rupture length, total displacement, degree of deformation, long term slip rate on fault, as a means of differentiating and ranking faults. And I evaluated the earthquake potential of the OZD. Would you define what you mean by qualitative?

A Qualitative would best be defined by things like looking at the geomorphic features along a fault zone, how much surficial disturbance there is. You can see a difference visually. You might even be able to measure parts of that. So it is basically a qualitative comparison of what this fault looks like on the surface as opposed to another fault. It is hard to measure that visual impact.

Q Okay. And then do you make what you would call predictions or projections based on this qualitative comparison that you are talking about?

A We don't make predictions, but we make comparisons between faults.

Q Okay. Now what is the quantitative approach? Would you define that?

A Well, quantitative, in my way of thinking, is where you can actually measure something and derive a number. Geologic slip rate is a quantitative measure of the degree of activity, at least one of the quantitative measures. Fault length, if you can really define it, if you have good geologic maps and good exposures, can be a quantitative measurement.

Q Would something which you would call a quantitative method, would this leave out any judgmental calls, that is, what is included and what is excluded from something as far as developing a formula?

A No. I think you probably have to use judgment in arriving at a number. In geology, numbers aren't written on rocks. You have to develop them. So you do have to use judgment in developing these numbers.

Q How would you classify the determination of what earthquake faults and events were included in your slip rate method for San Onofre? How would you classify that kind of decision, that is, which events you used on that particular chart?

A I don't know how I could answer it by saying how would I classify that, other than we define a style of faulting in a tectonic setting for the fault of interest, the one that we are primarily investigating. If we want to compare that with other faults then we have to find other faults that have that same style of deformation or in a similar tectonic environment so that we are comparing like -- similar types of faults.

Q There is a judgment involved on whoever makes this decision as to which ones to include and which ones to not include.

A Yes. Based on certain criteria, as I have just outlined.

Q On page 5 -- correction -- page 6, line 8 to 9, you state there: The most conservative maximum magnitude is MS 7. What does "most" mean there?

A That means more conservative than any other conservative estimate we might have made.

Q Okay. Let me ask you some possible interpretations of this and ask you whether you agree with them or not. Does most mean that none other could possibly be assigned by any geologist or seismologist?

MR. PIGOTT: Do we have the assumption of reasonableness in there?

BY MR. WHARTON:

Q Well, what I am saying, you say most conservative maximum magnitude is MS 7. I am looking for the word "most". In your opinion does using the word "most" mean that no one -- there is not any geologist with credentials who would assign a magnitude of MS 7, having knowledge of all the features that you know, that you have knowledge of and the knowledge which you have?

MR. PIGOTT: I am going to object as being an unrealistic question or calling for speculation, calling for any geologist with any credentials. There may be some up in Napa State Hospital, for all we know, that would put any kind of assignment on it. I mean we have to have a feeling of reasonableness on these kinds of questions.

MR. WHARTON: If I can --

JUDGE KELLEY: By the way, I think when you last said it you said 7 rather than more than 7.

MR. WHARTON: Right. That's what I meant to say.

JUDGE KELLEY: You meant to say more than 7, right?

MR. WHARTON: That's correct.

JUDGE KELLEY: Is your question fairly rephrased whether the witness thinks that there are any qualified geologists around who might disagree with that and might think that it ought to be higher than 7?

MR. WHARTON: No. I am trying to get to -- it is a thorny problem. I am trying to get to the meaning of "most" here. I mean does "most" have any real meaning? He could say conservative maximum magnitude, but he is saying here the most conservative maximum magnitude. This is like a new word that is thrown into all the words we hear, like "appropriate" and "reasonable" and "conservative". Now we have the "most conservative".

JUDGE KELLEY: What is that page again? I'm sorry.

MR. WHARTON: It is on page 6, line 8-9.

JUDGE KELLEY: Can you have another run at the question and see where that gets us.

MR. WHARTON: Okay.

BY MR. WHARTON:

Q In your opinion, would any magnitude higher than MS 7 be rejected by the overwhelming majority of the scientific community?

MR. CHANDLER: Mr. Chairman, I would like to note that we will join in objection to these questions as a general proposition. I don't think this witness has any ability to testify as to what the vast majority of qualified geologists might suggest at all. He can speak for himself and I think this testimony reflects the views of Edward Heath.

MR. WHARTON: If I could respond to that, I could probably get right down to it then.

BY MR. WHARTON:

Q This word "the most conservative magnitude is MS7", that is your personal opinion based on your experience and knowledge.

A That is correct.

Q Okay. Have you consulted with others in your field outside of Woodward Clyde and the consultants for Southern California Edison as to whether this is the most conservative maximum magnitude, that is, MS 7 is the most conservative maximum magnitude?

MR. PIGOTT: I would object to the relevancy of his having consulted with persons not assigned to this project or not on this project. I don't understand what the direction of proving that is. Whether he has talked to other geologists or not is irrelevant to his opinion.

JUDGE KELLEY: Overruled. That goes to the weight of the thing rather than the question itself.

You can answer the question.

THE WITNESS: In regard to the use of the word "most" describing conservative or conservatism, I have not asked any other geologist outside of this project whether they would agree with the use of the term "most".

BY MR. WHARTON:

Q Now in using the word "reasonable", in your opinion -- this is referring to page 5, line 24 -- 6.5 is the reasonable maximum earthquake magnitude. Would in your opinion an assignment of a 6 be a reasonable maximum also?

A No, it would not.

Q Why wouldn't it?

A Because the zone has already experienced a magnitude 6.3 event.

Q Would assignment of a 7 be reasonable?

A No, it would not.

Q It would be not reasonable?

A I would not call it a reasonable maximum earthquake magnitude in the terminology that I apply to a magnitude 6.5. It would be a very conservative or a most conservative maximum magnitude as opposed to a reasonable magnitude.

Q I take it, then, that you would say that a 7.5 would be unreasonable.

A Yes, I would.

Q Okay. What are the characteristics here that would make a 6.5 a reasonable determination and a 7.5 an unreasonable determination? And I am asking that for the context of trying to get a better handle on the word "reasonable".

A I am using the term "reasonable" to say that in my opinion it is reasonable that a magnitude 6.5 could occur on the zone.

Q I'm sorry. I didn't hear the last part of your answer.

A I am saying it is reasonable to estimate that a magnitude 6.5 could occur on the zone. In this case I want to identify it is the Newport-Inglewood zone of deformation that we are talking about.

Q You'd say that -- when you testified before that a 6 is not reasonable because there was already an event 6.3 on that, so that would rule that one out, is that correct?

A As a maximum magnitude, yes.

Q All right. So what you are doing then is you are going just a little bit higher than an event that has already occurred on that particular fault and in that context you consider that a reasonable assessment.

MR. PIGOTT: Objection. He's got 20-some odd pages of testimony saying how he got to 7, not simply a little bit above. That is a misconstruction of the -- it is objectionable on the ground that it is misconstruing the witness' testimony.

MR. WHARTON: Mr. Chairman, I am trying to get in here -- we have testimony that below the event that occurred on the fault is unreasonable, that is, a 6. The event that occurred he testified is 6.3. I am asking now whether his assignment of a 6.5, just a little bit higher than the one that already occurred in modern time, is reasonable. And this would go to getting us a better idea of what his idea of reasonable is. It is a decision that he is making. We have to get inside his mind and decide did he think a little bit higher than 6.3 is reasonable. If that is his opinion, he should state that and then you understand where he is coming from and why he is stating that.

JUDGE KELLEY: I think the question itself is proper but that you should wrap up this line and move on to another point very shortly.

MR. WHARTON: Okay.

BY MR. WHARTON:

Q Would you say assignment of a 6.5 is a conservative estimate?

A I think it is conservative in that it is higher than what has been noted on the zone.

Q So that would be your basis for conservatism?

A No, I didn't say that was my basis for conservatism. There is some conservatism in the estimate.

Q Okay. How much larger is a 6.5 than a 6.3, quantitative terms?

A It is a logarithmic scale and I don't know what two-tenths of a -- you know, it may be twice as large.

Q Put it this way, would a 6.5 generally cause ground accelerations much higher than a 6.3?

A Only slightly.

Q Only slightly? And you would determine that 6.5 is a conservative estimate.

A Yes.

MR. WHARTON: I would like at this time to have the testimony done by Dr. Brune as expert examiner. If there are any objections to Dr. Brune doing the cross examination, I will go into voir dire with Dr. Brune; otherwise, I would just simply move that Dr. Brune be able to cross examine Dr. Heath.

JUDGE KELLEY: Any objections?

MR. PIGOTT: I'm going to ask for a showing as to the basis on which he states that he is -- ask for a showing and potential voir dire of his qualifications, yes.

MR. CHANDLER: The Staff has no objection to participation by Dr. Brune.

JUDGE KELLEY: Mr. Wharton, would you present Dr. Brune?

MR. WHARTON: Yes. The Board has received copies of the written testimony of Dr. Brune. Attached to the document is a statement of Dr. Brune's qualifications. I can refer to those qualifications or I will go through the biographical sketch with Dr. Brune individually, whichever you prefer. All of it is in the record for the Board to look at. If you want me to go through individually, I will.

JUDGE KELLEY: Could you summarize briefly Dr. Brune's educational background and present employment? I believe the list of publications is quite lengthy and we need not get into that.

MR. WHARTON: Dr. Brune, would you tell us where and when you got your undergraduate degree?

DR. BRUNE: University of Nevada in 1956.

MR. WHARTON: And what was that degree in?

DR. BRUNE: Bachelor of Science in Geological Engineering.

MR. WHARTON: And did you receive subsequent degrees?

DR. BRUNE: Yes. I received a PhD from Columbia University in seismology.

MR. WHARTON: Would you state your research and/or professional experience?

DR. BRUNE: I worked at Lamont Dougherty Geological Observatory of Columbia University for a number of years as an adjunct professor of geology and a geophysicist with the National Oceanographic and Atmospheric Administration. I then went to Cal Tech as an associate professor in the Division of Geological Sciences, worked at the seismological laboratory for 4-1/2 years, and then went to Scripps Institute of Oceanography as Professor of GEophysics, where I still am.

MR. WHARTON: Would you state what honors and awards you have received?

DR. BRUNE: The biographical sketch that is submitted outlines most of them. Fellow, Geological Society of America, 1975. President, Seismological Society of America, 1970. G. K. Gilbert Award in Seismic Geology, 1967. Nominated New York Academy of Sciences, 1966, Member, 1970. Fellow of the American Geophysical Union, 1967. First recipient of J. B. MacElwain Award by the AGU in 1962.

MR. WHARTON: Okay. Would you state your present employment and the work you are presently working on?

DR. BRUNE: Yes. I am a Professor of Geophysics at the University of California at San Diego. In recent years I have carried out a number of studies relating to seismicity and tectonics in Southern California and northwest Mexico and to earthquake source mechanism and strong ground motion, particularly in Northern California and Mexico. I am currently a principal investigator on contracts and grants funded by the United States Geological Survey and the National Science Foundation which pertain to earthquake hazard in Southern California and northwest Mexico by the USGS, strong ground motion in northwest Mexico, National Science Foundation, earthquake mechanism and strong motion along the San Jacinto fault, USGS, and special studies of strong motion generated by the Imperial Valley earthquake of 1979, funded by the National Science Foundation.

MR. WHARTON: Have you read the written testimony presented in this case?

DR. BRUNE: Yes.

MR. WHARTON: And have you read particularly the written testimony of Mr. Heath?

DR. BRUNE: Yes, I have.

MR. WHARTON: And have you prepared for cross examination of the witnesses in this?

DR. BRUNE: Yes, I have.

MR. WHARTON: And -- I believe that is concluded and would move that he be accepted as an expert examiner.

MR. PIGOTT: A couple questions.

JUDGE KELLEY: All right.

MR. PIGOTT: Dr. Brune, have you ever conducted a cross examination of a witness previously?

DR. BRUNE: No, I have not.

MR. PIGOTT: Have you read what has been identified as Exhibit No. 3 EGH-1? NRC Staff Question 361.38, Parts A, B, and D?

DR. BRUNE: Yes.

MR. PIGOTT: Have you examined each of the -- examined and read through each of the witnesses -- Mr. Heath's exhibits?

DR. BRUNE: Most of them, but I am not sure about every one.

MR. PIGOTT: Which ones have you read? Let me ask you this way, which ones have you not read?

DR. BRUNE: Shall I go through them from the beginning?

MR. PIGOTT: Please.

(Pause)

MR. PIGOTT: Do you have a set of the exhibits to cross examine from?

MR. WHARTON: Yes, we do. I don't know if Dr. Brune has a set of exhibits right here.

MR. CHANDLER: I have provided Mr. Brune with a copy of the exhibits so he can identify.

MR. PIGOTT: Has Staff just provided a copy of the exhibits now?

MR. CHANDLER: At this moment, yes.

MR. PIGOTT: Okay. Let the record reflect that.

DR. BRUNE: The questions that are referred to, like 361.38, I read those questions in the FSAR, but I have not read through them in this final form here. If they are different, then --

MR. PIGOTT: Have you read through them with respect to preparation for the cross examination of this witness?

DR. BRUNE: I read through in their original form, but not in the form they are in this book. If they are different.

MR. PIGOTT: As a part of your preparation for cross examination of this witness, have you read that exhibit?

DR. BRUNE: Not precisely this one. No.

MR. PIGOTT: All right. How about this next exhibit, EGH-2, which I assume you now have?

(Pause)

DR. BRUNE: No, I have not specifically read that particular one.

MR. PIGOTT: How about Exhibit 3, EGH-3, which is No. 5 in this proceeding?

DR. BRUNE: No, I have not read that one. Again, I am assuming that it is similar to the ones in the FSAR. But if it is not, I have not read it.

MR. WHARTON: Mr. Chairman, Dr. Brune has testified that he has read the reports as in the FSAR. That is sufficient. Now if Mr. Pigott is saying these are different than what was in the FSAR, I would like him to say that they are specific. Dr. Brune does not know whether they are different or not. He has read all the material in the FSAR that this is. I fail to see where this is going. He has already read the material.

JUDGE KELLEY: Mr. Pigott, let me ask you whether the particular exhibits that are sponsored by Dr. Heath, are they substantially the same or similar to portions of the FSAR or are they different?

MR. PIGOTT: Not necessarily. For instance, the last one, Exhibit No. 5, is a report of the evaluation of maximum earthquake site ground motion parameters, et cetera. I do not believe that that is a part of the FSAR.

JUDGE KELLEY: Apart from that, though, are most or all of the others part of the FSAR?

MR. PIGOTT: Well, I would have to go through it now. I can't, because as we discussed earlier, the FSAR is a voluminous document. No. 3, which is a Q&A from -- a Staff Q&A, is in the FSAR. No. 4 I do not believe is in the FSAR.

Correct me if I am wrong, please. No. 5 -- his Exhibit No. 3 is not in the FSAR. No. 6 is in the FSAR, is an NRC Staff question and response. EGH-5, which is Applicant's No. 7, is not in the FSAR. EGH-6,Exhibit No. 8, is a Staff question and response. That is in the FSAR.

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EGH-7, which is Exhibit No. 9, again, is a Staff question and response. That is in the FSAR.

And EGH-8, No. 10, which is a NRC Staff question and response is also in the FSAR.

JUDGE KELLEY: Well, I think you have made your point. Some are in the FSAR, some are not, some Dr. Brune has read, some he has not.

May I ask you, I gather that your primary preparation for this immediate cross-examination was in reading the testimony?

MR. BRUNE: Yes, plus some of the references to the FSAR.

JUDGE KELLEY: But basically the focus was on the testimony, and so the record is clear, the question here is under 2.733 of the Commission's Rules, which provides for examination by experts, and sets forth certain criteria.

I think obviously the more material you read, the better position you are in to conduct a cross-examination, and as we go on, and if you are going to do a lot of this, I am going to grant this motion, and I think you are in general very well qualified to conduct this examination, based on your credentials, but I would urge you to read the exhibits and study them, as well as the testimony, by way of preparation.

MR. PIGOTT: If my objection could be noted?

JUDGE KELLEY: Your objection is noted.

MR. CHANDLER: Mr. Chairman, before Dr. Brune undertakes to do whatever cross-examination he may, I have a couple of questions which I would like to ask Dr. Brune, just for purposes of clarification, with respect to a statement he made during the brief voir dire by Mr. Wharton.

JUDGE KELLEY: Go ahead.

MR. CHANDLER: Thank you.

Dr. Brune, I believe you indicated that you are currently serving as a principal investigator on a number of contracts and grants funded by the United States Geological Survey and the National Science Foundation, which pertain to earthquake hazards in Southern California, Northwest Mexico.

Do any of these activities or efforts entail a relationship with the USGS which involved review of the San Onofre Nuclear Generating Station Application for Opperating License?

MR. BRUNE: No, it did not.

MR. CHANDLER: And have you in the past, in connection with any -- well, let me ask you:

Have you had any prior relationships with the U. S. Geological Survey, other than those that you are currently involved in?

MR. BRUNE: No.

MR. CHANDLER: I have no further questions, Mr. Chairman.

JUDGE KELLEY: Proceed.

CROSS-EXAMINATION

BY MR. BRUNE:

Q Mr. Heath, I would like to begin with attenpting to understand the context of your testimony, in terms of the offshore zone of deformation and the potential for a large earthquake, in particular, how it fits into the conclusion from the SER. We had discussed previously the first part of that, and I will quote that:

"The present evidence indicates an extensive linear zone of deformation at least 240 kilometers long, extending from the Santa Monica Mountains to at least Baja California. We and our consultants consider this zone of deformation to be potentially active and capable of an earthquake whose magnitude could be commensurate with the length of the zone."

First of all, do you agree that the OZD is capable of an earthquake whose magnitude is commensurate with the length of the zone?

A I don't believe the length of the zone has very much to do with the maximum magnitude that could be assigned to the zone. It is a zone of deformation; it is not a fault zone. It has to be looked at as a zone of deformation of segmented faults with interlying folds, not as a throughgoing

Q Are you precluding the possibility then that a rupture could proceed along the three segments that you have outlined: the NIZD, the SCOZD, and the RCZD?

A Are you asking me: A single rupture could go--

Q Yes, proceeding along the full length of the OZD.

Is that the context of your testimony that that could not occur?

A I think that is extremely unlikely. I think we have good geologic evidence that it has not happened since that zone was initiated some four to five million years ago. We have good geologic evidence that there has never been one throughgoing rupture. If it hasn't happend over the last four to five million years, I think it extreemely unlikely that it could happen in the near future.

Q Well, in this context, are you saying that a rupture could not proceed along, say, the NIZD, accompanied by a rupture on the SCOZD, at the same time and the same earthquake, or in what sense are you saying that you could not have a rupture along the full length of the OZD?

A Well, there are several things that relate to this:

One is the zone is characterized by a number of short and disconnected segments. We have very good evidence of the style of faulting for the Newport-Inglewood portion, because of the extensive oil well data, and studies that have been made in that area.

The longest segments along the Newport-Inglewood that you could connect with a more or less throughgoing fault would extend from the area of Newport Beach up to past Signal Hill, maybe including the Cherry Hill Fault. This is a segment that a major portion of which ruptured in 1933.

That fault zone stops to the north, before getting to the Dominguez Hills anticline, and there is no throughgoing fault in that area, and there are several segments as you go north through the Athens-Rosecrans area, and up to the Baldwin Hills Inglewood fault zone in that area.

If a fault ruptured through the whole length of the Newport-Inglewood zone, the 70 or so kilometers, it would have a large magnitude, it would be expected to rupture through the surface over most of that length. The geologic record that we have clearly shows that no such event has occurred on the Newport-Inglewood zone.

Q Well, at this stage, I am not specifically getting into your evidence. I am trying to get the context of what your position is on whether or not a rupture could proceed along the length of the OZD, or some fraction of it, in particular, your interpretation of the word "commensurate," in the SER is, and whether you are in agreement with it. That isthe main point I am trying to establish now, that is, do you agree with the statement, and if you do or don't, what is your interpretation of the meaning of the word "commensurate"?

A Well, I can't disassociate my opinion with the geologic facts as I know them along the zone. My interpretation of the statement "commensurate with its length," would mean that we would consider the whole fault, and -- pardon me, I almost made a mistake -- the whole zone of deformation, and look at the whole zone, not exclude any part of it, look at the potential all the way along the zone. Of course, in particular, we are looking at what the earthquake potential is opposite the site, but not limit ourselves to that, look at both ends, so to speak, of the zone as well.

That is the way I would interpret "commensurate with its length." I can't interpret it as a fault of so long, because it is not a throughgoing fault. It is a zone of faults and folds.

Q All right, then youinterp[illegible] the word "commensurate" to mean that when it is stated that it i[illegible]pable of an earthquake whose magnitude could be commensurate with the length of the zone, you mean that some fraction of the zone will be taken and the rupture will be assumed to occur along some fraction of the length, but not the whole length.

A That is correct.

Q I am a little unclear about your response to the question I asked as to whether or not a rupture could proceed along the NIZD, the Newport-Inglewood Zone of

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Deformation, and the South Coast Offshore Zone of Deformation, during one earthquake. You said it was improbable, but could you clarify that a little more?

A Only the fact that I feel it is improbable, there is very little evidence of throughgoing faults through the area where one would want to connect these two zones, across the offshore extension of the San Joaquin Hills high. We do not have evidence, strong evidence, or as I know it, evidence of a throughgoing break, which would directly connect the north end of the SCOZD with the south end of the NIZD.

Also we see that the Newport-Inglewood Fault breaks up and splays out towards its south end. Some of the traces head towards the San Joaquin Hills and appear to die out. Several of them do trend in the offshore area, but the amount of displacement along the fault is being divided up by these -- taken up over several faults as it splits up at the south end.

Q Then is it possible -- We will go away from the word "probable," and say: Is it possible that there is a throughgoing zone at depth - well, let us take those two alternatives:

First of all, that there is a throughgoing zone which could rupture at depth along both the NIZD and the SCOZD?

MR. PIGOTT: I am going to have to object to the

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form of the question. I don't want to object too much on the forms of questions of persons who are examining in the capacity of Dr. Brune, however, the use of the word "possible," in an unrestricted context, I think has the possibility -- to use the bad word -- of ambiguity, and certainly a lack of meaning. I think we have to have some kind of a standard of reasonableness, or including any unreasonable end of the spectrum, but it is just vague and uncertain the way it is phrased.

JUDGE KELLEY: It has been pretty vague and uncertain for three days now, in this very area, it seems to me, reasonable, credible, likely. We have been trying to nail these things down, and that is important. I don't mean to make light of it at all. If we could come up with some lexicon that everyone agreed on, particularly the experts, we would be in much better shape. One fals back on English meanings, for lack of any defined term-of-art definition.

MR. PIGOTT: For purposes of this examination, Mr. Chairman, if the questioner would give us his interpretation of the word "possible," I am sure that we would at least attempt to adopt that meaning to the word when responding to his questions, but that -- it is the two ships peerless, passing in the ocean--

MR. BRUNE: Could I rephrase the question?

JUDGE KELLEY: Why don't you try that, yes.

MR. BRUNE: I can rephrase the question so that it probably avoids--

JUDGE KELLEY: With perhaps a self-contained portion, explaining a bit about what you mean by the word that is used.

BY MR. BRUNE:

Q Could you, yourself, define what you mean by "probable," in this context?

MR. PIGOTT: I don't think that is -- Well, I am sorry, have we struck the last question, and then gone on to a separate question of the witness's definitions?

JUDGE KELLEY: Well, you had your question about a throughgoing zone and its possibility.

MR. BRUNE: Yes.

JUDGE KELLEY: I think it is unfair to ask this witness what he means by "probable," without reference to let us say a line of his testimony where he used the word. I think we just need to tie these things down as much as we can. Perhaps with that kind of guidance you could have another try at it, perhaps the prior question in some slightly altered form.

MR. BRUNE: I was referring to his use of the word "probable" in his answer to my question, or "improbable," when I asked him whether or not there could be a rupture along the three zones, and he said it was highly improbable,

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I believe was the quote. We could go an look at it.

I don't want to belabor this point.

BY MR. BRUNE:

Q Can you help us out in this respect?

A I hope so.

I used the word "improbable," because I think it is probable that -- it is most probable -- maybe we could use that one -- that earthquakes will occur on faults in the areas where they have occurred in the more recent past.

We have a well-defined fault zone at the south end of the NIZD that I described a minute ago. If an earthquake was to occur in the general area, it is more probable that it would occur there than further south, where we do not have a well-defined fault zone, but we have a fold structure that may have some faulting in it, that is the San Joaquin Hills High. Therefore it is improbable that it would break through there.

That is what I am trying to say. There are more probable areas that we would expect fault rupture, and some areas where we would not. We might expect folding, or something other than faulting.

Q Okay, I believe I understand you. In that context you are saying it is more probable that it would rupture somewhere else, and that is the sense in which you meant "improbable."

A Yes.
Q Could I go to Page 5 of your testimony?
In your answer to the question on Line 12:
"What is the purpose of your testimony in this proceeding?"
"One of the issues in this proceeding is whether based on the geologic and seismic characteristics of the OZD, including its length, assignment of MS 7 as a maximum magnitude earthquake for the OZD..." and we have heard the rest of the words.
I specifically refer to the -- in your answer -- the phrase "including its length," and in order to understand the context of what is going to follow, I would like to proceed to the figure in the FSAR, in 36138-1, which is Professor Shlemon's curve of plotting earthquake magnitude along the bottom, as a function of length of surface rupture along the fault.
Do you have that figure?
A Yes, I do.
Q In this context, could you explain to the Board how in practice you go about using, as you did in your testimony, using this kind of curve to estimate the magnitude for a given length of surface rupture assumed?
A All right, you start out by quoting an answer to a question, where on Line 15 i use the term "including its

length." This was in reference to the commensurate length discussion we had a little while ago. We are considering its length, as I discussed earlier, to include all of the zone, to look at all of the portions of the zone. That is what the length means. We are going to look at it from the north end up by the Santa Monica Mountains, all the way down to where it goes offshore in the San Diego Bay Area. It is a zone of deformation.

Dr. Shlemon's curve that you refer to in Figure 361.38-1 is based on the length of surface rupture. Certainly the OZD does not have a surface rupture length even commensurate with its length. It has only short segments of surface rupture. So it is not appropriate to apply the length of the OZD to an analysis such as that presented by Dr. Shlemon, and commonly used. It is known as the half-length method or the third length. We are not dealing with a throughgoing fault.

Q In your testimony, you have used this curve, however, to associate lengths along segments and so forth with magnitudes, is that not correct?

A That is correct.

Q Okay, could you explain for the Board, how you -- what the procedure -- At this time I am just trying to get how you assign a magnitude, based on this figure here.

Suppose, for this context, that the length is given, as it is later on in your testimony. You have certain lengths. The length is given, now how do we find the magnitude?

MR. PIGOTT: Excuse me, just for clarification, this is a question without relation either to a length of the OZD or any other particular fault, but simply how you would use this figure, is that correct?

MR. BRUNE: That is correct.

MR. PIGOTT: Okay.

WITNESS HEATH: I think the figure as it is commonly used, and I think its recommended use by Dr. Shlemon is simply to make an estimate of what you would expect the surface rupture length of an earthquake that you are trying to evaluate, a future earthquake. If you can estimate what the surface rupture length might be, from that expected event, then you can go to this curve, and you have to know, as he shows here and explains in this paper that this curve came out of, that different styles of faulting have different surface rupture length magnitude relationships.

Therefore, you have to define the style of faulting, such as on this curve. He has the "A" curve represents the regression line through the normal slip fault data, and on down, so you define the type of fault that you are dealing with, go to the appropriate line. You can simply read across from the estimated surface rupture length that you anticipate, over to its intersect with that line,and then drop down to the earthquake magnitude scale. Reading the curve that way, you get an estimate based on the data base of what the magnitude might be of the earthquake.

Q In the present proceedings, and in your testimony, you have used primarily Curve E, is that correct, for strike slip earthquakes?

A Yes, I have.

Q Now, as we look at this figure, we see a large number of points varying off of the curve, and if we select out, for example, those points which have an "E" after them, which are the ones, I believe, that were used to get the E Curve, is that correct?

A As I understand it, yes.

Q We see that they vary quite a large amount off of the curve.

Now, the procedure you just explained,you look at the length of rupture, go across to the line, and read a magnitude off of the line itself. Now, this procedure does not take into account the possible scatter in the data around that line, is that correct?

A No, it gives you a mean number.

Q It gives you a mean number.

Does the mean number mean that approximately that

50 percent of the time, or 50 percent of the data points, the magnitude will actually be greater than the value you read off the curve?

A I believe that that would be the appropriate way to state that,if the data set is valid.

I would like to point out that the data set is derived from a worldwide data base,and even Curve E is developed using strike slip faults all over the world, some of which may be similar, and some of which may be different from whatever fault you may be looking at. So I think it is wise to look at the data base itself, and determine what faults are used in the data base, rather than going to a statistical analysis, just accepting the data base, and say well, we will take one standard mean deviation, or something like that.

Q Well, in this particular case, you, in your testimony, used Curve E, is that correct?

A Yes.

Q Now, in estimating the magnitude for a given fault length in this manner, would you say that the value which you come up with, with you have called the mean value, is also a conservative value?

A Taken strainght across the board, not relating this to -- Let me ask: Are you referring to the work that we have done relating to the OZD, or is this still another general question on the use of the curve?

Q This is a general question on the use of this curve, but in the context of the places later on in your testimony where you have used this curve to assign a magnitude for a given length.

A The conservatism in use of the curve comes from the fault length or the surface rupture length that you assume going into the curve. The conservatism doesn't come from the use of the curve itself.

Q In this context, is it true that if you picked a certain length of fault segment, and go to the curve for magnitude based on that fault segment, if we now assume that the actual fault ruptured that distance, whatever it numbered, hypothetically let us say 62 kilometers, as Shlemon did in the SER. If we take that and assume that as the length of rupture -- so that is no longer in question. Then based on that length of rupture, we estimate a magnitude which is, as you have stated, the mean magnitude in which in that data base 50 percent of the earthquakes which had that same length would have higher magnitude, in that context do you define the magnitude as conservative? In other words, corresponding to the mean estimate?

A No, as I said before, the conservatism comes from accepting the--

MR. WHARTON: Mr. Chairman, I would ask the Board to direct him to answer the question. Mr. Brune has aksed him twice, and he has not yet answered this question.

MR. PIGOTT: How would we know, until he finishes the answer?

JUDGE KELLEY: Go ahead.

I will give the witness an opportunity. I also think the question was very long, and I thought rather hard to understand.

Go ahead.

WITNESS HEATH: I think I understand the question, but it is very complicated, and it is not really a yes-or-no question.

I have already stated that I don't believe there is any conservatism built into the curve, so if you just took a number and went through the curve, it would not be conservative.

MR. BRUNE: Okay, that is what I was trying to get at.

MR. PIGOTT: Excuse me. Have you finised your answer? Has the witness finished his answer?

WITNESS HEATH: No, I was going to again emphasize that the conservatism that is commonly used in here is to accept a long or a conservative surface rupture length, an use that in the curve, if that is where the conservatism comes. You know, commonly this curve is used on faults where you have a well-defined length and you can take half length rupture, realizing that most faults rupture less than half length. You can take a conservative length and go into the curve, and you come out with a conservative estimate.

BY MR. BRUNE:

Q In that procedure, which I believe is the procedure that Dr. Shlemon used in the SER, is that right?

A He used several procedures. I am not sure which one you are referring to.

Q But in that procedure, if the value you end up with corresponds to a curve in which still most of the data on the magnitudes falls to the right of the curve, would you still use the word "conservative" for that?

MR. PIGOTT: I am going to object. I think the question has been asked and answered that he did not consider a simple application of these curves to be conservative. It is a misconstruction, I believe, of the witness's testimony, which is objectionable.

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JUDGE KELLEY: I would like to have it read back. Could you repeat the question?

(The reporter played back the requested question.)

MR. WHARTON: It is a different way of asking the question but it's not the same question.

JUDGE KELLEY: Go ahead. Answer the question, please.

THE WITNESS: It's not the same question because he said you have a curve where most of the data falls to the right of the curve. I think we're dealing with a curve where half of the data falls to the right and half of it falls to the left.

If that is the question, then I would say, if you go in with a conservative length, you come out with a conservative answer, yes.

MR. PIGOTT: Mr. Chairman, this witness has now been on cross-examination, I think, a little over an hour and forty minutes.

JUDGE KELLEY: I think my mind is on the same track.

We will quit for 15 minutes. It's 10 after 3:00. We will come back at 25 after.

(Brief recess)

JUDGE KELLEY: Back on the record.

Dr. Brune.

BY MR. BRUNE:

Q I'd like to finish understanding exactly how conservatism is built into the procedure for estimating magnitude from rupture length.

To make it concrete, could we go to your testimony, Page 21, Line 23 and 24, "The longest segments of each of the OZD ranges from 27 to 48 kilometers," and, if you assume full rupture length and obtain an estimate of maximum magnitude from Shlemon's supra relationships, you get magnitude ranges from 6.6 to 6.9.

I believe I understood from your previous testimony that you are saying that all the conservatism that's necessary is already built into the 48 kilometers. So, in your opinion, one does not have to add any more conservatism; is this correct or not?

A I don't think I made the statement that it was all built into the 48 kilometers. That hasn't come up yet. I mean you're bringing it up now but I didn't make that statement.

Q To begin with, does the 48 kilometers include all the conservatism that you wish to bring into in estimating the magnitude for that rupture length?

A Yes.

Q So what would the rupture length be that you were assuming could occur before you increased it to take into account that conservatism?

A The 48-kilometers zone is the maximum map subsurface length of the Rose Canyon Fault, the offshore portion near Oceanside till it comes onshore and down in, I think -- including the Old Town Fault. That is a subsurface length: that is the total length of the map zone.

Conservatism comes from assuming that you could have surface rupture over that entire length and it would all rupture at one time.

Q Okay. Just to be completely clear. If, in fact, that did occur, that there was now this conservative situation that did occur, that a rupture occurred along the full 48 kilometers, now you have proceeded to use Shlemon's curve to estimate a magnitude of 6.9; is that correct?

MR. PIGOTT: Excuse me. Are you asking the witness to assume a surface rupture of the full 48 kilometers to be applied to the curve?

MR. BRUNE: I'm asking him to associate -- to tell us the procedure he used to associate with the 48 kilometers a magnitude of 6.9.

THE WITNESS: The way it was used is we said we have subsurface information to show that we have never had a rupture longer than that, and, therefore, this is limiting. You can't have a surface rupture longer than that, longer than the subsurface rupture. And this is also saying that, essentially, in the last several million years we have not had a rupture any longer than that. Therefore, we would not have one in the future. So we have taken the maximum length of that zone as a conservative length and gone into the curve and have come up with an estimate from the curve in the manner that I described earlier.

The conservatism is built in in assuming that the entire thing might have ruptured in the past because we are talking about events here rather than predicting future events, and that the thing could have ruptured to the surface. We don't have evidence that it ever did rupture to the surface. So, in assuming the total length, you have really a couple of layers of conservatism built into the length that you go into the curve with.

BY MR. BRUNE:

Q Well, now, if we assume that, in fact, it did rupture, the full 48 kilometers, and then go and use Shlemon's curve to estimate the magnitude which would correspond to that rupture, the number you have come up with is the mean curve; is that correct?

A That's a compound question.

Q It's a hypothetical question.

A "If we assume, and then the number you came up with" -- either assume it or ask me what I did.

Q Okay. A hypothetical question. If a rupture of

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48 kilometers occurred, based on Shlemon's data, what would you estimate to be the magnitude corresponding to that?

A That would be 6.9 off of Shlemon's curve.

Q Okay. Would that be the mean value that Shlemon associates with ruptures of that length?

A The way his curve is constructed and to use his curve, it would be.

Q This means then, does it not, that, in his data set, 50 percent of his data have higher magnitudes then the curve with the same slope going through that point?

MR. PIGOTT: I'm going to object on the grounds that it is argumentative. I believe we have spent many minutes and many questions establishing that there are certain elements of conservatism in the way that this witness has used the data before applying it to the Shlemon's curves, even for comparative purposes, and the question posed by Dr. Brune, I believe, misconstrues that testimony in order to arrive at some result that he apparently argues to be the appropriate method. I believe it's an argumentative question.

MR. WHARTON: Mr. Chairman, we've gone through this testimony and each one has been leading one step after the other after the other and this is the ultimate question:

"Using your data, using Shlemon's method, come up with a mean. Does that mean 50 percent or more?" That's a very simple question and it's straightforward.

JUDGE KELLEY: There seems to me to be a logical progression in the questioning.

Does this carry you, then, to the end of this particular line of questioning?

MR. BRUNE: Very close to it, yes.

JUDGE KELLEY: All right. Go ahead.

MR. PIGOTT: Is the question in mi[illegible], Mr. Heath?

THE WITNESS: No, it isn't. [illegible] guess I'd like it restated or repeated because I don't know whether we're talking about a hypothetical use of the curve or actual --

BY MR. BRUNE:

Q I'm talking about a hypothetical case where there [illegible]as actually a rupture of 48 kilometers based on Shlemon's data.

The value you came -- not that you came up with but the value that one would associate with it by Shlemon's curve is a mean value and that means that 50 percent of the data from a large population would be higher. This is a hypothetical question.

A That is correct.

Q Okay. That's the end of that.

I would like to direct your attention to Page 6 of your testimony, Line 8, and your identification of MS-7 as the most conservative maximum magnitude for the OZD.

Do you know of any other people who have studied

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the OZD and have come up with a larger magnitude or have studied parts of the OZD -- for example, the South Coast Offshore Zone of Deformation have come up with a larger magnitude than 7.

A Yes, I do but that is not the context of this statement that you read to start this question off with. The context there is the most conservative maximum magnitude that we can estimate, not that anybody can estimate.

Q Could you tell me who these people are who have a larger magnitude?

A Well I certainly don't know all of the work that has been done by others in the way of making estimates along there. I'm aware of several reports that have been done. One was by Woodward Clyde. We made a study of a number of LNG sites along the coast of California; one of them was at Camp Pendleton. Estimates were made during that study of the earthquake potential at all of the different sites and the standard methodology used for that was for comparative purposes, and the half-length method, as proposed by Shlemon, was used. If you apply the half length just unrestricted to the OZD using the 240 kilometers that was originally recommended or defined as by the U. S. Geological Survey, then you come up with a 7-1/4 estimate and that estimate was listed in the LNG Report.

Q I believe I have this LNG Report in my hand.

It's called Geotechnical Evaluation of Potential Island and Offshore California LNG Import Terminal Sites; is this correct?

A I believe so.

Q Okay. On Page --

MR. WHARTON: Mr. Chairman, we would like to identify that exhibit as Intervenor Carstens. I believe it will be number 1. I believe at this time, if there is no objection, there is sufficient identification of that document to introduce it into evidence.

MR. PIGOTT: I'm sorry. Who is proposing this document?

MR. WHARTON: Intervenor Carstens.

MR. PIGOTT: Carstens as your witness or --

MR. WHARTON: No. We don't necessarily have to have --

MR. PIGOTT: What witness are you having sponsor this exhibit?

MR. WHARTON: The witness has identified this particular document as being the Woodward-Clyde Report that he had just testified to.

I think under the circumstances of the case and the way it has been proceeding so far it's appropriate to introduce that particular document into evidence.

MR. PIGOTT: I'm going to object.

MR. CHANDLER: Before objecting, Mr. Chairman, I'd like to know if the Intervenors will provide the Staff with a copy of that report in accordance with the regulations of the Commission.

JUDGE KELLEY: Do you have copies?

MR. WHARTON: I will get copies. I can identify it at this particular time. I don't have further copies. If it's agreed to be admitted into evidence, I can provide the copies tomorrow morning.

MR. PIGOTT: I object simply to the procedure being rather beyond what's contemplated in the rules, i. e., providing the parties with the exhibits and the appropriate numbers to the Board and so on. And, to simply read in a title and then expect it to go directly into evidence, I think is a little bit presumptuous. You haven't given us the exhibit. You have not identified whether or not you want to use the whole document, what portions of the document. Just waving it and asking it to go into evidence I think is not an adequate basis.

JUDGE KELLEY: The objection is sustained.

I think that the parties should have an opportunity to at least take a look at this document before we get to its admission.

You can refer to it for purposes of cross-examination. It would not be in evidence.

BY MR. BRUNE:

Q I am reading from Page 1-6 of this report: "The South Coast Offshore Zone of Deformation lies approximately three miles southwest of this portion of the site." and that is referring to a section on offshore Camp Pendleton.

MR. PIGOTT: Could I at least ask, if we are going to cross-examine the witness on a document, that he be provided with a copy of the document and that I be allowed to review what is being used for cross-examination?

JUDGE KELLEY: That certainly seems fair.

Will you have copies of this by tomorrow morning?

MR. WHARTON: Yes. I can have copies of it tomorrow.

JUDGE KELLEY: Could you defer this portion of your examination, then, pending the time when others can see what you are referring to?

BY MR. BRUNE:

Q Are you then aware of others besides this particular study that have come up with larger design earthquakes or maximum earthquakes for the OZD than 7?

A Are you talking for design purposes?

Q In any context. The estimated magnitude that could occur along the OZD.

MR. PIGOTT: Excuse me. I'm not trying to

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belabor this, but are you talking about everywhere from the south end of the Rose Canyon through to the San Gabriel Mountains or to the --

MR. BRUNE: Yes, inclusive. At any point along the OZD.

MR. PIGOTT: All right. Before you had asked about the SCOZD; that's all.

BY MR. BRUNE:

Q Are you aware of any other studies that have come up with magnitudes either in the design context or in some other context for the OZD that are higher than 7?

A Yes. I believe there's an environmental report put out by the Orange County -- I don't recall the complete name of that. I believe they came up with an estimate of 7.5 for that on the OZD.

Q Is that the only other one that you are aware of?

A There's a FEMA report that evaluated some major earthquakes for public safety purposes, as I recall, and I believe they used a 7.5 magnitude.

Q That was 7.5?

A I believe it was 7.5. But neither of these are design documents. They're estimates and the FEMA report did not state how they arrived at that. And they actually -- well I don't remember the wording. I don't know if we have a document here of that, but they did provide a disclaimer in there saying that this estimate was not for design purposes and that, if structures were to be to design, they should have special studies to establish what the maximum magnitude should be used for design. While estimates have been made, it's a big difference just making an estimate and then actually coming up with one tha is to be used for a particular site and a particular design, a particular type of facility.

Q Could you explain that difference?

A Well, certainly. If you're going to design a structure at some particular location, you look at the site conditions and you also look in a greater depth into what the hazards are. If it's earthquakes, you look at much greater depth as to the study. You don't make just a quick analysis off of a curve such as Shlemon provides for that purpose. You don't just measure a fault, divide by 2 and look it up. This is commonly done in studies where you want a first approximation of a magnitude but you're not using it for design purposes. It doesn't have to be super accurate.

Q Are you aware of a report made to Stewart Udall on the Bolsa Island plant?

A I'm aware of it, yes.

Q Do you know what magnitude they assigned to the NIZD in that report?

A I believe they --

MR. PIGOTT: Excuse me. Could we have an

13 identification of the report being referred to precisely?

MR. BRUNE: This is Geological/Seismological Factors Pertaining to the Proposed Construction of a Nuclear Power Desalting Plant at Bolsa Island, California, a report to Stewart L. Udall, Secretary of Interior, dated October, 1967.

JUDGE KELLEY: I suspect this could raise a similar problem to the one we just talked about except that, in the context of discovery a month or two ago, a question was raised about what we'll call the Bolsa Island Report, and the Board asked the staff for copies; we were given copies.

Mr. Pigott, do you have a copy of that report?

MR. PIGOTT: I don't have a copy of it here. I'm sure we have it in the audience and will be available if there's some questioning on it. I don't know where they're going with it yet, Mr. Chairman.

MR. WHARTON: I believe at this point the question is very general on the Bolsa Island Report.

A detailed question will be will he have enough copies?

MR. PIGOTT: Well perhaps I could see if we can wrestle a copy up here.

JUDGE KELLEY: Could you hold a moment at least until they get a copy?

Is there something else you could move to and then come back again to that perhaps, the Bolsa Island question?

MR. BRUNE: Well, at this stage I was merely referring to it for the purposes of identification.

JUDGE KELLEY: Right. We have the title in the record.

BY MR. BRUNE:

Q So, in that report, they came up with a magnitude of what?

A Eight.

Q Magnitude 8.

JUDGE KELLEY: Does the witness have one now? Is that what --

MR. PIGOTT: He is now supplied with a copy.

JUDGE KELLEY: Well go ahead, then, why don't you, with the questions that you have.

MR. BRUNE: Okay.

BY MR. BRUNE:

Q Is that a design earthquake, to your knowledge?

A I don't know if it is design. I think it was a recommendation that magnitude 8 be considered for the design. I don't know -- the design, as I understand it, was to be based on the ground acceleration that was also recommended at that time and that was .5 G's.

So the ground acceleration level there was

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relatively low for what we would consider a magnitude 8 event. So I'm not sure if magnitude was the important thing. It seems to me that the ground acceleration was what they were really going to consider for design and that was really only a half a G, which is lower than what we were considering here for the San Onofre site.

Q I'm referring specifically to the possibility of a magnitude 8 earthquake. Do you feel that it is safe to assume that the people that wrote this report at least themselves thought that a magnitude 8 earthquake was possible?

MR. PIGOTT: I'm going to object to calling for speculation as to the intentions or the assumptions of the committee that drafted that report.

JUDGE KELLEY: Sustained.

BY MR. BRUNE:

Q Given that they did come up with a magnitude 8 earthquake -- and we don't know for sure right now whether it was a design earthquake or not -- how does this fit in the context of your use of the word "conservatism"? Let me pursue that line. It's more conservative than magnitude 7, I presume; is that correct?

A Outwardly it would appear so, yes.

Q Do you feel that it is too conservative in some sense?

A Yes, I do. You have to remember this report was put out in 1967. The work leading to it was done prior to that, so we're looking at something that was developed maybe 14, 15 years ago. They make some statements in there that they don't know very much about the zone, the deformation, that they are applying this to, and they said, "Therefore, by necessity, we must be very conservative and consider a large event -- I don't think they used the word commensurate but in accordance with the possible length of this." And, at that time, they had in mind, as I understand, relating it to another long zone, such as the San Andreas, in equating it to a magnitude that would be comparable to something like the San Andreas Fault.

As I have already stated, I think that there's a vast difference between the Offshore Zone of Deformation and the San Andreas. So I would say 8 would be way overly conservative.

Q Overly conservative?

A That's --

MR. PIGOTT: I believe he said way overly conservative, if you want to hang on words.

BY MR. BRUNE:

Q Way overly conservative.

We've spent a lot of time with this, but could you explain how it fits in the context of your statement of "most conservative" when you said that magnitude 7 was the

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most conservative.

A Well we have spent several years studying this Zone of Deformation.

Since the time when the Bolsa Island Report came out, there's been a number of earthquakes. There's been a lot of recording. There's been a vast multiplication of the data base. We've had a lot of reports out by Bonilla and Buchanan on fault magnitude relationships, the state-of-the-art paper by Shlemon and others. So our data base and our knowledge of how to use the data base has improved immensely.

We have looked at all of the techniques, I think, by including the degree of activity approach. We brought it up to the state of the art as it is today. This information leads me to the conclusion that magnitude 7 is a conservative maximum magnitude and that 8 is unrealistic.

Q You mentioned the FEMA report which came up with a magnitude 7.5 but not a design magnitude.

Are you aware of USGS Open File Report 115 which also estimated a magnitude?

MR. PIGOTT: Could we have a more specific identification or a specific identification?

JUDGE KELLEY: Can you read a specific title into the record for that?

MR. BRUNE: I'm reading from a report from the United States Department of Interior and Geological Survey.

"Scenarios of Possible Earthquakes Affecting Major California Population Centers with Estimates of Intensity and Ground Shaking by U.S. Geological Survey, Open File Report 81-115, 1981."

MR. PIGOTT: Thank you.

BY MR. BRUNE:

Q Have you seen this report?

JUDGE KELLEY: Could I just ask for the sake of clarity -- could you tell me what an "Open File Report" is?

MR. BRUNE: I believe I can explain that.

JUDGE KELLEY: Oh, fine. Would you?

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MR. BRUNE: I did not read the complete title. At the bottom of the front page, it says, "this report is preliminary and has not been review for conformity with US Geological Survey editorial standards."

JUDGE KELLEY: So it is a draft.

MR. BRUNE: That is right. The open file means that it has been made available to the public for their use.

J ::: KELLEY: Okay, but it is sort of preliminary draft form type of a report?

MR. BRUNE: Well, it could be the final report. It has a disclaimer at the bottom. That is what makes it -- the difference. It has been made available to the public, and they can use it whatever they want -- in whatever way they want, but the disclaimer at the bottom means, don't hold us to our normal standards.

MR. PIGOTT: I only passingly object to the characterization of Dr. Brune. Not that I think he is trying to be incorrect, but I have a feeling that it may be incomplete. I think perhaps when we have USGS people here, it might be well worth while to find from them the very --

JUDGE KELLEY: Fine. That is something -- this afternoon, and we will get it from the source when the time comes.

BY.MR. BRUNE:

Q I read from that report. The title of this section is "Magnitude 7.5 earthquake on the Newport-Inglewood fault zone, Southern California." The next heading reads, "characteristics of earthquake to be expected." An earthquake of magnitude 7.5 can be expected to be produced by a 110 kilometer rupture along the Newport-Inglewood fault zone. The 110 kilometer length would integrate both offshore and -- onshore and offshore reaches of the fault zone.

Horizontal slip of approximately three meters can be expected to be distributed over an area as wide as three kilometers. The postulated break on the fault zone would be at least twice that of the 1933 rupture.

In your opinion, is the magnitude 7.5 earthquake also too conservative?

MR. PIGOTT: I am going to object. I really don't think that the reading of a paragraph, apparently almost a full paragraph, there are several sentences of highly technical material, in a very brief cryptic way, without the full context of the report before the witness is an appropriate way to ask for an expert opinion with respect to those conclusions.

JUDGE KELLEY: Let me ask the witness whether -- are you familiar with this report? Have you read it before?

THE WITNESS: I am not sure. He identified it by a number, and I don't know that I recall that number. I would have to ask, is that the report that is essentially the same as chapter 2 in the FEMA document?

MR. BRUNE: I am not sure, but I believe it is.

BY MR. BRUNE:

Q I mean I -- you don't know yourself whether it is or not?

A I don't recall the number of the report, so I really don't know which report you are holding in your hand.

Q Okay. Then you are not sure that you have read it.

A That is right.

MR. PIGOTT: Well, I think with this identification, nobody can be sure what you are referring to.

JUDGE KELLEY: Well, let me say then that we have already put over until tomorrow cross-examination on one document, and it seems to me that it may be a short time at that, but at least you could look it over and be better positioned to respond to any detailed questions on it after you have had a chance to do that, so why don't you just pass on over to your next set of questions?

BY MR. BRUNE:

Q On page six, line 9, after stating that the most conservative maximum earthquake is MS-7, you state a larger earthquake is inconsistent with the geologic and seismologic features of the OZD. I would like to -- could you amplify on the use of the word "inconsistent" in this context?

A Yeah, we -- we looked at the geologic record as it is recorded in the layers of earth that have been laid down for the last four to five million years, and we have seen the lengths of ruptures that have occurred along the zone. We have looked at the geomorphic evidence at the surface and the amount of deformation that has occurred, and evidence of surface ruptures.

Without going into a long explanation of all of this, summing up all of the geologic information that we have, we see no evidence that these sediments have been disturbed by an event as large as 7. Therefore it is inconsistent with this, these geology parameters, that we could have something larger than 7.

Q Just to be sure about the context of this, are you referring to one magnitude 7 that could have -- only one and no more that could have ever occurred or are you referring to repeated magnitude 7's? In other words, are the features inconsistent with the occurrence of just one magnitude 7 or are you stating that they are inconsistent with repeated magnitude 7 earthquakes?

A Well, that is very difficult to say. There are really no absolutes in this world. It is certainly inconsistent with any multiple events such as that. We don't know of any displacements, fault lengths -- I should say fault segment lengths -- that would have allowed anything as

5 large as 7, so you could say it doesn't appear that there has ever been one, but that is a fairly absolute statement, and I am not sure you can say -- it is like saying never, it could never happen.

But there is no -- nothing to indicate that one has ever occurred that large.

Q Is it your testimony that the evidence, however, is sufficient to preclude such an event having occurred?

A I think that is what I mean by inconsistent with it, yes.

Q In this context, it precludes ever having even one magnitude 7?

A Well, with a slight reservation, of, you know, never having had one.

Q You state on page 6 line 23, that the rupture length versus magnitude method alone is not appropriate based on the uncertainties in the data base available for the OZD. Could you explain what you mean by the uncertainties in the data base which preclude the use of that method?

A Well, we don't have very good evidence of displacement per event, for instance, along the -- anywhere along the OZD. That type of data has not been developed. A fault that has as low a slip rate as the Newport-Inglewood and apparently the rest of the OZD doesn't produce much in the way of surfacial features or disturb the Quaternary geology

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enough that you readily obtain data on displacement per event, so the application of that methodology, I think, is fairly restricted here.

The similar thing might be said about the fault length methodology. And one thing in particular that the standard application using half length is not applicable, because of the segmented nature of the zone. Again, we don't have evidence of -- good evidence of surface rupture along a large portion of the zone.

If we did, we might be able to show that the surface ruptures were quite limited, and that smaller magnitude events were more common to the zone than large events. We don't have that type of data. We therefore have to rely on subsurface data, either from drilling along the Newport-Inglewood or the offshore seismic profiles on the SCOZD. These are limitations to the application of either of these methods.

Therefore, we are saying you shouldn't look at just one of these and come up with a number and fly with it. I am saying you should look at all available methods and try to put the data together and come up with a consistent number, something that is consistent with all of the methods. That would then, I think, be an appropriate way to estimate it, or appropriate magnitude that you would come up with.

Q If it were not for the special difficulties with the OZD, what is the -- in your opinion -- a standard way that we would attempt to estimate a magnitude for the fault?

A Well, I hate to say what a standard method is. I know from reading the reports that we have talked about here and others around, that quite frequently the half length method as defined by Dr. Shlemon in his state of the art paper is probably the most commonly used method, but it has a lot of shortcomings, and in looking at something as significant as a nuclear reactor, I don't think you can rely on that just because it is the easiest and the most common method.

We have looked at that method. We have fully evaluated it. We have tried to apply it where it is applicable to the offshore zone of deformation, but we have looked at all other methods that we can to add to that, and see if we can't establish some consistency.

Q Are any of these other methods that you refer to, are they methods that you would call standard methods, in cases other than the -- a case like this with the difficulties of the OZD?

MR. CHANDLER: Mr. Chairman, I would like to ask for some clarification. The prior question as well as in this document refers to difficulties and special difficulties with the OZD. Could we have a definition from Dr. Brune of what he is speaking of?

MR. BRUNE: I am referring to page 6, line 24. The type of uncertainties referred to in the data base available for the OZD.

MR. CHANDLER: I have no objection to Dr. Brune using the word that the witness has used, but I don't believe the witness has used "difficulty" or "special difficulties".

MR. BRUNE: Okay.

MR. WHARTON: Mr. Chairman, just one second. I just got a note from Glenn, and myself, and I think if I were to ask Dr. Brune, we are being a little bothered by the cigar smoke over on the left. It is kind of a long afternoon, and the fellow in the back, if we could just ask that.

JUDGE KELLEY: Motion granted. I am not sure where it is coming from. All right.

BY MR. BRUNE:

Q On page seven -- we will leave that topic for now, the previous one -- on page seven you describe the new method or the method for estimating earthquake magnitude, this is line 7, page 7, line seven, the method for estimating earthquake magnitude is based on comparing the degree of fault activity on the OZD with that of similar faults in Southern California and in similar tectonic environments around the world.

In this new method, or this method that is being introduced, is this a deterministic method in the sense that it estimates the magnitude based on the mechanics of the fault and the mechanics of the observed faulting, or does it include some elements of probabilistic thinking in it also?

A No, it is -- it really is neither. It is based on observing the geologic characteristics that are associated with active faults, comparing these in more or less a ranking procedure, so we are essentially ranking faults based on their degree of activity, and comparing them one to the other, so that -- well, that is the end of my answer.

Q So -- and when you do this ranking and then come up with an estimate of magnitude, that magnitude, does it contain elements of probability in it, in the sense that the magnitude is more likely to occur on this zone because of this degree of activity or less likely, or is it a mechanistic limitation? In other words, are you saying that a certain magnitude greater than 7 can't occur?

MR. P OTT: I am going to object to the form of the question. It is compound and complex. It seemed to be starting one direction, and then went to an "in other words" phrase, which I am not sure what it did to the first part of the question.

JUDGE KELLEY: Could you try simplifying the question?

MR. BRUNE: I will rephrase the question.

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BY MR. BRUNE:

Q In this method, when you come up with a different magnitude for a different zone, based on this degree of activity, is that magnitude -- does that magnitude estimate contain elements of probability in it? Yes Answer. Yes, please answer that question first?

A It does in the -- to the degree that you might say one fault is more probable of having a large event than another fault is. The probabilities are in a comparative nature. The probability is higher that a certain fault would have a large event, than a small -- than another fault, but it is also deterministic in that the -- there are several applications of the degree of activity where based on a large data base of empirical data, we have established a relationship, and we can say that this certain number based on that relationship would not be exceeded.

Q In -- on page 10, line 21, you state that the OZD consists of three tectonic elements, the Newport-Inglewood zone of deformation, south coast offshore zone of deformation, Rose Canyon fault zone.

In a geologic and tectonic sense, what is it specifically that identifies these as segments?

A As separate segments, is that the question, or why are they named such?

Q Yes, why are they called segments?

A Well, they are called elements here because basically we were not trying to segment the zone. The Newport-Inglewood zone of deformation has been well-defined and understood for a number of years. Towards the south end, it splays out, and appears to end. You go offshore a little further south, and there is another zone of deformation. It has some similar characteristics. As we talked about earlier, there is no good direct connection between the two zones.

As you go south in the South Coast offshore zone of deformation, it tends to die out, I think a little bit southwest of Oceanside, and is in an en echelon pattern with the north end of the Rose Canyon fault zone, which then continues on down, and goes onshore in La Jolla.

They are really separated in space, is probably the best reason to refer to them as elements. They have also been identified in the literature separately, by many researchers and geologists.

Q Have you read the testimony of Perry L. Ehlig?

A I think major portions of it, yes.

Q On page 27 --

MR. PIGOTT: Excuse me, whose testimony are you referring to, Dr. Brune?

MR. BRUNE: Perry L. Ehlig.

MR. PIGOTT: I am sorry, let me -- is it more than just a few words?

MR. BRUNE: No.

MR. PIGOTT: Or should I get my copy?

MR. BRUNE: It is just one sentence.

MR. PIGOTT: All right, let us try it then, okay.

BY MR. BRUNE:

Q The OZD was probably part of a system of right lateral faults which formed the Pacific North American plate boundary within the California continental borderland between -- during the middle Miocene.

Do you agree that the OZD at one time was a plate boundary?

MR. PIGOTT: If I could just pause, would the witness like to see that language? That is classic Dr. Ehlig --

THE WITNESS: Not particularly, I think I understand the question.

MR. PIGOTT: Okay.

THE WITNESS: I think it very well could be -- have been in the -- particularly the northern sections, the area of the Newport-Inglewood zone, where we do have different basement rocks on either side of it.

As you go south offshore, the uncertainty becomes greater, and certainly as you get down into the area of San Diego, where we have similar, at least cretaceous rocks on both sides, I think definitely it was not part of the plate boundary in that area. The plate boundary would probably be

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further offshore, so it may coincide, the northern end, with an old plate boundary.

BY MR. BRUNE:

Q And it is possible that the central part could also have correlated with the plate boundary?

A It is possible. We don't really have the deep drilling data there that would be necessary to know if there is a discontinuity in the basement rocks, or a difference in the two basement complexes in that area. We just don't know whether it is in the area under the SCOZD or further offshore.

Q If both the SCOZD and the NIZD had been a part of the plate boundary, would they have been at that time segmented in the sense you are referring to them now, or would they -- the way you used the word segment, would you still use it in that case?

A Well, it is -- I understand the question. It is a very difficult thing to answer because we really don't know what was going on at that time, and we just have several theories, but I would have no problem accepting them being connected, essentially one zone, one major plate boundary at that time.

However, you have to realize that the plate boundary is not always a straight single-fault zone, such as the present plate boundary of the San Andreas San Jacinto faults, Imperial fault further south. It is segmented.

Q But in this case -- you use the word segmented -- they are still connected. Is that right? When you are referring to the Sierra Prieto fault and the other faults you have mentioned --

MR. PIGOTT: Oh, I am going to -- objection. I am going to object to the question as being ambiguous and unclear. I hear a brand-new name being thrown in there, Dr. Brune, in Sierra Prieto, and --

JUDGE HAND: Excuse me, Mr. Pigott. The Chairman is out of the room for a moment, and I am not prepared or able to respond to the objection you are making, so I think we are going to have to go back and recreate it for the Chairman, if we can.

MR. BRUNE: Could I clear up the question, and --

JUDGE HAND: Why don't we take a five-minute break.

(Brief recess)

JUDGE KELLEY: On the record. There was a question on an objection, is that correct?

MR. BRUNE: I will withdraw the question.

JUDGE KELLEY: Very well.

MR. PIGOTT: I will withdraw the objection then.

BY MR. BRUNE:

Q Proceeding -- I direct your attention to page 12 of your testimony, line 15 through 20. The most recent period of deformation along the NIZD appears to have begun contemporaneous with the deposition of uppermost Miocene marine sediments, and has continued at more or less the same rate to the present time.

Is this statement -- does this statement also apply to the SCOZD section south of the NIZD?

A It was not written to include that, but essentially it can. I think that that same statement could be applied to the SCOZD.

Q Thank you. On page 13, a question in a similar vein, lines 7 through 9 --

A Is that 13?

Q Page 13. You cite some evidence which you then conclude suggests that intermittent horizontal displacement has produced an average slip rate since late Miocene. In the same sense, does that statement apply to the SCOZD?

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A Would you give me time to read the whole sentence? It is at the end of a very long one.

Q Okay.

A (Pause while the witness reads.) I really don't know. We don't have that type of data for the SC OZD. We do see some similarities in comparing the style of faulting of the NIZD and the SC OZD. As I point out elsewhere, the model of wrench deformation, as pointed out by Harding in 1973, showing a narrow band of faults and folds in the miocene and pliocene sediments overlying a deep seated right lateral fault, I think is a realistic model. And we see a similar pattern offshore, not in as much detail because of the nature of the offshore geophysical data.

But I think at least my model presumes that you are having a similar type of deformation in the offshore zone, as you are on the NIZD. It doesn't appear to be deformed as much, the folds are not as steep, the flanks are flatter. It looks like there is less deformation. But I don't think it is an unreasonable model to assume that at least some degree of similar deformation is occurring in the offshore zone.

Q You state on page 14, lines 1 and 2, in the context of the SC OZD, that the tectonic style is similar to that of the NIZD but of a lower level of deformation.

MR. PIGOTT: Again, could we have full quotations when we have these references? I mean, that -- picking up the last half of a sentence with really no reference to the subject matter.

JUDGE KELLEY: I think it would be useful to read the complete sentence, unless it runs on at extraordinary length.

BY DR. BRUNE:

Q Starting on page 13, line 24: Local northwest to west trending anticlinal folds in the shallower horizons are also associated with this zone -- and in this case we are talking about SC OZD -- and together with the faults appear to reflect a tectonic style similar to that of the NIZD but of a lower level of deformation. As I understand it, in the previous two questions you indicated that the deformation was going on but now you are saying that it is lower level on the SC OZD than the NIZD. Do you mean that the slip rate is lower or what do you mean by lowe level? Do you imply anything --

A I am implying that the total cumulative deformation in these basically pliocene units that are reflected in Horizon B are not as deformed on the SC OZD as they are on the NIZD, suggesting that there has been less displacement.

Q Do you have a tectonic or mechanism that you use to explain how one segment of the fault, one section of the fault, will have a certain slip and, on the same line further down, there will be less slip? Is there a model that you use to explain this?

A Well, in the whole continental borderland area th- are a number of faults and one can only presume that these faults are taking up various amounts of the drag related to the plate boundary that is causing a northwest-southeast shear in this area, presume that if the displacement is not occurring on one fault a commensurate amount of additional displacement might be occurring on one of the other offshore faults in the general area.

Q On page 14, line 6, you state the RCFZ is believed to die out toward the south in the vicinity of the international border west of Imperial Beach. When you use the word "believe", could you explain to me who you are referring to believes this?

A As I recall, the Kennedy and Wellday, in their 1980 publication, indicated they believed it to die out in that direction. They have not mapped it. Their maps show it ending. But I believe they also make a statement -- I don't recall the exact wordage -- I think they made a statement that the evidence dies out as you approach the international border is perhaps the way they stated it.

Q So you are stating here that Kennedy believes this.

A Yes.

Q Is that the only person you are referring to when you use the word "believe"?

A Kennedy and Wellday. I don't know which one did the actual work. Yes. I am referring to their work. They have done, as you know, the most extensive work in that area.

Q On page 15, you discuss the various interpretations of the Rose Canyon fault zone by Threet and Moore and Kennedy and others. You mention that they have quite different interpretations of this. Have you formed your own opinion as to which of these two alternatives proposed here is the most reliable from a geologic point of view?

A No. I have reviewed the data presented by Kennedy and others associated with him over the years. I have reviewed the report by Threet and also work that was done by a geologist in our San Diego office down here. Their review is presented in one of my exhibits here. I believe it is Applicants' Exhibit 8, my Exhibit No. , EGH-6. It is in response to an NRC question. It is in response to Question K. I have also read that and am familiar with the conclusions that they drew. They basically hold a similar position to that of Threet. Because that data supercedes the work of Kennedy and geologically it makes sense to me, I think I would hold with that view as opposed to Kennedy's.

Q On page 16, line 23 to 26, you state: Of the three elements of the OZD, the NIZD has by far the highest levels of both historical and recorded seismic activity. In your interpretation, does the historic record -- or your opinion -- does the historic record of seismicity that we have in this area, is it sufficient to say that this is not just a temporary condition, that in some time down the road there might be a different -- a different section might be the highest? In other words, are you taking the fact that it currently, in the short historic time we have observed it, it is the highest, are you taking that to mean that over a long geologic time it also is the highest?

MR. PIGOTT: Which of the three questions would you like to --

BY MR. BRUNE:

Q Excuse me. I will re --

MR. PIGOTT: Objection. Compound and complex.

DR. BRUNE: I will rephrase the question.

JUDGE KELLEY: Okay.

BY DR. BRUNE:

Q Do you take the fact that the present seismicity on the NIZD is higher than for the other elements of the OZD to indicate that over a longer geologic time that would always be true?

MR. PIGOTT: And could we have a definition of longer geologic time? I would like the timeframe we are dealing with.

DR. BRUNE: Say periods of like a million years.

MR. PIGOTT: Fine. Thank you.

THE WITNESS: I would agree that the present, what we call the historic geologic time is very short and we are certainly seeing only a portion of the total seismic record. I also think, based on the geologic observations we have made along the zone, that it is reflecting more activity on the portion of the zone that has experienced the most deformation over the last million to even four million years.

BY DR. BRUNE:

Q Thank you. On page 17, line 9, you mention that the NIZD is a conservative model, and then I refer to No. 4 of your reasons, and 4: It is closer to the area of high stress at the interaction between the San Andreas fault system and the Transverse Range than are the other segments of the OZD to the south. Are you inferring from this that the actual in situ stress along the fault, along the SC OZD and RC FZD, are less than along NIZD?

MR. PIGOTT: I'm going to object to that. I don't think there is any reference in there to the SC OZD in No. 4, if that is in fact the reason you are referring to.

JUDGE KELLEY: I'm sorry. I happened at that moment to be looking at something else. Could you direct me to --

DR. BRUNE: Well, in Section 4 it refers to the other segments of the OZD. Since the topic is the NIZD, I take "other sections" to mean the SC OZD and RCFZ.

BY DR. BRUNE:

Q Is that correct?

A I'm sorry. I was rereading this. I can go back to your first question and answer it.

Q Yes, please.

A Of course we don't know what the stress is in the segments because it is very difficult, if not impossible, to measure it. But this statement says that the str.ke slip displacement on the Newport-Inglewood portion at the north end is interfered with by the position of the Transverse Range. Therefore, slip on that fault in that segment has to overcome this resistance. Therefore, you might build up more stress prior to an earthquake there than you would on the other two segments, which are a little freer to move and release their stress at a lower level.

Q In regard to the stress along the NIZD and SC OZD, could you make an estimate of what the effect on the stress field would have been as a result of the occurrence of the 1933 earthquake in Long Beach?

MR. PIGOTT: I think I am going to object at this point. I believe that Mr. Heath is addressing this from a geologic standpoint. I gather the context of the last question to call for an opinion of a seismologist and would consider it beyond the scope of the direct examination of Mr. Heath.

JUDGE KELLEY: Sustained.

BY DR. BRUNE:

Q Could we now go to your Table 36138.2?

JUDGE KELLEY: That is one of the exhibits and that is one of the responses to Staff questions, is that right?

DR. BRUNE: It is a figure in his testimony.

THE WITNESS: Figure EGH-F, is that the one?

DR. BRUNE: Yes.

JUDGE KELLEY: Fine. Thank you.

BY DR. BRUNE:

Q In Underneath the San Andreas Fault column you have in the second item down, the Imperial - Cerro Prieto segment, 180 kilometers, Imperial Valley to Gulf of California. I take it from this that you interpret the Imperial and Cerro Prieto faults to be one segment.

A That's what the table would show. I am not sure that I would characterize it now as one segment. I believe there are two segments.

Q You would rather characterize it as two segments.

A I believe so, yes.

Q On what basis?

A On the basis that they don't line up directly one to the other.

Q At the time you inferred that they were one segment, have you changed your interpretation of what constitutes a segment? In other words, I am trying to understand how it can be classed as one segment earlier and now classed as two segments.

A Well, I am really not quite sure why we did it that way in the first place and I really think I would have to look at a map and study it before I could tell you which I, you know, would really prefer. I essentially can't answer that question directly.

Q Do you know the approximate amount of right stepping between the Imperial and Cerro Prieto fault?

A No. That's what I was trying to recall and that's what I don't recall right now and I would really have to look at a map.

Q Well, if we assume that it was something of the order of 15 kilometers -- quite uncertain --

MR. WHARTON: Mr. Chairman, we are getting into an area, he referred to right stepping. I wonder if Dr. Brune could define that for you so you know what he is talking about.

MR. PIGOTT: I don't think that is appropriate. I think that if there is to be information put on the record on which we are to rely, either you do it by evidence or you do it by some kind of question and answer form. Unless you want to call it a special tutorial. I don't know. But that seems to me to be a little out of order at this time.

MR. WHARTON: Mr. Pigott had his three-hour class this morning, which I objected to being further than I thought it was going to be. I think it is important that you understand just this basic concept. It can be treated simply as informational as this morning was.

JUDGE KELLEY: I think we can have a brief special tutorial with the understanding that this is, although transcribed, not evidence. It is merely background explanation which Dr. Brune will now give us, if you would.

DR. BRUNE: If it is more appropriate, I can ask Mr. Heath. Mr. Heath responded to the question. I presume that he knows what I meant.

JUDGE KELLEY: Well, let's go the way we have decided to go and if you could just give us your understanding of --

DR. BRUNE: My understanding of right stepping means that in the case of a plate boundary, as you have going down the Imperial Valley from the San Andreas fault, say connecting up to the Imperial fault and then to the Cerro Prieto fault, you have a series of faults which, as you proceed down the main trace, the trace you are on comes to an end and we jump over to the right and it connects up across a zone, a spreading zone or what they call a rhombochasm in-structure, but there is a complexity there and the main trace of the fault jumps off to the right a certain distance and then goes on for a while and then jumps off to the right again. So that is the meaning of right stepping.

MR. PIGOTT: Could I have one clarification? It would appear you indicated that there was something or some structure of activity, a rhombochasm, I believe, or some other whatever it was that you mentioned. It isn't just a -- or tell us, what is between it? Is it just undisturbed structure between the end of one and the pickup of the next or is there some kind of a mechanism that continues on this activity?

DR. BRUNE: No. There is a breaching -- a branching mechanism across between the two which, in the case of right lateral motion, as we have along the San Andreas fault, results in the material being pulled apart in this transition zone. So you have a zone of tension as you follow down the fault and it comes to an end and jumps over to another fault to the right. With the kind of plate motion that we have in California, this causes pulling apart of the section in between, intention. So you have normal faulting, downdrop blocks, and various other complications as you jump across one of these right stepping zones.

JUDGE KELLEY: Okay. We are back into the presentation of evidence, then, at the end of Dr. Brune's explanation.

BY DR. BRUNE:

Q The purpose of this is just to get an idea of when one calls it a segment and when one doesn't. I was saying that in the hypothetical case that the right step was 15 kilometers, is that such that you would call it two segments?

A Yes, I believe so, as I said earlier. I think that -- now, as I opened up in response, I would say that it definitely was two segments. I don't know why it was grouped together before.

Q Is there -- suppose that the right stepping had only been say one kilometer. Would you have then also called it two segments? I'm trying to find out where the boundary is between two segments and one segment.

A I can tell. I'd probably go with one, you know, one kilometer offset might be -- I would still say it is segmented, but they are close enough that you might even expect rupture across something like that. But, you know, as you get further and further towards the middle, it is more and more difficult to say what is reasonable. I think where you have evidence of a rhombochasm or a spreading center then that is another item to consider in separating them into segments.

Q On page 20 -- well, we are still referring to this table, but I am going back to an earlier part of your testimony. On page 20, lines 1 and 2, you state that the seismicity is lower along the OZD than for other major strike slip fault zones in Southern California. Going back to your table, Figure EGH-F, the column under Historic Seismicity mentions that the seismicity for the OZD, hypothesized OZD, the seismicity is high in the north, low in central and southern areas, whereas the Whittier - Elsinore fault is given moderate seismicity.

It seems to be saying in that table that the OZD is actually higher in seismicity or historic seismicity than the Whitter - Elsinore.

///

A No. I think the table says that it's higher in the north and lower in the south, and I think that that is the way it is.

Q Okay. The word "high" then in this case is not to be compared with "moderate" in the previous column?

A We use the terms across the line there of "low", "moderate", "high" and "very high". And then I think that they're pretty self-explanatory, if that's what we're talking about.

Q Well, what I'm saying is, under the column Hypothesized OZD, it says the historic seismicity is high in the north, low in central and southern areas. Whereas, over on the Whittier-Elsinore-Laguna-Salada, it says that the seismicity is moderate.

It seems from that to me -- and correct me if I'm wrong -- that, on the basis of that, at least in the northern part of the OZD, the seismicity is higher than it is on the Whittier-Elsinore.

A That is correct.

Q Okay. And that is consistent with the fact that, in the line below, the hypothesized OZD has had a magnitude 6.3 on it, whereas the Whittier-Elsinore has only had a 5.5 to 6 magnitude; is that correct?

A That's correct.

I might add that you're inferring that we're only dealing with maximum magnitudes. We're also dealing with some of the other lesser events and the -- while we have had a large magnitude on the NIZD and a number of smaller events up there, we have had low seismicity over the rest of the OZD and particularly on the OZD opposite the site. We're talking about averaging the zone in this table. On an average, I don't think it is any higher -- as high as it is for the Whittier-Elsinore-Laguna-Salada fault zone.

Q Well then just for clarification, going back to Page 20, Line 1, the statement that seismicity is lower along the OZD than for other major strike-slip fault zones in Southern California, is that correct in view of that table?

A Well, as a general statement, I think it's a fair representation. Obviously, there's a tremendous difference in seismicity along the OZD between the north, central and southern portions.

If you put it in a table and average it out, you know, you might have to go to seismic moments or something to find out what the true thing is. But I think in general there is lower seismicity along the total length of the OZD than there is along the total length of the Whittier-Elsinore-Laguna-Salada fault.

Q On Page 20, Line 6 through 11, the three -- I'm quoting from your testimony. Three: "The maximum historical earthquake on the OZD is the 1933 Long Beach event of MS-6.3."

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Four: "The estimated maximum magnitude for the zone could be expected to be somewhat greater than the historical MS-6.3 but less than that for the more active zones, such as the Elsinore, San Jacinto, and San Andreas."

We are into one of these statements which I have a little difficulty grasping all the qualifying words. Could you explain to us what you mean by estimated maximum magnitude in this case?

A I mean if you were to take the present-day seismicity into account, and that is what we are discussing in this paragraph, and based on that to make an estimate of the maximum magnitude -- let me see here -- estimate the maximum magnitude for this zone or the other zones, I am saying that you would estimate a lower magnitude for the OZD than you would on the zones that have had higher historic seismicity.

Q In -- further on you say the estimated maximum magnitude for the zone could be expected to be somewhat greater. Could you amplify on what you mean by expected to be somewhat greater, and explain what you mean by somewhat in particular?

A I am simply saying in that statement that the fact that we have had a 6.3 in itself does not mean that it is the maximum event. We could have something higher. But it would be lower than those for the other zones.

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Q Well, how much higher could it be? I mean --

A I hedge somewhat because this is not the type of analysis that leads you to a hard number, so I don't know how much higher --

Q Okay.

A -- based on the seismicity.

Q I see, but based on that evidence alone, just the historic seismicity by itself then, that that is the reason "somewhat" is vague in this case?

A That is right. Yeah.

Q Based on that evidence alone, it could be considerably higher than 6.3 then?

MR. PIGOTT: Objection, calling for speculation.

BY MR. BRUNE:

Q Yeah, is this -- I mean, taking into account the uncertainties, can I rephrase the question?

JUDGE KELLEY: Yes.

BY MR. BRUNE:

Q Taking into account the uncertainies, then, that you mentioned, such that this method is not a hard method, then based on that method alone, the maximum magnitude could be considerably greater, or what would you say, other than it doesn't limit it?

A I find it very difficult to make a -- to come up with a number on that. We can rank these faults and see that,

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you know, you might expect something very large for the San Andreas, something smaller for the San Jacinto, something smaller for the Whittier-Elsinore, something smaller than that for the OZD, but whether these steps are half a magnitude steps down, or point six -- there is a separation in there, but I can't come up with a hard number.

Q Is it your feeling that magnitude 6.3, then, based on other lines of evidence than simply the historic record, is close to the maximum that could occur on the zone?

A Yeah, based on other information, yes, I believe so. I have stated that in my testimony, that the rupture length, of 30 to 33 kilometers, which is calculated from the aftershock zone, for the 1933 event, is close to the total fault length in that -- or segment length in that area south of Dominguez Hills, of about 36 kilometers, so you don't have much more zone to rupture to create a much larger event.

Q On page 20, line 21, you state that commonly the consideration of fault length is used by selecting the half fault length as a maximum potential rupture length. In using the word commonly, are you referring to a number of studies, or what is the implication of the word "commonly?"

MR. PIGOTT: I am going to object as taking the quote somewhat out of context, inasmuch as the following sentence describes "commonly." If we are going to have quotations as to a part of -- as to a part of a sentence or a thought, I would request that it be based on the full thought.

MR. WHARTON: He is referring here to his method is commonly applied. He is not referring to what the next sentence is. It is -- we are talking about trying to understand the meaning of words that are being used. I think it is appropriate to pursue that.

JUDGE KELLEY: Well, there are two commonly's, right, in sentences back to back. I am going to overrule the objection. It seems to me that it is somewhat ambiguous, and you are entitled to call for an explanation from this man, which I gather is what you did.

MR. BRUNE: Yeah.

JUDGE KELLEY: Do you want to repeat the question, or are you prepared to go ahead?

THE WITNESS: I am prepared to answer the question. "Commonly" here in the first sentence, starting on line 21, refers to the -- my belief that the -- it is most frequently used. It is the -- basically that, that of the various methodologies in the last few years, the most common one that people use, which you read about in the literature, is the half fault length method.

BY MR. BRUNE:

Q Does it ever occur that a fault ruptures the full length in this context?

A Is it ever inferred that --

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Q Has it ever occurred that an earthquake has ruptured the full fault length in this context?

A Anywhere in the world?

Q Yes.

MR. PIGOTT: I find this question certainly ambiguous or unclear. Maybe I am not supposed to understand it, but it is a little over-broad or ambiguous. I am not sure what the proper word would be. It could be specified.

MR. WHARTON: Has an earthquake ruptured the full fault length anywhere in the world?

JUDGE KELLEY: Well, but could you -- as it strikes me, that -- where do earthquakes start, at three or four? I mean, do you mean little earthquakes or medium earthquakes or big earthquakes? It does strike me as broad and hard to answer.

MR. WHARTON: Mr. Chairman, it is, I believe five o'clock. We have had a long afternoon. We are not going to complete the cross-examination today. This would seem to me an appropriate time to adjourn, and I do have school business I have to attend to at 5:30 if it would be possible.

JUDGE KELLEY: Well, let me poll the parties.

MR. PIGOTT: I would not object to a recess at this time. It has been the full afternoon for this witness.

MR. CHANDLER: We are prepared to go forward, Mr. Chairman, but in light of the other parties' willingness to

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recess, it is fine.

JUDGE KELLEY: Well, my only concern, I guess, is that we are getting under way these first two or three days in what promises to be a pretty long hearing, and I think we are sort of feeling our way on the appropriate hours. We had today I guess a respectable but not all that great day in terms of getting things done. I am certainly not personally opposed to stopping at this point, but we have been thinking, see, 9:00 to 5:30 -- now, off the record by the way -- can we just at this point go off the record.

(Discussion off the record.)

JUDGE KELLEY: There has been a discussion off the record as to when the Carstens Intervenors should file certain documents. One document would be a listing of sequence of subpoenaed witnesses, and they are to file that by Friday of this week. The other document or set of documents would be outlines of the anticipated testimony of these subpoenaed witnesses on the assumption that there will not be direct testimony filed for them, but that in lieu of that, Counsel for the Carstens Intervenors will give to the other parties in some detail reasonable notice of what he expects to elicit from those various witnesses, and that is due next Wednesday.

MR. WHARTON: Very well. Thank you.

MR. CHANDLER: Mr. Chairman, I have one -- well,

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actually a couple of housekeeping items. One, with respect to the subpoenaed witnesses, I have indicated to I believe both Counsel for the Applicants and Intervenors the desire that has been expressed to me by the Office of General Counsel of the Department of Interior on behalf of the U.S. Geological Survey to enter an appearance with respect to the subpoenas for Drs. Lohr (ph) and Joyner.

In order to make some arrangements for their appearance, that is, for Counsel's appearance, at the moment, I am dealing with -- I have been discussing this with Counsel in Washington, and again, it is a logistics problem. If we could have some indication or set some time aside, if they do wish to file a motion to quash, I think it would be desirable.

JUDGE KELLEY: Can I just get a little clearer? I know you know I have talked about this briefly off the record, too, but as to those two witnesses, is it established and clear that they are going to move to quash, or just what exactly do they have in mind?

MR. CHANDLER: It is my understanding that that is their intention, Mr. Chairman. I obviously cannot speak for them. I have had only brief discussions with them. This all has been happening rather -- well, for whatever reason, late in the proceeding, and at a time where we were all involved in many other activities, and my communications with them have been very limited.

JUDGE KELLEY: Have those subpoenas been served, Mr. Wharton?

MR. WHARTON: They were given to the messenger service for service on Monday. I haven't received final word that they have been served yet.

JUDGE KELLEY: Just this past Monday?

MR. WHARTON: Yes.

JUDGE KELLEY: And they were going by messenger to New York -- Washington?

MR. WHARTON: Well, it goes to an attorney service, and the attorney service takes it from there, and they handle it whatever way they want to.

JUDGE KELLEY: I don't recall under the rules -- is there a time limit for moving to quash? Are you trying to nail down when all this is supposed to happen, is that right, Mr. Chandler?

MR. CHANDLER: Well, what I am suggesting is one of two different -- well, one of tw different procedures. One, we ought to have a date certain for their appearance, the witness's appearance, but perhaps a more desirable approach would be to set aside some brief period of time on a day certain, if the Department of Interior wishes to move to quash, to present that motior, in advance of the appearance of these witnesses, so if the motion were granted, for example, there would be no ne_d for them to appear.

JUDGE KELLEY: Well, that seems to me to be obviously desirable. If there is going to be a motion to quash, then we see it and we rule on it -- now, I am just turning pages myself. Is there any specified time limit for quashing?

MR. CHANDLER: 10 CFR Section 2.720(f) on motion made promptly, and in any event at or before the time specified in the subpoena for compliance by the person to whom the subpoena is directed, and on notice to the party at whose instance the subpoena was issued, the presiding officer, or if he is unavailable, the Commission may: 1) Quash or modify the subpoena if it is unreasonable or requires evidence not relevant to any matter in issue; or 2) condition denial of the motion on just and reasonable terms.

JUDGE KELLEY: Well, okay, so there is no specific date certain. It is promptly, and obviously it should be done as soon as possible, so Mr. Wharton knows whether they are coming or not. Could you, and I mean Mr. Chandler, Mr. Wharton, and Mr. Pigott if he is interested, nail down with the Interior lawyers just precisely what their intentions are? You said they -- have they already made it clear they will come out here?

MR. CHANDLER: Either they will come out, or I understand they have local Counsel, that is, they have regional offices with a member from the solicitor's office who would appear.

JUDGE KELLEY: Well --

MR. CHANDLER: And I do not know whether it was their intention to file a written motion to quash as opposed to making an appearance and making an oral motion to quash.

JUDGE KELLEY: Well --

MR. CHANDLER: If it is the Board's desire to have it in writing, I would have to convey that and I would do that promptly.

JUDGE KELLEY: Do you have an idea -- the trouble with writing, of course, is it just takes longer. If you were getting into your case after the Fourth of July break, would these gentlemen be up front or in the middle, or how much time pressure is involved?

MR. WHARTON: My understanding is that Dr. Bohr has to go to Canada on July 22nd, so we would probably be talking about between July 8, and July 17, I suppose.

JUDGE KELLEY: Well, this kind of a thing is a pretty simple document to write. We don't have to write legal treatises. Could you convey to the Interior attorneys that if they are going to move to quash, we would like to have it in writing, but we would like to have it out here in our hands by the middle of next week?

MR. CHANDLER: I will convey that, Mr. Chairman.

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I don't know that that timetable will be workable for them.

JUDGE KELLEY: Surely they know by now what they are objecting to, if they are going to object.

MR. CHANDLER: Yeah, I certainly would expect that is true, except they have not yet seen the subpoenas, to my knowledge, as Mr. Wharton indicated they have not yet been served. This is totally anticipatory.

JUDGE KELLEY: Well, I was assuming, maybe unfairly, that they would have these subpenas in hand, like tomorrow, Friday at the latest.

MR. CHANDLER: I will certainly convey the Board's desire on that.

JUDGE KELLEY: This is not in the form of an order. They are not going to be parties, as far as I know. Could you tell them that the Board would like to have -- one, we would like it in writing, and two, we would like it by the middle of next week?

MR. CHANDLER: I certainly will, Mr. Chairman.

JUDGE KELLEY: All right. And then Mr. Wharton can take a look at it and see whether he wants to pursue it and file an opposition to that, and then we will have a ruling on it.

And then if you could -- I assume you will talk to them, and then you can let me know if there are other elements, or problems.

MR. CHANDLER: I will be happy to advise --

JUDGE KELLEY: Okay.

MR. CHANDLER: Sure. There was a second matter

JUDGE KELLEY: I guess you took a look at that room. Did the other lawyers take a look at that room we are thinking about -- yes?

MR. CHANDLER: I was just inquiring whether the Board felt it was necessary to still be on the record.

JUDGE KELLEY: Not for this. I am sorry.

(Whereupon, at 5:19 p.m., Wednesday, June 19, 1981, the hearing was adjourned, to reconvene at 9:00 a.m. the following day.)

This is to certify that the attached proceedings before the

NUCLEAR REGULATORY COMMISSION

in the matter of: SAN ONOFRE NUCLEAR GENERATING STATION

Date of Proceeding: June 24, 1981

Docket Number: 50-361/362-OL

Place of Proceeding: San Diego, California

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Thomas Willis
Ruth Portune
Michael Wolfe

Official Reporter (Typed)

Thomas Willis Ruth Portune

Wolfe

Official Reporter (Signature)