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NUCLEAR REGULATORY COMMISSION
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Enclosure.

JUN 12 1986

MEMORANDUM FOR: Hans Schierling, Senior Project Manager
PWR Project Directorate #3
Division of PWR Licensing-A

FROM: Gus Giese-Koch, Contract Management and Oversight
Engineering Branch
Division of PWR Licensing-A

SUBJECT: COMMENTS ON THE DIABLO CANYON LONG TERM SEISMIC PROGRAM SITE VISIT AND TECHNICAL MEETINGS DATED APRIL 14, 15, and 16

The purpose of the site visit was to familiarize those on the NRC - Long Term Seismic Program (LTSP) review team and on the NRC - Advisory Panels on numerical ground motion modeling (NGM) and on soil-structure interaction (SSI) with the Diablo Canyon Power Plant site, its topography, and general layout. The subsequent technical meetings dealt with the progress made by the Pacific Gas and Electric Company's (PG&E) LTSP team on the several phases of the program.

That portion of the site visit dealing with general topography of the site and the location of seismic strong motion monitoring instrumentation was very informative in that, while showing the exact locations of the instrumentation inside the plant the guides pointed out the seismic restraints and seismic reinforcements which were visible throughout the plant. The seismic instruments outside the plant structures are located such that variations in ground motion as a result of local topography can be observed. Two instruments are located on (surface) rock out croppings on the hillside northwest of the plant site. One instrument is located on a cliff overlooking the cooling-water-intake cove southeast of the plant site. Records obtained from these instruments can be compared to those located on the foundation of the plant foundations to gain further insight in the soil-structure interaction phenomenon.

The remainder of the visit was devoted to a discussion of work accomplished and a presentation of the planned integration of the several phases of the program and the particular types of analyses planned to satisfy the objective. The discussions on the results obtained to date and the approaches planned to accomplish the several objectives were comprehensive and covered a large amount of material. In particular, the accomplishments in the NGM modeling program were commendable. In general the NRC staff and its consultants concluded that the site visit and subsequent presentations gave structure to the NGM and SSI aspects of the program and laid out in detail the approaches contemplated to satisfy the license condition imposed upon the Diablo Canyon Power Plant.

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However the staff did voice concern in certain areas of the program, specifically:

- The studies contemplated which would utilize regional geology, historic seismicity, and geotectonics to structure the ground motion modeling appeared to be ambitious to the point where the (extensive) theoretical analyses contemplated, would yield data which may not lend itself to verification by empirical results and therefore may be of limited use.

  For instance because of uncertainties in the soil-structure interaction parameters, the error bands associated with these uncertainties have to be considered, vis a vis the lack of empirical verification. Hence, these error bands may be of such magnitude as to offset any refinements in theoretical models and render them significant.

- Attenuation relationships for small earthquakes are not necessarily the same as those for large earthquakes (m_b >5). That is, near source nonlinear behavior has been observed in data from earthquakes of signifcantly different magnitudes. Hence, the use of local seismic net work data from small earthquakes should be accompanied by realistic assessments of this apparent nonlinear behavior.

- In refining the soil structure interaction models and the subsequent analyses of the response to earthquake motion, the ultimate goal of these studies should be kept in mind, that is, the data to be obtained will be used in part to verify the original design parameters. Thus the parameters to be obtained should compatible with those used in the original design.

- There should be a high degree of interaction between those delegated with the specialized studies which are the backbone of the program to ascertain that the independently obtained results can be readily aggregated into the overall program.

Individual comments of NRC's consultants are attached as noted.

Gus Giese-Koch

Gus Giese-Koch, Contract Management
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cc: See next page

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May 19, 1986

Dr. Morris Reich, Division Head
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Dear Dr. Reich:

Following is my report on our visit to the Diablo Canyon Nuclear Power Plant site on April 14 and 15, the associated presentations, and the meeting of the Soil-Structure Interaction Panel with representatives of PG&E on April 16, 1986:

<u>Comments on Visit and Presentations of April 14 and 15</u>

1. The visit to the plant site and the progress reports on the various studies being carried out were highly instructive. They provided valuable insights into the nature of the problem and into several of the issues involved.

2. The work now in progress is quite comprehensive and its objectives are significantly better defined than in the past. However, the component studies still are not sufficiently well coordinated, and the relationship of these studies to the ultimate needs of the project do not appear to be as clearly defined as would be desired at this stage of the effort.

   Some of the studies on geology and ground motion impressed me to be in the nature of basic research projects which, while of interest in themselves, do not give promise of proving of value to the early definition of the ground motions needed for the soil-structure and fragility analyses. Furthermore, some of these studies appear to be carried out without the benefit of interaction with the groups responsible for closely related phases of the project.

   I believe that increased attention need be given to coordinating the component studies and to focusing their objectives more sharply to the ultimate project goal. Priority in the future should be given to those studies which offer the greatest potential of yielding results of value to the project. Unless this is done at an early date, valuable time may be wasted, and it may prove impossible to address adequately all important aspects of the problem within the specified period.

3. For the soil-structure interaction studies, an early definition is needed of all the factors that may affect significantly the

characteristics of the anticipated ground motions at the plant site, and of the effects and relative importance of these factors.

4. Several members of the Soil-Structure Interaction Advisory Panel had suggested that local topography might influence significantly the characteristics of the ground motions at the plant site. While this matter has not been addressed to specifically in the studies conducted so far, in response to personal inquiries, two members of the Advisory Panel on the Ground Motion Studies expressed the view that local topography is unlikely to be an important factor in this case. An early resolution of this issue is recommended.

5. The ground motion requirements for soil-structure interaction and fragility analyses are not clear, and should be clarified. The rationale for using different ground motions for the two studies simply escapes me.

6. I believe that improved interaction must be established between the Advisory Panels on Ground Motion and Geology and between the Panels on Ground Motion and Soil-Structure Interaction. This would require occasional meetings of the respective panels, or the participation by members of one panel in meetings of the other panel and of its working groups.

7. The planned installation of additional instrumentation to record future earthquake ground motions at the site is welcome. Consideration may also be given to the installation of downhole instrumentation, which would yield information on the attenuation of the ground motion with depth, the propagation path of the seismic waves, and further data on the depthwise variation of the properties of the rock deposits.

Comments on Soil-Structure Interaction Studies

8. The progress of the work on soil-structure interaction since the first meeting of the relevant Advisory Panel has been impressive. The work has been well thought out and executed, and the plans for the immediate future are reasonable and proper. The studies aimed at assessing the accuracy and reliability of the CLASSI and SASSI computer programs were particularly well implemented, although the interrelationship of the results that can generally be obtained by the two approaches has not been fully established yet. Subject to the qualifications noted in the following paragraphs, there is no need for changing the immediate course of the planned effort.

9. Notwithstanding the satisfactory progress of the effort to date, the long-range objectives of the soil-structure interaction studies are not clear. I consider it of the utmost importance that definite answers be provided at an early date to the following fundamental questions:

   - What response quantities are of interest in these studies?
   - How will the results of this effort be used?
   - What is the relationship of the soil-structure interaction studies to the fragility studies and why are the ground motion requirements in the two cases different?

More specifically, will the results of the soil-structure interaction analyses be used to formulate design criteria for comparison with those used in the original design of the project, or is it intended to evaluate the maximum forces or motions at selected sections or elements of the various structures and then compare them with the levels deemed to be permissible? If neither of these, then precisely how will the results be employed? The answers to these questions given at the April 16 meeting were not satisfactory in my view.

The nature and scope of the future studies and the degree of sophistication that would be warranted in the analyses will clearly depend on how the results will ultimately be used. Without a clear definition of the ultimate intent, it would be impossible to plan intelligently the longer term course of this effort.

10. As already noted under item 6, there is a need for closer interaction between the Advisory Panels for Soil-Structure Interaction and Ground Motion studies.

11. The final stages of the planned work on soil-structure interaction involve response history analyses for highly sophisticated and complex structural models. It is planned that these analyses be carried out for a single earthquake ground motion record, which will presumably possess all important characteristics of those expected at the plant site. The use of a single ground motion for this purpose is considered to be inadequate. It is recommended that a minimum of three such records be employed, even if it becomes necessary to simplify the modeling of the structures. Alternatively, the natural frequencies of the structures should be varied over frequency ranges that are representative of those associated with the inherent uncertainties of the problem, and the structures reanalyzed for the modified properties. The first approach is clearly preferable.

12. The analyses involving complex mathematical representations of the structures should be supplemented by studies involving simpler, approximate methods of analysis. To quote from my report of November 26, 1985:

    "Provided they capture the essential elements of the problems, these simpler approaches may be used in the initial stages of the project to make rapid estimates of the effects and relative importance of the multitude of parameters that influence the response, and in later stages, to help guide the planning of the more elaborate analyses and the interpretation of the resulting data. The all-too-common tendency of unduly complicating the modeling and analysis of the structure-foundation-soil system and of relying totally on seemingly precise, highly complex analyses, should be resisted".

    The promise to include such approaches in future studies should be monitored on a regular basis.

13. I had the opportunity to review briefly the design procedure used for the tanks at the plant site. I was advised that these tanks are anchored at the base, and that the impulsive components of the hydrodynamic effects were evaluated from the rigid tank solution

by replacing the maximum ground acceleration in the expressions for the various response quantities by the spectral value of the pseudo-acceleration corresponding to the natural frequency of the fundamental antisymmetric mode of vibration of the tank-liquid system. I was further advised that the maximum hydrodynamic effects due to the vertical component of ground shaking were taken equal to the hydrostatic effects. This method of analysis is satisfactory and compatible with the latest available information on the subject.

14. The seminar-like meeting in San Francisco was highly fruitful, ~~and~~ it is suggested that similar meetings be held periodically in the future. For improved effectiveness, it is suggested that

    a. Copies of all material presented at the meeting be distributed several days ahead of the meeting; and

    b. The meeting preferably be held over parts of a two-day period to provide the participants the opportunity to reflect overnight over the items covered during the first day and, if necessary, to discuss them further the following day.

15. Considering the complexity of the analyses planned in this phase of the work, I believe that an <u>independent</u> check of some of the results would be desirable, and recommend that consideration be given to means of obtaining such spot checks. Rather than reproducing specific analyses, it is suggested that alternative, simpler procedures be employed to obtain order of magnitude estimates of critical response quantities and to assess the sensitivity of the results to the uncertainties that are inherent in the problem.

In closing, I wish to note that I regard the questions raised under item 9 to represent my most important contribution to the deliberations of the groups responsible for the soil-structure interaction studies.

Yours sincerely,

A. S. Veletsos

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212-690-4228
21 April, 1986

Dr. Morris Reich
Head, Structural Analysis Division
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Re: Comments on Meeting of 14-16 April, 1986 with SSI Panel on Long Term Seismic Program for the Diablo Canyon Nuclear Power Plant

Dear Dr. Reich:

This letter report presents a summary of my comments on the presentations made by the DCLTSP Project Team on the Phase II and Phase III aspects of the program for DCNPP. As you are aware, I had made many of these comments to the various Project Team members at the time of their presentations.

(1) Empirical Ground Motion Study:

The program presented by the Project Team, although in a preliminary stage, appears reasonable and well thought out. The results from this study will probaby play a major role in the SSI and structural phases of the project. It should be mentioned that the planned response spectra criteria being used to scale all the empirical motions (frequency range and amplification factors) are relatively arbitrary in nature and will drive the deterministic and stochastic phases of the structural response studies. It is not clear how the results of the numerical ground motion studies are to be married to the empirical program. In addition, it is unclear how the site specific spectra so determined, which presumably will be different from the one being used at this time, will be incorporated into the program.

(2) Numerical Ground Motion Study:

It seems that the current ground motion calculations being contemplated will only be capable of producing results below 1 hertz, while the structural frequencies of interest are in the range of 2 - 20 hertz. No discussion was presented at the workshop as to how this discrepancy will be resolved.

The only numerical technique suggested to treat the impact of local rock layering effects on site response is the two-dimensional computer code based on the finite element method. The computer code presented is a temporal code, that is, one in which the solution is marched out in time from specified disturbances input to the finite element mesh at arbitrary locations relatively far from the site. However these finite element program inputs presumably will be obtained from the outputs of the numerical ray-tracing solutions generated from assumed specified faulting conditions. There is existing in the literature a long history of similar "rock-island" calculations, in which the output from a near-field calculation is used as input to a far-field calculation which is based on a different numerical method. Such studies have primarily been associated with weapons studies associated with the SSI problem. A problem that is often encountered in these type calculations is the development of serious spurious numerical signals generated at the finite element boundaries, since the two computer approaches are fundamentally different in character. It is not clear if the Project Team has considered how the different numerical approaches are to be married to yield reasonable numerical predictions of ground motions at the site.

The only two-dimensional finite element computer program mentioned which is capable of treating the far-field problem does not include material damping in its current formulation. If damping is to be included, the form of the damping model used will not coincide with the damping models incorporated into the SSI computer codes (CLASSI and SASSI). Both of these latter codes are frequency domain solutions and use two-dimensional Voigt damping models in their material formulation. If this damping formulation is carried over into the time domain computer program proposed for the finite element ground motion study, numerical instabilities will develop since these formulations lead to infinite wave speeds. It is important for the SSI calculations which are typically sensitive to damping formulations that the two material descriptions be made compatible. It is requested that the Project Team provide information to the SSI Panel members on the specific formulations currently contemplated for use in the ray-tracing and finite element formulations, with specific emphasis being given to material descriptions to be used.

(3) SSI Study:

The general comment concerning this phase of the program is that the procedures currently envisaged appear to be well thought out and complete. I have some relatively minor questions and seek clarification.

The coherence data presented by the Project Team for the low level site-measured accelerograms indicate that significant discrepancies occur above about 8 hertz. It is not clear to me that these discrepancies indicate noise in the system at these low acceleration levels, or rather inadequacies in the structural models being used in the SSI study at the higher frequency ranges of interest. These inadequacies, if they exist, would have serious impact on equipment and piping responses. Presumably, model improvements could be determined using system identification techniques. The question then would be how to determine model improvements applicable to the higher acceleration levels of interest.

In all of the structural calculations being made, modal damping characteristics are being assumed for the structure. Can these low level measurements be used to evaluate the adequacy of the structural damping models contemplated for future use.

I recommend that reports and computer user manuals of the SASSI computer code be provided to BNL for further study. This would be important to assist in the evaluation of the significant effort being made by the Project Team to correlate the results of the CLASSI and SASSI studies.

Nonlinear effects in the SSI program (particularly those arising from liftoff and nonlinear structural response) cannot now be considered by either of the computer programs mentioned above. It is not clear how these will be incorporated into the program. Obviously, if these are significant effects, there may not be any point in conducting complicated SSI calculations for the linear problem. In addition, the DC plant site is not a uniform, horizontally bedded site, as is being considered in the SSI calculations. The effects of the variations in the rock surfaces on the input ground motions used in the calculations may be as significant on structural response as the SSI effects themselves.

A final comment concerns the currently planned program to locate seismic instrumentation at the site. All current plans presented to us consider only surface mounted instrumentation. It is clear that these instruments will be seriously influenced by local topographic features, making their output difficult to interpret. However, it is my sense that the response of the plant facilities will not be influenced so much by local topography but rather by local geologic features, such as layering, fracturing, etc. It is my opinion that deep instrumentation is more important than surface instrumentation. This is particularly true if significant wave types and incidence angles (which are of concern to the SSI problem) are to be determined. It is clear that the numerical ground motion study will not be able to provide significant input into this aspect.

Considering these comments, my recommendations to the Project Team are as follows:

(a) Prior to the development of the full computer production runs, the Team should present their detailed plans to the SSI Panel for review. These plans should include a discussion of which effect is to be evaluated by which set of computer runs.

(b) Early in the program, the Team should evaluate whether liftoff is a concern. If it is important, it may completely modify the program plan.

(c) Obviously, our SSI panel should closely interact with the Ground Motion Panel, as the adequacy of the inputs generated may be more important to the computed responses than the SSI effects.

In closing, I would like to emphasize that the SSI Panel members all endorsed the requirement that we should continue to be kept intimately aware of the detailed developments being made on the Ground Motion program. I personally found the presentations being made in the other areas of the problem extremely helpful. I would like to take this opportunity to thank the members of the Project Team for the effort they made in their presentations. Finally, I would like to reiterate my request to the Team to provide information to us on the details of the numerical methods being contemplated in the numerical ground motion studies.

Respectfully submitted,

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April 18, 1986

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RE: NRC Panel for LTSP of Diablo Canyon Power Plant
Soil Structure Interaction Program

Dear Dr. Reich:

Following the visit of the Panel at DCPP (14 April 1986) and the meetings with PG&E (14-16 April 1986), and after carefully studying all the produced documents, I would like to make some comments and offer some suggestions regarding the Soil Structure Interaction (SSI) Program.

The overall progress made by PG & E and its consultants since our first meeting (October 1985) appears to be satisfactory. The program is fairly well focused, an amount of preliminary work has been done, and the plans for future work are well thought out. It seems to me that the SSI program is ahead of the Geology/Seismology/Ground Motions studies.

I have the following suggestions:

1. I strongly believe in the benefits of a multi-step approach to soil-structure interaction analysis, especially for situations involving complex geometries and through-soil structure-to-structure interaction, as is the case with DCPP. Thus, I would like to suggest that for each structure (reactor containment building, turbine building, auxiliary building) CLASSI or SASSI (as appropriate) be used to compute:

(a) the impedance functions of the foundation-soil system

(b) the "effective" foundation input motion considering solely kinematic interaction effects (scattering analysis)

(c) the seismic response of the structure

Tasks (a) and (b) are intermediate steps in the computation of (c). The results of these two steps can be, at least roughly, checkd either against known published solutions from the literature, or against approximately derived results. Such comparisons will build confidence on the soil-foundation models before the latter can be used in final comprehensive seismic time-history analyses. Moreover, through such comparisons, an improved understanding of the mechanics of soil-foundation-structure interaction will undoubtedly develop; such an understanding would be useful in properly interpreting the final results of the SSI Program.

2. For getting a hedge on the importance of structure-to-structure interaction it might be a good idea to analyze <u>two</u> closely spaced structures (e.g. reactor-containment and auxiliary buildings) for kinematic and inertial interaction effects. The work already done in testing the impedance predictions of CLASSI and SASSI for two square neighboring foundations (task 3.1 of Work Plan) must be considered as a first step in this direction. If it turns out that structure-to-structure interaction plays only a marginal role, it may be advantageous to limit the number of final seismic analyses of the whole plant.

3. An important task of the "Ground Motions" Program is to develop a suite of 10 realistic acceleration histories, using available accelerograms recorded on rock sites during shallow-crustal M>6.5 earthquakes at distances R<10km. These accelerograms will be applicable to the DCPP site subjected to a strong earthquake originating at the Hosgri fault. These 10 empirical ground excitations are scheduled to be delivered very soon. I suggest that at least <u>two</u> such histories be used in the final seismic SSI analysis. The first may be selected to give a response spectrum that falls near the average of the 10

response spectra. The second may be chosen as the accelerogram whose response spectrum shows the largest differences in frequency content with the first history. The results of the corresponding two SSI seismic analyses are not to be treated statistically. Instead, they sould be viewed as a parametric study, in which the characteristics of the excitation is the variable parameter. This is as important as the studies in which S-wave velocity is the parameter.

4. In modeling the superstructure of the turbine building attention should be paid in properly reproducing the effects of the four reinforced-concrete buttresses along the long sides of the building.

Concluding, I would like to endorse the format of the one-day workshop between PG&E representatives and NRC and its consultants. The San Francisco 4/16/86 SSI workshop proved very successful.

It may be a good idea that the next such workshop takes place after one complete set of analyses has been performed by the PG&E group and a summary of the findings has reached the NRC consultants.

Respectfully,

GGazetas

George Gazetas

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17 April 1986

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Dear Jean:

This letter report contains my comments on the presentations made by personnel of P.G.&E. during the 14-15 April meeting at the Diablo Canyon Power Plant site, and specific recommendations on the agenda for the proposed workshop on ground motions.

My general impressions on the P.G.&E. presentation was favorable. Since the December meeting, on which I expressed strong disappointment, major efforts have been spent in defining their specific tasks and initiating work toward completing them.

In the presentation by Yi-Ben Tsai, our comments on the December meeting were adequately summarized and the issues raised by us were addressed seriously. In particular, I am in favor of the balanced approach in which the advantages of both empirical and numerical methods are exploited for the best possible estimation of ground motions.

Among our comments as summarized in Tsai's presentation, however, the third item, namely, "For high frequency range (2 to 20HZ), a sound physical model for earthquake is still lacking. Stochastic modeling is needed", was not addressed satisfactorily in the present meeting. The introduction of statistical fluctuation in the time of slip in Somerville's presentation affect the high frequency excitation in an ad-hoc arbitrary manner because the size of sub-event and consequently the size of sub segment size was arbitrarily chosen. The segment size appears to play the same role as the barrier interval as used by Papageorgiou and Irikura, but the physical and geological meaning was absent. I had a general feeling that the P.G.&E. ground motions personnel and consultants are in general pessimistic about the possibility of defining the heterogeneity of fault plane (which is most crucial for the estimation of acceleration in the 2-20HZ frequency range) from geological, seismological and geophysical (GSG) data. I felt that Kevin Coppersmith who works in the area of GSG is more optimistic about the possibility. There is a need for closer interface between geologists and the ground motion program.

To my knowledge, there are at least two approaches published in estimating the heterogeneity size of the fault from observable. Papageorgiou and Aki (BSSA, 1983) showed an empirical relation between the maximum slip and barrier interval for five major California earthquakes. If Coppersmith can evaluate the characteristic slip of the Hosgri fault segment near Diablo Canyon, we can use the empirical relation to estimate the barrier interval for the Hosgri fault.

The other method is based on the agreement between the barrier interval estimated from strong motion data and the average length of fault segmentation observed by geologists. Coppersmith mentioned recent advances in estimating quantitatively segmentation of fault in the meeting. I feel strongly that this is the area where a significant progress can be made in the present project.

Another important parameter in strong motion prediction which was totally neglected is the upperbound of frequency call f_{max}. f_{max} is a controversial subject because it may be attributed to source, path or site effects or their combinations, but is an important factor in controlling the peak acceleration. It should be the subject of study.

I believe that the f_{max} for major California earthquakes is caused by the smearing effect of finite width of fault zone. If so, the f_{max} of large earthquakes can be infered from the departure of self-similarity in either the corner frequency vs seismic moment relation or the frequency vs magnitude relation for small earthquakes. Both relations can be obtained from the local station network data which are about to be collected.

Another deficiency in the P.G.&E. presentation is the study of Q. Effective methods are now available for determining the apparent Q for high frequencies and have been applied to various regions of the Earth. In seismically active regions like California, Q is found to be strongly frequency dependent, and exceeds 1000 for frequencies higher than 10HZ. A serious effort must be made to measure frequency dependent Q for the region surrounding the Diablo Canyon site.

I am willing to participate in the workshop proposed in the end of our meeting to discuss the issues I have raised above, and also other important issues such as the site effect (topography and 3-D geological heterogeneity) to be understood from the analysis of data to be collected by the proposed array of seismographs in the Diablo Canyon site.

Sincerely yours,

Keiiti Aki

Keiiti Aki

REPORT ON SITE REVIEW OF DCPP AND PG&E LTSP
April 14 and 15, 1986

Dr. Ralph J. Archuleta
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Clearly the addition of Dr. Y. Ben Tsai and Dr. William Savage to the PG&E staff has made for a more focused seismological program than what was presented in December 1985. During these two days we were given a lot of information as to how PG&E is proceeding with implementation of its LTSP. I have two major concerns around which most of my comments are centered. First, the seismological studies are not that site specific. Second, the source description for the Hosgri fault and perhaps the San Miguelito fault was so vague that it is impossible to say how or if an earthquake on either will be modeled.

Consider the first site specific studies. There has been minimal analysis of the Nov. 12, 1984 accelerograms. This earthquake is the prototype Green's function for DCPP. Is the currently accepted velocity structure between the Hosgri and DCPP consistent with phases on the accelerograms? Do the SV/SH and P/SV amplitude ratios agree with predicted values based on the local velocity structure? How does one explain the amplitude variation among the various stations? The focal mechanism clearly shows oblique slip, rake angle ~ 45^{o}. How is this reconciled with assumptions that Hosgri is to be modeled as strike slip?

Suppose we assume that the Hosgri fault is the dominant fault in the area. Let's further suppose we can subdivide the fault plane into smaller subelements. Each subelement contributes to the total ground motion of DCPP. For each of these subelements what is the tradeoff between attenuation (Q), geometrical spread (~1/R) and the velocity structure (reflection and transmission coefficients)? In brief, we were given information that indicated how Q, dipping velocity structures, enclosed basins affect the ground motion. What I would like to know is how important are these factors to the ground motion estimate at DCPP. Which factors are most important? How does one decide on the ranking of importance? How tightly constrained by data are the numerical values for these factors?

A directly related question concerns the site response itself. What is the effect of DCPP being located on the edge of a basin. The cross section of the velocity structure indicates a syncline beneath the plant, in essence, a basin. What control is there on the velocity contrast between the basin and the host rock? Will the location of DCPP be more susceptible to amplification of high frequency waves trapped in this basin? I do think that the proposed installation of more

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accelerometers and seismometers at DCPP will greatly enhance one's understanding of local site effects . I have some reservations about PG&E's choice of instruments which I will discuss below.

My second major concern is the vagueness of PG&E's approach to modeling the source. The reports on the use of empirical Green's function did not provide me a sense of correctness. I am skeptical that recordings made in the Imperial Valley can be used to simulate an earthquake on the Hosgri fault. The whole purpose of using an empirical Green's function is to include the path and site effects, especially for high frequencies, in calculating the expected ground motion. The empirical Green's function is particularly useful when the velocity structure is not well determined or when the velocity structure has obvious lateral heterogeneities which cannot be easily, if ever, modeled by computer codes. Simply correcting for the surface velocity between Imperial Valley and DCPP does not validate the use of ground motion recorded in the Imperial Valley for estimating ground motion at DCPP.

Although numerical modeling of ground motion plays a significant role in PG&E's LTSP, there was almost no discussion of how synthetic seismograms would be computed. The impression I had was that every variable would be random. Why? This randomization may be necessary for high frequencies but at low frequencies I doubt that this is appropriate. Suppose randomness is necessary. What probability distribution function is to be used for the amplitude? for the phase? for the rake angle? for the strike? What geological constraints are there on rake or strike of the fault? How are these to be incorporated? What will be the assumed slip time function on the fault? The partitioning between deterministic and stochastic processes is critical in the generation of synthetics. The whole issue of how the numerical modeling of the earthquake process was to be done was never addressed in this meeting.

In brief, how is PG&E going to take the site specific faults, the local site effects, the intervening velocity and Q structure and combine this will a numerical representation of an earthquake to produce synthetic time histories of ground motion at DCPP? In fairness to PG&E, it looks like they have many parts to this puzzle. However, unless the strategy for putting the puzzle together becomes clear, it is difficult to ascertain which parts are most important and thus deserve the most scrutiny.

Specific Comments
Instrumentation

Although the everyday activities of DCPP generate a lot of background noise, I think that the DCPP location needs more than one 3-component velocity transducer. A M 2.5 only 10 km from the plant managed to trigger the strong motion instruments. However, if that M 2.5 had occurred 30 km from the plant, the signal would probably not trigger the accelerometers. For the empircal Green's function

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approach, which is heavily emphasized by PG&E, nothing is more important than recording small earthquakes at DCPP. I think that the proposed accelerometers along AA' and BB' are worthwhile. The four accelerometers at the corners of the turbine building may provide the necessary information coherence and direction of arrival. I am not sure what preliminary analysis has been done as to the adequacy of this array for the above mentioned pupose. It may become necessary to supplement these four with a downhole instrument.

Velocity Structure

The velocity structure at the plant site and in the region is obviously important. The local velocity structure of DCPP to depths of 2 or 3 km seems to be unknown. The accelerograms recorded from the Nov. 12, 1984, earthquake show a lot of variation over a small distance. This distance is comparable to the distance from the cooling intake water supply to the reactors themselves. How much differential motion can be sustained along those pipelines?

Although Trehu and Wheeler (1986) present their interpretation for a refraction profile from San Simeon to the Great Valley, this data should be examined independently. The velocity model given by Trehu and Wheeler has some rather striking features that deserve close attention. What velocity model is going to be used when the numerical modeling is being done? How well known is the S-wave velocity structure?

When the offshore refraction profiles are being shot, every effort should be made to get S-wave data, especially at the DCPP site itself.

Ralph J. Archuleta

S-CUBED

A Division of Maxwell Laboratories, Inc.

16 May 1986

D. Jean Savy
Lawrence Livermore National Laboratory
P. O. Box 808
Mail Stop L-106
Livermore, California 94550

Dear Jean:

The following is my report on the meeting between the NRC staff and P.G. and E., held on April 14 and 15, 1986, at the Diablo Canyon power plant.

With respect to the work plan for ground motion, my overall impression is that the plan now envisioned has a good balance between empirical and theoretical approaches. The proposed methodologies are well matched to the engineering objectives. An appropriate set of tools (empirical Green's functions, numerical Green's functions via ray and finite difference methods, etc.) are available to the research team. The need for new data from closely spaced instruments at the site is being addressed (through the proposed spatial coherency array). The plan calls for a phased introduction of modeling results of increasing complexity into the engineering analyses, and is, I think, highly responsive to the comments made by the ground motion consultants last December.

The need now is for the consultants to receive rather detailed information about the proposed modeling methods, and I believe that the planned workshop will be an excellent vehicle for this. The following is a list of comments and questions which I would like to see addressed in such a workshop:

1. *The empirical Green's function method.* This approach appears to be an attractive means for getting the numerical modeling program off the ground quickly, and the preliminary results shown at the meeting looked promising, i.e., the Parkfield spectral shapes were well reproduced by this scheme, even using Imperial Valley recordings as Green's functions. As an aside, I think the method as proposed (using Imperial Valley recordings) is really more of an

empirical source function method than an empirical Green's function method, in that recordings from rather inappropriate (compared to DCPP) paths are being used, as a price for exploiting the high-frequency source information contained in the Imperial Valley recordings. I would like further details about the path corrections applied to the Imperial Valley recordings, including any correction for the difference in Q between Imperial Valley and DCPP paths. I would also like to see a detailed description of any randomization procedures employed in the Green's function summation. Validation studies of the method need to be presented in detail, including comparisons to recorded time histories and response spectra with absolute amplitudes shown.

2. *Numerical Green's function method.* Parameterization of the slip function as well as randomization applied to rupture velocity and slip function need to be spelled out in detail, since seemingly minor features of the slip function and rupture velocity can have a drastic effect on the computed ground motion at the very high frequencies of interest in the study. Which data for which events will provide the basis for validation of the source and path modeling?

3. *Array recordings at Diablo Canyon.* How will the spatial coherency array be configured and how will the observations be used in concert with the numerical ground motion procedures to provide realistic S.S.I. input? Signal coherence at the site is obviously of importance in evaluating the reality of the base-averaging (τ) effect, and I think some combination of array recordings and numerical modeling may be required to quantify the coherence of ground motion to be expected from a large earthquake.

Sincerely,

Steven M Day

Steven M. Day
Program Manager
Theoretical Geophysics

SMD:et

ENCLOSURE 4

PG&E VIEWGRAPHS
(13 SECTIONS)

ENCLOSURE 4

SECTION 1

DIABLO CANYON LONG TERM SEISMIC PROGRAM

PLANT SITE VISIT

MONDAY, APRIL 14, 1986

9:15 A.M.	INTRODUCTORY COMMENTS - NRC INTRODUCTORY COMMENTS - PGandE
	TOUR OF PLANT STRUCTURES
	DESCRIPTION OF SITE GEOLOGY AND TOPOGRAPHY
LUNCH	
	TOUR OF PLANT SITE AREA
	OVERVIEW OF RELATED GEOLOGY, SEISMOLOGY AND GEOPHYSICS ACTIVITIES OF LTSP

LSC:rle
4/11/86

DIABLO CANYON LONG TERM SEISMIC PROGRAM

PLANT SITE VISIT

TUESDAY, APRIL 15, 1986

8:45 A.M. REQUIREMENTS FOR GROUND MOTION PRODUCTS

OVERVIEW OF GROUND MOTION TASKS

A. MAY 1986
B. JUNE 1986
C. SEPTEMBER 1986
D. FEBRUARY 1987
E. JULY 1987

DISCUSSION

WORK TO DATE

LUNCH

GROUND MOTION MODELING TECHNIQUES

DISCUSSION

SOIL/STRUCTURE INTERACTION ANALYSIS

DISCUSSION

NRC CAUCUS/SUMMARY

LSC:rle
4/11/86

ENCLOSURE 4

SECTION 2

BACKGROUND

LONG TERM SEISMIC PROGRAM (LTSP)

PHASE I DEVELOPMENT OF PROGRAM PLAN

- Program based on Diablo Canyon Operating License Condition.
- Developed from four planning meetings with NRC staff and their advisors and consultants.
- LTSP submitted, January 30, 1985.
- Program review by NRC staff, consultants and advisors.
- NRC staff written comments, May 9, 1985.
    - Some elements overly ambitious - may require modifications to allow Program completion within three years.
    - Maintain flexible program to accommodate new developments as Program progresses.
    - While Program is comprehensive:
        - Lacks clear definition of topics to be addressed.
        - Lacks sense of priorities for evaluating topics.
        - Lacks specific plans about content and extent of studies to gather new data to evaluate specific topics.

PHASE I DEVELOPMENT OF PROGRAM PLAN (CONTINUED):

- Meeting (May 22, 1985) with NRC staff to respond and discuss written comments.

- PGandE submitted written response, June 11, 1985, consisting of supplemental clarifying information for items discussed in Program Plan.

  - Studies and investigations have not been deleted from Program.

  - Program will include seismic recording stations supplemental to the existing USGS stations. Also, evaluating feasibility of installing instruments in the offshore area.

  - PGandE agrees - some elements were overly ambitious and will consider this during the Phase II Scoping Study. Allow appropriate modifications to complete Program within three years while maintaining Program objectives.

  - The Phase II Scoping Study will develop scope of work for Phase III.

- Program Plan approved by NRC, July 31, 1985.

DIABLO CANYON
LONG TERM SEISMIC PROGRAM
CONSULTING BOARD

Clarence R. Allen	Seismic Geology and Tectonics
Bruce A. Bolt	Seismology and Ground Motions
C. Allin Cornell	Probability/Risk Assessment
Thomas M. Leps	Engineering
Cole R. McClure	Geology
H. Bolton Seed	Ground Motions and Soil/ Structure Interaction

BOARD FORMED OCTOBER 1984

- Advise and provide guidance
- Review Program Plan
- Have strong influence on Program Development
- Significantly involved in Phase II activities in establishing priorities and scope of work

LSC - 3/11/86

CONSULTING BOARD MEETING SCHEDULE

1. October 25, 1984
2. January 7, 1985
3. January 21, 1985
4. March 7, 1985
5. June 12, 1985
6. July 17, 1985
7. September 26, 1985
8. November 1, 1985
9. January 21, 1986

LSC - 3/11/86

DYNAMIC CHARACTER OF LONG TERM SEISMIC PROGRAM

- Program must be flexible to achieve successful completion of Program objectives.

- Elements of Program Plan must not be viewed as absolutes.

- To be successful, Program must be structured to accommodate change.

- Program evolves as work progresses within framework of approved Plan.

LSC - 3/11/86

LTSP PHASE II SCOPING STUDY

PURPOSE

Develop Scope of Work for Phase III

- Balanced
- Integrated
- Focused on Important Topics
- Clear Sense of Priorities
- Realistic Schedule

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4/11/86

PHASE II GROUND MOTIONS EFFORTS

- Provide closer tie between engineering requirements and Ground Motions Program

- Define schedule for Ground Motions requirements and structural program in accordance with their requirements

- Provide balanced, integrated program utilizing both empirical and numerical methods

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4/11/86

THIS MEETING

PURPOSE

- To provide an opportunity for members of the Soil/Structure Interaction Panel and the Ground Motions Panel to visit the Diablo Canyon Plant Site

- To discuss the Phase III Ground Motions and Soil/Structure Interaction Programs

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4/11/86

ENCLOSURE 4

SECTION 3

OVERVIEW OF LTSP GEOLOGY/SEISMOLOGY/GEOPHYSICS ACTIVITIES

PURPOSE: To summarize those aspects of the GSG activities that are related to the ground motion program

- Summary of aims of GSG scope of work
- Emphasis on seismic source characteristics and methods to assess them

DCPP LICENSE CONDITION

1. "...update the geology, seismology, and tectonics in the region..."

2. "...re-evaluate the magnitude of the earthquake used to determine the design basis..."

3. "...re-evaluate the ground motion at the site..."

4. "...assess the significance of conclusions...to assure adequacy of seismic margins."

GEOLOGY/SEISMOLOGY/GEOPHYSICS

SIGNIFICANT CONSIDERATIONS

- "Significant considerations" are those technical factors that make a major contribution to the engineering impact at DCPP of potential earthquakes and thus are evaluated to be important to one or more elements of the license condition.

Examples: Sense of slip, maximum magnitude, and slip rate on a nearby capable fault.

METHODS USED TO IDENTIFY

SIGNIFICANT TECHNICAL CONSIDERATIONS

- Fault-specific seismic sources
- Logic trees
- Analytical Techniques
  - Relative hazard values
  - Relative deterministic ground motions
  - Contributions to uncertainty
  - Relative magnitude contribution
  - Scenario testing
- Judgmental Approaches
  - Historical significance
  - NRC staff considerations
  - LTSP Consulting Board suggestions

GEOLOGY/SEISMOLOGY/GEOPHYSICS

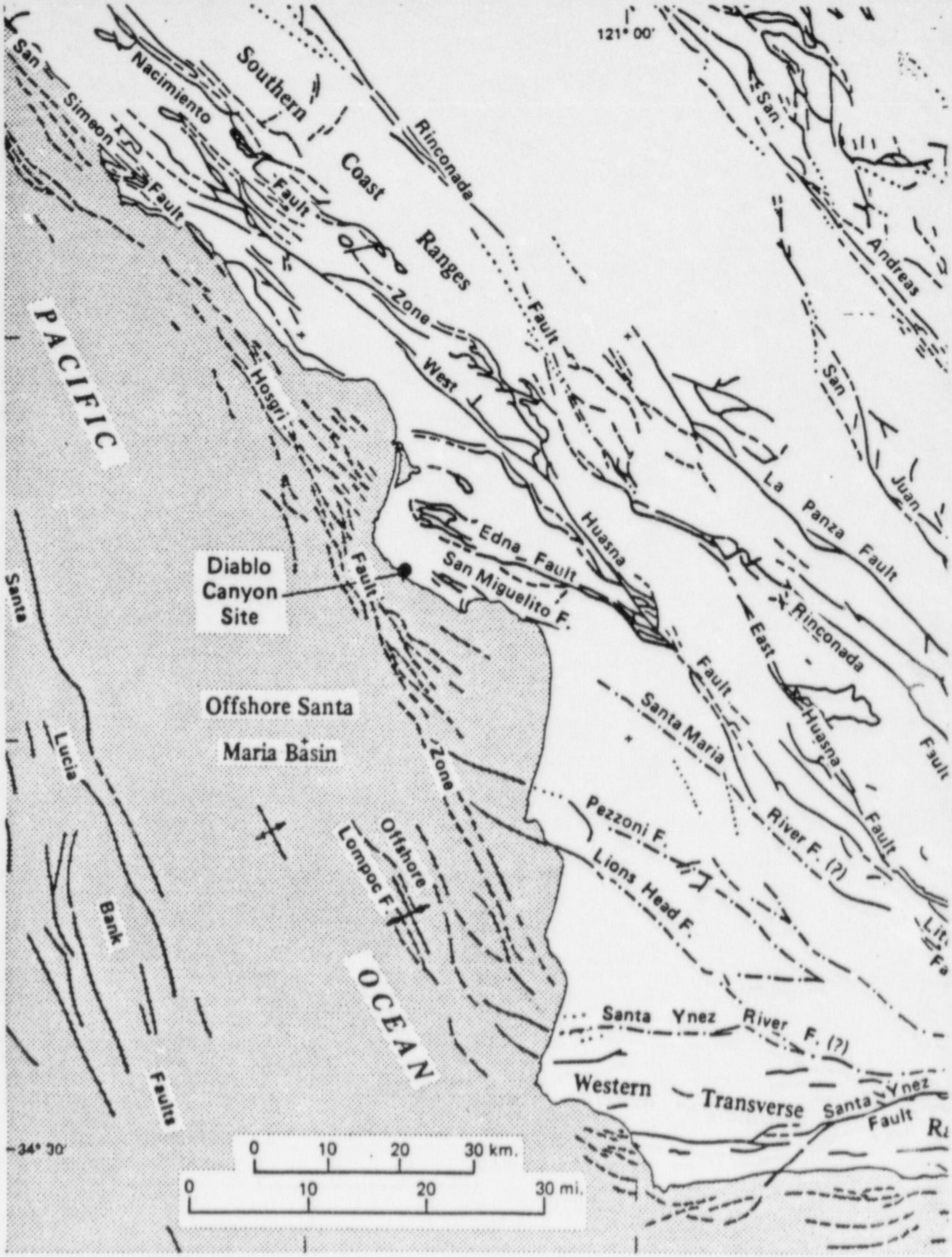
SIGNIFICANT CONSIDERATIONS (cont'd)

Consideration	Significance	Task Where Addressed
WEST HUASNA, RINCONADA, NACIMENTO		
• Sense of Slip	• Tectonic model	2, 3, 6, 8
• Slip Rate	• Kinematic relationship • Earthquake recurrence	2, 6, 8
1927 EARTHQUAKE		
• Location, Size, Focal Mechanism	• Association with fault • Tectonic model	1, 3
UNKNOWN RELEVANT FAULTS AND FOLDS		
• Existence and Capability	• Existence as seismic sources	2, 4
• Physical Characteristics	• Maximum magnitude and earthquake recurrence	2, 4
TECTONIC MODEL		
• Development of Integrated Model	• Distribution of interplate strain • Consideration of tectonic hypotheses (listric faulting. decollement, etc.) • Implications to seismic sources and seismicity	8
SOURCE CHARACTERISTICS		
	• Deterministic ground motions • Probabilistic risk assessment	9

GEOLOGY/SEISMOLOGY/GEOPHYSICS

SIGNIFICANT CONSIDERATIONS

Consideration	Significance	Task Where Addressed
HOSGRI FAULT		
• Sense of Slip	• Tectonic model/kinematic relationships	1, 2, 3, 8 ...
• Dip/Downdip Width	• Tectonic model • Proximity to site	1, 3, 7, 8
• Total Length/Segmentation	• Maximum magnitude • Tectonic Model	1, 3, 8
• Slip Rate	• Earthquake recurrence • Kinematic relationship	1, 2, 8
EDNA and SAN MIGUELITO FAULTS		
• Capability	• Existence as seismic source	2, 4
• Sense of Slip	• Tectonic model	2, 4, 8
• Total Length	• Maximum magnitude	2, 4
• Slip Rate	• Earthquake recurrence	2, 4, 8
LITTLE PINE - FOXEN CANYON FAULT		
• Capability	• Existence as seismic source	2, 3, 5
• Sense of Slip	• Tectonic model	2,3,5,7,8
• Total Length	• Proximity to site	2, 5, 7, 8



Map Symbols

Mapped fault, dotted where concealed.

Trend of proposed subsurface fault.

Anticlinal fold, expressed as topographic feature of the sea floor.

Fault Data Sources

Jennings (CDMG), 1975

McCulloch et. al. (USGS), 1980 (Santa Lucia Bank area)

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Hall, 1977 (Santa Maria River F. (?))

Sylvester and Darrow, 1978 (Santa Ynez River F. (?))

SANTA MARIA BASIN REGIC

SUBTASK 9.1 SPECIFICATION OF SEISMIC SOURCES

- Identification of capable and potentially capable seismic sources

- Parameters in logic trees for each source:

  - Capability:

    - recency of slip
    - association with seismicity
    - structural association

  - Geometry:

    - fault dip
    - downdip width
    - total length

  - Maximum Magnitude:

    - sense of slip
    - segmentation
    - rupture length
    - displacement per event
    - slip rate
    - maximum historical

  - Earthquake Recurrence

    - slip rate
    - size distribution model
    - recurrence model

DOMINANT GSG CONTRIBUTORS TO UPPER HAZARD CURVES IDENTIFIED IN PHASE II SCOPING STUDIES

- Hosgri fault
- Strike-slip fault type
- Distances less than 6 km
- Mmax $\sim$ 7
- Magnitudes 6-7
- Slip rate 6 mm/yr

SEISMIC SOURCE CHARACTERISTICS

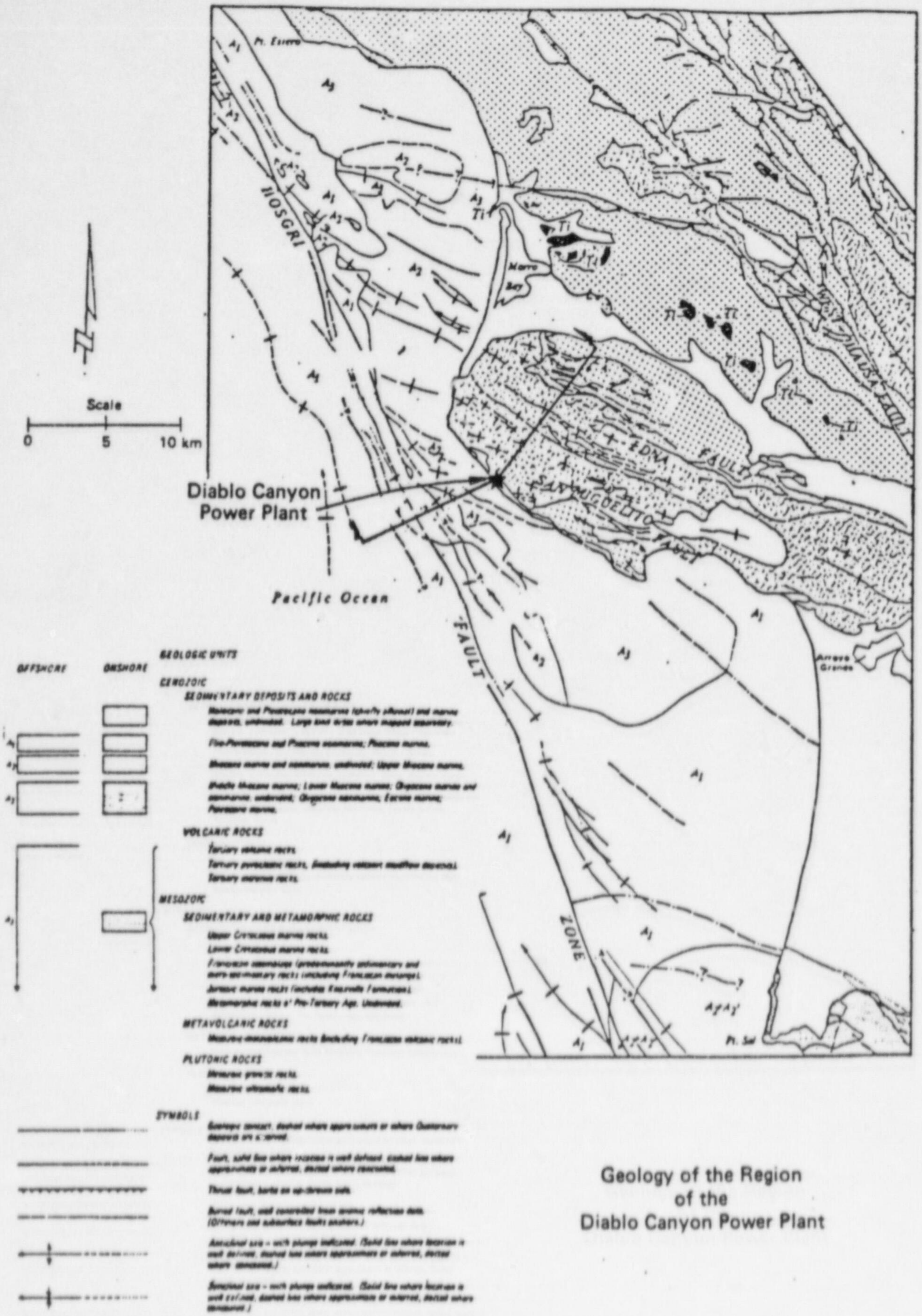
HOSGRI FAULT

Consideration	Significance	How Assessed in LTSP
Recency of slip	• Capability	• Onshore neotectonics and Quaternary
Sense of slip	• Tectonic model • Mmax estimates • Implications to slip rate • Ground motion estimates	• Offshore geophysics • Structural contour and isopach mapping • Focal mechanisms analysis
Downdip geometry	• Tectonic model • Mmax estimates • Ground motion modeling • Hazard modeling	• Offshore geophysics • Focal depth analysis • Regional tectonic considerations

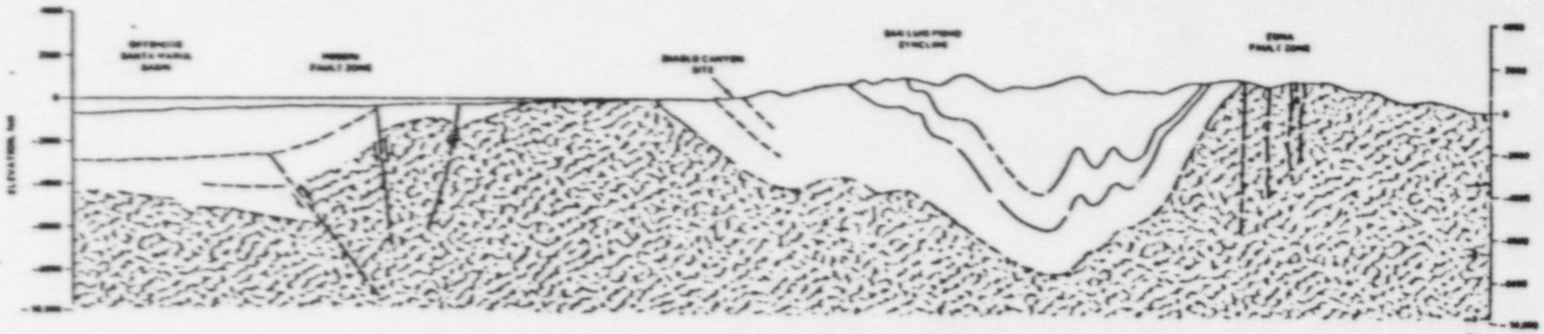
Consideration	Significance	How Assessed in LTSP
Segmentation	• Mmax estimates • Ground motion modeling • Hazard modeling	• Detailed fault mapping onshore and offshore • Considerations of geologic complexities • Patterns of seismicity
Maximum Magnitude (rupture, length area, d/c)	• Deterministic ground motions • Hazard modeling	• Detailed fault mapping onshore and offshore • Onshore neotectonics studies
Slip Rate	• Tectonic model • Recurrence rate • Hazard modeling	• Onshore neotectonics and Quaternary geology studies • Regional tectonic considerations • Geodetic data
Recurrence Models (size; spatial/ temporal)	• Hazard modeling	• Onshore neotectonics and Quaternary geology studies • Seismicity analysis

ENCLOSURE 4

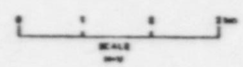
SECTION 4



Geology of the Region
of the
Diablo Canyon Power Plant



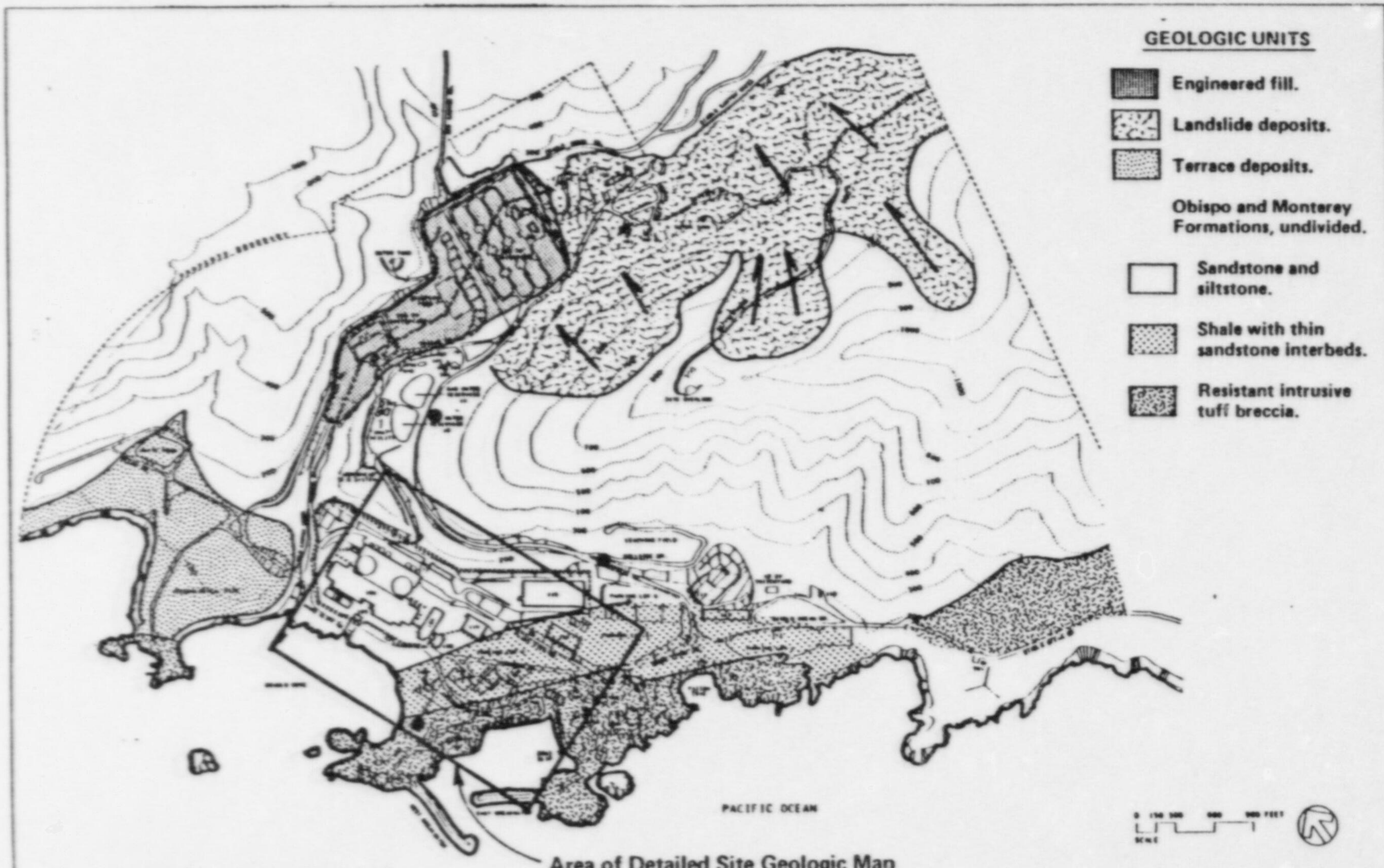
REGIONAL CROSS SECTION, VIEW NORTHWEST



GEOLOGIC UNITS

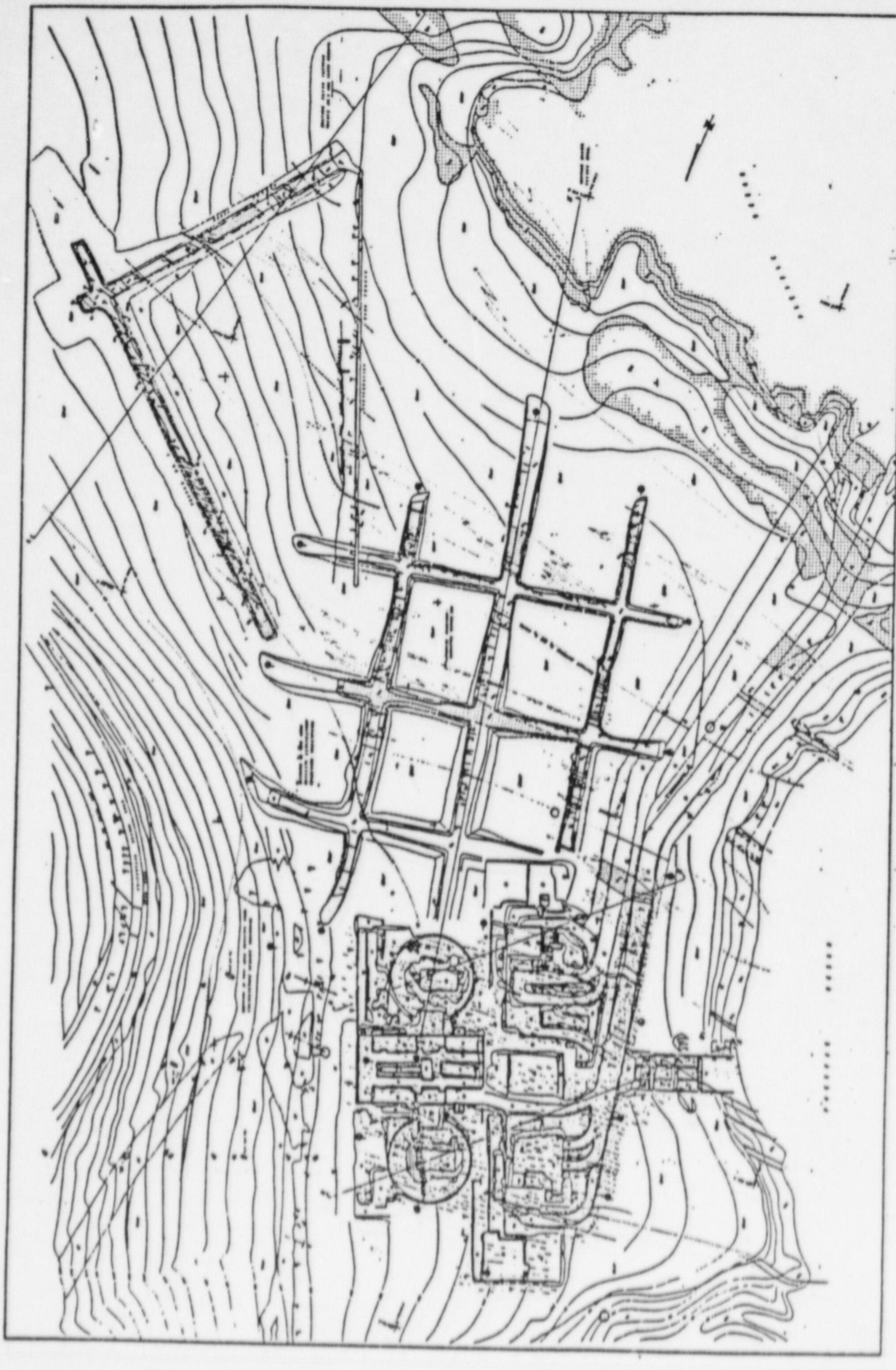
- U. Miocene-Pliocene Pismo Formation
- Miocene Monterey Formation
- Miocene Obispo, Rincon, and Vaqueros Formations
- Jurassic-Cretaceous Fransiscan Formation—Great Valley Sequence ("Basement")

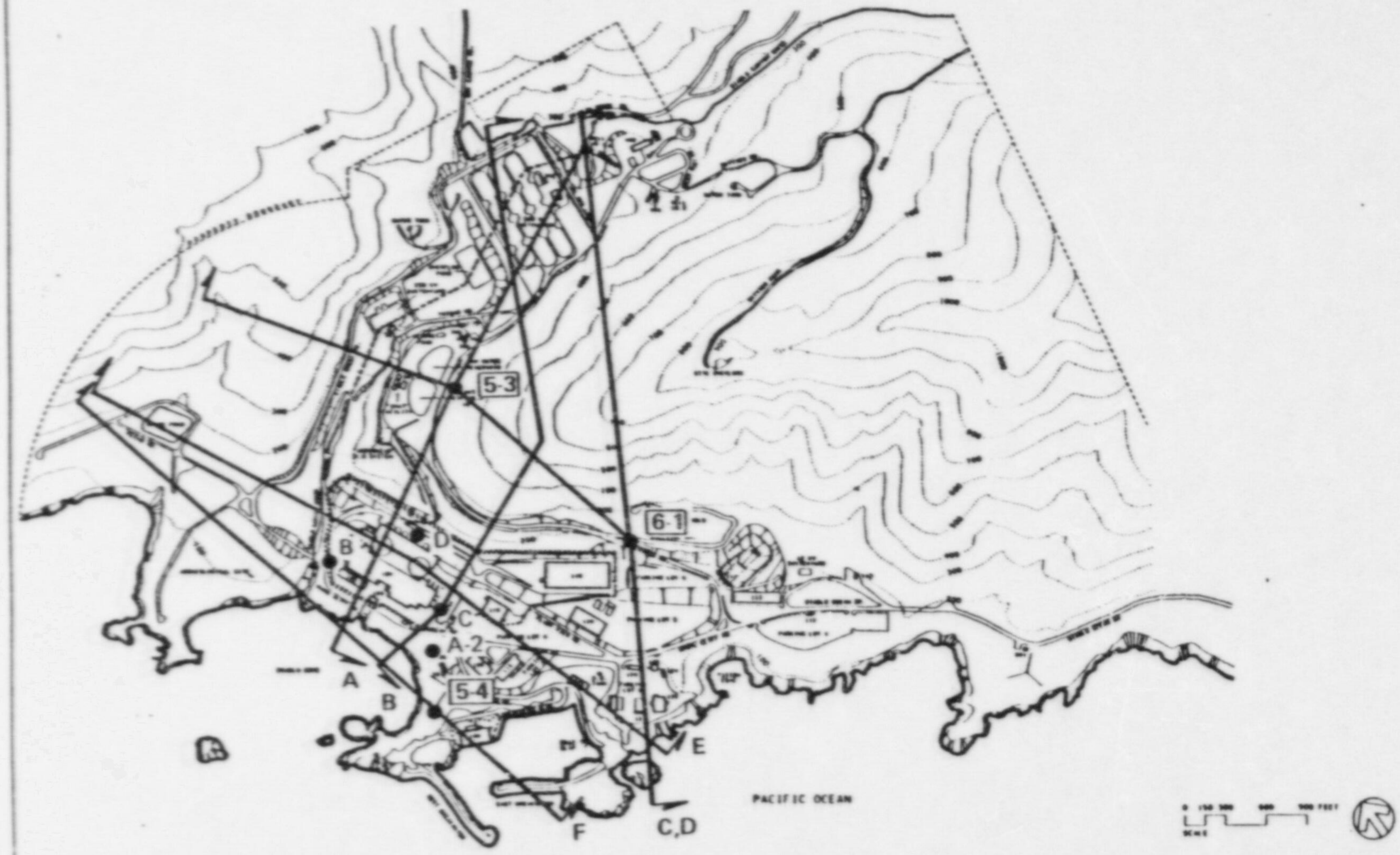
III-11



GENERALIZED GEOLOGIC MAP

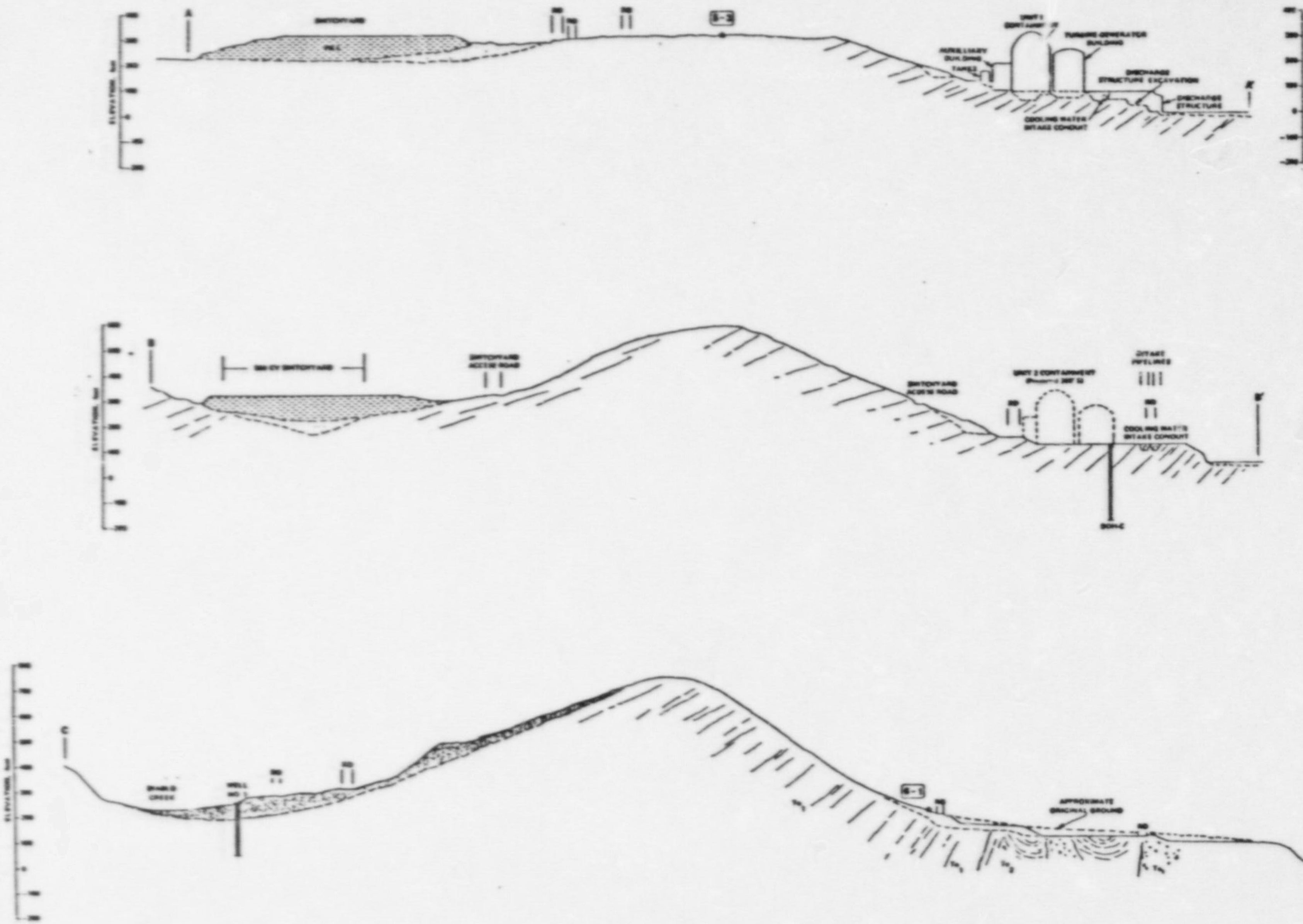
PERMANENT FACILITIES MAP

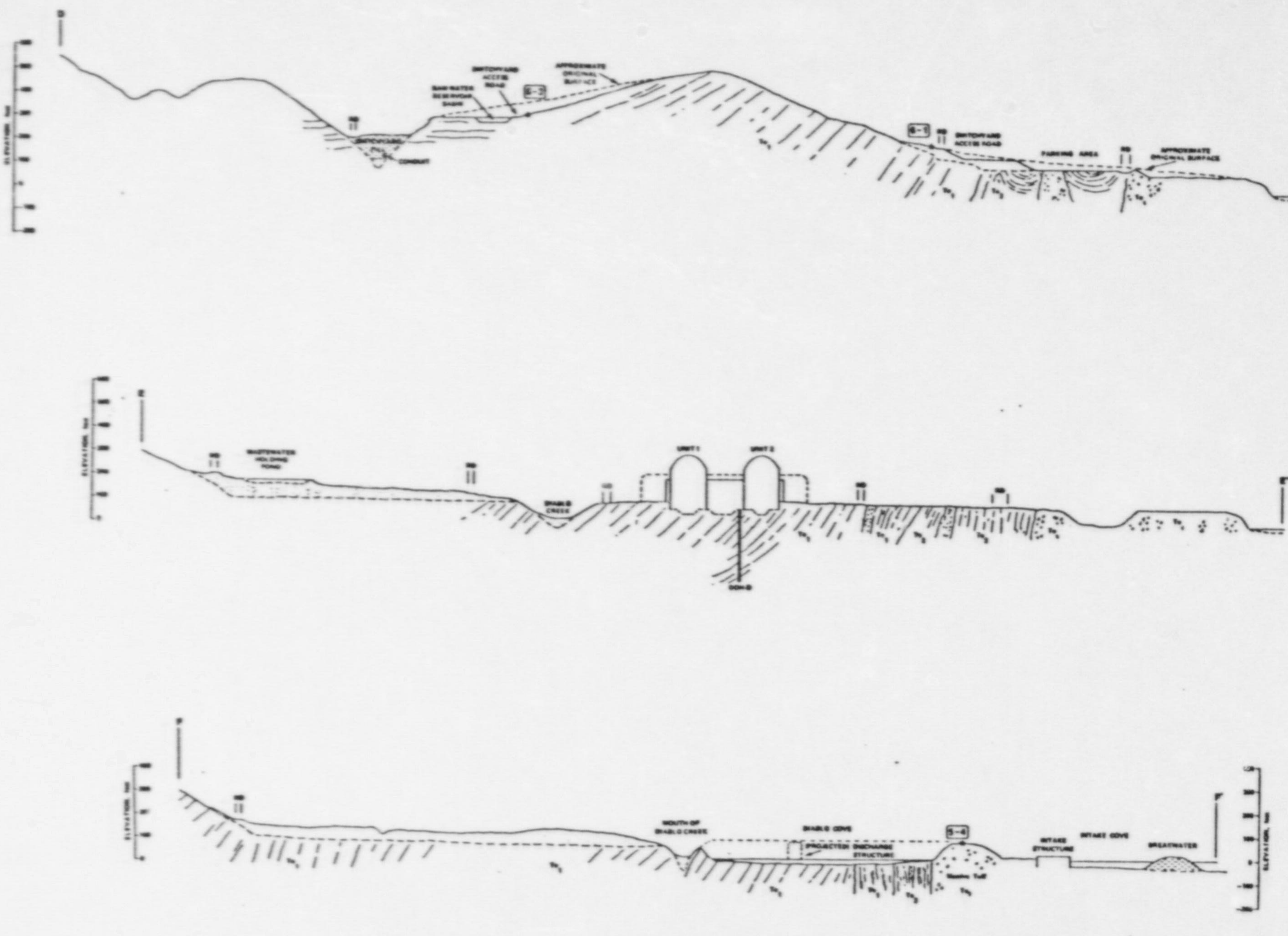


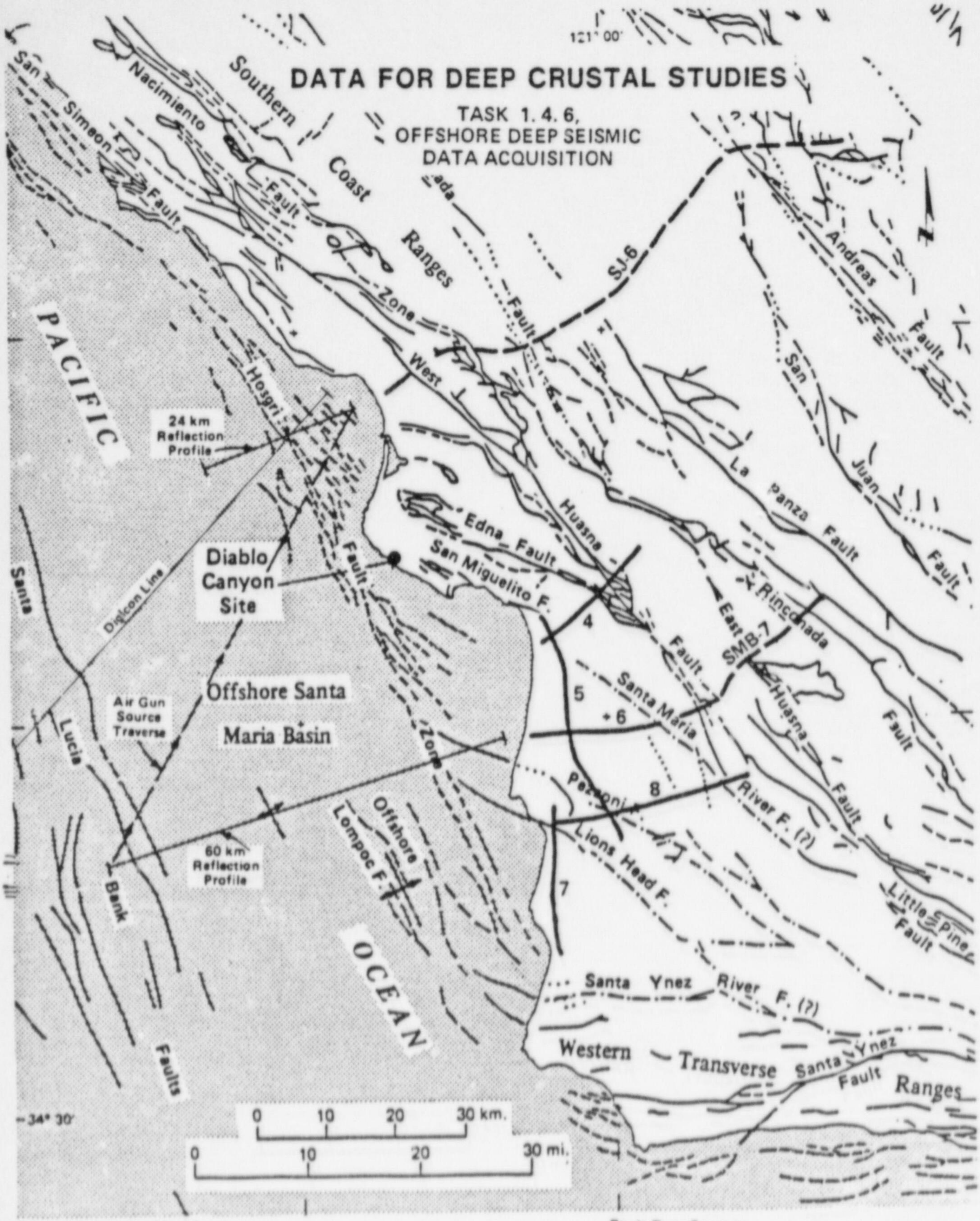


MAP SHOWING LOCATIONS OF PROFILES AND STRONG MOTION ACCELEROGRAPH SITES

PERMANENT FACILITIES MAP


ELEVATION, feet
SWITCHYARD
TURBINE-GENERATOR BUILDING
DISCHARGE STRUCTURE EXCAVATION
DISCHARGE STRUCTURE
COOLING WATER INTAKE CONDUIT
SWITCHYARD ACCESS ROAD
UNIT 2 CONTAINMENT
APPROXIMATE ORIGINAL GROUND


ELEVATION, feet
APPROXIMATE ORIGINAL SURFACE
SWITCHYARD ACCESS ROAD
S-2
S-1
SWITCHYARD
CONDUIT
PARKING AREA
WASTEWATER HOLDING POND
DIABLO CREEK
UNIT 1
UNIT 2
MOUTH OF DIABLO CREEK
DIABLO COVE
PROJECTED DISCHARGE STRUCTURE
S-4
INTAKE STRUCTURE
INTAKE COVE
BREAKWATER



Map Symbols

- Mapped fault, dotted where concealed.
- Trend of proposed subsurface fault.
- Anticlinal fold, expressed as topographic feature of the sea floor.

Fault Data Sources

Jennings (CDMG), 1975

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Hall, 1977 (Santa Maria River F. (?))

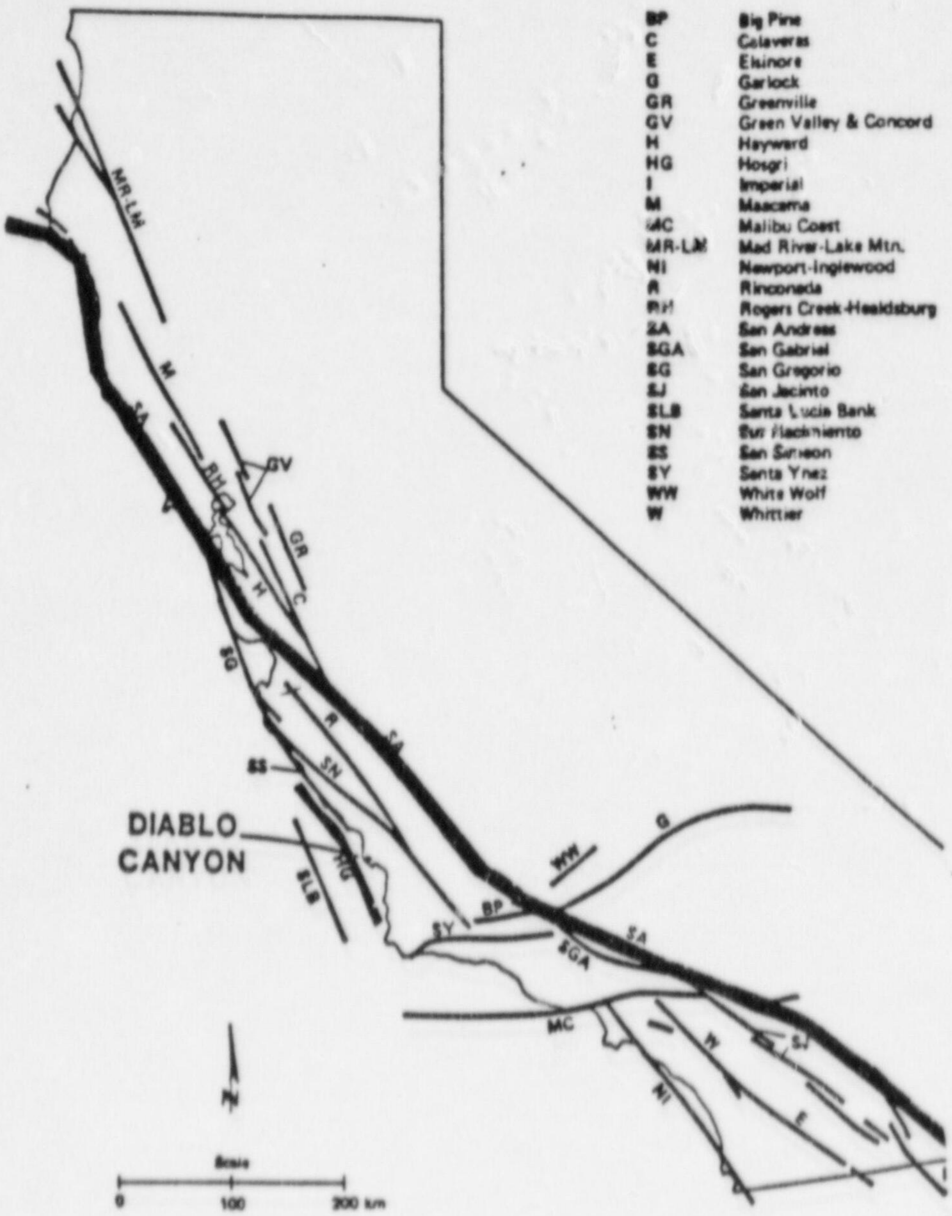
Sylvester and Darrow, 1978 (Santa Ynez River F. (?))

SANTA MARIA BASIN REGION

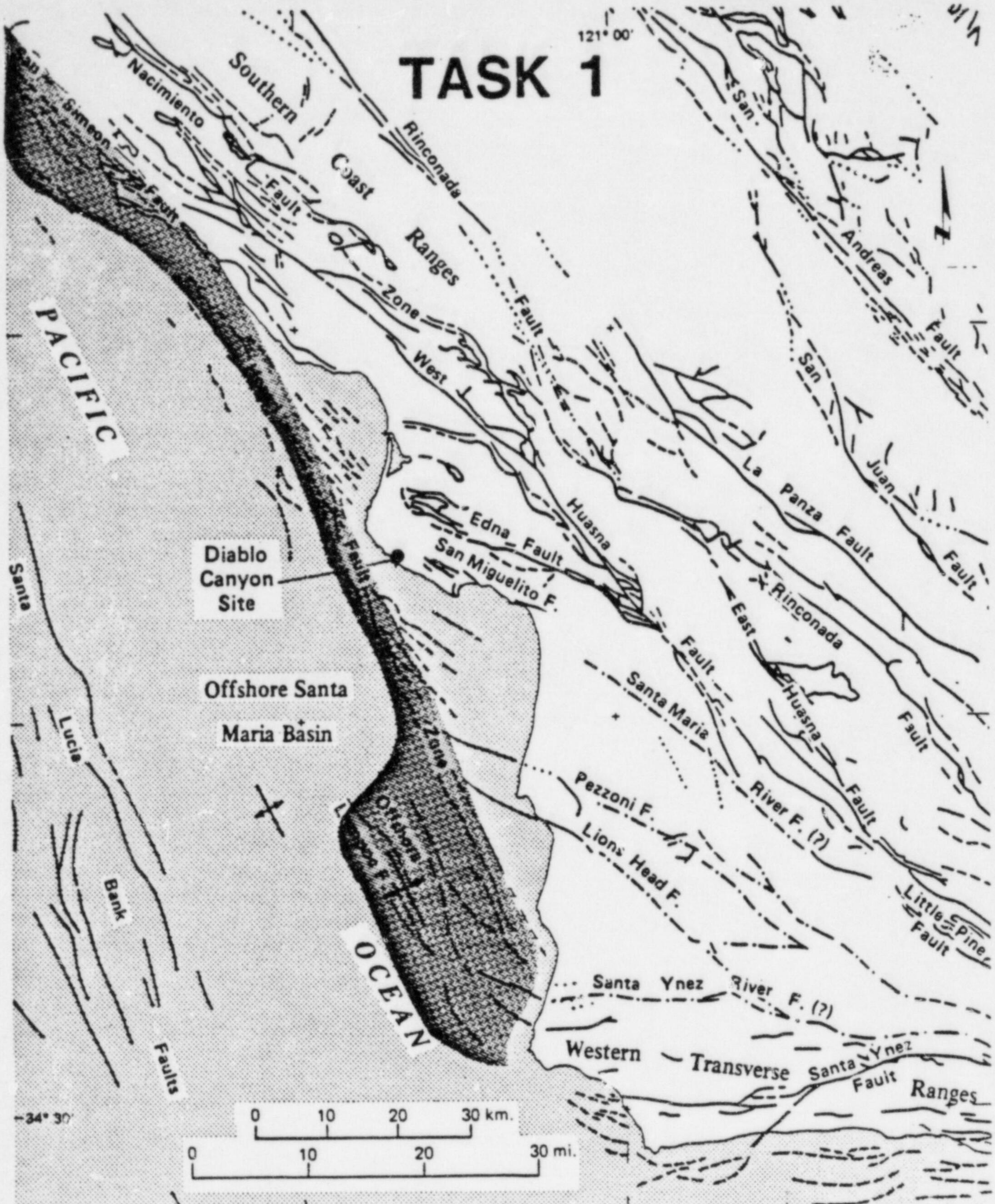
ENCLOSURE 4

SECTION 5

Diablo Canyon
Long Term Seismic Program
Location Map



TASK 1



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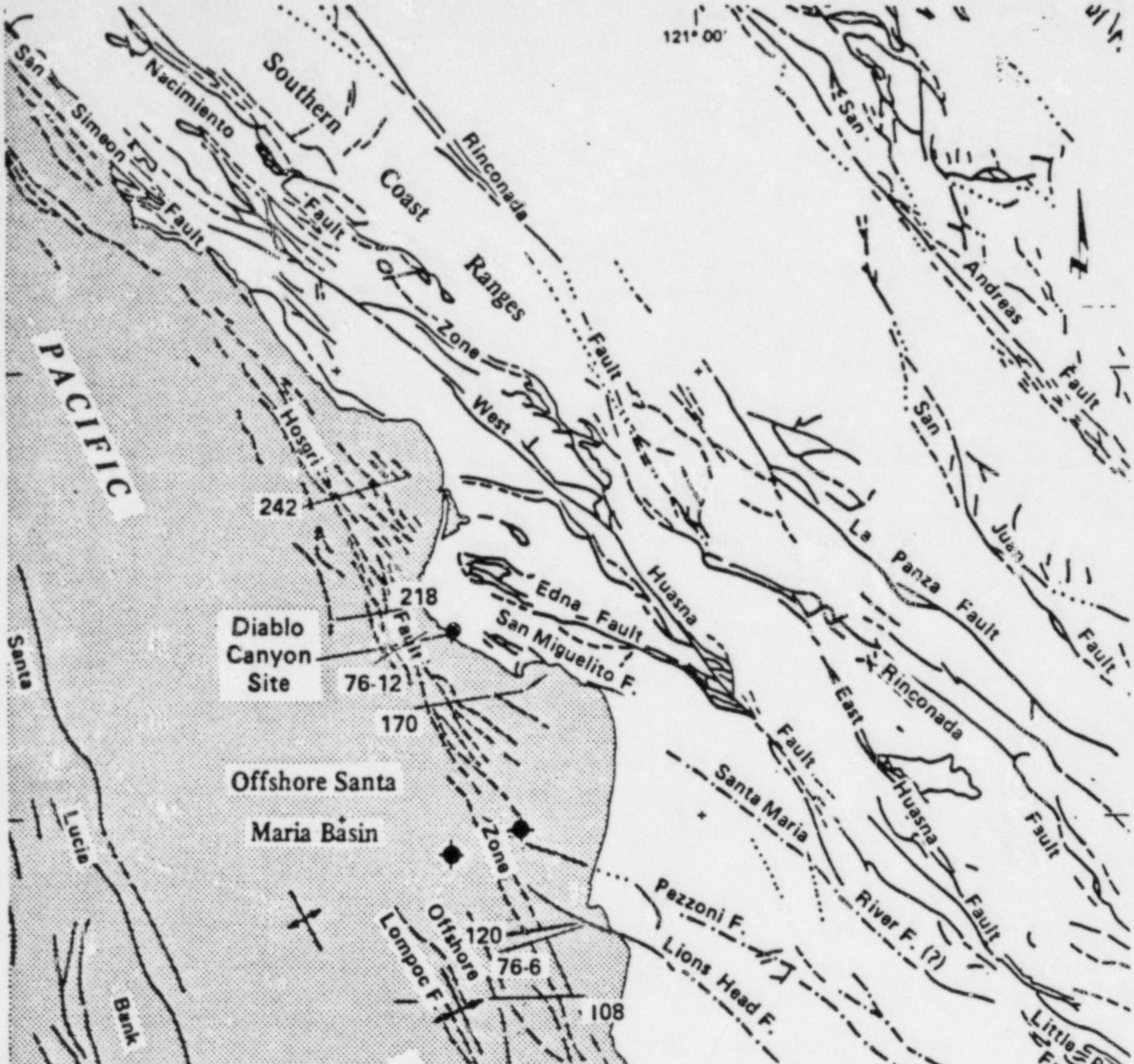
SANTA MARIA BASIN REGION



Map Symbols

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- Wells

Fault Data Sources

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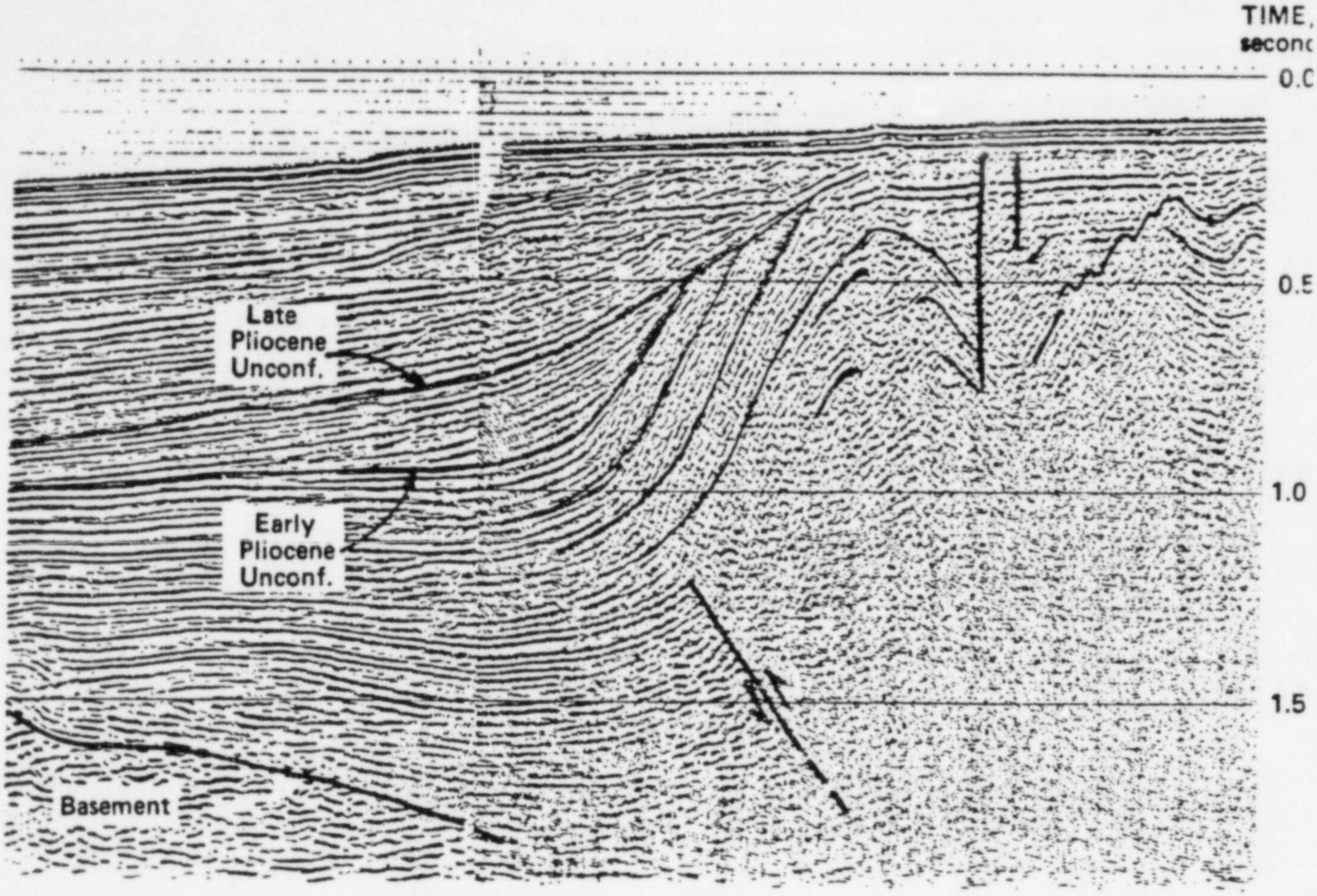
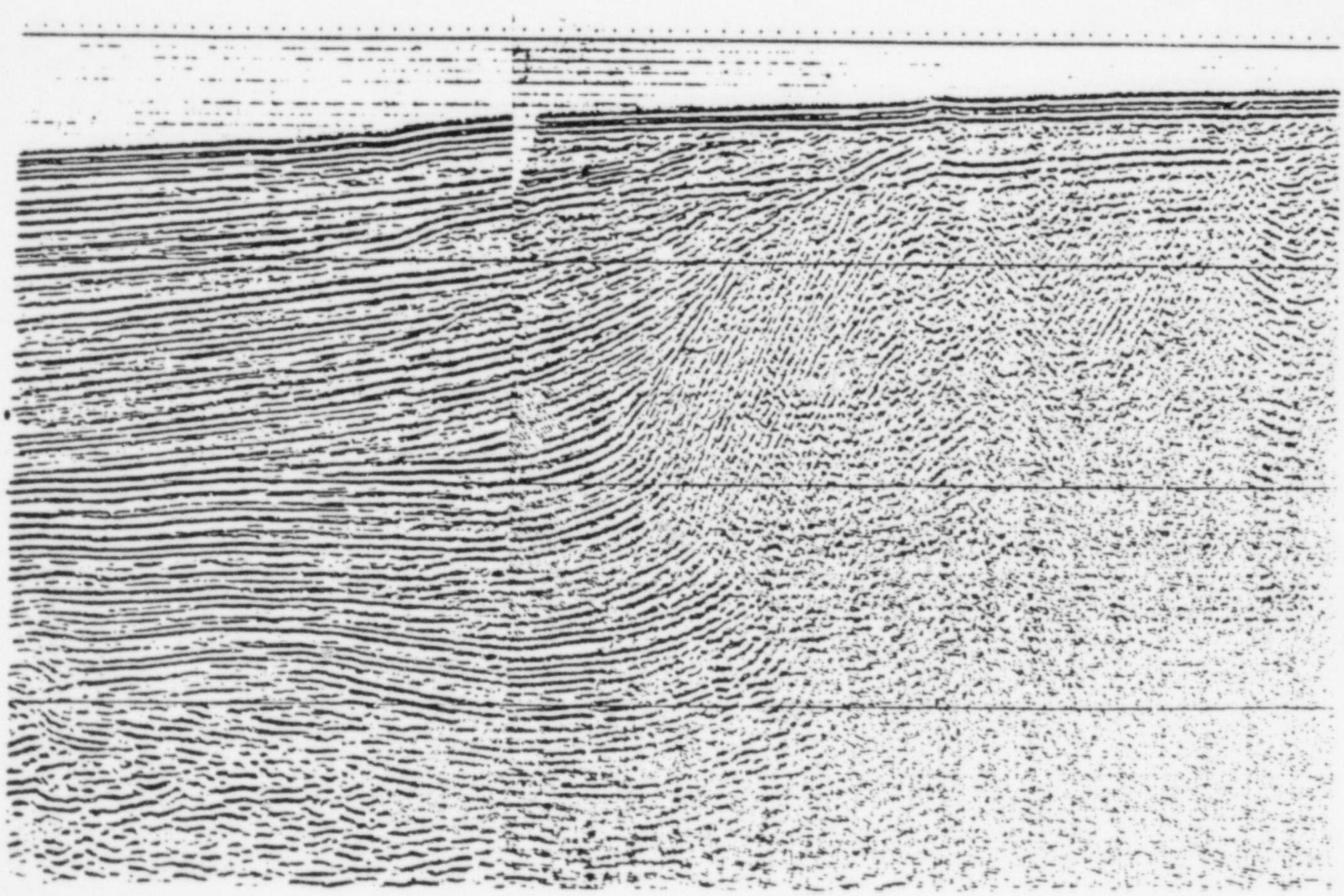
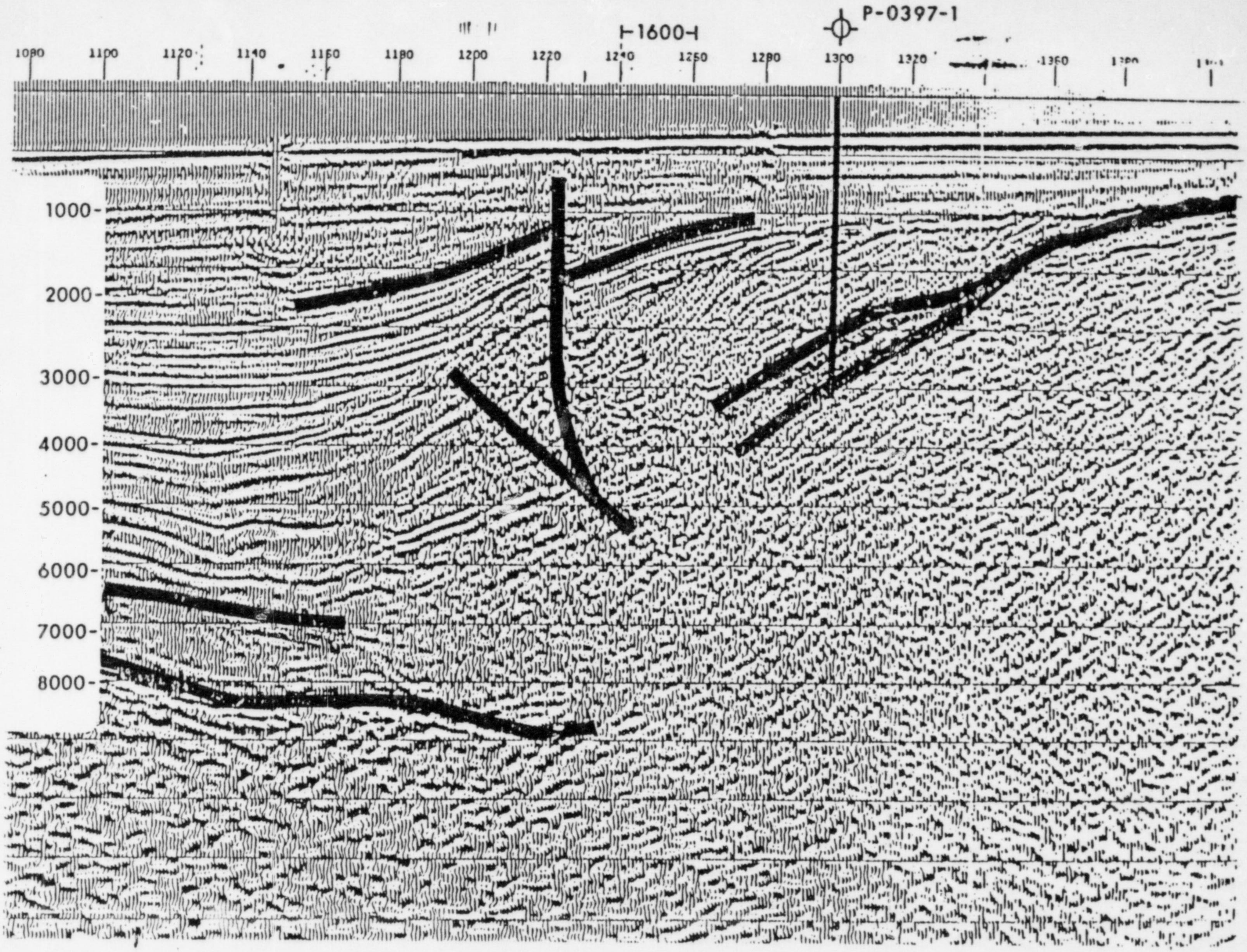
SANTA MARIA BASIN REGION



Vertical Exaggeration 1.5 - 1.75 X



CGL Line 76-12


P-0397-1
1600
1080
1100
1120
1140
1160
1180
1200
1220
1250
1280
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1320
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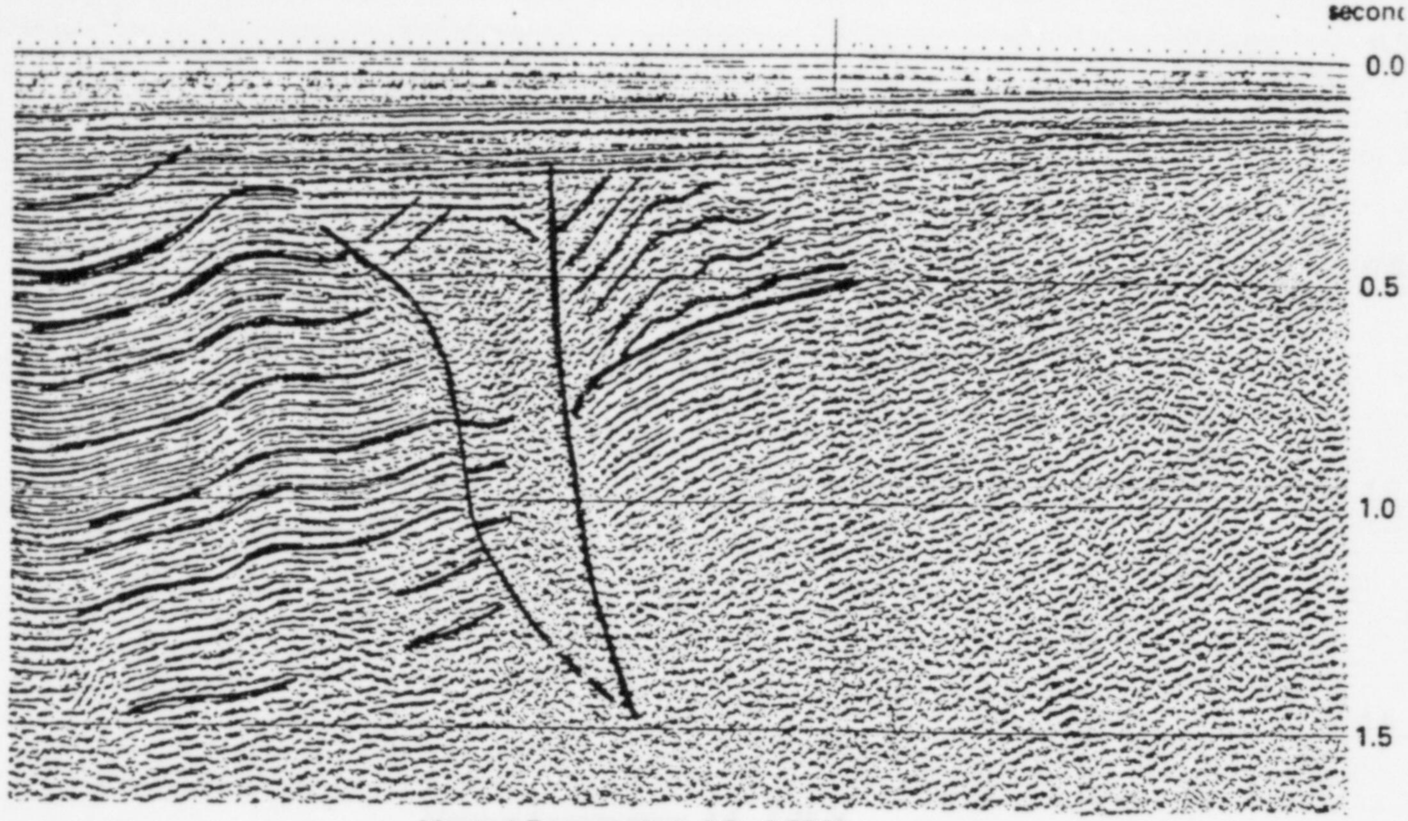
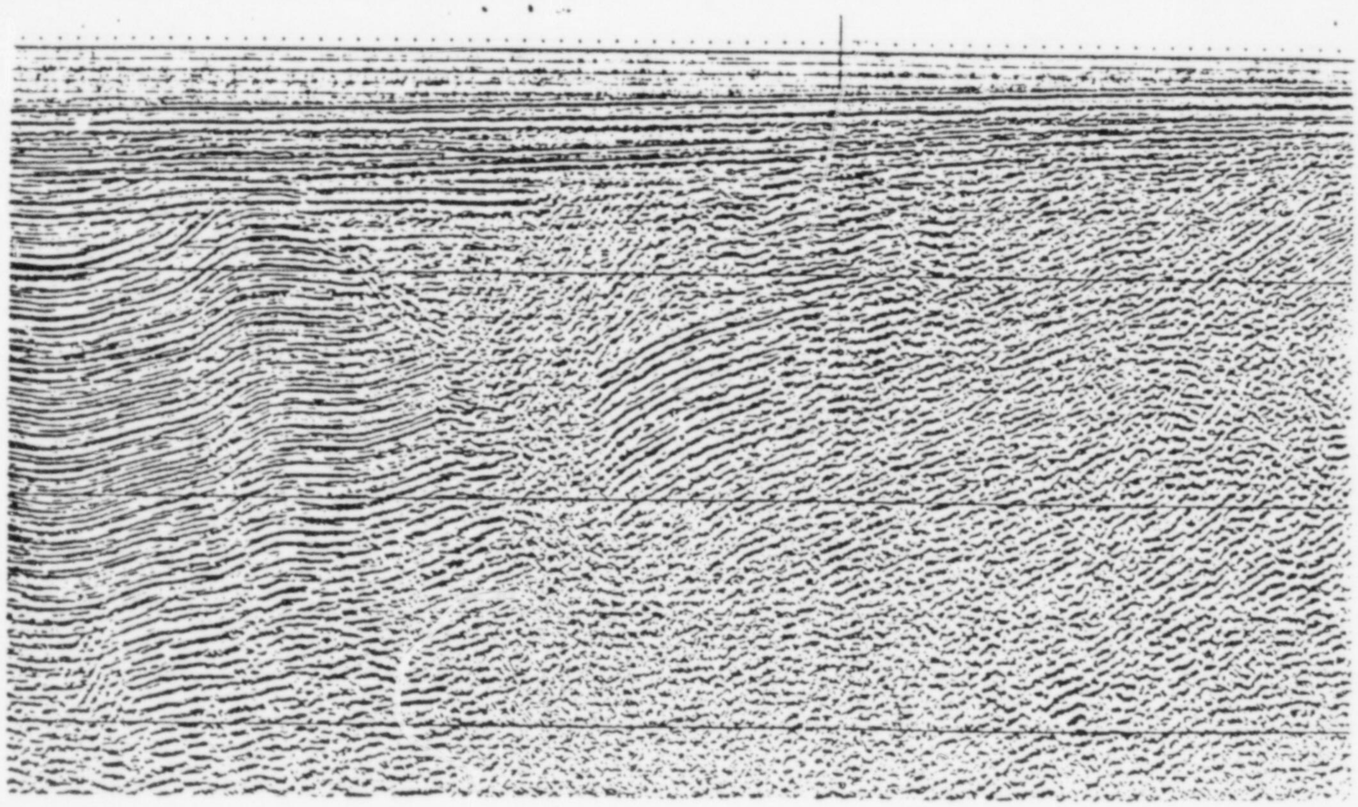
5000-
6000-
7000-
8000-

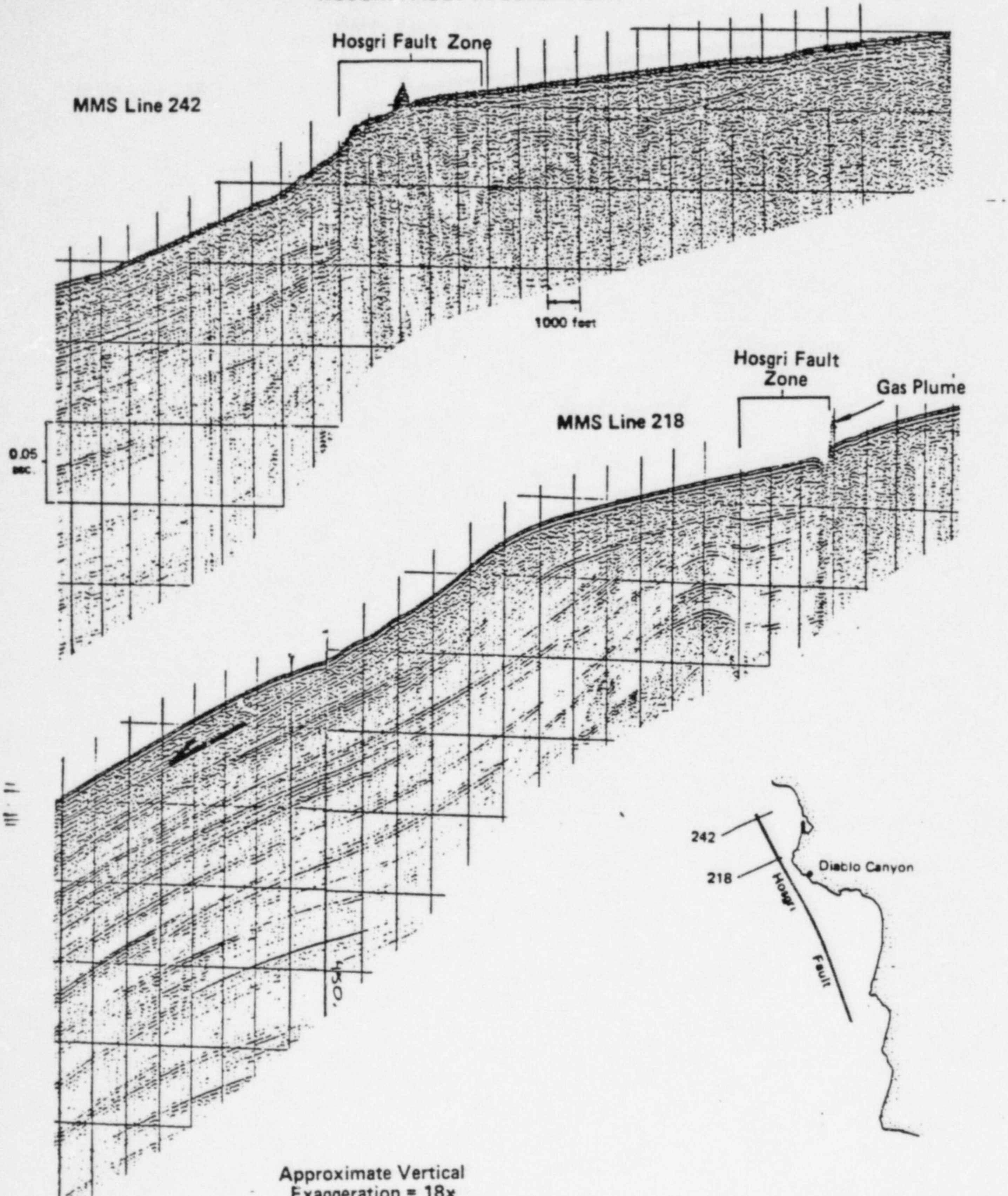


Vertical Exaggeration 1.5 - 1.75 X

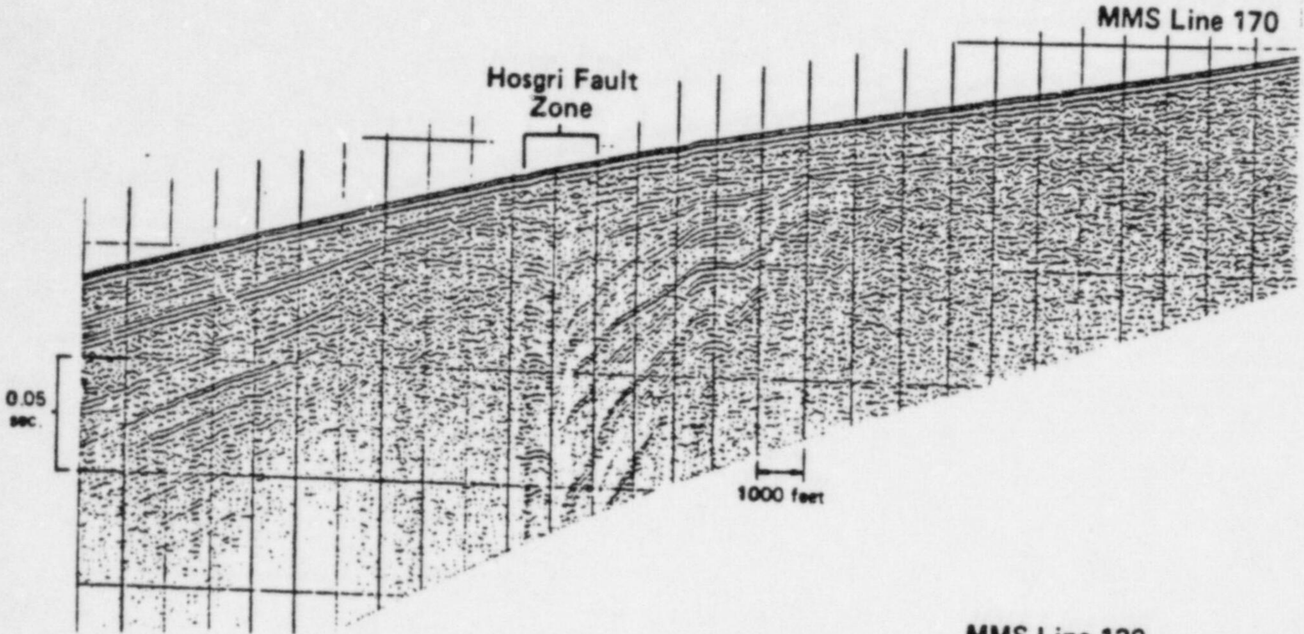


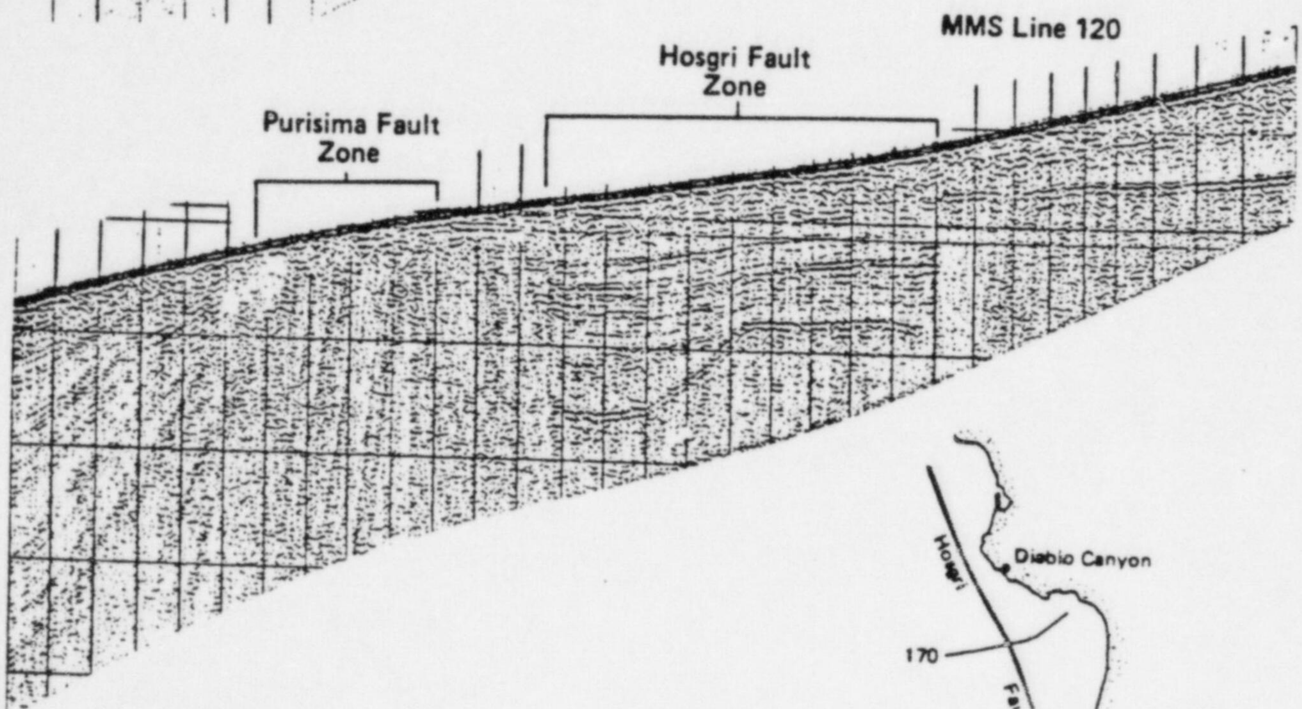
CGI Line 76-6

HOSGRI FAULT IN ESTERO BAY

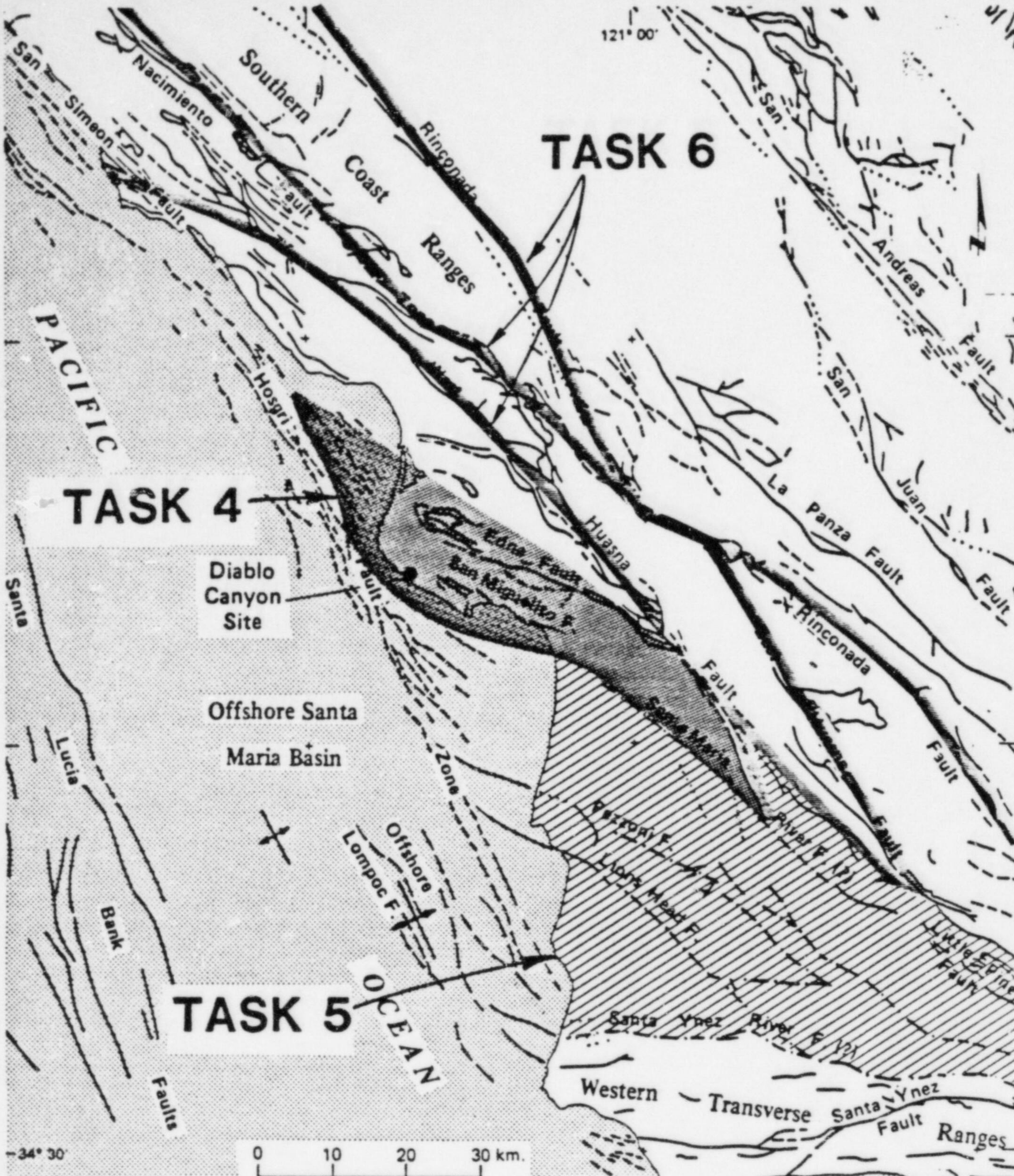


HOSGRI FAULT
PT. SAN LUIS – PT. SAL





Approximate Vertical
Exaggeration = 18x



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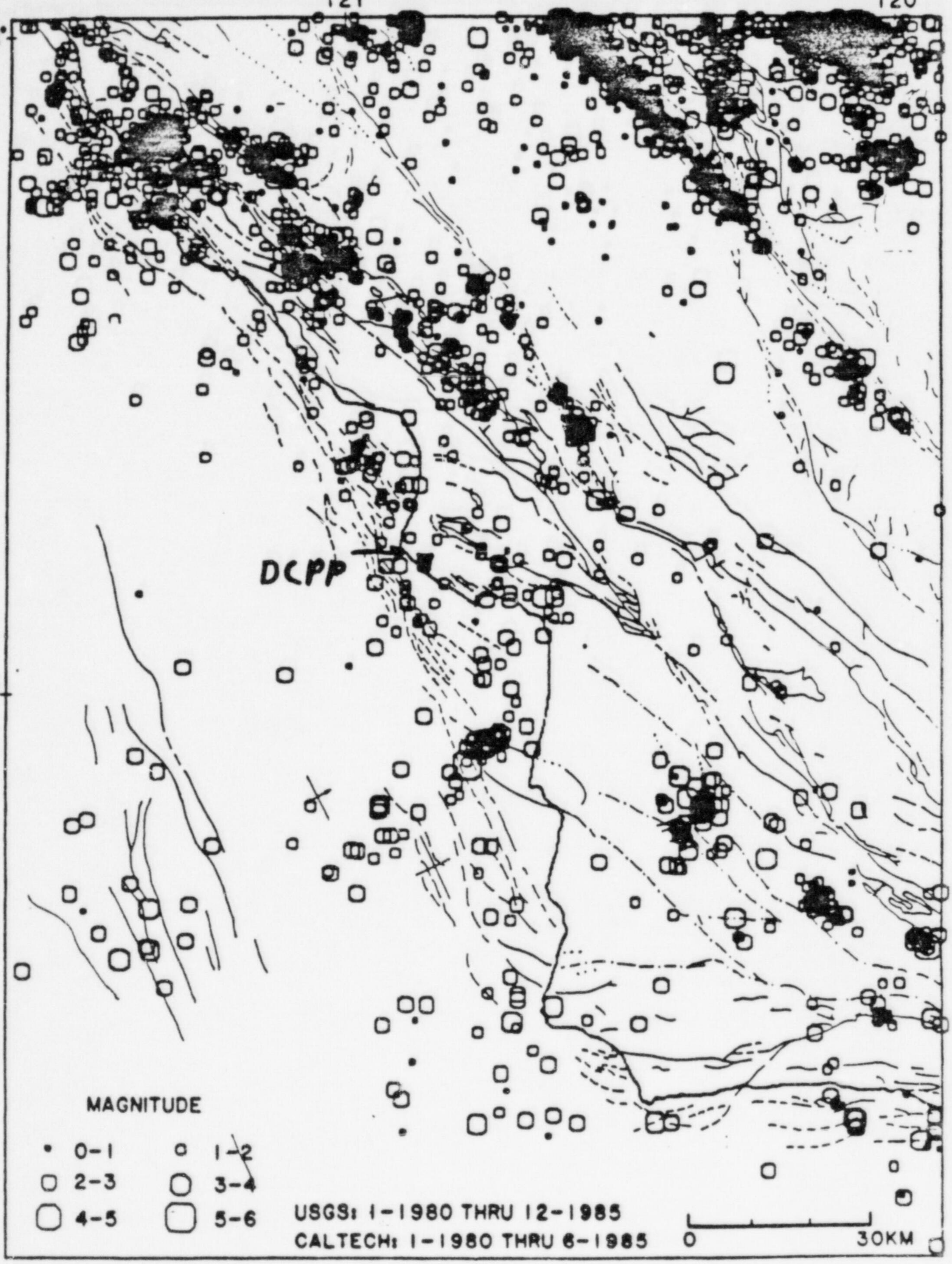
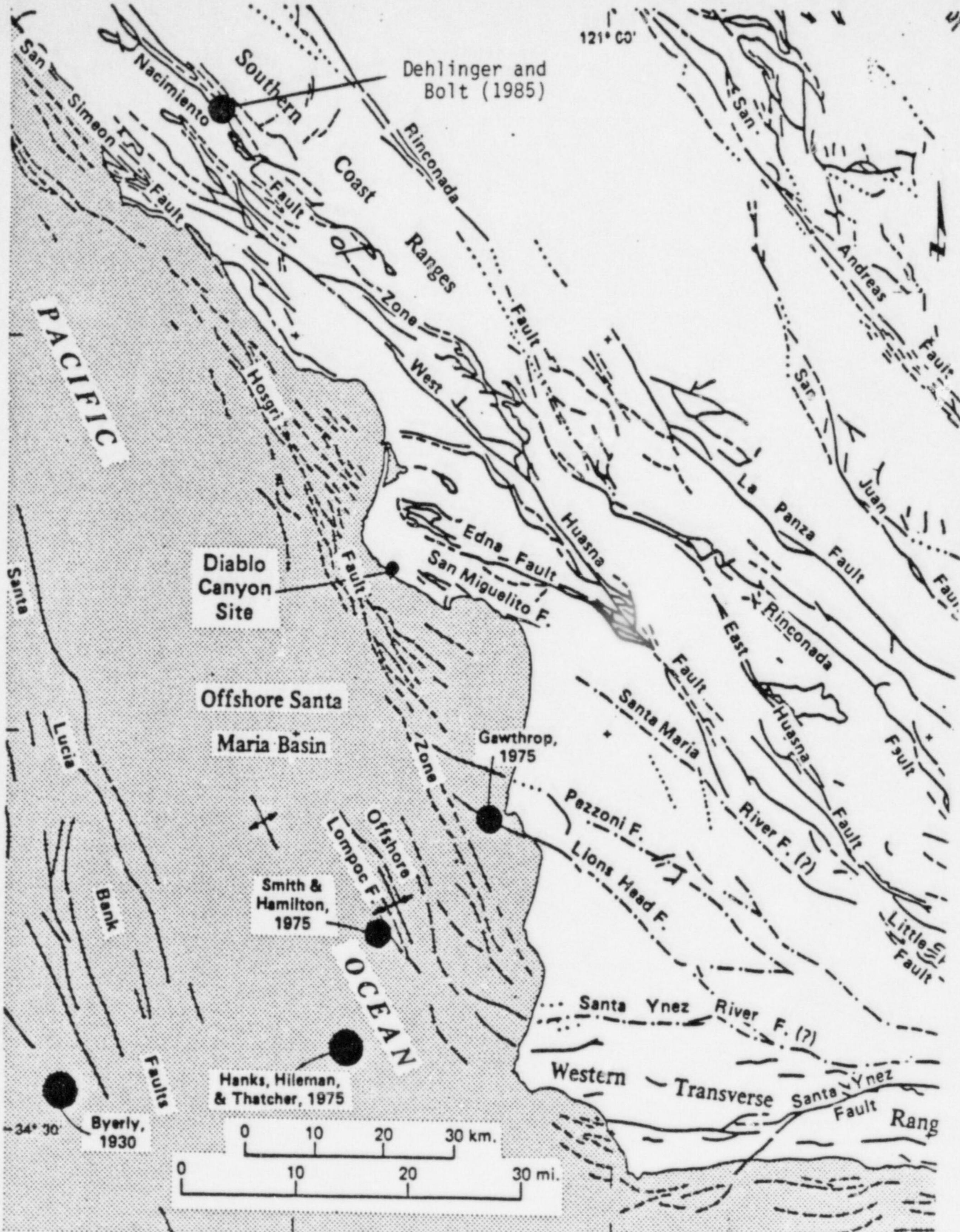
SANTA MARIA BASIN REGION

ENCLOSURE 4

SECTION 6



121°
120°
36°
35°
DCPP
MAGNITUDE
0-1
1-2
2-3
3-4
4-5
5-6
USGS: 1-1980 THRU 12-1985
CALTECH: 1-1980 THRU 6-1985
0
30KM



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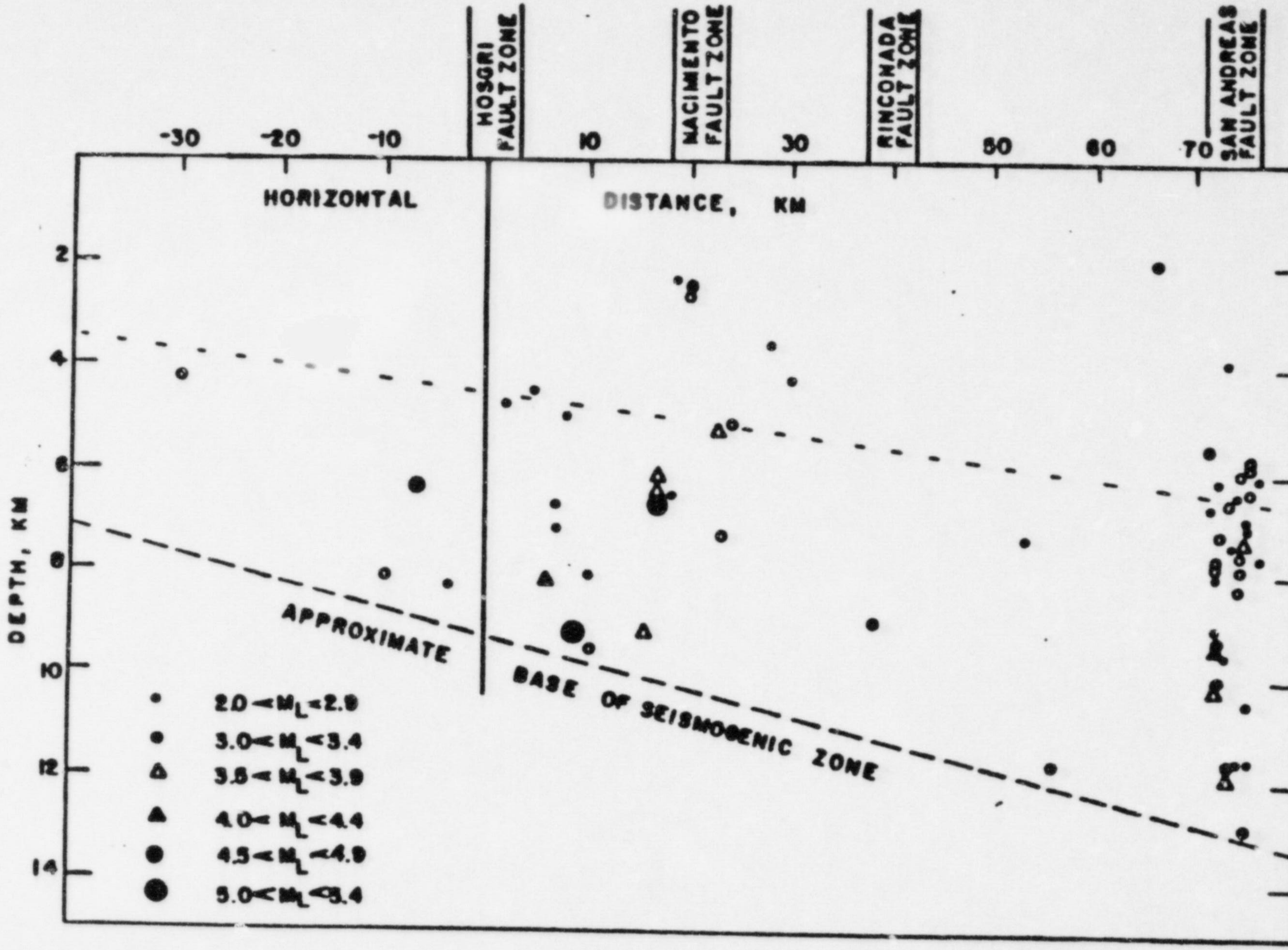
Epicenters of 1927 and 1952 Earthquakes

SANTA MARIA BASIN REGION



from Dehlinger & Bolt (1985)

FOCAL MECHANISMS

SELECTED CENTRAL COAST RANGE QUAKES

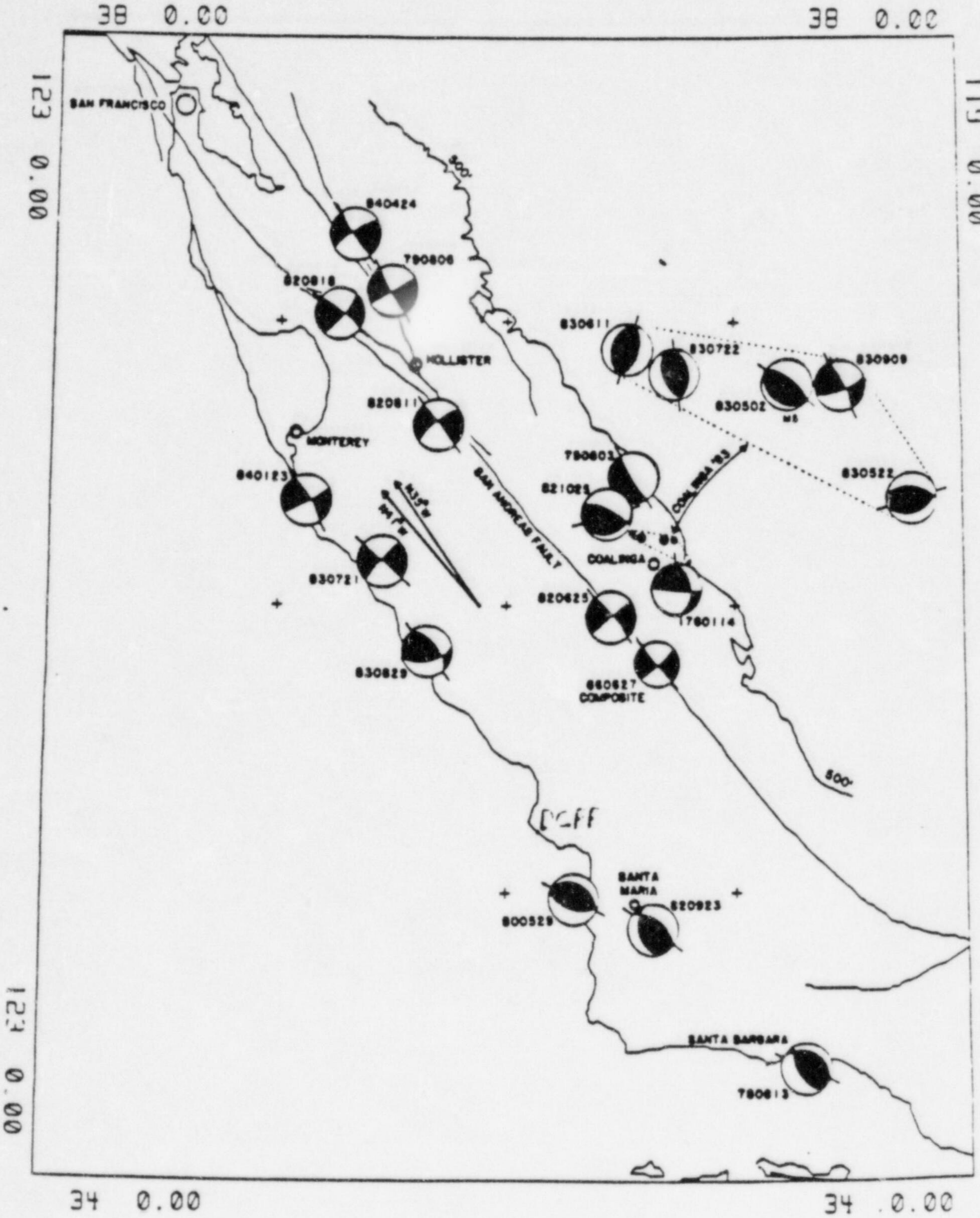


Figure 4

taton (1985)

CENTRAL COAST SEISMIC NETWORK

Objectives

Acquire data for further understanding of the tectonic model and seismic potential of coastal central California

- Hypocentral locations
- Focal Mechanisms
- Magnitudes and seismic moments
- Crustal structure

Design Considerations

- High credibility of data
- Allow independent analyses
- Reliable, efficient operation

CENTRAL COAST SEISMIC NETWORK

A. Field Stations

1. 13 vertical-component, 5 three-component stations

2. One-Hertz seismometers, calibration coils

3. 60-db dynamic range using FM telemetry

4. increase to more than 100-db dynamic range using analog or digital telemetry alternative

B. Central Recording System

1. Data acquisition computer

   - event detection in real time

   - preliminary location and magnitude

   - alarm notification

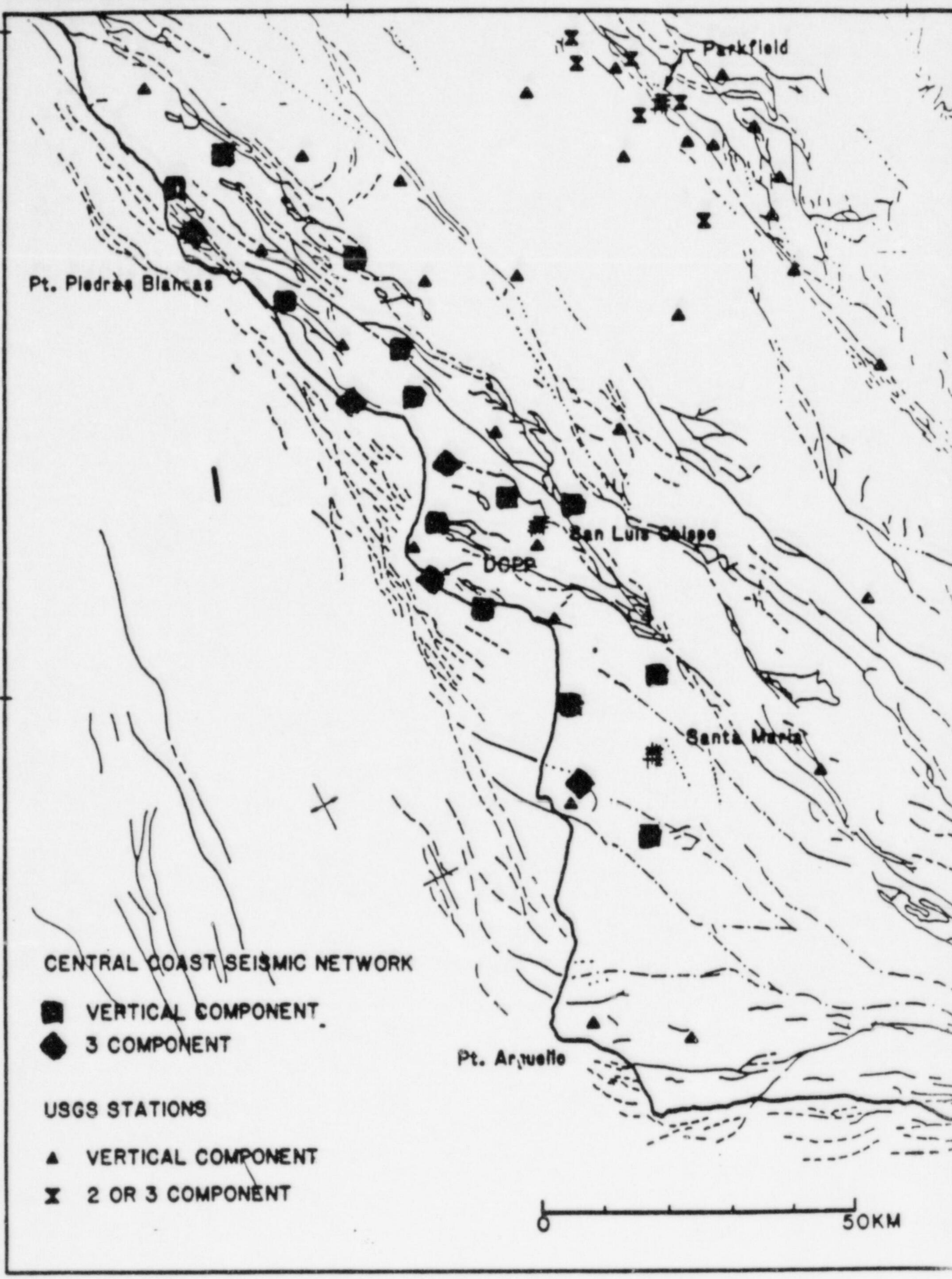
2. Visual Drum Recorders

3. Seismic Work Station

   - finalize analysis from on-line system

   - prepare routine and special reports

   - serve as host for receiving data from other institutions


121°
120°
36°
35°
Parkfield
Pt. Piedras Blancas
San Luis Obispo
DCPP
Santa Maria
Pt. Arguello
CENTRAL COAST SEISMIC NETWORK
VERTICAL COMPONENT
3 COMPONENT
USGS STATIONS
VERTICAL COMPONENT
2 OR 3 COMPONENT
0
50KM

III-11

NETWORK CALIBRATION

OBJECTIVES OF CALIBRATION

- o Improve velocity model
- o Determine station corrections for network

RELATED OBJECTIVES

- o Study deep Hosgri zone structure
- o Study site wave propagation properties

PLANNING FOR NETWORK CALIBRATION

CALIBRATION SOURCES

- o onshore explosions (quarries, calibration shots)
- o offshore airgun shooting
- o earthquakes in onshore and offshore areas

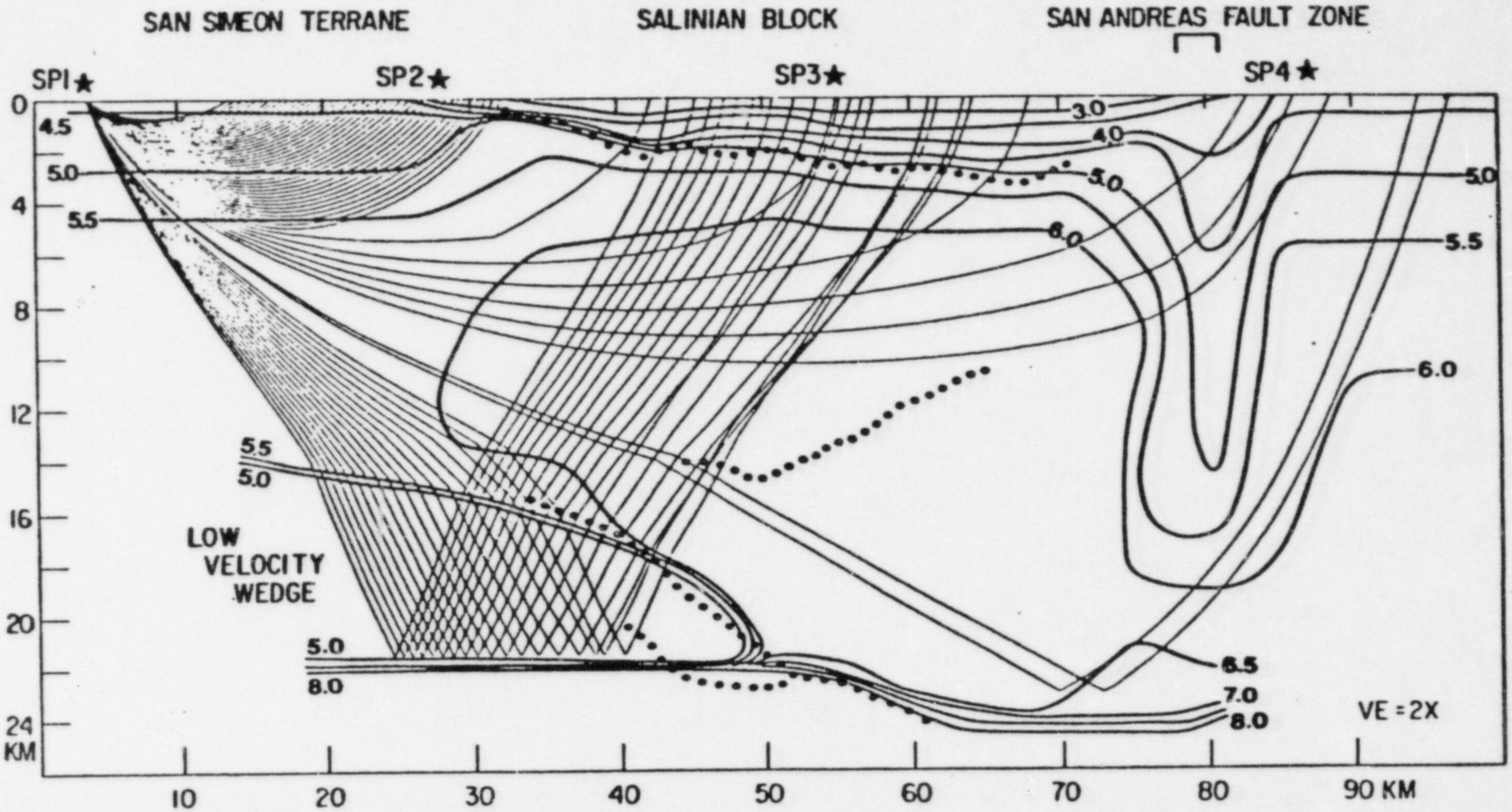
RECORDING SYSTEMS

- o Central Coast Seismic Network, USGS & other stations
- o pop-up OBS's
- o DCPP site recorders (permanent and temporary)
- o offshore deep reflection line

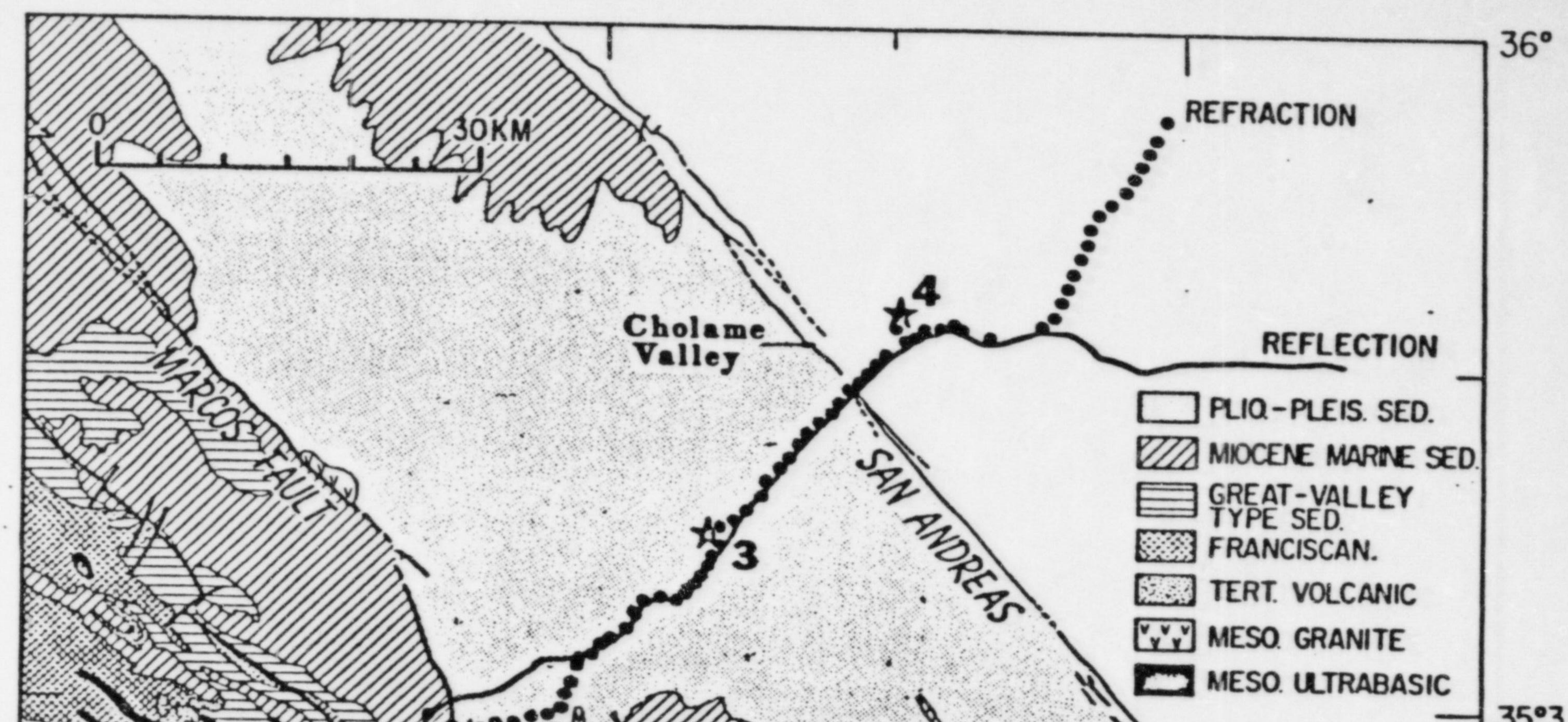
ANTICIPATED RESULTS

- o improved onshore and offshore velocity model, including S-wave velocities
- o station corrections for PG&E, USGS networks
- o deep crustal data in Hosgri zone
- o data on seismic wave propagation at DCPP

III · II



TREHU AND WHEELER (1986)



TREHU AND WHEELER (1986)

CUSP/GROPE 0.0, EVENT 50261, PROCESSED : 06-NOV-85 519 (GREENWICH TIME), CULPRIT :D_H. PAGE : 1

****
ORIG : 19 OCTOBER 1985, 527 20.16 GMT (SATURDAY)
****

Pt. Sal
M 1.36

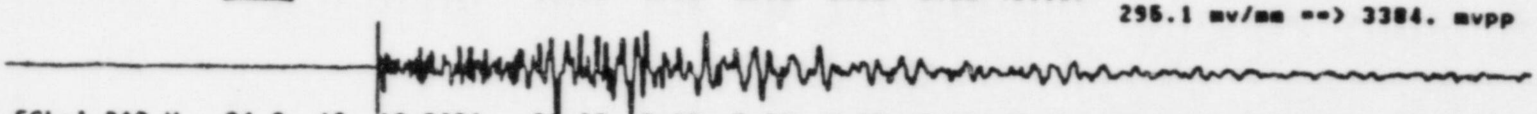
	LATITUDE	LONGITUDE	DEPTH	ORIGIN
HYPOCENTER :	34 56.91	-120 43.04	0.54 KM	20.16 S
	34.94844	-120.71732		

STATISTICS :	RMS	ERLAT	ERLON	ERZ	ERT	GAP	DMIN	NPH	NORM
	0.20	0.27	1.43	1.66	0.00	174	11	12	L2

SRC NET DEV SERIES
ECL-1 CAL ECL 85OCT19.527:1009/1009

SRC	STA	C	DIST	TOA	AZM	ONSET	PICK	TOBS	-TCAL	+DLY	=RES	
ECL-1	PML	V	11.6	92	121	PIU1	31.06	2.90	2.90	0.00	0.00	(0.15)

295.1 mv/mm --> 3304. mvpp

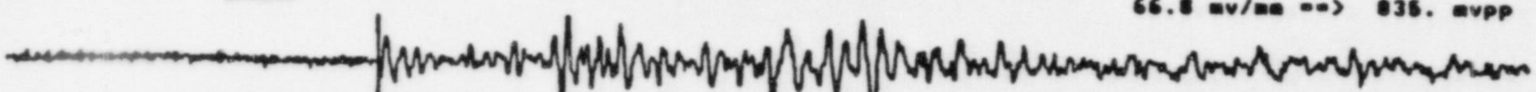


ECL-1 PAB V 24.3 42 10 PID1 33.19 5.03 5.31 0.00 -0.28 (0.15)

176.0 mv/mm --> 2002. mvpp

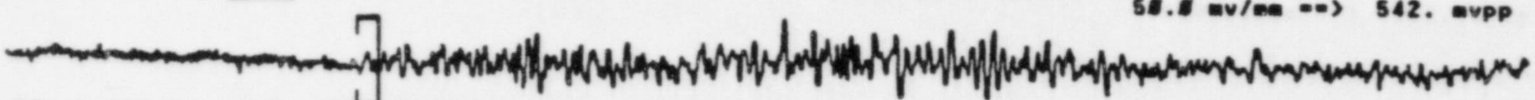
ECL-1 PBI V 32.4 42 43 PID1 34.83 6.67 6.68 0.00 -0.02 (0.16)

66.8 mv/mm --> 835. mvpp



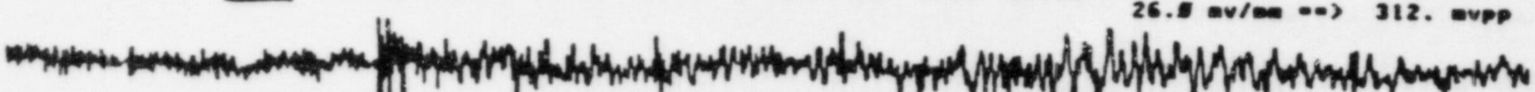
ECL-1 PPB V 37.0 42 336 PE3 35.49 7.33 7.60 0.00 -0.27 (0.25)

50.0 mv/mm --> 542. mvpp



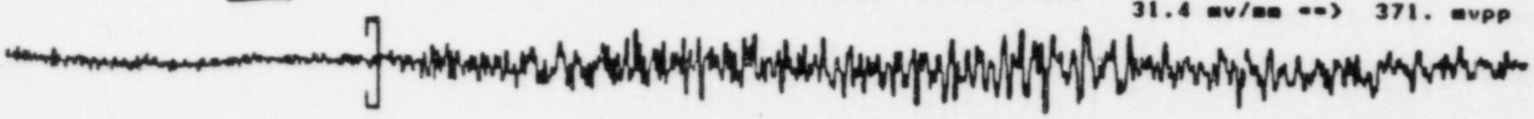
ECL-1 PTQ V 42.9 42 162 PID0 36.62 8.46 8.45 0.00 0.01 (0.16)

26.0 mv/mm --> 312. mvpp



ECL-1 SCC V 49.0 42 91 PE3 37.64 9.48 9.63 0.00 -0.15 (0.26)

31.4 mv/mm --> 371. mvpp



ENCLOSURE 7

SECTION 7

DOMINANT FREQUENCY OF STRUCTURES AND COMPONENTS

ITEM	FREQUENCY (CPS)
CONTAINMENT SHELL	4
CONTAINMENT INTERIOR	10
AUXILIARY BUILDING	13
INTAKE STRUCTURE	15
OUTDOOR TANKS	7
RCL PRIMARY EQUIPMENT	6
PIPING	3-20
TURBINE BUILDING	
CONCRETE	
DIAPHRAGMS	6
WALLS	13
STEEL SUPERSTRUCTURES	2

IMPORTANT CHARACTERISTICS OF TIME HISTORIES

- o FREQUENCY RANGE OF INTEREST, 2 - 20 Hz
- o DURATION
- o VARIATION IN FREQUENCY CONTENT AND INTENSITY WITH TIME.
- o PHASING BETWEEN HORIZONTAL AND VERTICAL COMPONENTS OF THE EARTHQUAKES.
- o COHERENT/INCOHERENT COMPOSITION OF MOTION AS A FUNCTION OF FREQUENCY.

GROUND MOTION REQUIREMENTS FOR SSI ANALYSIS

1) HORIZONTAL AND VERTICAL PEAK GROUND ACCELERATION, VELOCITIES AND DISPLACEMENTS (HOSGRI, $M > 6.5$)

2) SITE SPECIFIC RESPONSE SPECTRA, HORIZONTAL AND VERTICAL

3) THE SUITE OF REALISTIC TIME HISTORIES WHICH ARE THE BASES OF THE SITE SPECIFIC RESPONSE SPECTRA

4) REALISTIC TOTAL DURATION AND STRONG MOTION DURATION

5) WAVE COMPOSITION OF THE FREE-FIELD GROUND MOTION (P, S_V, S_H, RAYLEIGH, ETC) AND ORIENTATION OF THE INCOMING WAVES

6) SPATIAL COHERENCY OF FREE-FIELD GROUND MOTION VS. FREQUENCY

GROUND MOTION REQUIREMENTS FOR FRAGILITY ANALYSIS

A SUITE OF REALISTIC TIME HISTORIES WHICH HAVE THE FOLLOWING CHARACTERISTICS:

- ABOUT 10 TIME HISTORIES
- BOTH HORIZONTAL AND VERTICAL COMPONENTS
- AN AVERAGE 5% DAMPED SPECTRAL ACCELERATION LEVEL OF 2.25G BETWEEN 3.0 AND 8.5 HZ AVERAGED OVER TWO HORIZONTAL COMPONENTS ON A LOGARITHMIC FREQUENCY SCALE
- ADJUSTED MAGNITUDES $>$ 6.5 M
- HYPOCENTRAL DISTANCES ADJUSTED TO HOSGRI CONDITIONS
- CORRECTED FOR SITE CONDITIONS

ENCLOSURE 4

SECTION 8

THE LTSP GROUND MOTIONS WORK PLAN

I. OBJECTIVES

II. SIGNIFICANT CONSIDERATIONS

III. ENGINEERING REQUIREMENTS

IV. SCOPE OF WORK AND SCHEDULE

V. TASK DESCRIPTIONS

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OBJECTIVES OF THE WORK PLAN FOR GROUND MOTIONS

1. TO UPDATE THE ASSESSMENT OF SEISMIC GROUND MOTIONS AT THE SITE
   - USE REFINED GEOLOGY/SEISMOLOGY/GEOPHYSICS INFORMATION
   - USE RECENT EARTHQUAKE DATA
   - USE SITE RECORDS
   - INTEGRATE RESULTS FROM EMPIRICAL APPROACH AND NUMERICAL MODELING

2. TO PROVIDE GROUND MOTION INPUT DATA FOR ENGINEERING ANALYSES IN THE LTSP
   - TIME HISTORIES
   - PEAK VALUES
   - RESPONSE SPECTRA
   - WAVE TYPES
   - INCIDENCE ANGLE
   - SPATIAL COHERENCE

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DEVELOPMENT OF THE PHASE III WORK PLAN FOR GROUND MOTIONS

NRC APPROVED PROGRAM PLAN FOR GROUND MOTIONS

↓

ADDITIONAL SCOPING ACTIVITIES

↓

PHASE III WORK PLAN FOR GROUND MOTIONS

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ACTIVITIES LEADING TO SIGNIFICANT

CONSIDERATIONS AND WORK PLAN:

1. IN-HOUSE GROUND MOTION WORKSHOPS:
   - o IDENTIFY SIGNIFICANT CONSIDERATIONS FOR GROUND MOTIONS.
   - o REVIEW RECENT ADVANCES IN GROUND MOTION STUDIES.
   - o DEVELOP GROUND MOTION TASKS.
2. ANALYSES OF GROUND MOTION CONTRIBUTIONS TO THE UNCERTAINTY IN SEISMIC HAZARD CURVES.
   - o IDENTIFY SIGNIFICANT GROUND MOTION CONTRIBUTORS TO THE UNCERTAINTY IN PROBALISTIC SEISMIC HAZARD.
3. INPUT TO ENGINEERING ANALYSES IN THE LTSP.
   - o DEVELOP A WORK PLAN TO MEET APPLICATION REQUIREMENTS.
   - o SET PROGRAM SCHEDULE.
4. CONSULTATION WITH GROUND MOTION SPECIALISTS.
   - o ENSURE ADEQUACY OF THE WORK PLAN.
   - o DISCUSS TECHNICAL ISSUES RELATED TO GROUND MOTION CHARACTERIZATION.

SIGNIFICANT CONSIDERATIONS FOR GROUND MOTIONS:

1. EMPIRICAL GROUND MOTION MODELS

   - PROVIDE A REASONABLE BASIS TO BEGIN TO ESTIMATE GROUND MOTIONS

2. INCORPORATION OF RECENT DATA

   - AUGMENT EXISTING EMPIRICAL GROUND MOTION MODELS

3. EVALUATION OF DISPERSION, TRUNCATION, AND SATURATION EFFECTS

   - PROVIDE INPUT NEEDED FOR SEISMIC HAZARD ANALYSIS

4. WAVE PROPAGATION AND SITE EFFECTS

   - PROVIDE INPUT NEEDED FOR SOIL-STRUCTURE INTERACTION ANALYSIS

5. NUMERICAL METHODS

   - EXTEND BEYOND EMPIRICAL GROUND MOTION MODELS
   - ENABLE PARAMETRIC ASSESSMENTS

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COMMENTS BY NRC GROUND MOTION PANEL

- NUMERICAL MODELING APPROACH IS IMPORTANT.
- CREDIBLE THEORETICAL PREDICTIONS FOR LOW FREQUENCY COMPONENTS OF GROUND MOTION CAN BE OBTAINED IN 3-6 MONTHS BY INCORPORATING UP-TO-DATE OBSERVATIONAL AND THEORETICAL UNDERSTANDING OF EARTHQUAKE SOURCE INTO PROVEN NUMERICAL PROCEDURES.
- FOR HIGH FREQUENCY RANGE (2-20 H), A SOUND PHYSICAL MODEL FOR EARTHQUAKE SOURCE IS STILL LACKING. STOCHASTIC MODELING IS NEEDED.
- DATA FROM SMALL EARTHQUAKES MAY BE USED AS GREEN'S FUNCTIONS FOR MODELING HIGH FREQUENCY COMPONENTS.
- DCPP SITE RECORDS MAY BE USED TO DERIVE TRANSFER FUNCTIONS AND TO CALIBRATE THE NUMERICAL MODELS.
- NUMERICAL MODELING CAN PROVIDE RELIABLE CHARACTERIZATION OF WAVE TYPE AND ANGLE OF INCIDENCE. IT MAY BE SUPPLEMENTED BY FIELD EXPERIMENTS USING ARTIFICAL SOURCES.
- THREE-COMPONENT SEISMOMETERS ARE USEFUL IN THE PLANNED SEISMIC NETWORK TO PROVIDE BETTER HYPOCENTER LOCATION, BETTER S WAVE VELOCITY AND Q STRUCTURE, AND POTENTIAL EMPIRICAL GREEN'S FUNCTIONS FOR NUMERICAL MODELING.
- THERE IS A NEED TO INSTALL A SMALL APERTURE GROUND MOTION ARRAY AT THE PLANT SITE TO STUDY LOCAL SITE EFFECTS.
- THERE IS A NEED FOR CLOSER INTERFACE BETWEEN ENGINEERING REQUIREMENTS AND THE GROUND MOTION PROGRAM.
- TIME MAY NOT BE ENOUGH FOR ALL PLANNED WORK.

COMMENTS BY NRC SOIL STRUCTURE INTERACTION PANEL

- TOPOGRAPHIC EFFECTS SHOULD BE ACCOUNTED FOR IN DEFINING THE FREE-FIELD GROUND MOTIONS BY USING RECORDS OBTAINED AT THE PLANT SITE AND BY NUMERICAL MODELING.
- CLOSE INTERACTION BETWEEN GROUND MOTION AND SOIL STRUCTURE INTERACTION EFFORTS IS IMPORTANT.

CRITERIA FOR GROUND MOTION INPUT TO FRAGILITY ANALYSIS

A SUITE OF REALISTIC TIME HISTORIES WHICH HAVE THE FOLLOWING CHARACTERISTICS:

- ABOUT 10 TIME HISTORIES
- BOTH HORIZONTAL AND VERTICAL COMPONENTS
- AN AVERAGE 5% DAMPED SPECTRAL ACCELERATION LEVEL OF 2.25 g FOR FREQUENCY BETWEEN 3.0 AND 8.5 H_Z AVERAGED OVER TWO HORIZONTAL COMPONENTS ON A LOGARITHMIC FREQUENCY SCALE
- ADJUSTED TO MAGNITUDES GREATER THAN 6.5.
- HYPOCENTRAL DISTANCES ADJUSTED TO HOSGRI CONDITIONS
- CORRECTED FOR SITE CONDITIONS

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4/10/86

GROUND MOTION INPUT FOR SOIL/STRUCTURE INTERACTION ANALYSIS

1. HORIZONTAL AND VERTICAL PEAK GROUND ACCELERATIONS, VELOCITIES, AND DISPLACEMENTS CORRESPONDING TO ASSUMED $M > 6.5$ EARTHQUAKES OCCURING AT THE HOSGRI FAULT.

2. HORIZONTAL AND VERTICAL SITE SPECIFIC RESPONSE SPECTRA ASSOCIATED WITH THE GROUND MOTION PARAMENTERS IN ITEM 1.

3. TOTAL DURATION AND THE DURATION OF STRONG PHASE OF SHAKING OF THE EXPECTED TIME HISTORIES ASSOCIATED WITH THE SITE SPECIFIC SPECTRA IN ITEM 2.

4. A SUITE OF PROPERLY SCALED REAL AND/OR SIMULATED TIME HISTORIES WHICH ARE THE BASIS OF SITE SPECIFIC SPECTRA OF ITEM 2.

5. WAVE COMPOSITION OF THE FREE-FIELD GROUND MOTIONS (P, SV, SH, RAYLEIGH WAVES, ETC.) AND ORIENTATION OF THE INCOMING WAVES.

6. SPATIAL COHERENCY OF FREE-FIELD GROUND MOTIONS AS A FUNCTION OF FREQUENCY.

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MAJOR GROUND MOTION TASKS

TASK 1 SELECTION OF ATTENUATION RELATIONSHIPS FOR PEAK GROUND ACCELERATION AND VELOCITY FOR THE SITE

TASK 2 ASSESSMENT OF RESPONSE SPECTRA FOR THE SITE

TASK 3 DEVELOPMENT OF ACCELERATION TIME HISTORIES FOR THE SITE

TASK 4 ASSESSMENT OF SITE-SPECIFIC GROUND MOTION CHARACTERISTICS

TASK 5 APPLICATION OF NUMERICAL MODELING OF GROUND MOTIONS

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TASK 1 SELECTION OF ATTENUATION RELATIONSHIPS FOR PEAK GROUND ACCELERATION AND VELOCITY

1.1 SELECT APPROPRIATE ATTENUATION RELATIONSHIPS FOR HORIZONTAL AND VERTICAL PEAK GROUND ACCELERATIONS AND VELOCITY FOR ROCK SITE

1.2 REFINE ATTENUATION RELATIONSHIPS WITH RECENT EARTHQUAKE DATA AND EVALUATE STATISTICAL DISPERSION AND UPPER BOUND CONSTRAINTS

- EMPIRICAL
- NUMERICAL MODELING

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TASK 2 ASSESSMENT OF RESPONSE SPECTRA

2.1 SELECT APPROPRIATE HORIZONTAL AND VERTICAL RESPONSE SPECTRA FOR ROCK SITE

2.2 REFINE RESPONSE SPECTRA WITH RECENT EARTHQUAKE DATA AND EVALUATE STATISTICAL DISPERSION AND UPPER BOUND CONSTRAINTS

- EMPRIRICAL APPROACH
- NUMERICAL MODELING

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TASK 3. DEVELOPMENT OF ACCELERATION TIME HISTORIES.

3.1 SELECT REPRESENTATIVE HORIZONTAL AND VERTICAL ACCELERATION TIME HISTORIES FOR ROCK SITE FROM EXISTING ACCELEROGRAMS

- NEAR-SOURCE RECORDS FROM EARTHQUAKES OF KNOWN SOURCE MECHANISMS

3.2 GENERATE REALISTIC ARTIFICIAL ACCELERATION TIME HISTORIES FOR ROCK SITE

- EMPIRICAL APPROACH
- NUMERICAL MODELING

3.3 ASSESS AMPLIFICATION FACTOR FOR SPECTRAL ACCELERATION AND EVALUATE DURATION OF STRONG MOTION

- CHARACTERISTICS OF GENERATED TIME HISTORIES.

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TASK 4 ASSESSMENT OF SITE-SPECIFIC GROUND MOTION CHARACTERISTICS

4.1 ASSESS GROUND MOTION VARIABILITY AT THE SITE

- RECORDS OF EARTHQUAKES AND SITE EXPERIMENTS
- NUMERICAL MODELING

4.2 IDENTIFY WAVE TYPES AND ASSESS SPATIAL COHERENCY AT THE SITE

- SITE RECORDS
- ARTIFICIAL TIME HISTORIES

4.3 INSTALL ADDITIONAL GROUND MOTION INSTRUMENTS AT THE SITE

- WITH CLOSER SPACINGS

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TASK 5 APPLICATION OF NUMERICAL MODELING OF GROUND MOTIONS

5.1 EVALUATE THE SELECTED ATTENUATION RELATIONSHIPS, RESPONSE SPECTRA, AND TIME HISTORIES

- LEVEL AND SHAPE
- DISPERSION, SATURATION AND TRUNCATION

5.2 ASSESS EFFECTS OF ALTERNATIVE FAULT TYPES, FAULT GEOMETRY, AND RUPTURE PROCESS FOR NEAR-SITE SOURCES

- DIRECTIVITY
- HIGH FREQUENCY RADIATION

5.3 ASSESS LOCAL SITE EFFECTS

- WAVE TYPES
- INCIDENCE ANGLE
- SPATIAL COHERENCE

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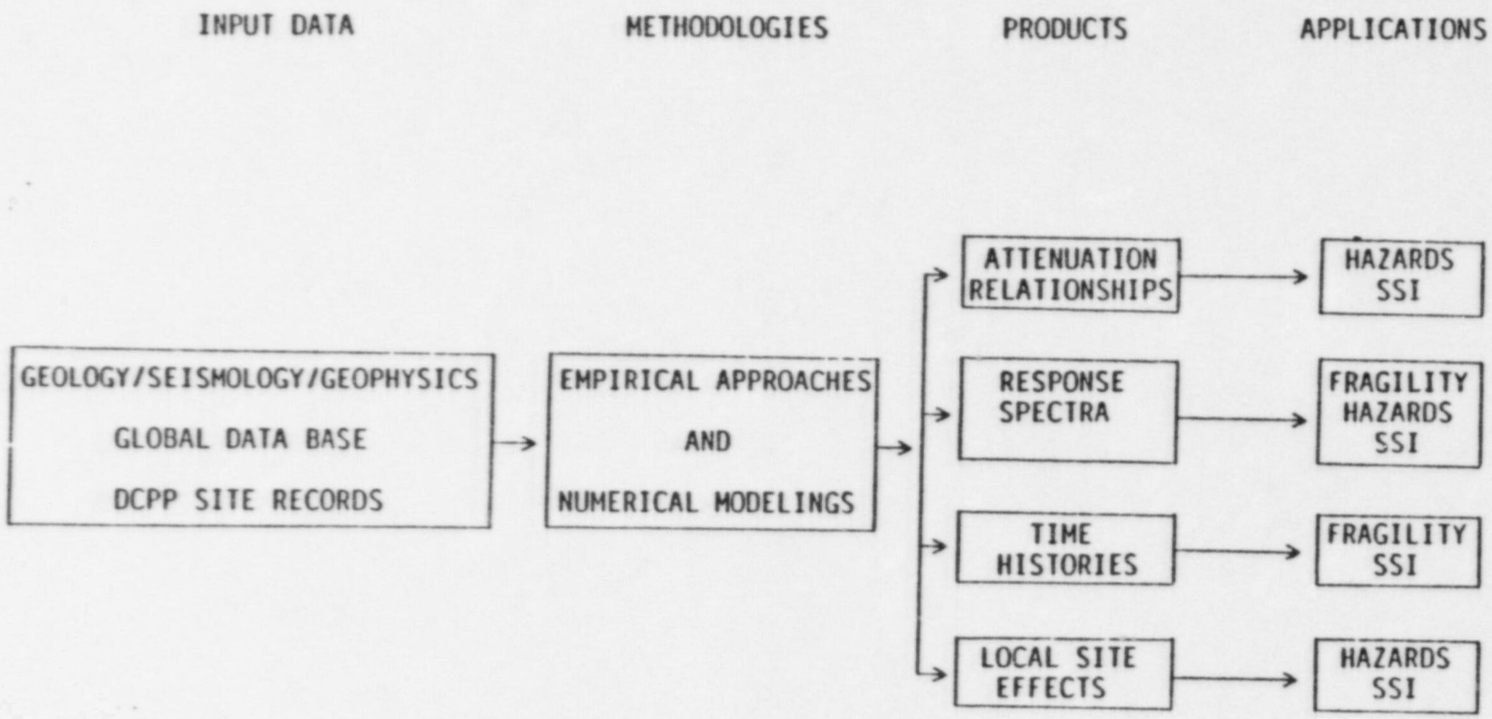
Figure 3-1

GROUND MOTION PROGRAM
TASK STRUCTURE



SCHEDULE FOR GROUND MOTION OUTPUT

DATE	FRAGILITY	SOIL-STRUCTURE INTERACTION	SEISMIC HAZARDS
MAY , 1986	SUITE OF REALISTIC TIME HISTORIES		
JUNE , 1986		PRELIMINARY PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES; BOUNDING INFORMATION OF WAVE CHARACTERISTICS.	
SEPTEMBER , 1986		REFINED PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES; PRELIMINARY WAVE CHARACTERISTICS.	REFINED RESPONSE SPECTRA.
FEBRUARY , 1987		NEAR-FINAL PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES; FURTHER REFINED WAVE CHARACTERISTICS; INITIAL INFORMATION OF SPATIAL COHERENCY.	
JULY , 1987		FINAL PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES, WAVE CHARACTERISTICS, SPATIAL COHERENCY.	FINAL RESPONSE SPECTRA.

A SUMMARY OF GROUND MOTIONS APPROACH TO MEET ENGINEERING REQUIREMENTS

ENGINEERING REQUIREMENT	APPROACH: EMPIRICAL	APPROACH: NUMERICAL	APPROACH: SITE RECORDINGS
1. PEAK VALUES	✓✓	✓	
2. RESPONSE SPECTRA	✓✓	✓	
3. REALISTIC TIME HISTORIES	✓✓	✓✓	✓
4. WAVE TYPES	✓	✓✓	✓✓
5. INCIDENCE ANGLE		✓✓	✓✓
6. COHERENCE	✓	✓	✓✓

✓✓ PRIMARY APPROACH

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GROUND MOTION OUTPUT BY MAY, 1986

OUTPUT	APPLICATION	GM TASK	INPUT DATA	APPROACH
TIME HISTORIES (H AND V)	FRAGILITY	3.1, 3.2, 3.3	ACTUAL RECORDS FOR MODERATE TO LARGE EARTHQUAKES	THEORETICAL AND EMPIRICAL SPECTRAL SCALINGS VERIFICATION AND SELECTION
			ACTUAL RECORDS FOR SMALL EARTHQUAKES	SEMI-EMPIRICAL NUMERICAL MODELING VERIFICATION AND SELECTION

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DEVELOPMENT OF REALISTIC TIME HISTORIES

FROM ACTUAL RECORDS

NO SCALING

- DIRECT USE OF ACTUAL RECORDS

CONSTANT SCALING

- TIME HISTORIES OR SPECTRAL AMPLITUDES

SCALING ACCORDING SOURCE SPECTRA OF P OR S WAVES

- THEORETICAL OR EMPIRICAL SOURCE SPECTRAL RATIO

EMPIRICAL GREEN'S FUNCTION SUMMATION

- ACTUAL RECORDS AS GREEN'S FUNCTION

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GROUND MOTION OUTPUT BY JUNE, 1986

OUTPUT	APPLICATION	GM TASK	INPUT DATA	APPROACH
PRELIMINARY PEAK VALUES (H AND V)	SSI	1.1	EXISTING ATTENUATION RELATIONSHIPS FOR ROCK SITE	LITERATURE REVIEW
PRELIMINARY RESPONSE SPECTRAL VALUES (H AND V)	SSI	2.1	EXISTING RESPONSE SPECTRA FOR ROCK SITE	LITERATURE REVIEW
TIME HISTORIES (H AND V)	SSI	3.1, 3.2	ACTUAL RECORDS OF EARTHQUAKES	SPECTRAL SCALING; EMPIRICAL GREEN'S FUNCTION SUMMATION
BOUNDING VALUES ON WAVE CHARACTERISTICS	SSI	3.1, 3.2	ACTUAL AND SYNTHETIC TIME HISTORIES	TIME-DOMAIN ANALYSIS

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PARTIAL LIST OF POST 1979 GROUND MOTION RELATIONSHIPS

RELATIONSHIPS BY	GROUND MOTION PARAMETER	DATA BASE
CAMPBELL (1981, 82, 83, 84)	PEAK GROUND ACCELERATION PEAK GROUND VELOCITY RESPONSE SPECTRAL ORDINATES	PRIMARILY WESTERN UNITED STATES CUT-OFF DATE OF DATA: OCTOBER 1979 IMPERIAL VALLEY
JOYNER, ET. AL. (1981, 82A, 82B, 85)	PEAK GROUND ACCELERATION PEAK GROUND VELOCITY RESPONSE SPECTRAL ORDINATES	PRIMARILY WESTERN UNITED STATES CUT-OFF DATE OF DATA: FEBRUARY 1980
SADIGH, ET. AL. (1983, 84, 86)	PEAK GROUND ACCELERATION PEAK GROUND VELOCITY PEAK GROUND DISPLACEMENT RESPONSE SPECTRAL ORDINATES	PRIMARILY WESTERN UNITED STATES CUT-OFF DATES OF DATA FOR 1983, '84 STUDIES: DEC. 1980; FOR 1986 STUDY: APRIL 1984

GROUND MOTION OUTPUT BY SEPTEMBER, 1986

OUTPUT	APPLICATION	GM TASK	INPUT DATA	APPROACH
REFINED PEAK VALUES (H AND V)	SSI	1.2, 4.1	RECENT STRONG MOTION RECORDS AT ROCK SITES DCPP FREE-FIELD RECORDS	COMPARISON WITH THE SELECTED ATTENUATION RELATIONSHIPS FOR POSSIBLE REFINEMENT
REFINED RESPONSE SPECTRA (H AND V)	SSI, SHA	2.2	RECENT STRONG MOTION RECORDS AT ROCK SITES	COMPARISON WITH THE SELECTED RESPONSE SPECTRA FOR POSSIBLE REFINEMENT
PRELIMINARY RESULTS ON WAVE CHARACTERISTICS	SSI	4.2	DCPP FREE-FIELD RECORDS FOR LOCAL EARTHQUAKES	TIME-DOMAIN ANALYSIS OF WAVE TYPES AND INCIDENCE ANGLES
TIME HISTORIES (H AND V)	SSI	3.2	EXISTING GEOLOGY/ SEISMOLOGY/GEOPHYSICS INFORMATION	NUMERICAL MODELING BASED ON PRELIMINARY SOURCE, PATH, AND SITE MODELS

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4/9/86

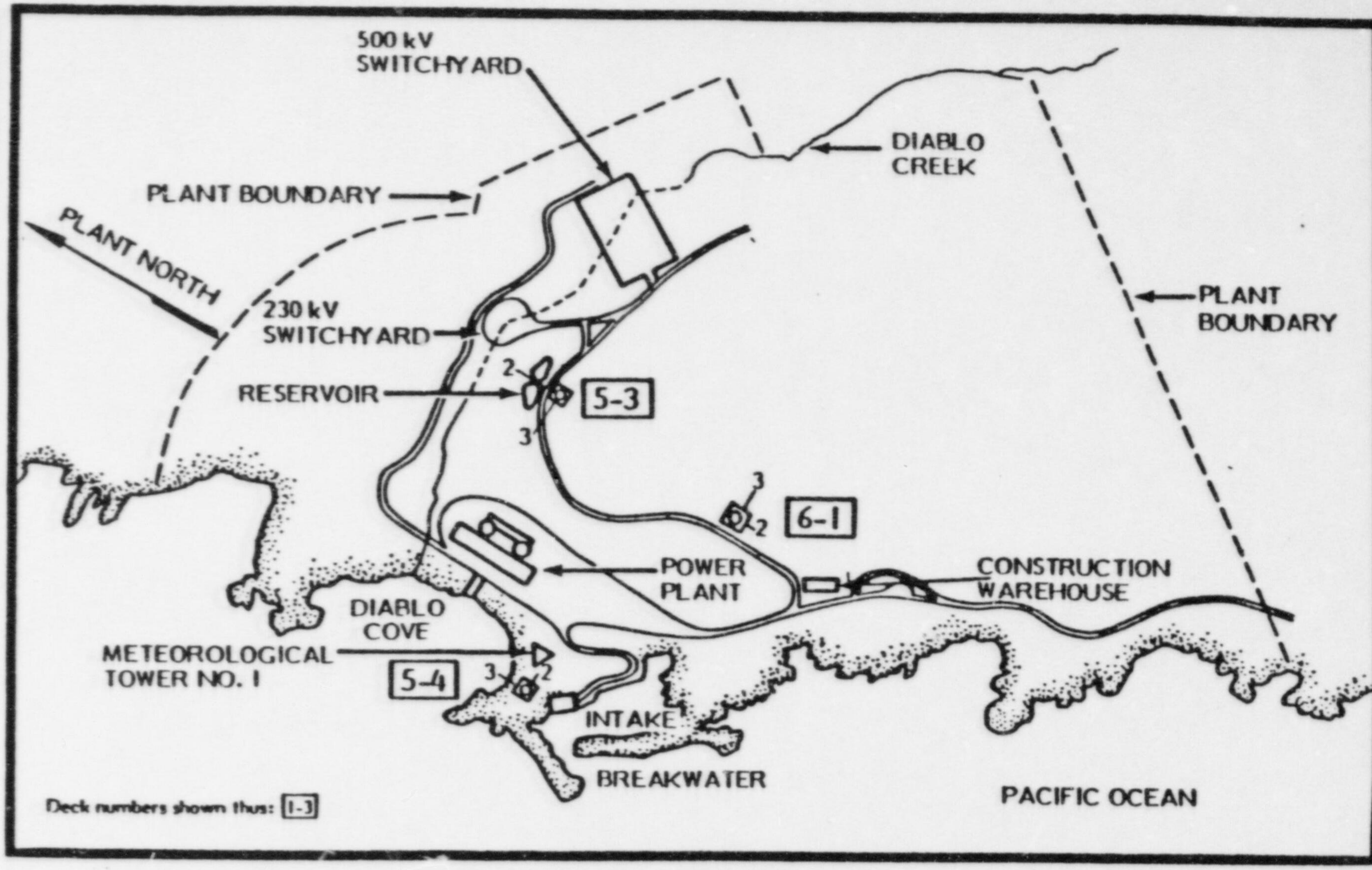
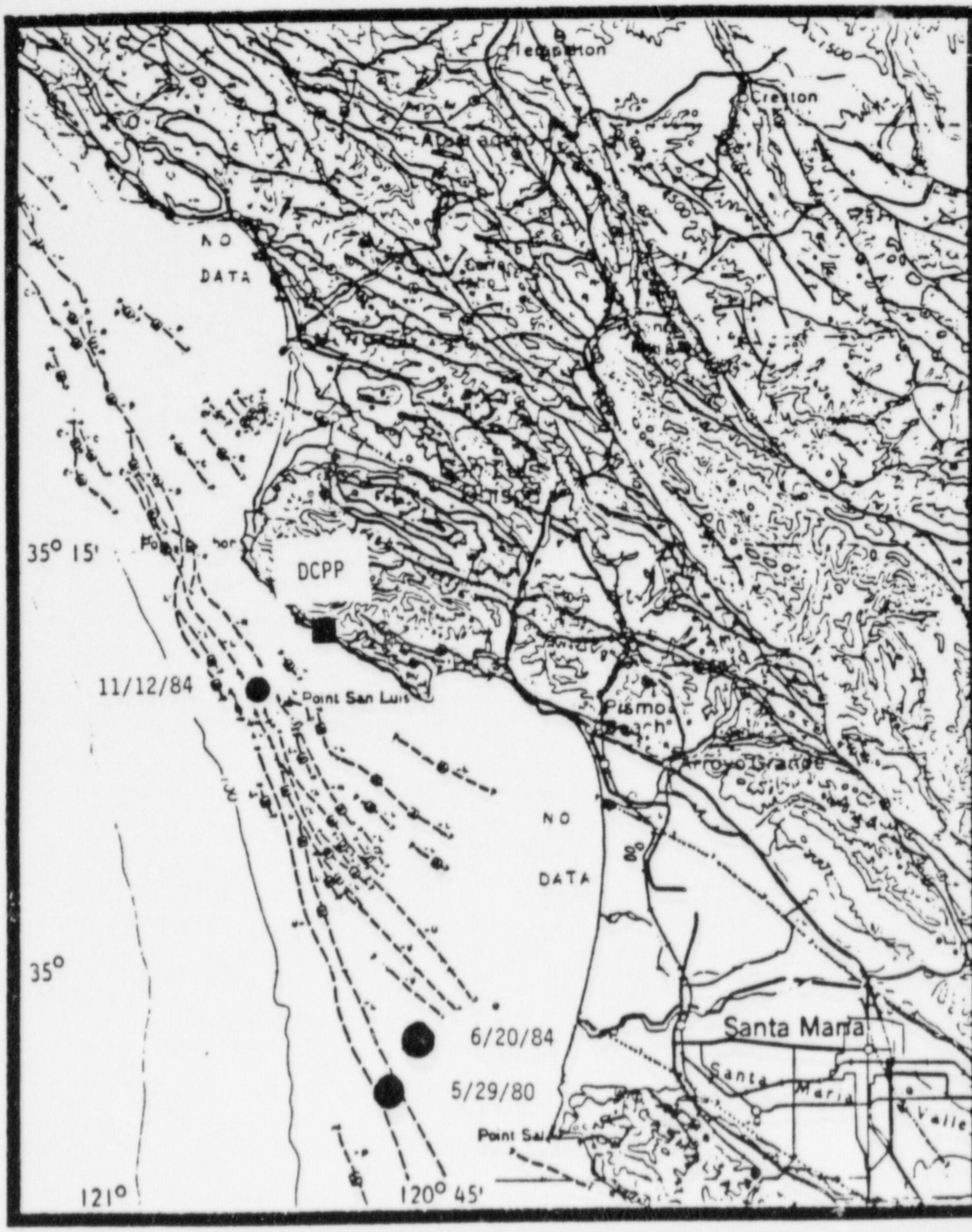


FIGURE 3

SUPPLEMENTAL SEISMIC INSTRUMENTATION
IN FREE FIELD
DIABLO CANYON POWER PLANT



Creston
NO
DATA
35° 15'
DCPP
11/12/84
Point San Luis
Pismo
Beach
Arroyo Grande
NO
DATA
35°
Santa Maria
6/20/84
5/29/80
Point Sal
121°
120° 45'

Table 3-1

GROUND MOTION RECORDS OBTAINED AT DCPP SITE

				Peak Ground Acceleration (g) Free-Field Site No.		
DATE	M_L	Δ (km)	DEPTH (km)	5-3	5-4	6-1
5/29/80	4.9	30	6.0	--	--	0.0097
				--	--	0.0118
				--	--	0.0120
5/2/83	6.7	110	8.4	0.0112	--	0.0096
				0.0095	--	0.0139
				0.0134	--	0.0111
6/20/84	4.7	30	9.4	--	0.0035	--
				--	0.0106	--
				--	0.0109	--
11/12/84	2.4	5	4.9	0.0050	0.0186	0.0099
				0.0058	0.0088	0.0267
				0.0078	0.0161	0.0118

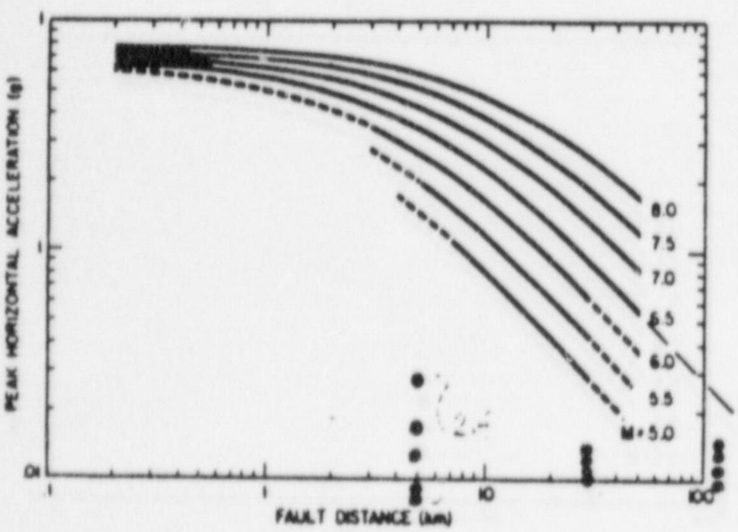
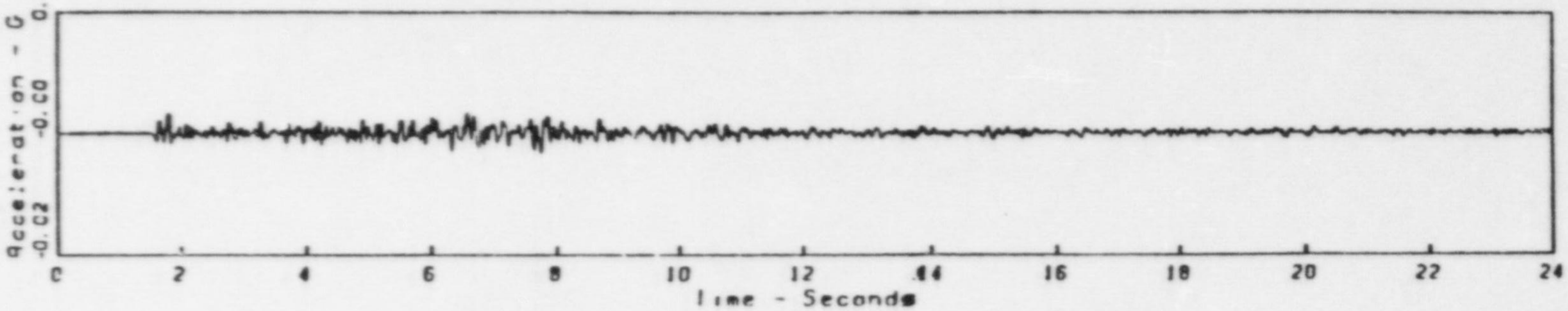


Figure taken from Campbell (1981a).

Analysis of June 20, 1984 Earthquake

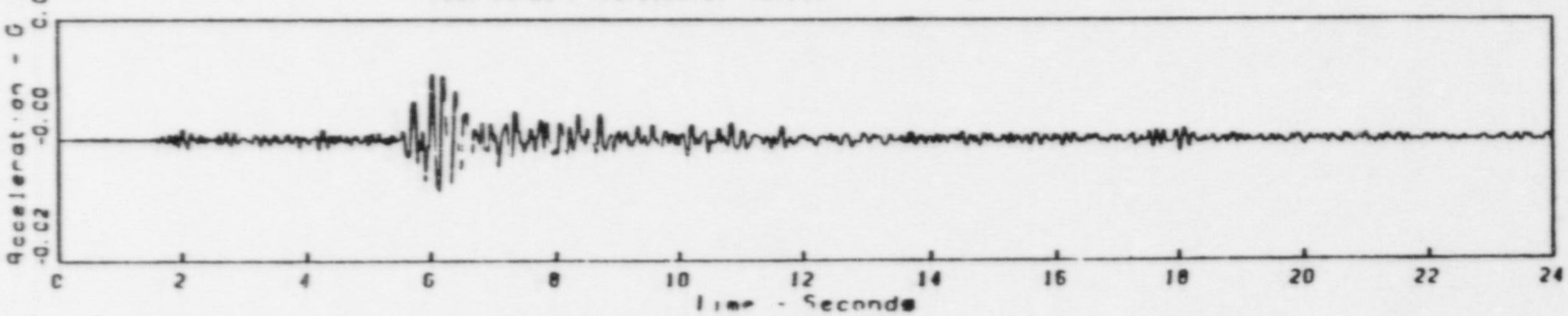
DECK 5-4 CHANNEL 1 -- Corrected

Peak Value = 0.0033 at 7.740



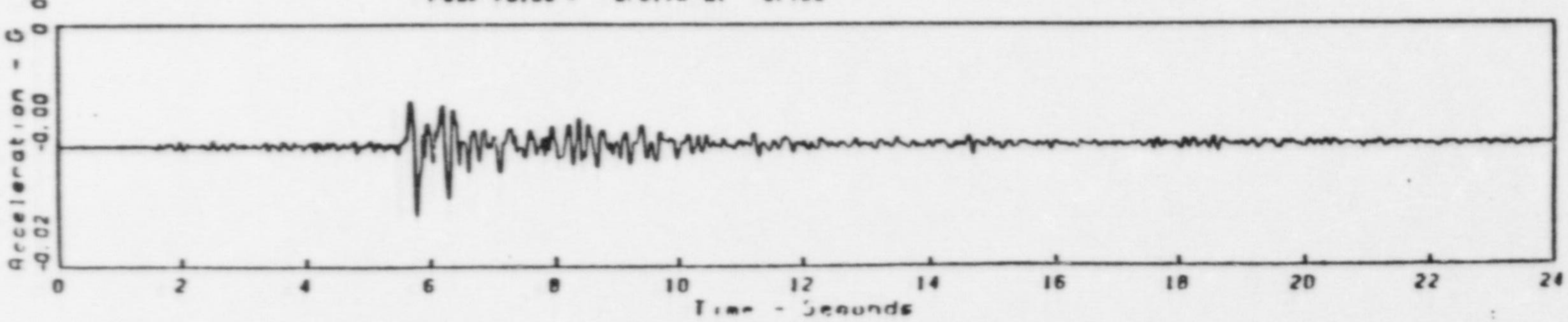
DECK 5-4 CHANNEL 2 -- Corrected

Peak Value = 0.0108 at 6.040



DECK 5-4 CHANNEL 3 -- Corrected

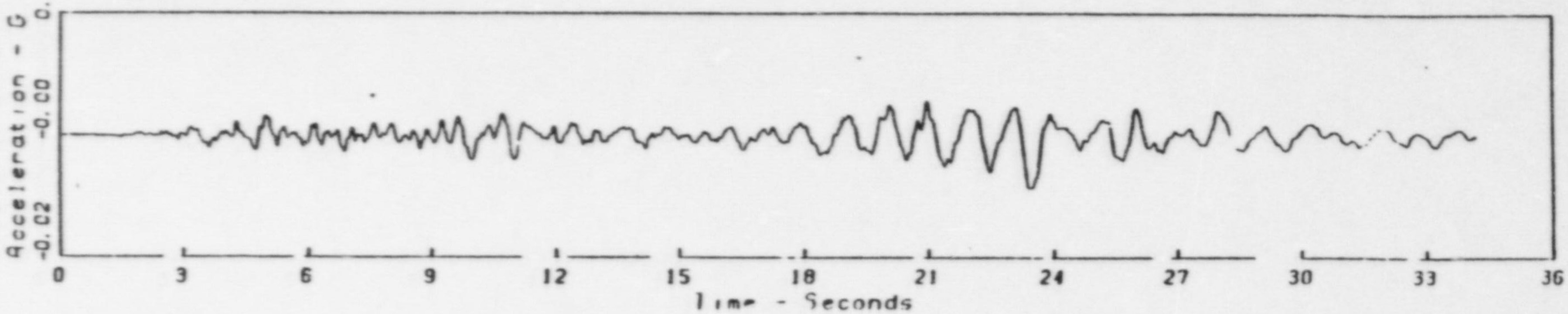
Peak Value = 0.0118 at 5.780



Analysis of 1983 Coalinga Earthquake

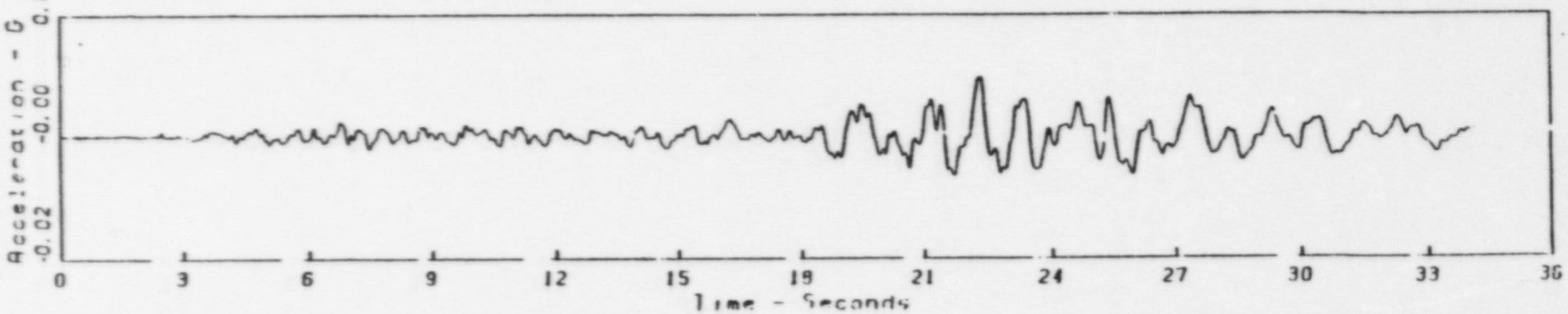
DECK 5-3 CHANNEL 1 -- Corrected

07/04/84 Peak Value = 0.0087 at 23.420



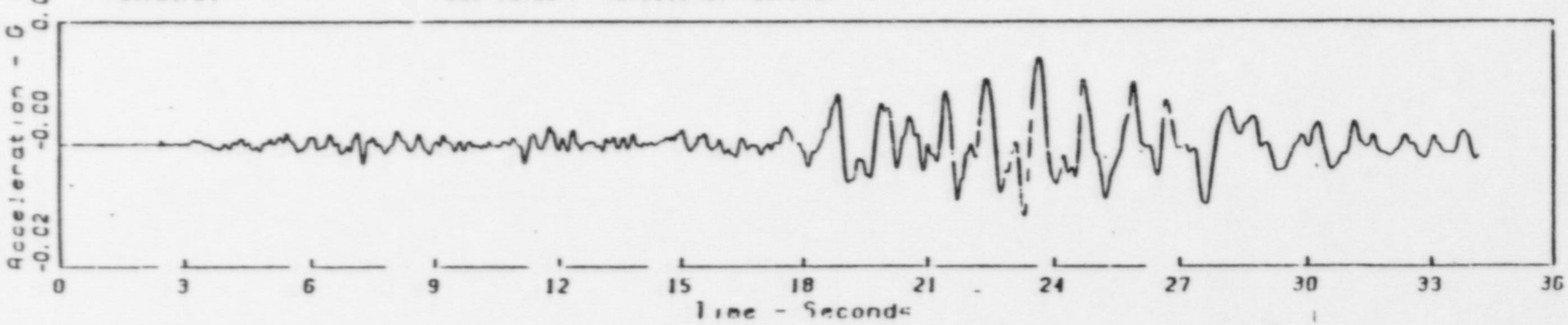
DECK 5-3 CHANNEL 2 -- Corrected

07/04/84 Peak Value = 0.0096 at 22.320



DECK 5-3 CHANNEL 3 -- Corrected

07/04/84 Peak Value = 0.0142 at 23.6PC



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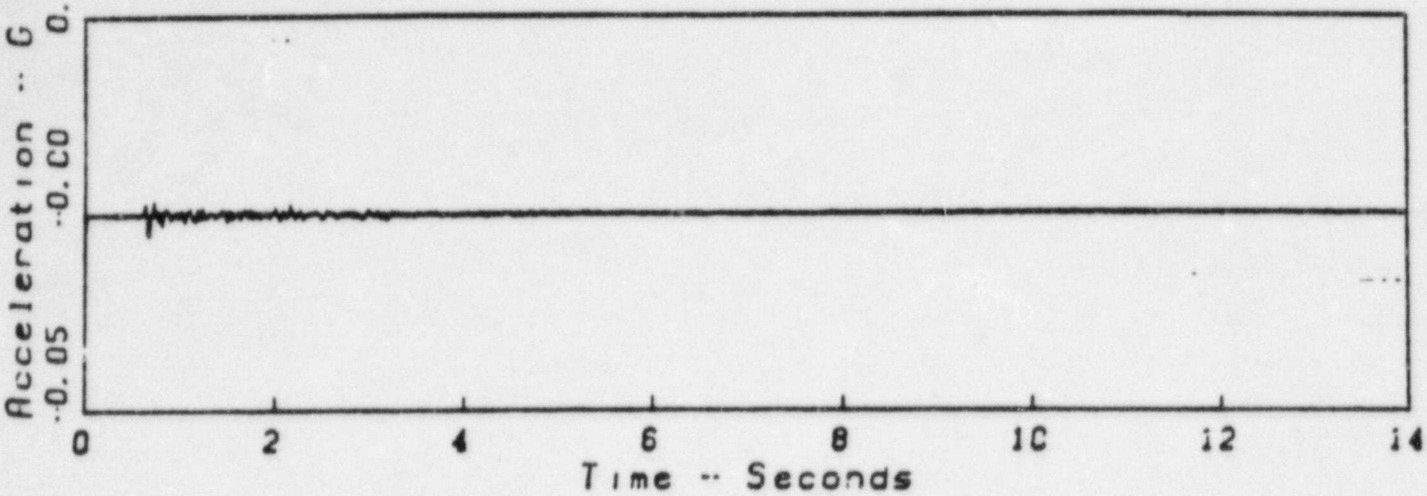
GROUND MOTION OUTPUT BY FEBRUARY, 1987

OUTPUT	APPLICATION	GM TASKS	INPUT DATA	APPROACH
NEAR-FINAL PEAK VALUES (H AND V)	SSI	1.2, 4.1, 5.1	REFINED G/S/G INFORMATION DATA FROM FIELD EXPERIMENTS	NUMERICAL MODELING TO EVALUATE ATTENUATION RELATIONSHIPS AND TO ASSESS STATISTICAL DISPERSION AND UPPER BOUND CONSTRAINTS
NEAR-FINAL RESPONSE SPECTRA (H AND V)	SSI	2.2, 4.1, 5.1	" "	NUMERICAL MODELING TO EVALUATE RESPONSE SPECTRA AND TO ASSESS STATISTICAL DISPERSION AND UPPER BOUND CONSTRAINTS
NEAR-FINAL TIME HISTORIES (H AND V)	SSI	3.2, 5.1	" "	NUMERICAL MODELING BASED ON REFINED PATH AND SITE MODELS
REFINED RESULTS ON WAVE CHARACTERISTICS	SSI	4.2, 5.3	" "	" "
INITIAL RESULTS ON WAVE COHERENCY	SSI	4.2, 5.3	DCPP FREE-FIELD RECORDS FOR LOCAL EARTHQUAKES DATA FROM FIELD EXPERIMENTS	CROSS-CORRELATION ANALYSIS ARRAY PROCESSING

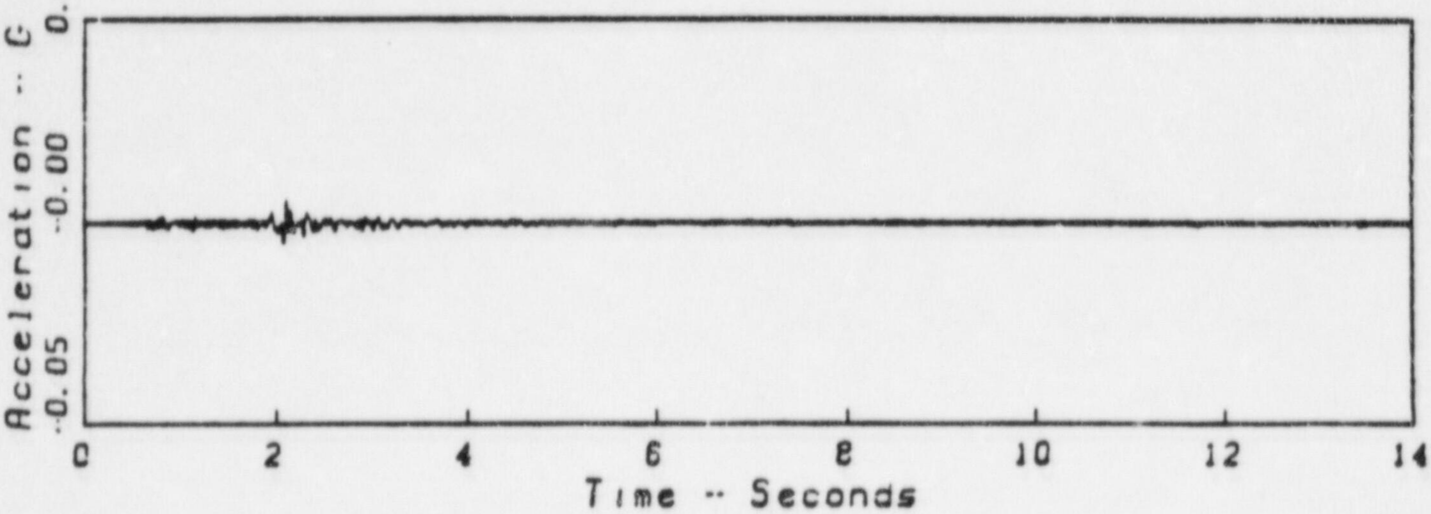
YBT:rle
4/9/86

SAN LUIS OBISPO NOVEMBER 12 1984

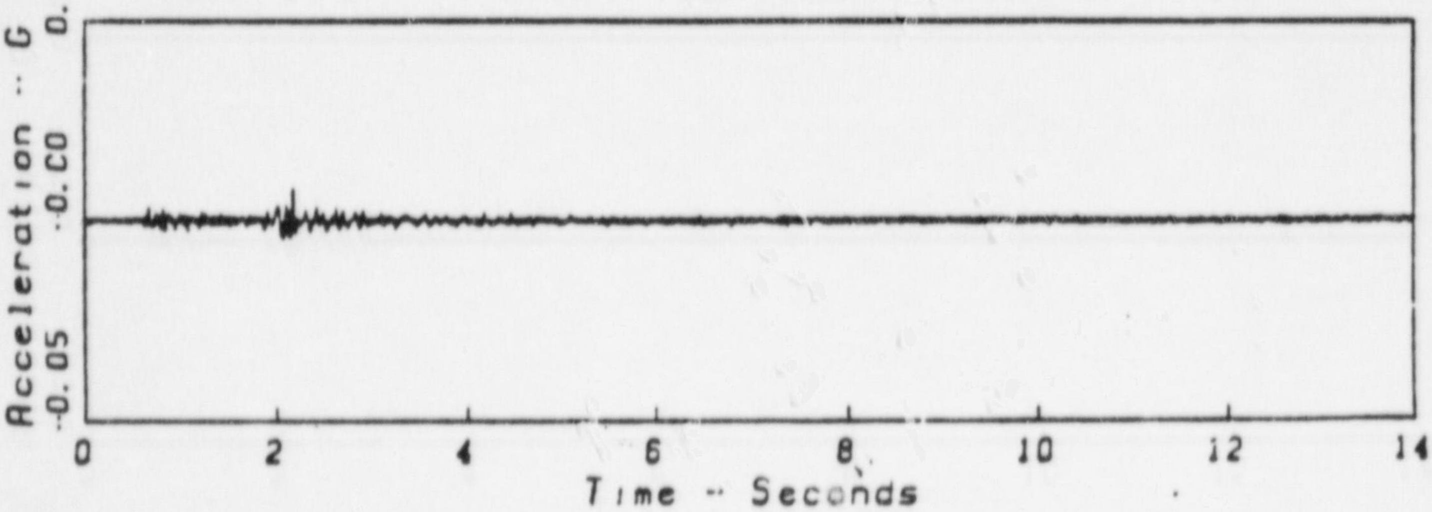
DECK 5--3 CHANNEL 1 Peak Value = 0.0050 at 0.680



DECK 5--3 CHANNEL 2 Peak Value = 0.0058 at 2.110

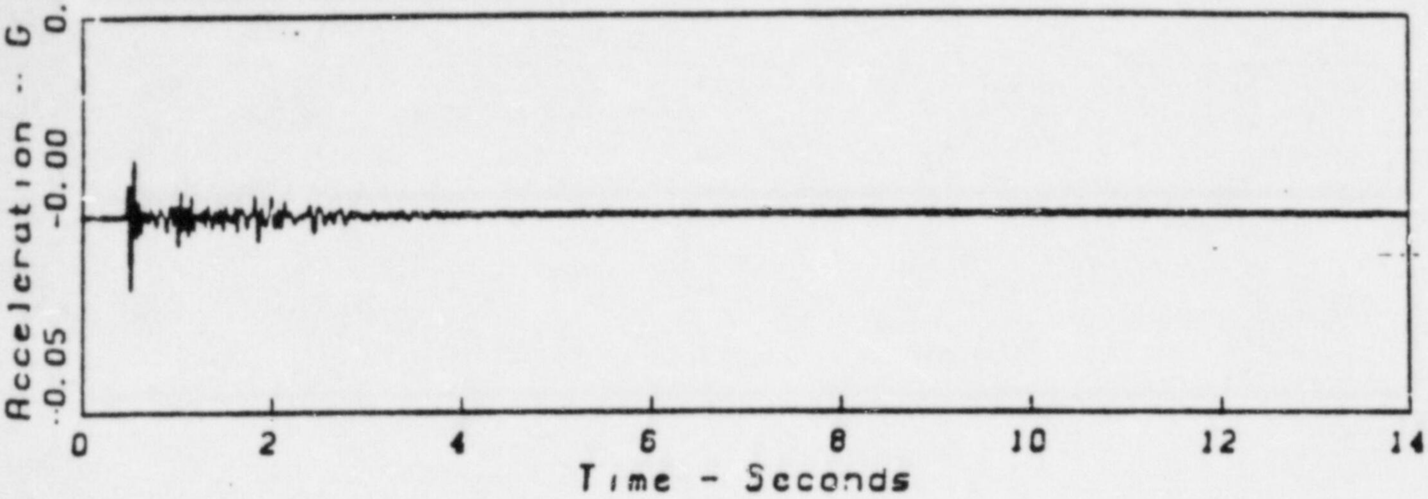


DECK 5--3 CHANNEL 3 Peak Value = 0.0078 at 2.180

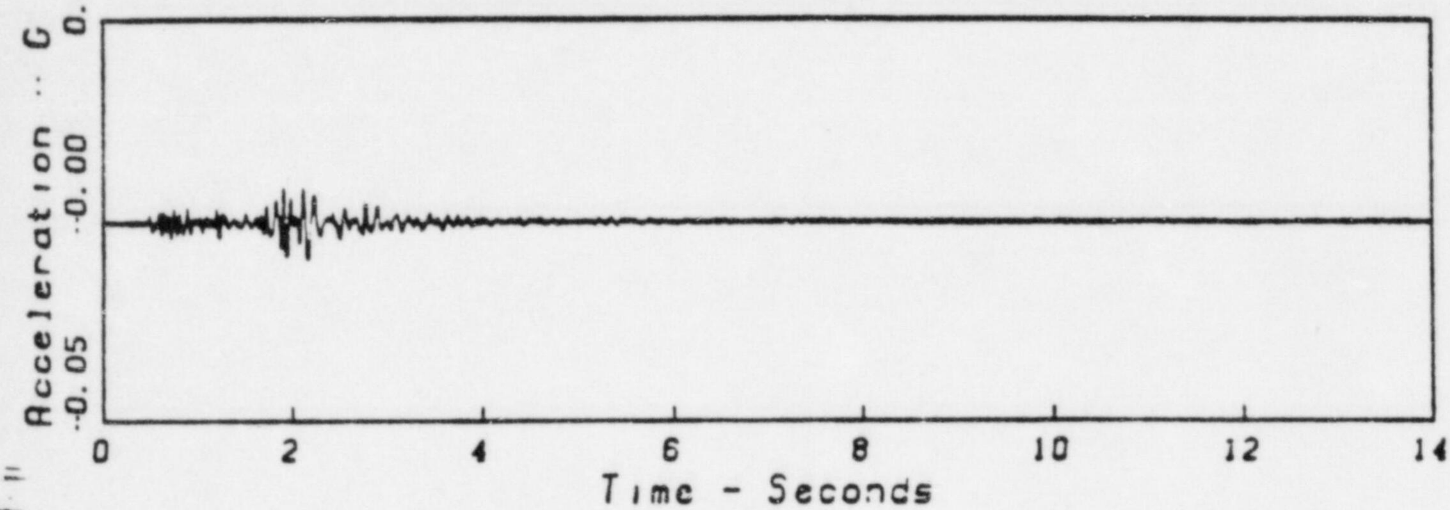


SAN LUIS OBISPO NOVEMBER 12 1984

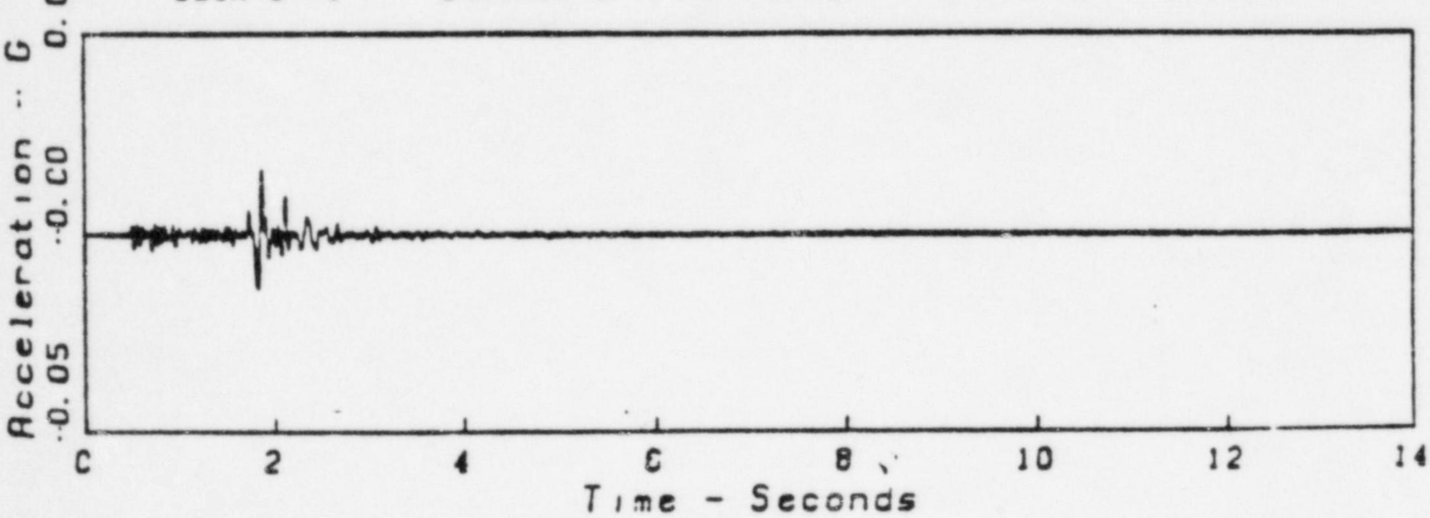
DECK 5--4 CHANNEL 1 Peak Value = 0.0186 at 0.510



DECK 5--4 CHANNEL 2 Peak Value = 0.0088 at 2.170

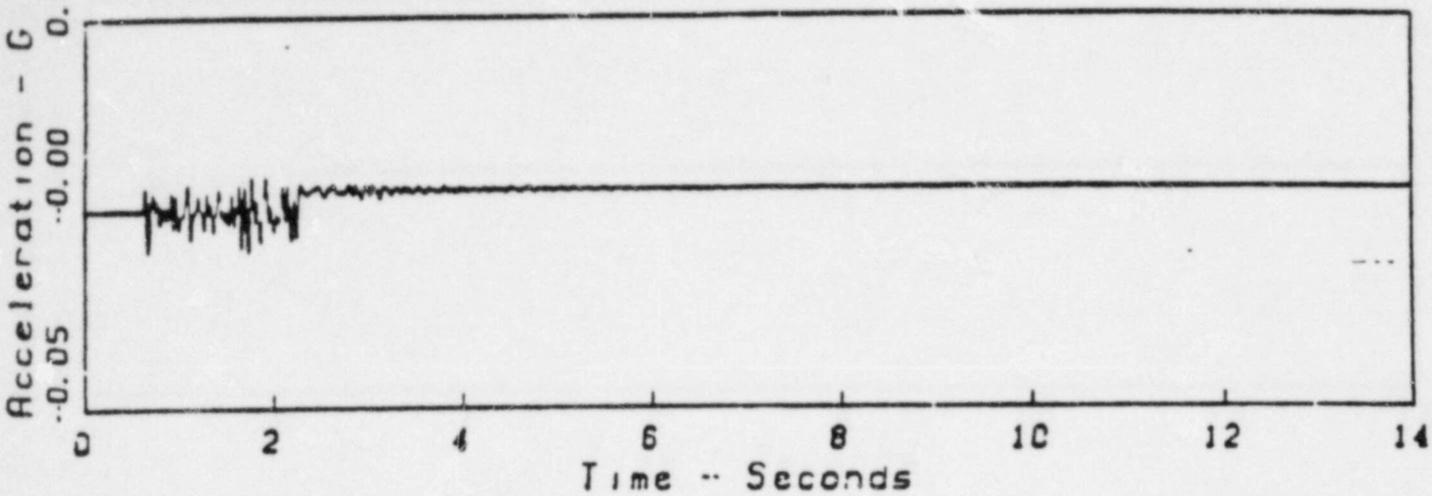


DECK 5--4 CHANNEL 3 Peak Value = 0.0161 at 1.870

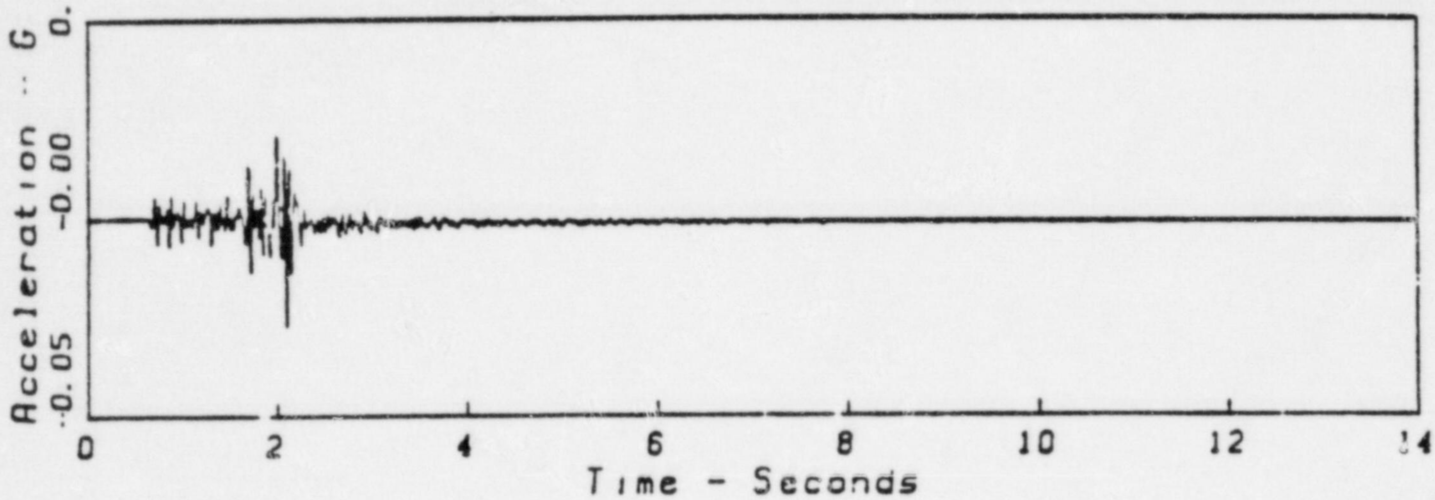


SAN LUIS OBISPO NOVEMBER 12 1984

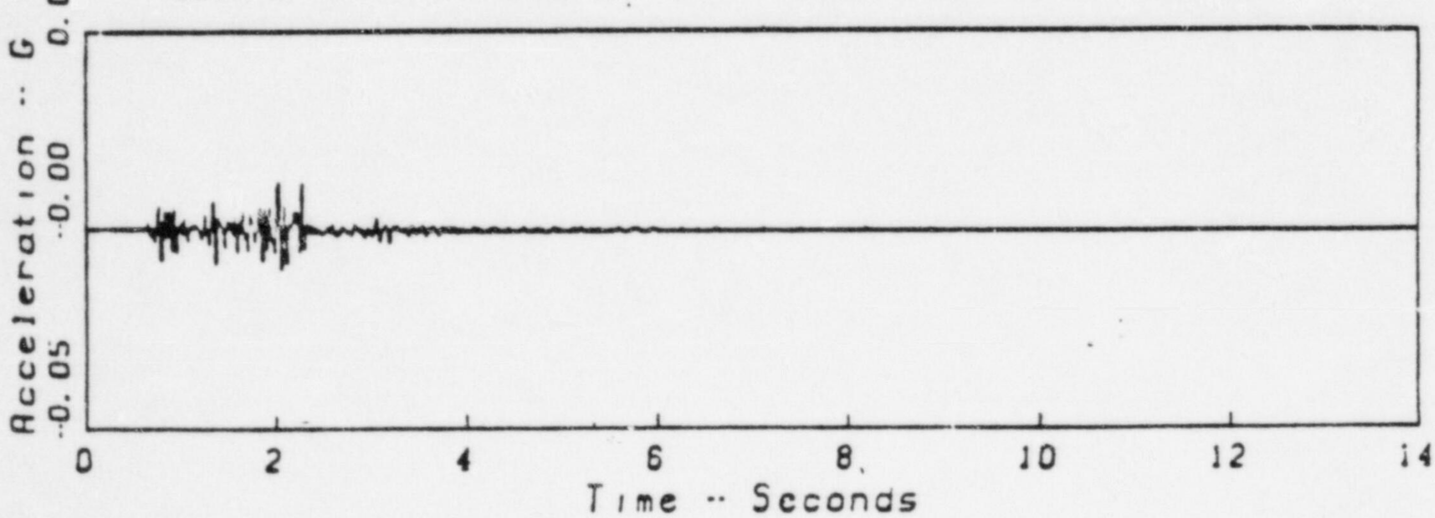
DECK 6--1 CHANNEL 1 Peak Value = 0.0099 at 0.670



DECK 6--1 CHANNEL 2 Peak Value = 0.0267 at 2.110



DECK 6--1 CHANNEL 3 Peak Value = 0.0118 at 2.030



ADDITIONAL FREE-FIELD INSTRUMENTS AT DIABLO CANYON

LOCAL SITE EFFECTS	POSSIBLE CAUSES	ADDITIONAL INSTRUMENTS
FOCUSING/DEFOCUSING	TOPOGRAPHIC RELIEF	LINEAR TOPOGRAPHIC ARRAYS
SCATTERING	GEOLOGIC CONDITIONS	SPATIAL COHERENCE ARRAY

* TWO LINEAR TOPOGRAPHIC ARRAYS ALONG PROFILES AA' AND BB' AND FOUR ALTERNATIVE CANDIDATE SITES FOR THE SPATIAL COHERENCE ARRAY ARE BEING CONSIDERED.

YBT:rle
4/9/86

GROUND MOTION OUTPUT BY JULY, 1987

OUTPUT	APPLICATION	GM TASK	INPUT DATA	APPROACH
FINAL PEAK VALUES (H AND V)	SSI	1.2, 4.1, 5.1, 5.2	FURTHER REFINED G/S/G INFORMATION	NUMERICAL MODELING BASED ON FINAL SOURCE, PATH AND SITE MODELS
FINAL RESPONSE SPECTRA (H AND V)	SSI, SHA	2.2, 4.1, 5.1, 5.2	" "	" "
FINAL TIME HISTORIES (H AND V)	SSI	3.2, 5.1, 5.2	" "	" "
FINAL RESULTS ON WAVE CHARACTERISTICS	SSI	4.2, 5.2, 5.3	" "	" "
FINAL RESULTS ON WAVE COHERENCY	SSI	4.2, 5.2, 5.3	" "	" "

YBT:rle

TASK 5 APPLICATION OF NUMERICAL MODELING OF GROUND MOTIONS

5.1 EVALUATE THE SELECTED ATTENUATION RELATIONSHIPS, RESPONSE SPECTRA, AND TIME HISTORIES

- LEVEL AND SHAPE
- DISPERSION, SATURATION AND TRUNCATION

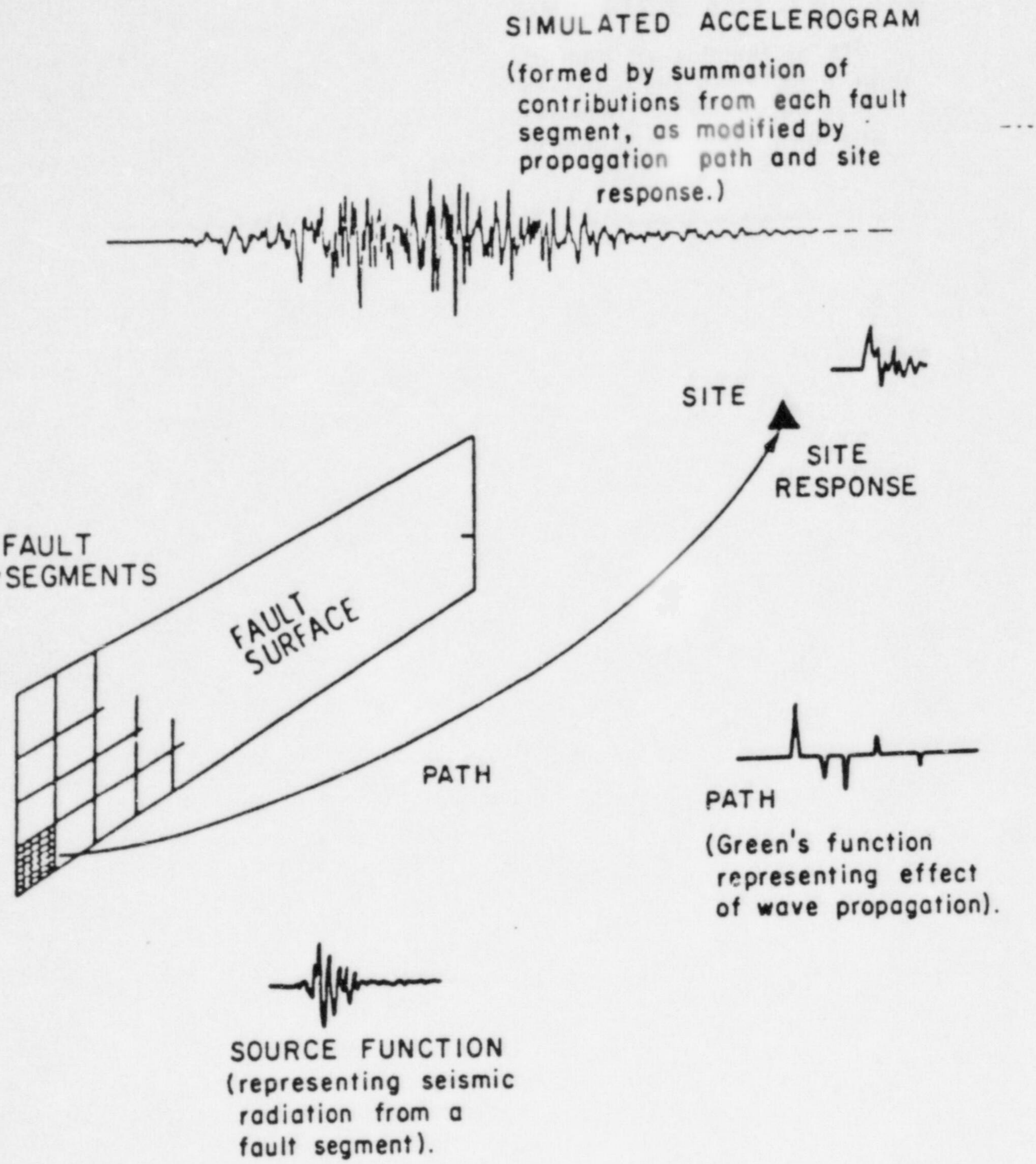
5.2 ASSESS EFFECTS OF ALTERNATIVE FAULT TYPES, FAULT GEOMETRY, AND RUPTURE PROCESS FOR NEAR-SITE SOURCES

- DIRECTIVITY
- HIGH FREQUENCY RADIATION

5.3 ASSESS LOCAL SITE EFFECTS

- WAVE TYPES
- INCIDENCE ANGLE
- SPATIAL COHERENCE

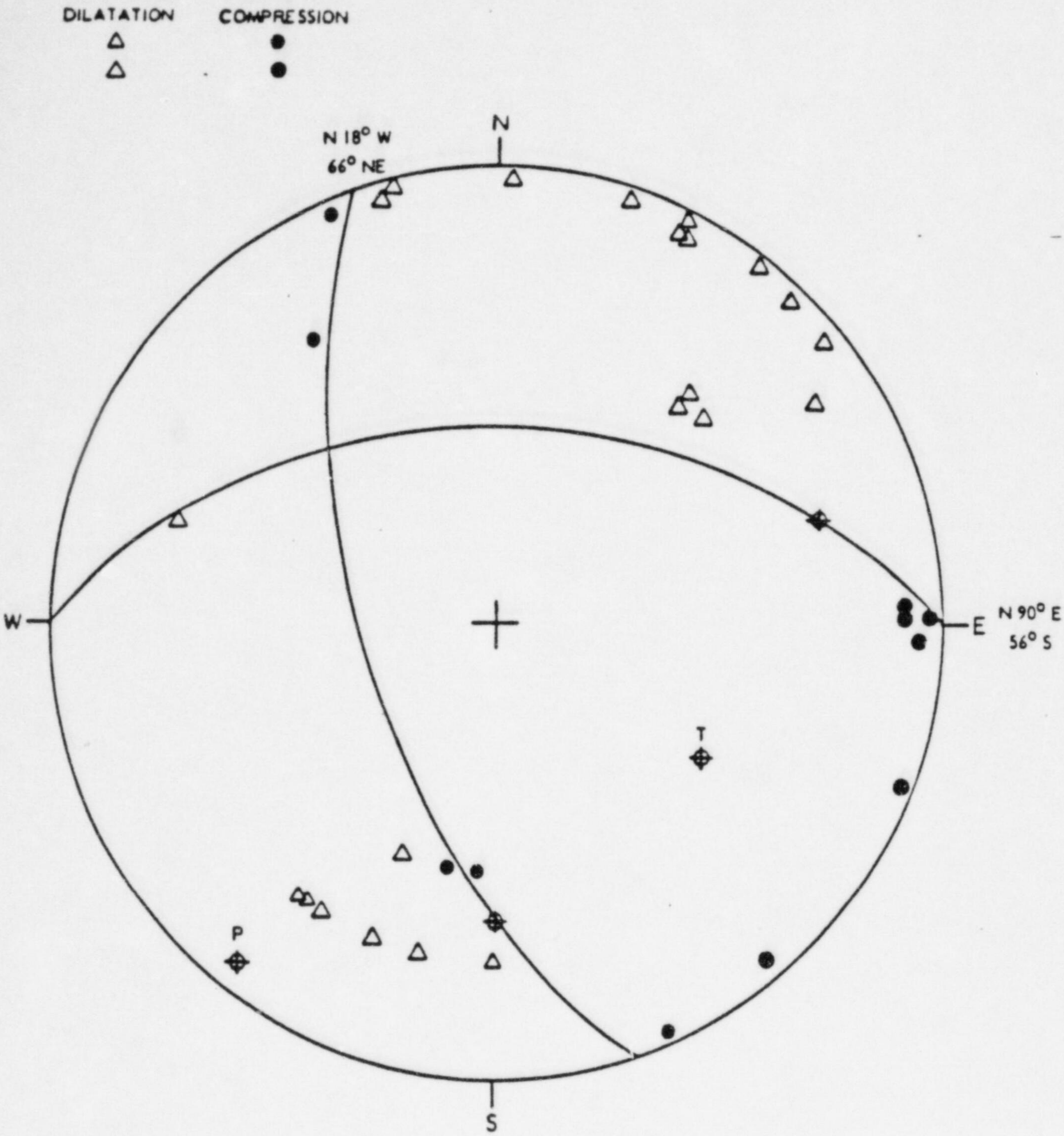
YBT:rle
4/11/86


SIMULATED ACCELEROGRAM
(formed by summation of contributions from each fault segment, as modified by propagation path and site response.)
SITE
SITE RESPONSE
FAULT SEGMENTS
FAULT SURFACE
PATH
PATH
(Green's function representing effect of wave propagation).
SOURCE FUNCTION
(representing seismic radiation from a fault segment).

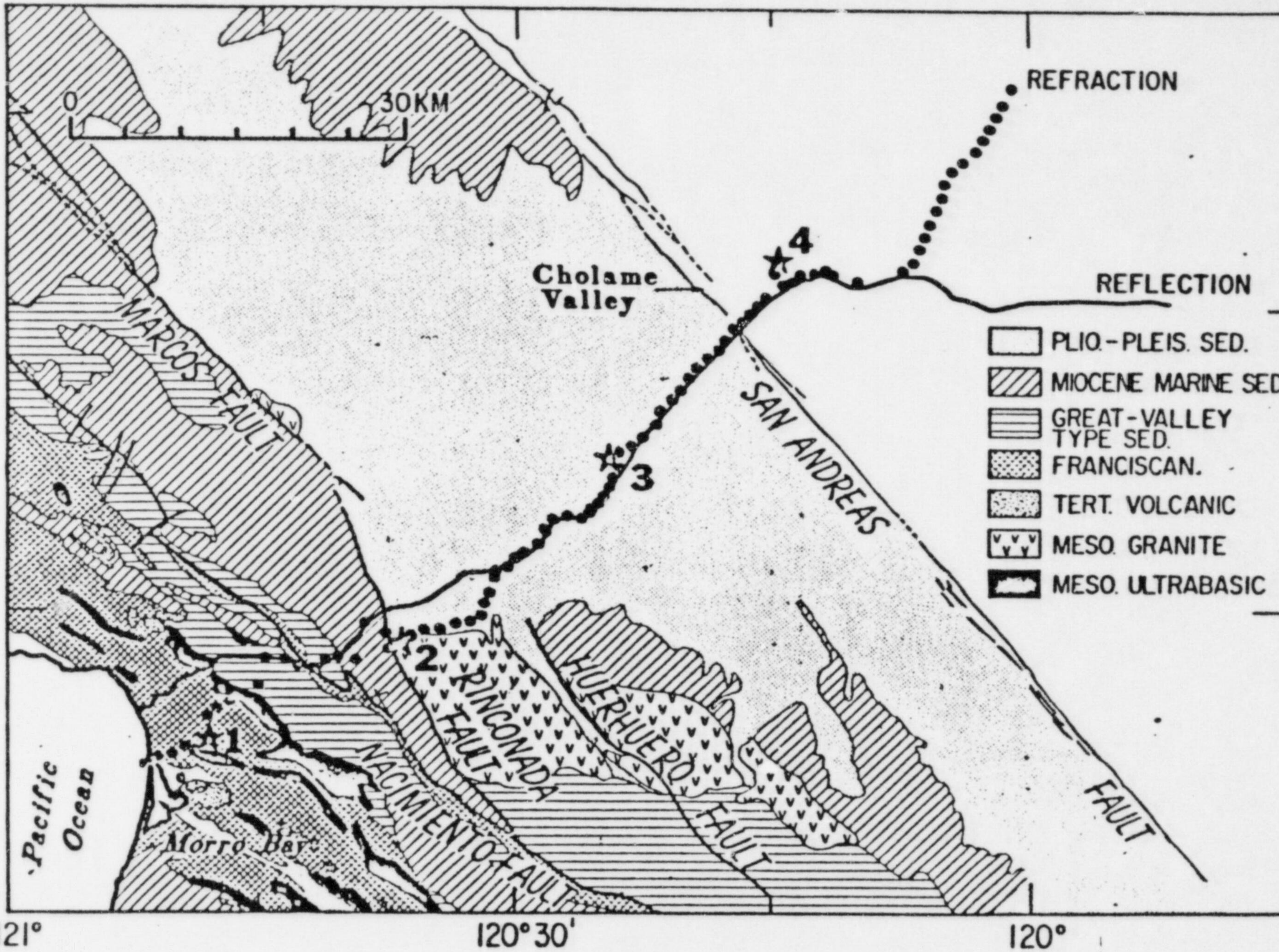
GROUND MOTION MODELING PROGRAM

STAGE I (4/86 - 8/86)	ASSEMBLE, MODIFY AND CALIBRATE EXISTING COMPUTER PROGRAMS; DEVELOP PRELIMINARY SOURCE, PATH, SITE MODELS FROM EXISTING INFORMATION.
STAGE II (9/86 - 1/87)	IMPROVE PATH AND SITE MODELS USING RESULTS OF SITE EXPERIMENTS; PRODUCE TIME HISTORIES, WAVE CHARACTERISTICS AND SPATIAL COHERENCY DATA BY FEBRUARY 1987.
STAGE III (2/87 - 6/87)	UPDATE SOURCE AND PATH MODELS USING ADDITIONAL GEOLOGY/SEISMOLOGY/GEOPHYSICS RESULTS; PRODUCE FINAL TIME HISTORIES, WAVE CHARACTERISTICS AND SPATIAL COHERENCY DATA BY JULY 1987. ASSESS EFFECTS OF ALTERNATIVE FAULT TYPES, FAULT GEOMETRY AND RUPTURE PROCESS BY JULY 1987.

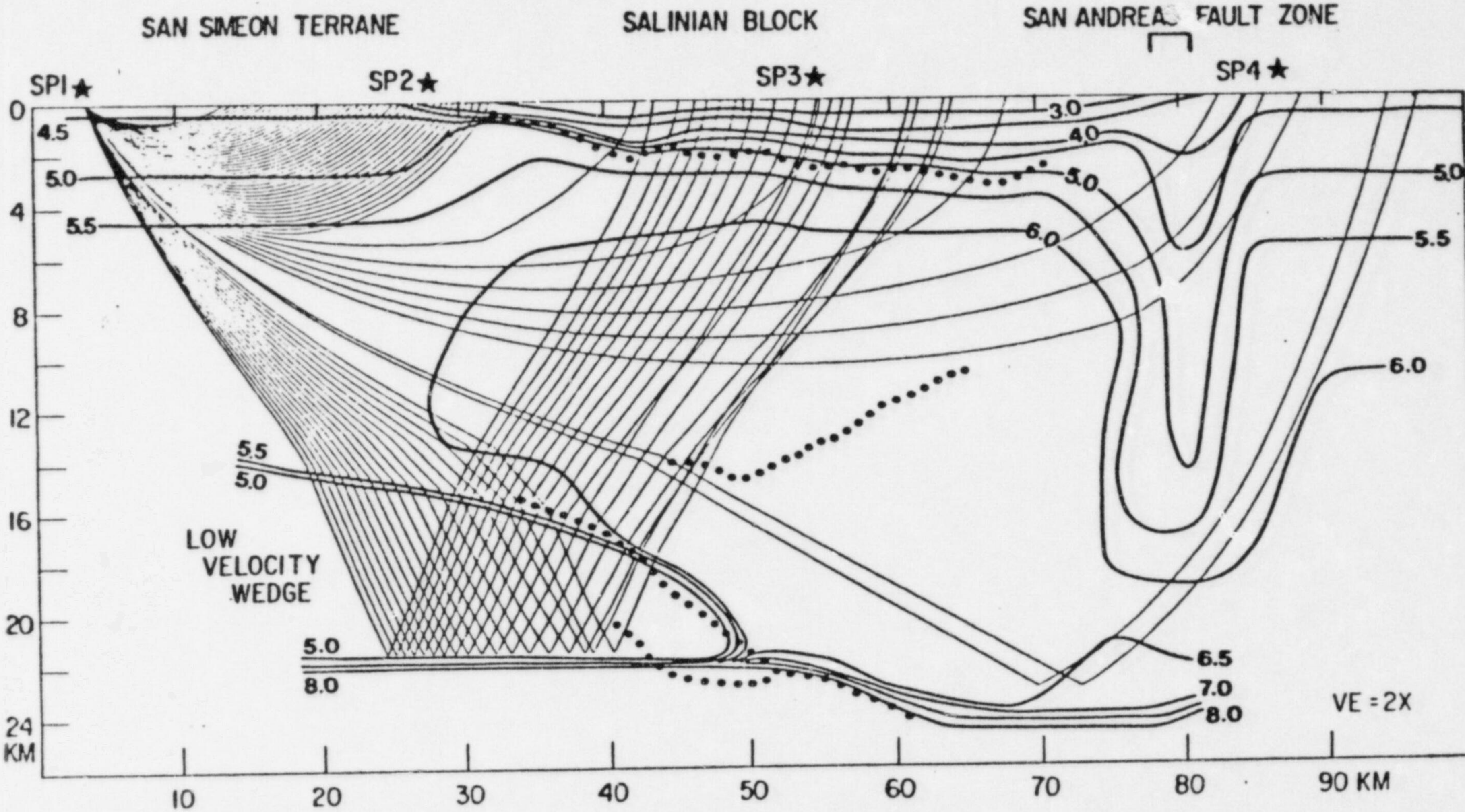
YBT - 4/9/86



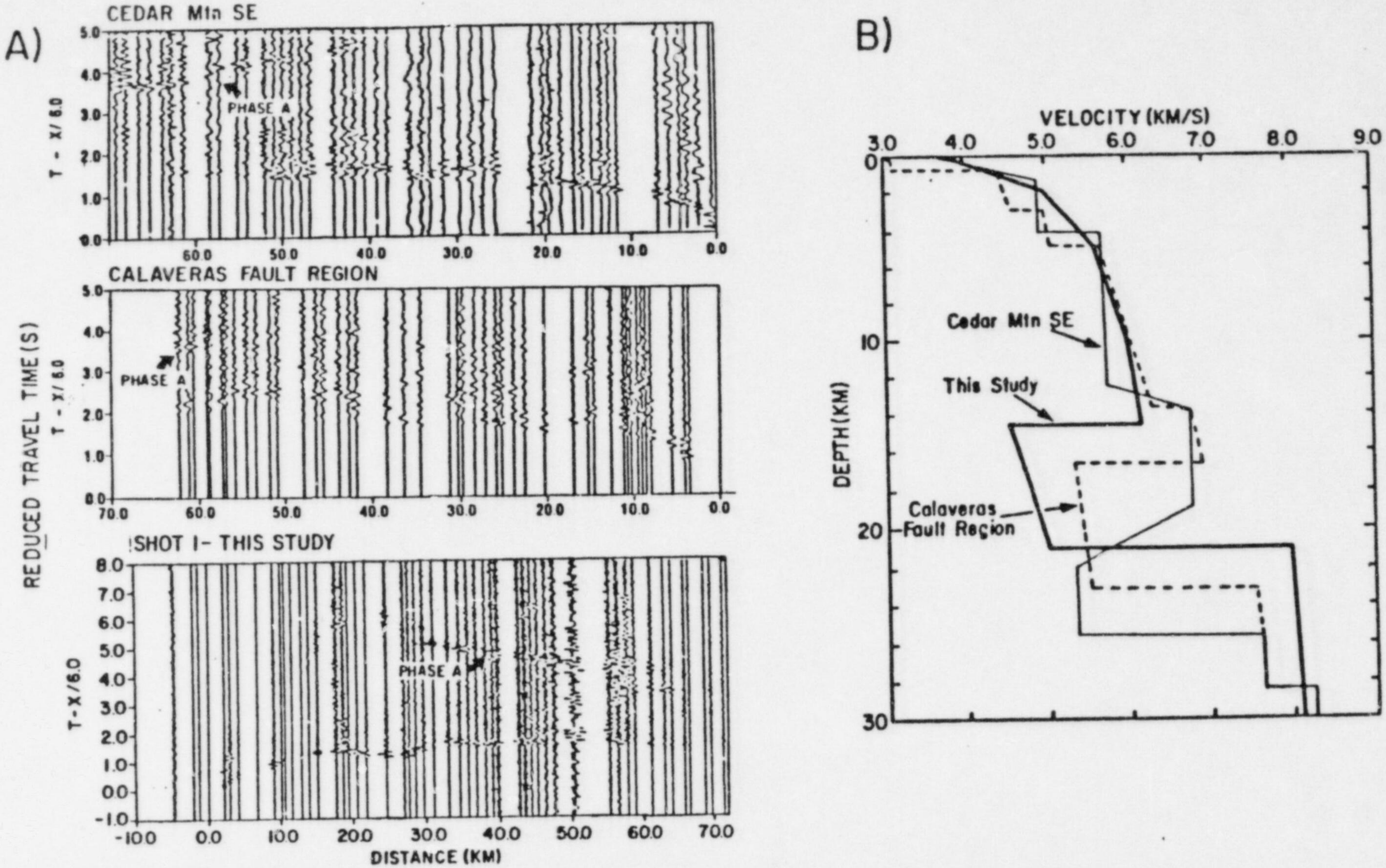
FOCAL MECHANISM REPRESENTATION (UPPER HEMISPHERE PROJECTION) OF NOVEMBER 12, 1984 EARTHQUAKE. THE SIZE OF SYMBOLS IS INDICATIVE OF THE CERTAINTY OF THE P POLARITY.



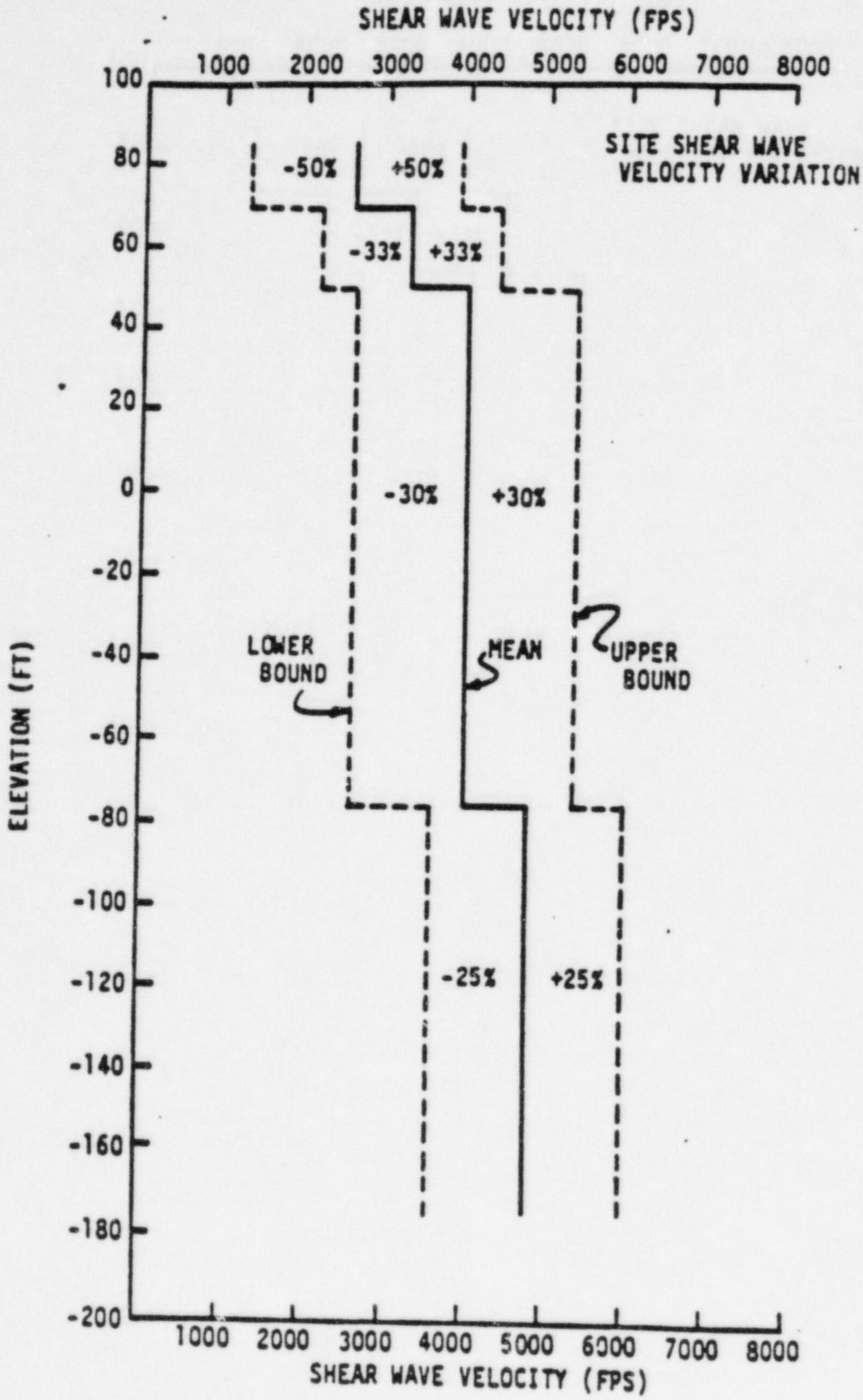
TREHU AND WHEELER (1986)



TREHU AND WHEELER (1986)



TREHU AND WHEELER (1986)



SHEAR WAVE VELOCITY PROFILE

ENCLOSURE 4

SECTION 9

SEISMIC MONITORING SYSTEMS

AT

DIABLO CANYON POWER PLANT

- BASIC SEISMIC SYSTEM
- SUPPLEMENTAL SEISMIC SYSTEM

BASIC SEISMIC MONITORING SYSTEM

INSTRUMENTATION

#	INSTRUMENT	VENDOR	LOCATION
3	Acceleration Sensors (Triaxials)	Kinemetrics (FBA-3)	See Fig. 1.1.1
1	Control Recorder (Analog)	Kinemetrics (SMA-3)	Control room
1	Playback Unit (Analog)	Kinemetrics (SMP-1)	Control room
6	Peak Accelographs	Engdahl Technology (PAR-400)	See Fig. 1.1.5
1	Response Spectrum Recorder	Engdahl (PSR 1200)	See Fig. 1.1.5
1	Earthquake Force Monitor (Triaxial)	Kinemetrics (EFM-1)	Control room
1	Trigger (Starter)	Kinemetrics (TS-1)	See Fig. 1.1.5

DCPP BASIC SEISMIC SYSTEM

INSTRUMENTS AND SENSOR LOCATIONS

Triaxial Strong Motion Accelerometers

Containment Base Slab, EL 89, 180°

Top Unit 1 Containment, EL 303.5, 225°

Aux Building, EL 64

Triaxial Peak Accelographs

Containment Base Slab, EL 89, 180°

Top Unit 1 Containment, EL 303.5, 225°

Intake near ASW Pump 1-2 Bay, EL 2

Turbine Building, El 85, Machine Shop

Aux Building, EL 140, Hot Shop Roll Up Door

Aux Building, EL 140, Near Control Room Door

Triaxial Response-Spectrum Recorders

Containment Base Slab, EL 89, 180°

Seismic Trigger

Containment Base Slab, EL 89

DCPP SUPPLEMENTAL SEISMIC SYSTEM

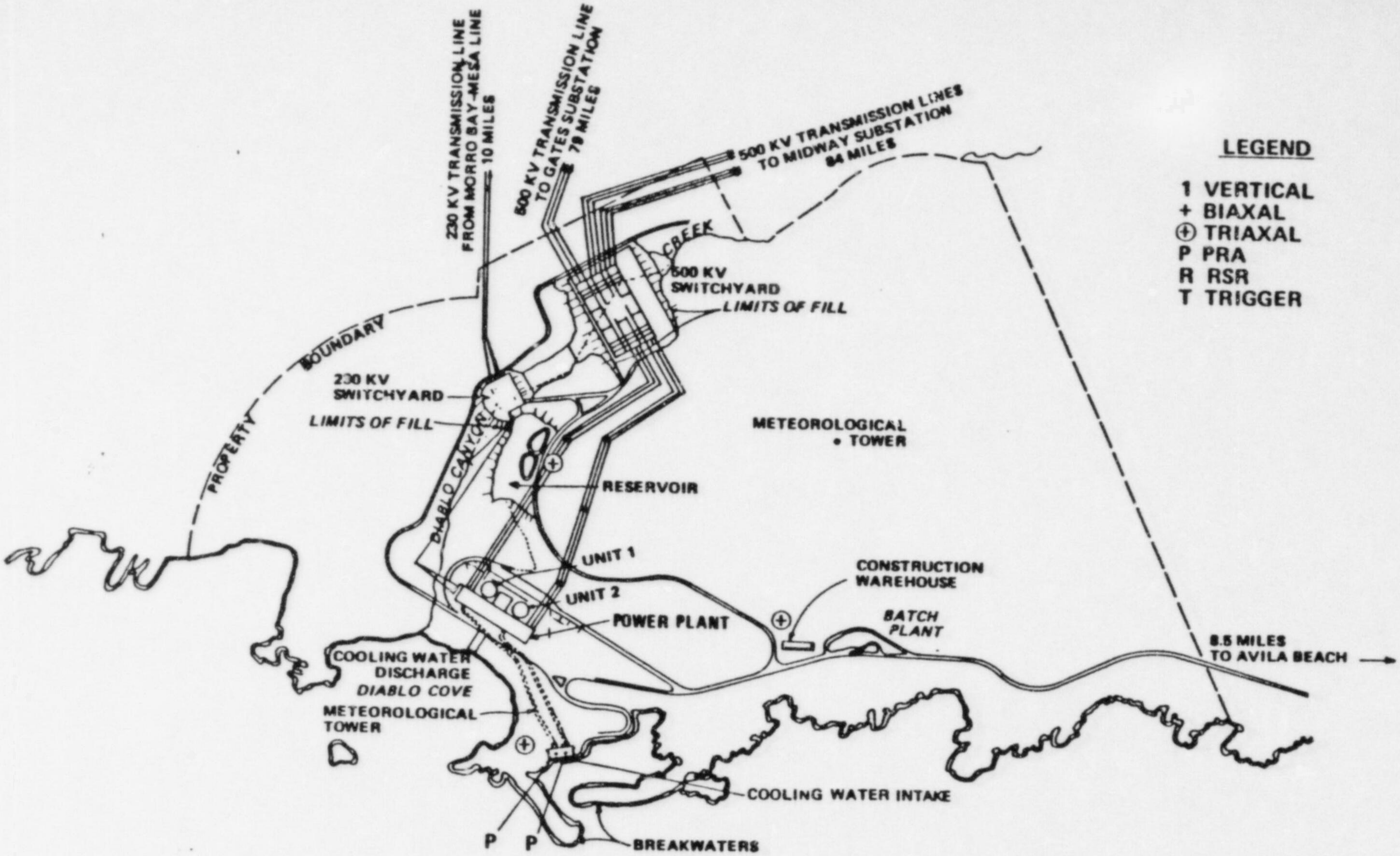
INSTRUMENTATION

#	INSTRUMENT	VENDOR	LOCATION
61 2 un- used)	Acceleration sensors 16 triaxial; 6-biaxial; 1 uniaxial	Terra Technology (SSA 302)	See Figure 1.1.1
7	Peak recording accelerographs	Engdahl (PAR 400)	See Figure 1.1.5
1	Seismograph recorder (Digital)	Terra Technology (DCS 302)	Aux. Bldg Area GW Unit 1 Elev. 100
1	Playback plotter (Analog)	Terra Technology (SMR 102)	Aux. Bldg Area GW Unit 1 Elev. 100
1	WWVB Radio Clock (Receiver & Antenna Nat. Bureau of Standards	Kinematics	Roof of Unit 1 Control Room

DCPP SUPPLEMENTAL SEISMIC SYSTEM

SENSOR LOCATIONS AND ORIENTATIONS

DCS-Deck Nos.	Sensor Type (See Note 1)	Channel No. (See Note 2)	Max G	Location: Elev. (ft)	Location: Unit	Location: Description	Orientation (See Notes 3 and 4): Ch 1	Ch 2	Ch 3
	TR		1	89	1	Outside Containment - Base, Basic (SMA 3) System & Trigger (See Note 5)	180	270	Vert
	TR		3	303.5	1	Top of Containment, Basic (SMA 3) System (See Note 5)	180	270	Vert
	TR		1	64	1, 2	Aux. Building (U) - (18), Basic (SMA 3) System (See Note 5)	180	270	Vert
1-1	TR		1	89	1	Outside Containment - Base, NW Sector	Vert	118	28
1-2	TR		1	89	1	Outside Containment - Base - NE Sector	Vert	240	150
2-4	Single	3	1	91	1	Containment - Near Reactor, Between SG 1-3 and SG 1-4	--	--	Vert
1-3	TR		2	140	1	Containment - Operating Deck, Near Steam Generator No. 1-1	Vert	180	90
1-4	TR		2	140	1	Containment - Operating Deck, Near Steam Generator No. 1-3	Vert	0	270
2-4	B	1 & 2	2	140	1	Containment - Operating Deck, Annulus-South (See Note 6)	90	180	See Deck 2-4
3-1	B	1 & 2	2	140	1	Containment - Operating Deck, Annulus-West	180	90	Blank
2-2	TR		3	231	1	Containment Liner, Dome Springline - NE Sector	Vert	60	330
2-3	TR		3	231	1	Containment Liner, Dome Springline - S Sector	Vert	180	90
3-2	TR		3	231	1	Containment Liner, Dome Springline - NW Sector	Vert	300	210
4-3	B	1 & 2	1	89	2	Outside Containment - Base, N Sector	Vert	90	See Deck 4-3 and 4-4
4-4	B	1 & 2	1	89	2	Outside Containment - Base, SE Sector	Vert	200	See Deck 4-3 and 4-4
5-1	B	1 & 2	1	89	2	Outside Containment - Base, SW Sector - Trigger "A"	Vert	328	Blank
3-3	TR		1	100	1	Aux. Bldg. - (Fuel Handling), Between SPT Fuel Pool & HVAC Filter Room	Vert	0	270
3-4	TR		1	100	1, 2	Aux. Bldg. (H) - (18), Wall Next to Stairs - W End	Vert	270	180
4-1	TR		1	100	1, 2	Aux. Bldg. (U) - (18), E end next to liquid holdup tanks - Trigger "B"	Vert	90	0
5-3	TR		1	--	--	Free Field, Near Reservoir	Vert	1	271
5-2	TR		1	85	1	Turbine Building, N End, Switch Gear Room	Vert	0	270
4-3 4-4	B	3	1	140	1	Turbine Building, N End, Turbine Deck	--	--	0, Deck 4-3 270, Deck 4-4
4-2	TR		1	85	2	Turbine Building, S End, Stairs	Vert	180	90
2-1	TR		1	89	1	Outside Containment Base, S Sector	Vert	0	270
6-1	TR		1	--	--	Free Field, Near Warehouse (See Note 7)	Vert	176	86
5-4	TR		1	--	--	Free Field, Near Meteorological Tower	Vert	84	354



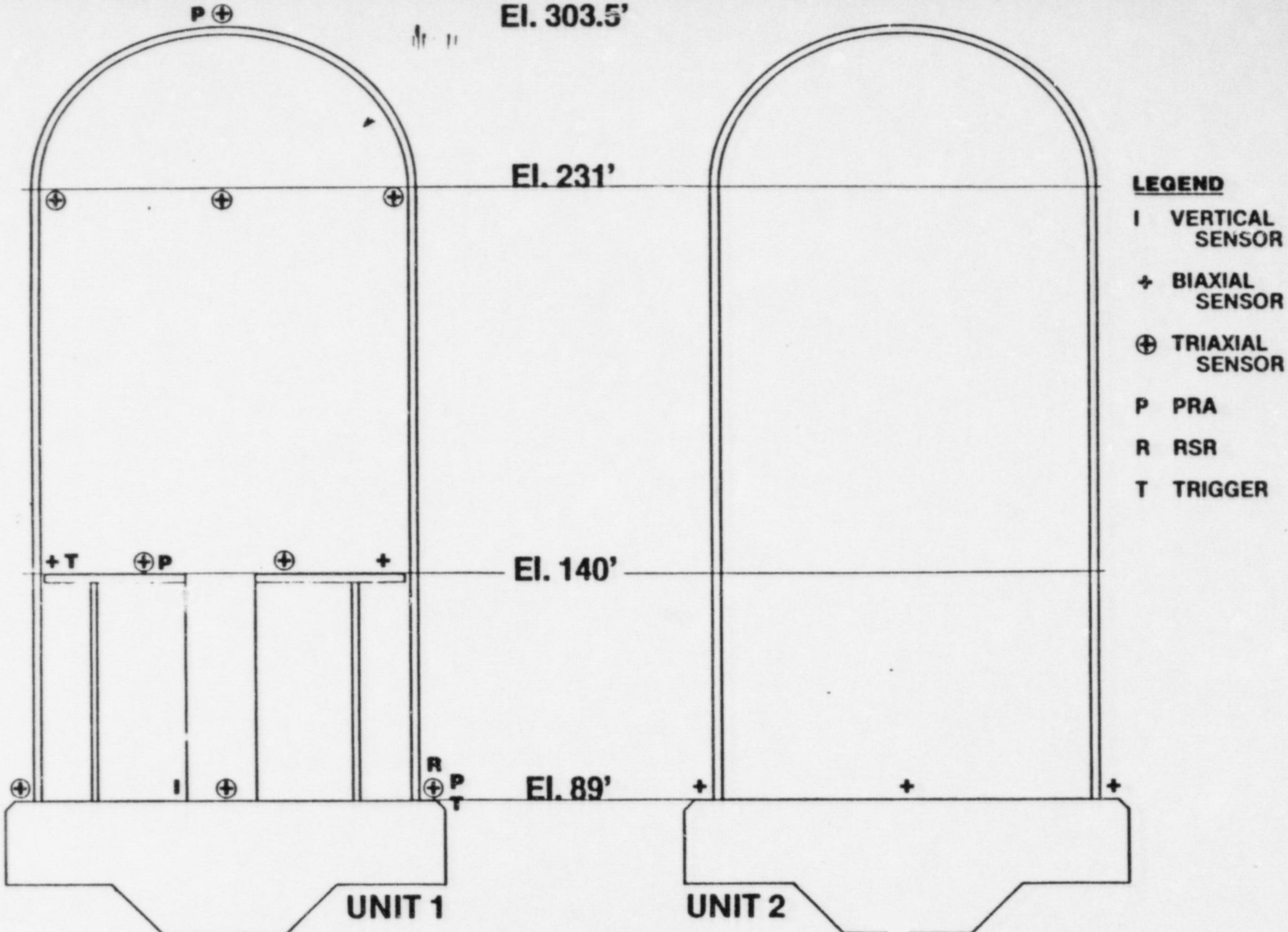
LEGEND

1 VERTICAL
\+ BIAXAL
⊕ TRIAXAL
P PRA
R RSR
T TRIGGER

0 400 800 1200 1600
SCALE IN FEET

UNITS 1 AND 2
DIABLO CANYON SITE

SEISMIC INSTRUMENTATION



SEISMIC INSTRUMENTATION
CONTAINMENT STRUCTURE
DIABLO CANYON UNITS 1 & 2

LEGEND

I VERTICAL

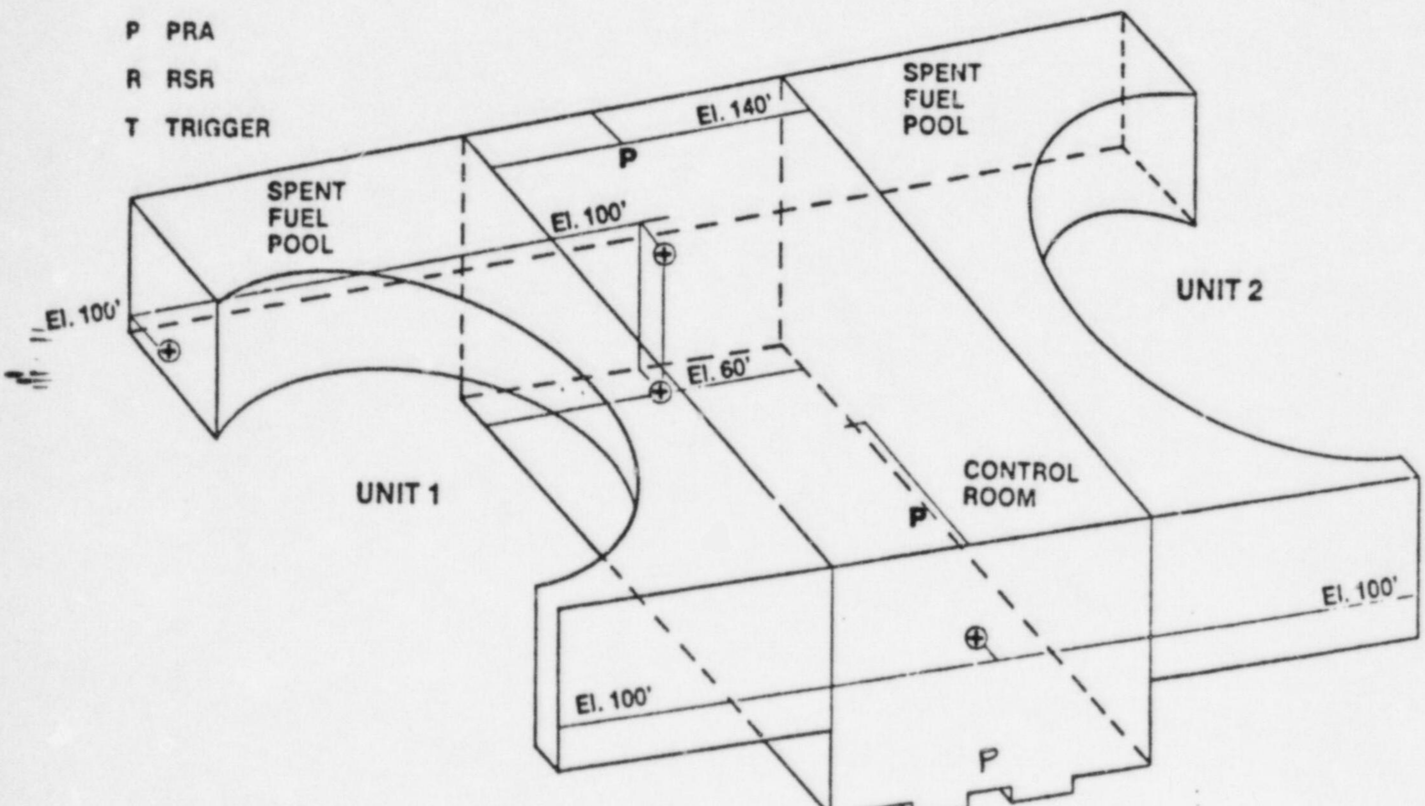
+ BIAXIAL

⊕ TRIAXIAL

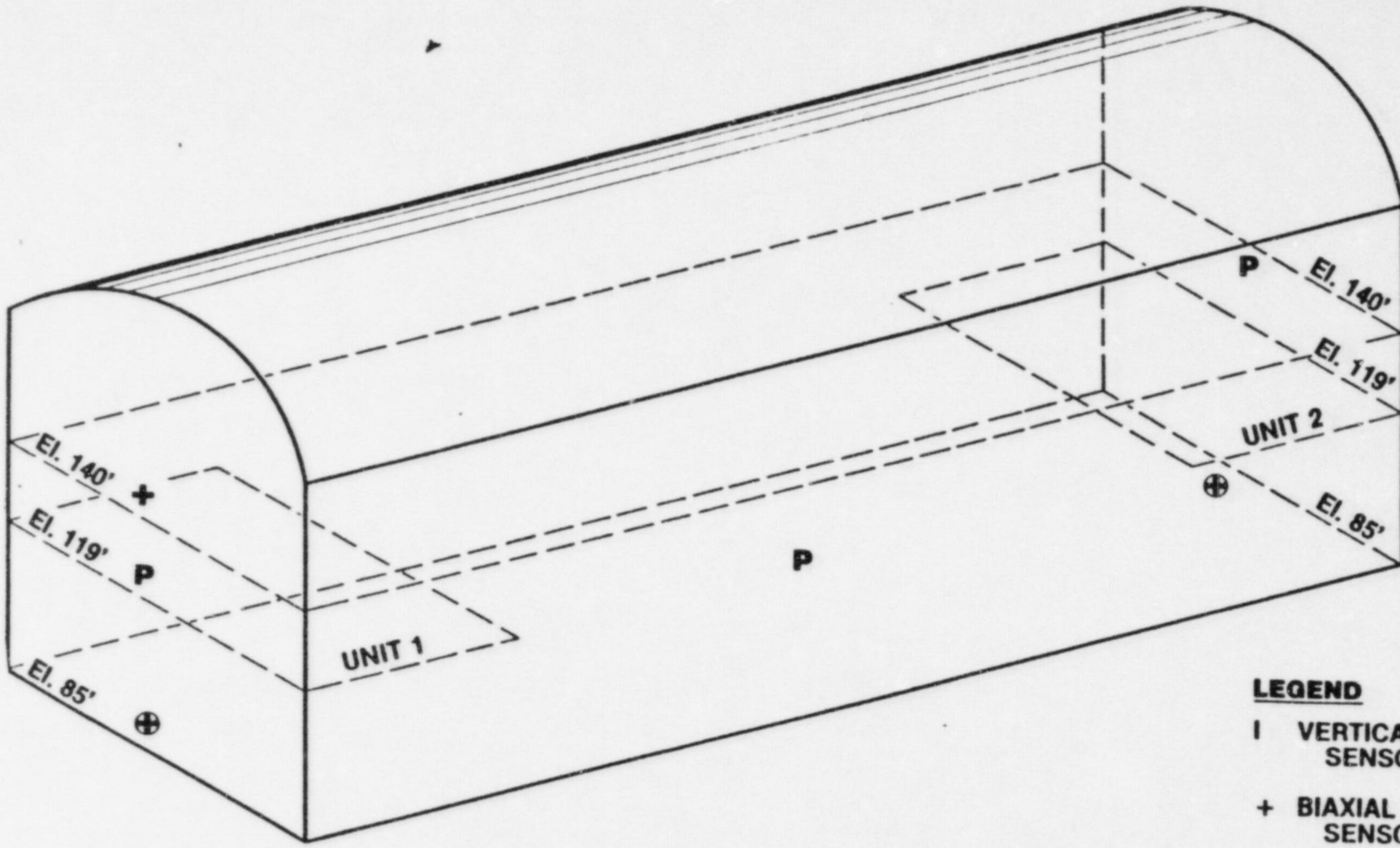
P PRA

R RSR

T TRIGGER



SEISMIC INSTRUMENTATION AUXILIARY BUILDING DIABLO CANYON UNITS 1 & 2



SEISMIC INSTRUMENTATION
TURBINE BUILDING
DIABLO CANYON UNITS 1 & 2

LEGEND

- I VERTICAL SENSOR
- \+ BIAXIAL SENSOR
- ⊕ TRIAXIAL SENSOR
- P PRA
- R RSR
- T TRIGGER

ENCLOSURE 4

SECTION 10

GENERATION OF REALISTIC ACCELERATION TIME HISTORIES BY SPECTRAL SCALING OF EARTHQUAKE RECORDINGS

Product: A Suite of Acceleration Time Histories

Criteria: Time histories appropriate and representative of:

- Magnitude M $\geq$6.5
- Distance R <10 km
- Site Condition Rock/Very Stiff Soil
- Shallow Crustal Earthquakes

General Approach: Empirical in nature

- Use of natural earthquake ground motion recordings
- Intent is to satisfy the above-specified criteria
- Preference given to candidate records which require minimal scaling adjustments

Scaling Categories:

- No scaling required
- Constant (rigid body) scaling
- Frequency dependent scaling

FREQUENCY DEPENDENT SCALING PROCEDURE

- **METHODS OF SCALING:**

  (a) Take Fourier transform of original time history

  (b) Scale Fourier amplitude spectrum using both empirical and theoretical scaling relations

  (c) Combine scaled amplitude spectrum with original phase spectrum; and

  (d) Take inverse Fourier transform of the combined complex spectrum to obtain scaled time history

- **CALIBRATION OF SCALING METHODS:**

  (a) Apply various scaling relations to scale selected accelerograms: magnitude range below 6.5

  (b) Compare original and scaled accelerograms: both in time domain and frequency domain

  (c) Decide on the scaling relation(s) to be used

- **GENERATION OF REALISTIC TIME HISTORIES:**

  (a) Select condidate recordings based on prescribed selection criteria

  (b) Adjust recordings to required magnitude, distances and site conditions using selected spectral scaling method

SPECTRAL SCALING RELATIONS

- **THEORETICAL SCALING RELATIONS:**

  (1) Brune's model (e.g. see Boore '83)

  (2) Joyner's model (e.g. see Joyner '84, Boore, '85)

- **EMPIRICAL SCALING RELATIONS:**

  Fourier Amplitude Spectra:

  (1) Trifunac (1976)

  (2) McGuire (1978)

  Response Spectral Ordinates:

  (1) Joyner and Boore (1982)

  (2) Sadigh ('83)/Sadigh, Egan, Youngs ('86)

CANDIDATE GROUND MOTION RECORDINGS FOR EMPIRICAL APPROACH

Earthquake	M	Station	Dist (km)	Site Class.	a_{max} (g)	Selection Criteria M	Selection Criteria Dist	Selection Criteria Site
31 Oct 1935 Helena, Mont.	5.6	Federal Building	6	Rock	0.156		●	●
22 Mar 1957 San Francisco	5.3	Golden Gate Park	9	Rock	0.1[illegible]7		●	●
10 Dec 1965 Koyna, India	6.0	Koyna Dam	10	Rock - Gallery	0.631	○	●	○
27 Jun 1966 Parkfield	6.4	Cholame - Shandon #5	5	V. Stiff Soil	0.467	◑	●	○
		Cholame - Shandon #8	9	V. Stiff Soil	0.279	◑	●	○
		Temblor	10	Rock	0.411	◑	●	●
12 Sep 1970 Lytle Creek	5.4	Wrightwood	15	V. Stiff Soil	0.205			○
		Devils Canyon	22	Rock	0.179			●
		Allen Ranch	21	Rock	0.086			●
09 Feb 1971 San Fernando	6.6	Pacoima Dam	3	Rock	1.17[illegible]	●	●	●
		Griffith Park Obs.	17	Rock	0.188	●		●
		Lake Hughes #12	20	Rock	0.374	●		●
		Lake Hughes #4	24	Rock	0.200	●		●
		Lake Hughes #9	24	Rock	0.147	●		●
		Castaic	25	V. Stiff Soil	0.335	●		○
23 Dec 1972 Managua	6.2	Esso Refinery	7	V. Stiff Soil	0.390	○	●	○
01 Aug 1975 Oroville	5.6	Oroville Dam	10	Rock	0.108		●	●
17 May 1976 Gazli, USSR	7.0	Karakyr Point	4		0.81	●	●	○
13 Aug 1978 Santa Barbara	5.6	SCE Goleta	9	V. Stiff Soil	0.285		●	○
16 Sep 1978 Tabas, Iran	7.5	Tabas	3		0.81	●	●	○
06 Aug 1979 Coyote Lake	5.6	Coyote Creek	3	Rock	0.250		●	●
		Gilroy #1	9	Rock	0.118		●	●
		Gilroy #6	3	Rock	0.422		●	●
15 Oct 1979 Imperial Valley	6.9	El Centro #8	4	Deep Soil	0.619	●	●	
		El Centro #4	4	Deep Soil	0.485	●	●	
		Differential Array	5	Deep Soil	0.487	●	●	
		Holtville P.O.	8	Deep Soil	0.259	●	●	
		Imperial F.F.	8	Deep Soil	0.237	●	●	
		El Centro #10	9	Deep Soil	0.231	●	●	
		Brawley Airport	9	Deep Soil	0.222	●	●	
		Superstition Mtn	25	Rock	0.202	●		●

[illegible] 1980 Livermore	5.0	[illegible]	4	V. Stiff Soil	0.2[illegible]4		●	○
		Morgan Territory	8	Rock	0.272		●	●
[illegible] May 1980 Mammoth Lakes	6.1	Convict Creek	9	V. Stiff Soil	0.451	○	●	○
		Long Valley Dam	16	Rock - Abut	0.427	○		●
		Long Valley Dam	16	Rock - Dnstm	0.159	○		●
25 May 1980 [illegible]	6.1	Convict Creek	17	V. Stiff Soil	0.250	○		○
		Long Valley Dam	20	Rock - Abut	0.508	○		●
		Long Valley Dam	20	Rock - Dnstm	0.112	○		●
[illegible] May 1980 Mammoth Lakes	5.7	Convict Creek	10	V. Stiff Soil	0.485		●	○
		Long Valley Dam	[illegible]	Rock - Abut	0.292			●
		Long Valley Dam	[illegible]	Rock - Dnstm	0.08?			●
[illegible] May 1980 Mammoth Lakes	6.[illegible]	Convict Creek	15	V. Stiff Soil	0.324	○		○
		Long Valley Dam	16	Rock - Abut	1.524	○		●
		Long Valley Dam	16	Rock - Dnstm	0.219	○		●
		Paradise Lodge	22	Rock	0.115	○		●
08 May 1983 Coalinga Aft	5.3	Anticline Ridge	13	Rock	0.290			●
		Skunk Hollow	13	Rock	0.353			●
21 Jul 1983 Coalinga Aft.	6.0	Anticline Ridge	13	Rock	1.153	○		●
		Sulphur Baths	13	Rock	0.136	○		●
[illegible] Jul 1983 Coalinga Aft	5.3	Sulphur Baths	13	Rock	0.201			●
24 Apr 1984 Morgan Hill	6.1	Anderson Dam	1	Rock	0.424	○	◐	●
		Coyote Lake Dam	6	Rock	1.304	○	●	●
		Gilroy #6	18	Rock	0.293	○		●
		Gilroy #1	20	Rock	0.100	○		●
23 Nov 1984 Bishop	5.9	Paradise Lodge	10	Rock	0.240		●	●
Dec 1985 Canadian	~ 7		~10			●	●	

III-11

DEVELOPMENT OF INPUT TIME HISTORIES

FOR FRAGILITY ANALYSES

For selected ground motion recording:

- evaluate 5% damped response spectrum for each component

- calculate mean spectral level for both horizontal components within frequency range of 3 to 8½ H_z

- define <u>scaling factor</u> to obtain mean spectral level of 2.25 g within frequency range of 3 to 8½ H_z, i.e.

$$S = \frac{2.25}{\frac{1}{n} \sum_{n} S_a(f_n) \Big|_{3\,Hz}^{8\frac{1}{2}\,Hz}}$$

- scale each time history component of the recording by the scaling factor

$$a_s(t) = \mathbf{S} \cdot a_o(t)$$

PRELIMINARY INPUT TIME HISTORIES

FOR

SOIL-STRUCTURE INTERACTION ANALYSES

From the selected ground motion recordings, define a limited group that best captures the preliminary ground motion characteristics to be empirically estimated for the DCPP site, including:

- Peak Ground Acceleration
- Peak Ground Velocity
- Peak Ground Displacement
- Response Spectral Content
- Relationship Between Horizontal and Vertical Components

ILLUSTRATIVE EXAMPLES

OF GENERATING REALISTIC TIME HISTORIES

USING EMPIRICAL APPROACH

- Calibration of scaling procedure
    - Adjustment for Magnitude/Distance
    - Adjustment for Site Condition
- Supplemental scaling required to develop time histories for fragility analyses

ENCLOSURE 4

SECTION 11

NUMERICAL GROUND MOTION MODELING - STATUS OF PRELIMINARY STUDY

OBJECTIVE - PROVIDE PRELIMINARY INPUTS INTO SSI AND FRAGILITY ANALYSES - MAY-JUNE 1986

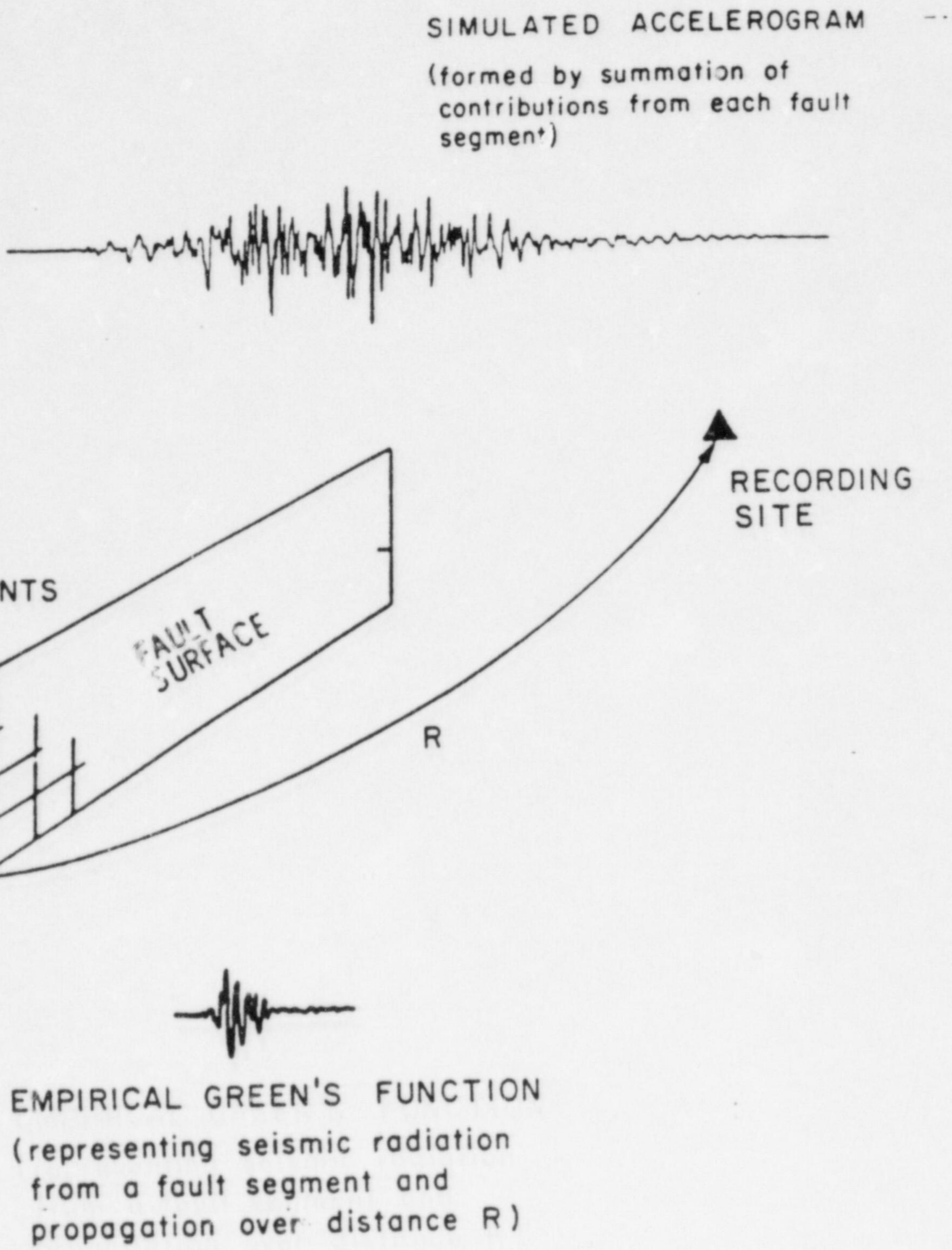
- PRINCIPLES OF GROUND MOTION SIMULATIONS USING EMPIRICAL GREEN'S FUNCTIONS
- PROPERTIES OF SIMULATED GROUND MOTIONS
- EXAMPLES OF PRELIMINARY SIMULATIONS
- GROUND MOTION INPUTS INTO SSI AND FRAGILITY ANALYSES

SCHEDULE FOR DELIVERY OF GROUND MOTION PRODUCTS

DATE	FRAGILITY	SOIL-STRUCTURE INTERACTION	SEISMIC HAZARDS
MAY , 1986	SUITE OF REALISTIC TIME HISTORIES		
JUNE , 1986		PRELIMINARY PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES; BOUNDING INFORMATION OF WAVE CHARACTERISTICS.	
SEPTEMBER , 1986		REFINED PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES; PRELIMINARY WAVE CHARACTERISTICS.	REFINED RESPONSE SPECTRA.
FEBRUARY , 1987		NEAR-FINAL PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES; FURTHER REFINED WAVE CHARACTERISTICS; INITIAL INFORMATION OF SPATIAL COHERENCY.	
JULY , 1987		FINAL PGA, PGV, PGD, RESPONSE SPECTRA, TIME HISTORIES, WAVE CHARACTERISTICS, SPATIAL COHERENCY.	FINAL RESPONSE SPECTRA.

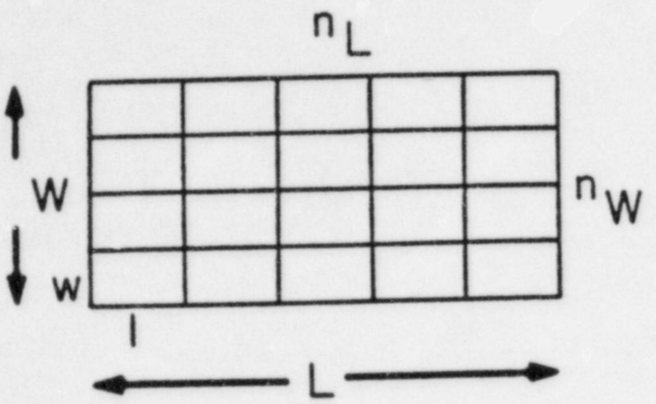
EMPIRICAL GREEN'S FUNCTION APPROACH

(HADLEY AND HELMBERGER, 1980)

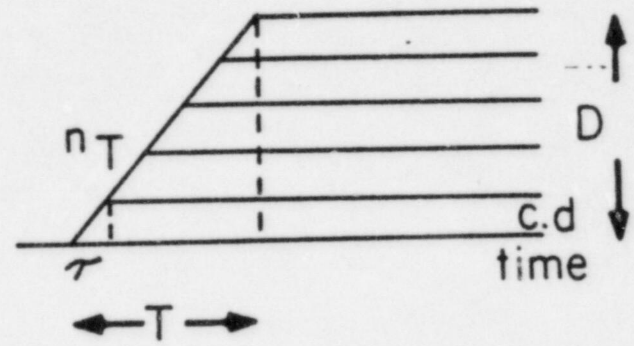


SCALING PROCEDURE

Segmentation of Fault



Slip Function of Segment



m_o (subevent) $= \mu\, dlw$

M_o (large event) $= \mu\, DLW$

M_o / m_o $= n_L \cdot n_W \cdot n_T \cdot c$

$m_o \rightarrow l \times w$ m_o known; l, w known or assumed from scaling relation

$n_L = L/l$

$n_W = W/w$

$n_T = T/\tau = L/l$ dynamic similarity condition

$T = T_R/8$ T_R = rupture time (Kanamori & Anderson)

c = constant required to preserve moment ratio

CRITERIA FOR SELECTION OF EMPIRICAL GREEN'S FUNCTIONS

CRITERION	ADEQUACY OF I.V. '79 23:19 AFTERSHOCK
SOURCE PARAMETERS:	
KNOWN SEISMIC MOMENT, LESS THAN 10^{24} dyne.cm (restrict dimensions to a few km)	✓
KNOWN HYPOCENTER	✓
KNOWN FOCAL MECHANISM	✓
PATH, SITE AND Q STRUCTURE:	
A) SIMILAR TO THAT FOR DCPP, or	
B) DIFFERENT BUT WELL ENOUGH KNOWN TO ALLOW SITE TRANSFER	
CRUSTAL STRUCTURE:	✓(B)
SITE STRUCTURE:	✓(B)
Q STRUCTURE:	✓(B)
STRONG MOTION RECORDINGS:	
THREE COMPONENTS	✓
WIDE RANGE OF DISTANCES	✓
WIDE RANGE OF AZIMUTHS	✓

PROCESSING OF
EMPIRICAL GREEN'S FUNCTIONS

1. ROTATION OF HORIZONTAL RECORDS TO RADIAL AND TRANSVERSE MOTION.

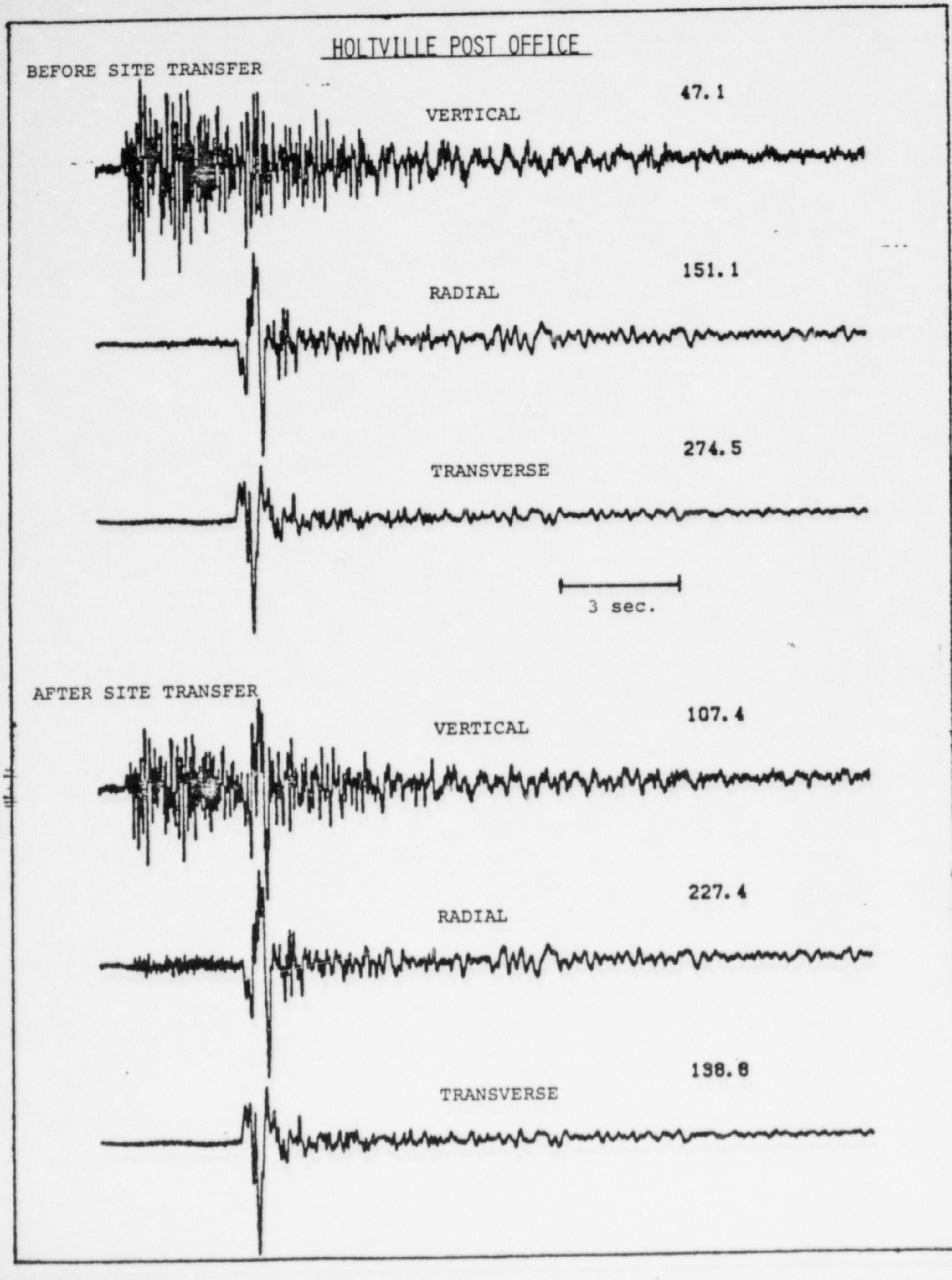
2. CORRECTION OF S WAVES FOR RADIATION PATTERN. (LIU AND HELMBERGER, 1985 SOLUTION)

3. SITE TRANSFER FROM IMPERIAL VALLEY CRUST TO DIABLO CANYON CRUST.

   A. ROTATION OF THE RADIAL S WAVES TO CORRECT FOR SHALLOWER ANGLE OF EMERGENCE AT DIABLO.

   B. SITE HARDNESS CORRECTION.

   (THE MAGNITUDE OF THE SITE TRANSFER CORRECTIONS WAS COMPUTED FROM THE CRUST MODELS OF FUIS ET AL. (1981) AND EATON ET AL. (1970) USING A GENERALIZED RAY THEORY ALGORITHM.)


HOLTVILLE POST OFFICE
BEFORE SITE TRANSFER
47.1
VERTICAL
151.1
RADIAL
274.5
TRANSVERSE
3 sec.
AFTER SITE TRANSFER
107.4
VERTICAL
227.4
RADIAL
138.8
TRANSVERSE

PROPERTIES OF SIMULATED GROUND MOTIONS

- SHEAR DISLOCATION SOURCE - RADIATION PATTERN, RATIOS OF COMPONENTS AND WAVE TYPES CORRECT
- SOURCE FINITENESS - REALISTIC REPRESENTATION OF EXTENDED SOURCE
- DISTANCE FROM SOURCE - REPRESENTED EMPIRICALLY WITH THEORETICAL CORRECTIONS
- WAVE PROPAGATION EFFECTS - INCLUDED EMPIRICALLY IN THE GREEN'S FUNCTIONS
- SITE RESPONSE - CORRECT ANGLE OF EMERGENCE AND VELOCITY STRUCTURE

REPRESENTATION OF HIGH FREQUENCIES

DETERMINISTIC MODELS:

ABOVE ABOUT 2 Hz, DETAILS OF THE SOURCE AND PROPAGATION PATH ARE DIFFICULT TO DESCRIBE USING DETERMINISTIC MODELS

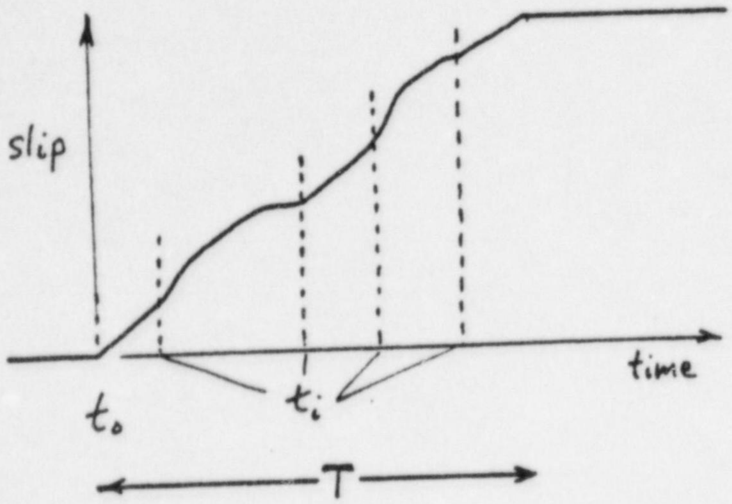
STOCHASTIC MODELS:

- RUPTURE VELOCITY - RANDOMIZE NUCLEATION TIME OF EACH ELEMENT
- SLIP TIME FUNCTION - RANDOMIZE NUCLEATION OF SUBEVENTS WITHIN EACH ELEMENT
- * SLIP DISTRIBUTION - RANDOMIZE AMOUNT OF SLIP ON EACH ELEMENT
- * RADIATION PATTERN - RANDOMIZE RADIATION PATTERN OF HIGH FREQUENCY ENERGY - CAN DO EMPIRICALLY
- * WAVE PROPAGATION - RANDOMIZE ELASTIC PROPERTIES OF SITE STRUCTURE

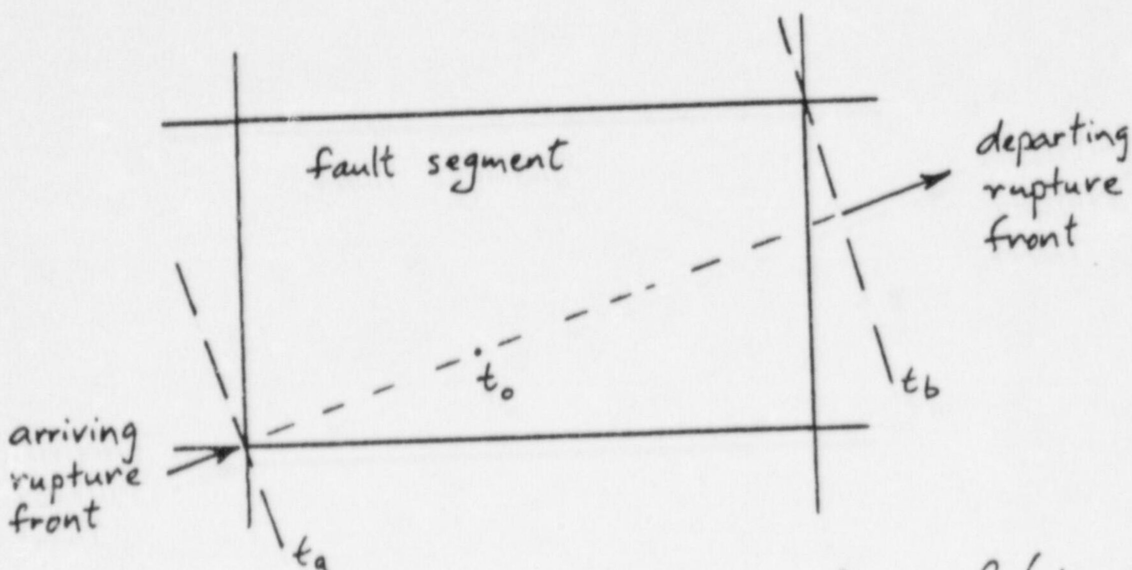
---

* TO BE IMPLEMENTED LATER

RANDOMIZATION OF SLIP TIME FUNCTION AND RUPTURE VELOCITY



$$t_i = R(t_o, t_o + T)$$
$$(i = 1, n_T)$$



$$t_o = R(t_a, t_b)$$

$R(x,y)$ = random number between x and y.

GROUND MOTION INPUTS INTO SSI AND FRAGILITY ANALYSES

3 - COMPONENT ACCELERATION TIME HISTORIES

RESPONSE SPECTRA

WAVE CHARACTERIZATION:

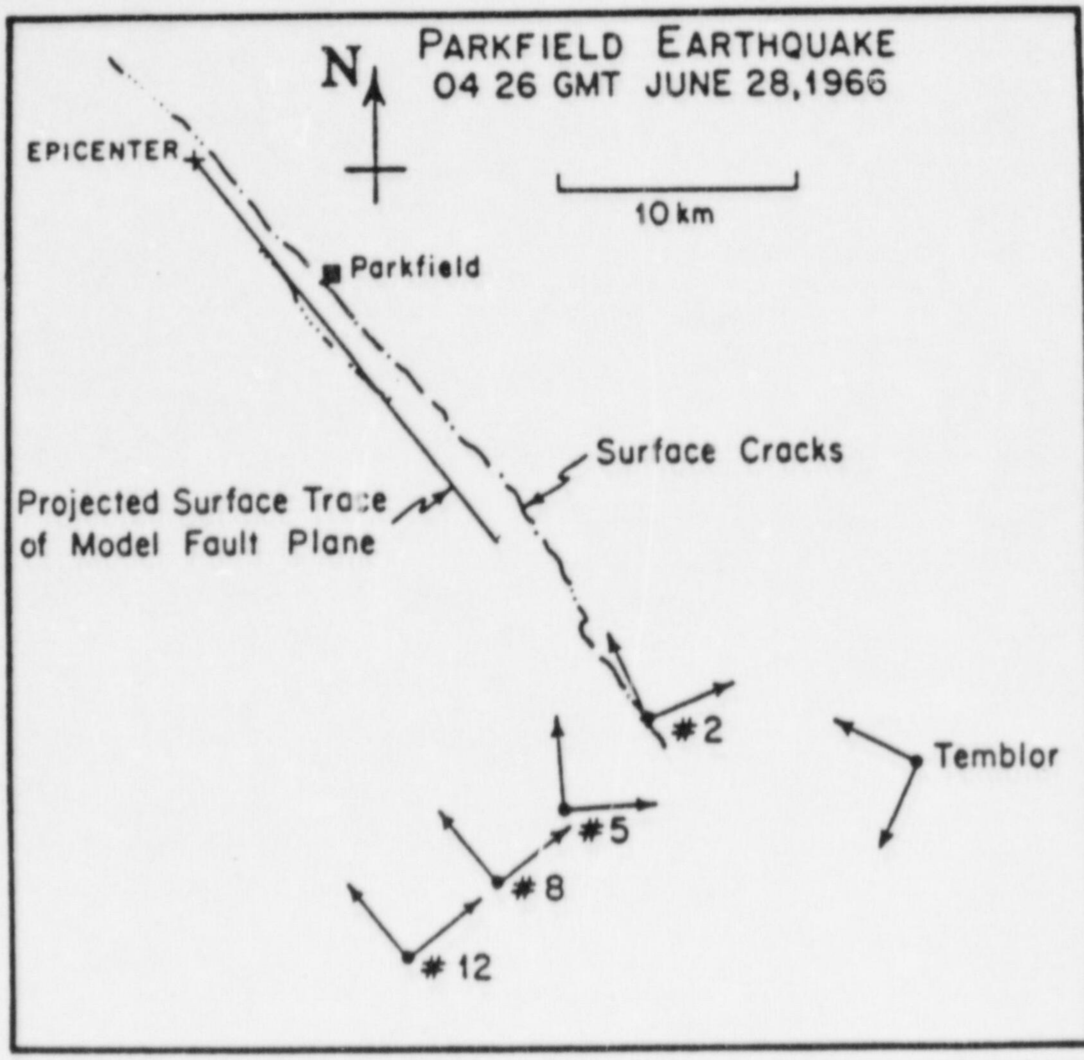
- WAVE TYPES - P, SV, SH, R, L
- BODY WAVES - REPRESENTED BY PLANE WAVEFRONTS
- TOTAL DURATION AND DURATION OF STRONG SHAKING
- * SPATIAL COHERENCE AND ITS FREQUENCY DEPENDENCE

---

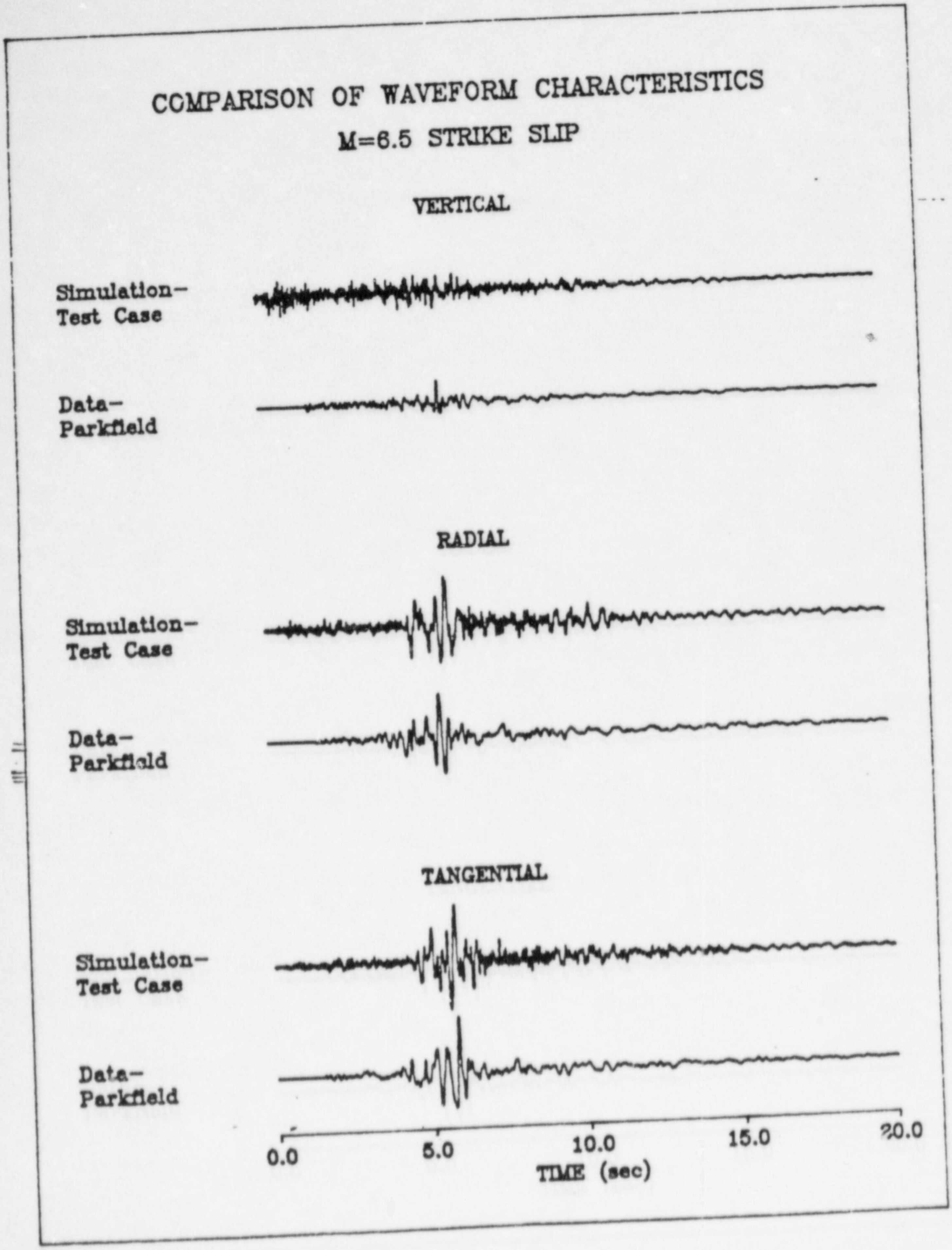
* TO BE IMPLEMENTED LATER

CRITERIA FOR TIME HISTORIES AS REALISTIC INPUTS INTO FRAGILITY AND SSI ANALYSES

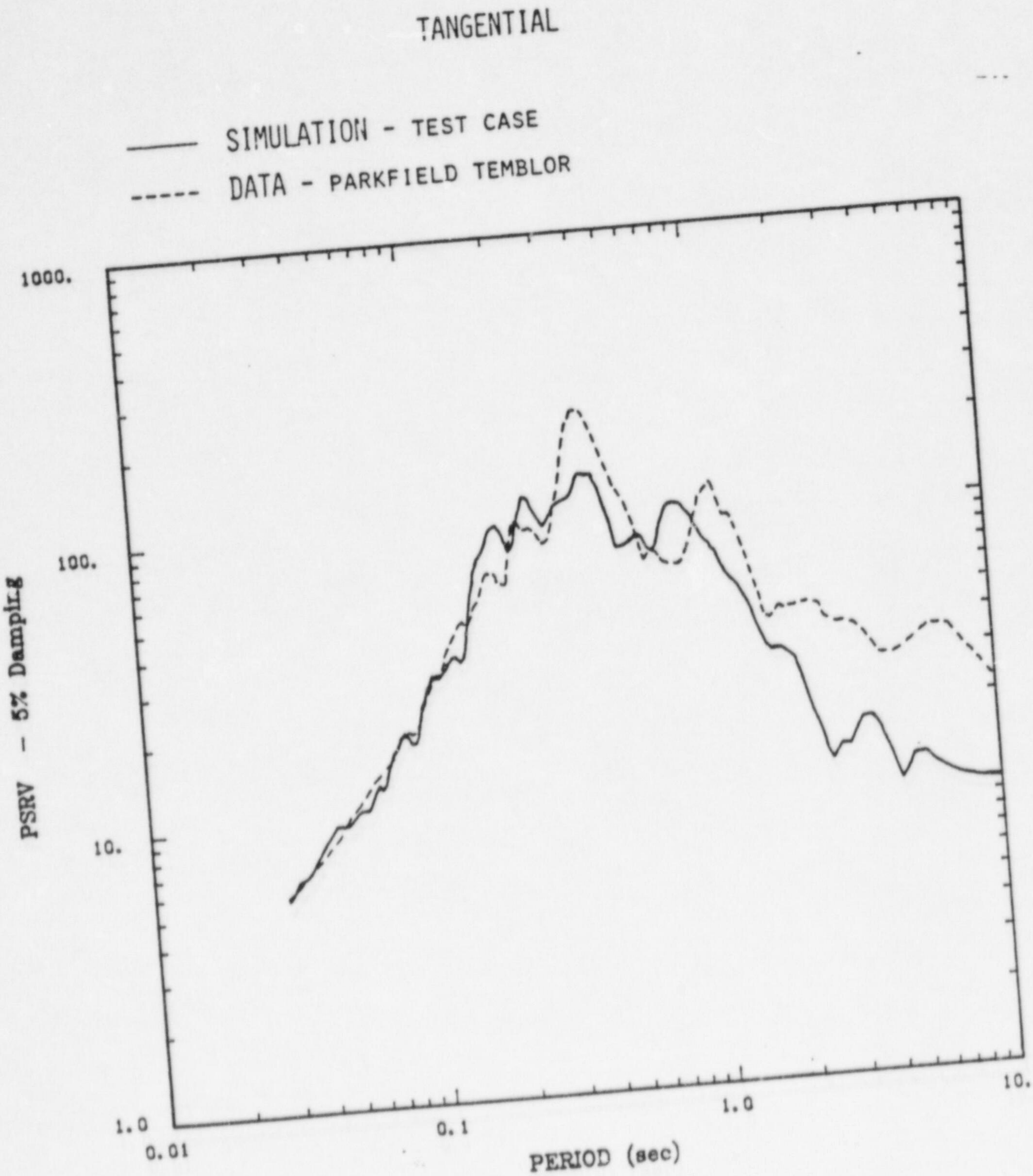
- SEISMIC PHASES (SH, SV, L, R) ARRIVING AT APPROPRIATE TIMES
- SEISMIC PHASES HAVING APPROPRIATE AMPLITUDE AND PHASE ON THE THREE COMPONENTS
- DURATION OF STRONG SHAKING AND OVERALL DURATION IN AGREEMENT WITH APPROPRIATE EMPIRICAL DATA
- RESPONSE SPECTRAL SHAPE IN AGREEMENT WITH APPROPRIATE EMPIRICAL DATA



MODIFIED FROM ARCHULETA AND DAY (1980)

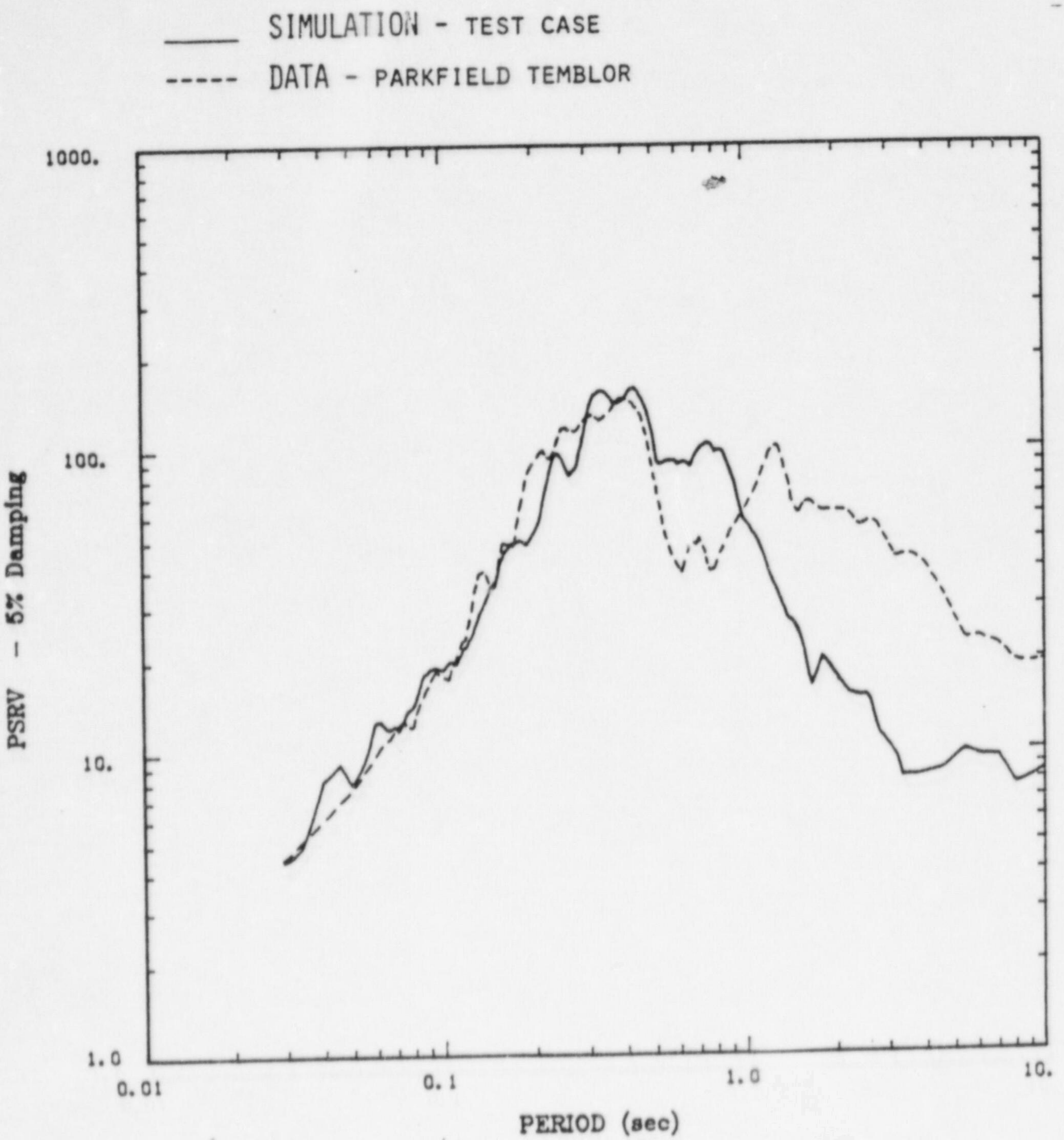

COMPARISON OF WAVEFORM CHARACTERISTICS
M=6.5 STRIKE SLIP
VERTICAL
Simulation-Test Case
Data-Parkfield
RADIAL
Simulation-Test Case
Data-Parkfield
TANGENTIAL
Simulation-Test Case
Data-Parkfield
0.0
5.0
10.0
15.0
20.0
TIME (sec)

COMPARISON OF RESPONSE SPECTRAL SHAPES - M=6.5 STRIKE SLIP
Scaled to 2.25g mean horizontal spectral accel. 3-8.5 Hz

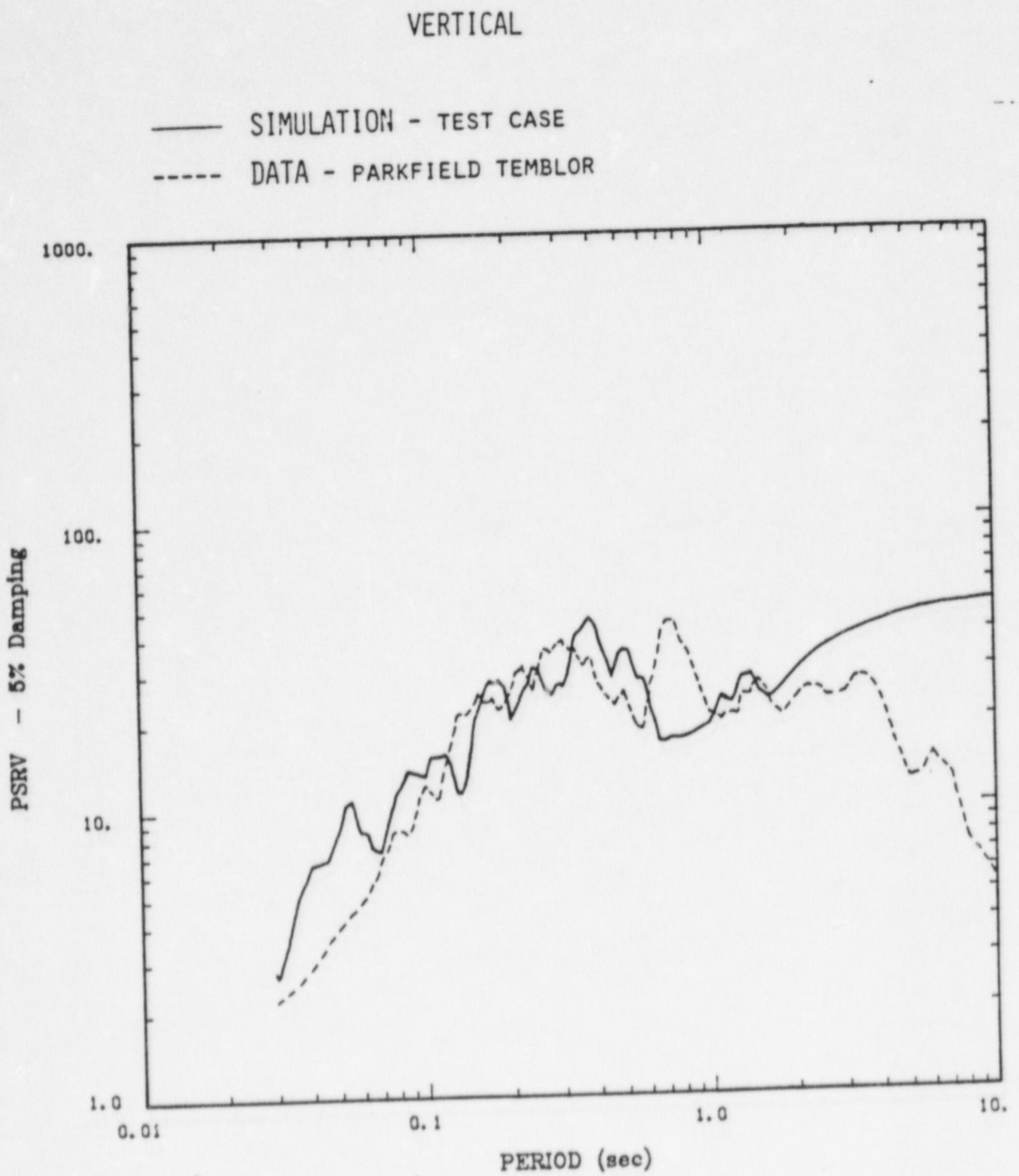


COMPARISON OF RESPONSE SPECTRAL SHAPES - M=6.5 STRIKE SLIP
Scaled to 2.25g mean horizontal spectral accel. 3-8.5 Hz

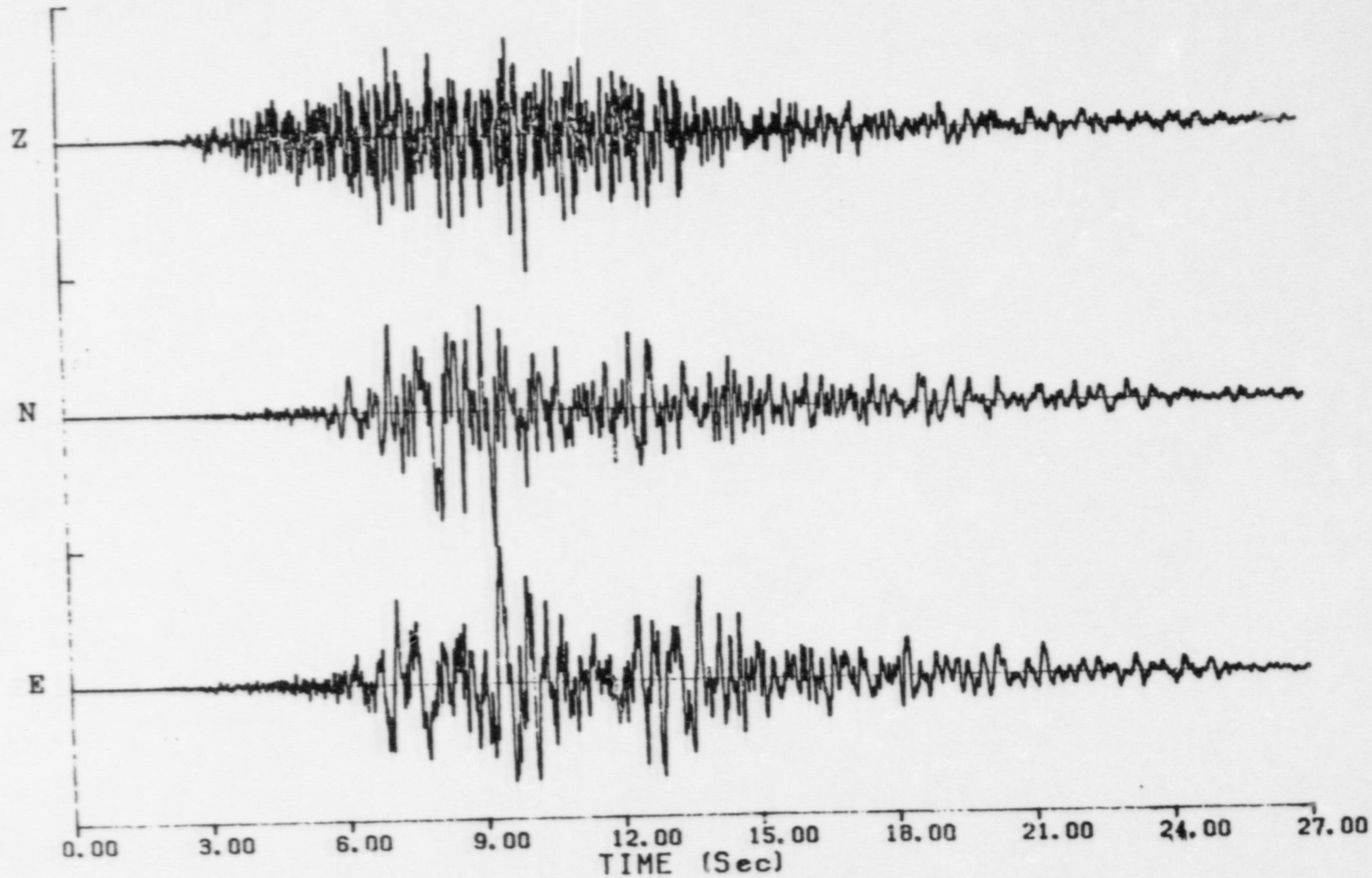
RADIAL



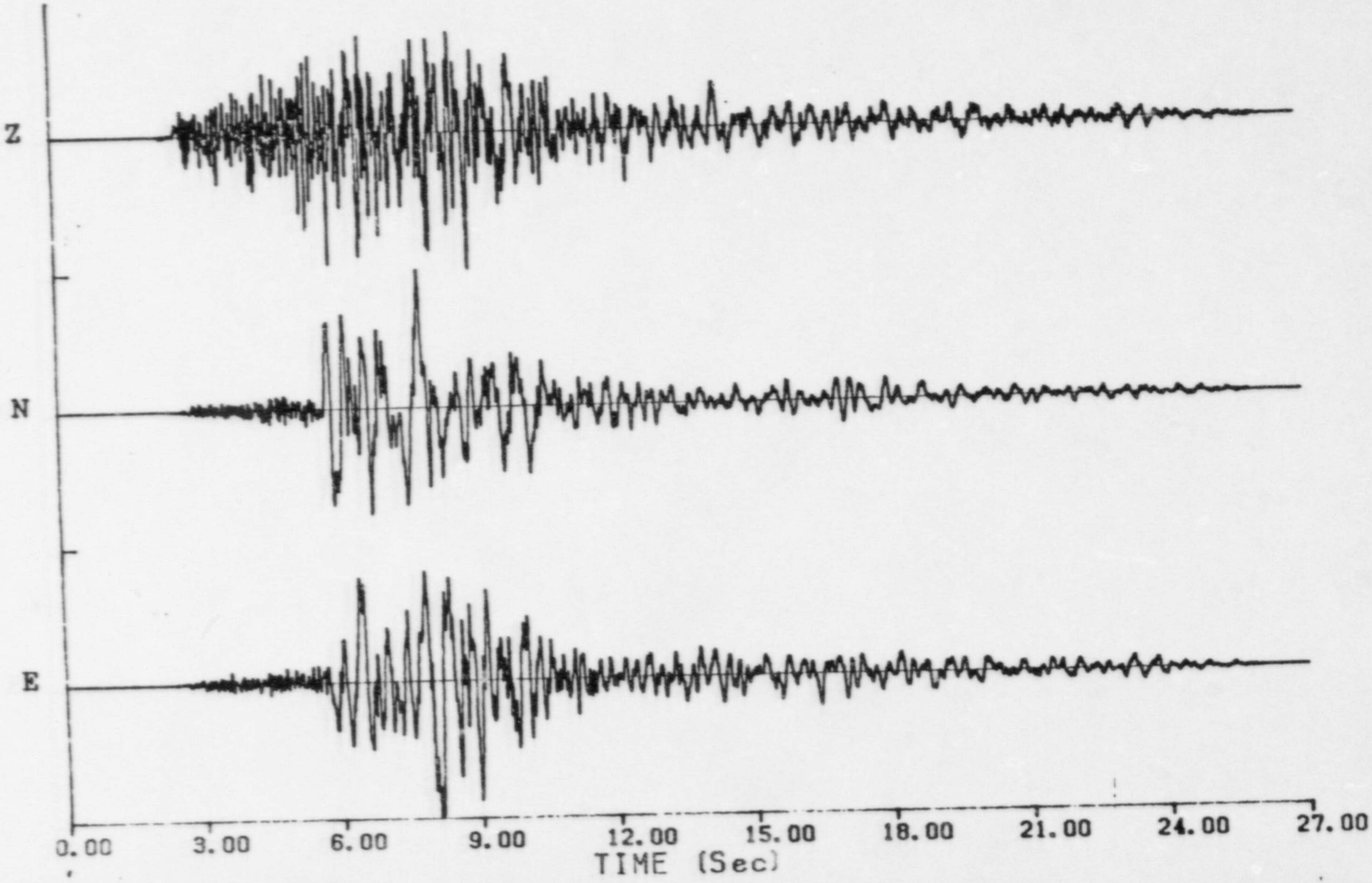
COMPARISON OF RESPONSE SPECTRAL SHAPES – M=6.5 STRIKE SLIP
Scaled to 2.25g mean horizontal spectral accel. 3–8.5 Hz



BILATERAL VERTICAL STRIKE-SLIP SIMULATION (M 7.0)



BILATERAL VERTICAL STRIKE-SLIP SIMULATION (M 6.5)



ENCLOSURE 4

SECTION 12

NUMERICAL GROUND MOTION MODELING

SOURCE

PRELIMINARY STUDY - UNIFORM SOURCE MODELS

REFINEMENT - INTRODUCE ASPERITIES, BARRIERS, DEPTH DEPENDENCE

- RETAIN LOW FREQ. COHERENCE/ HIGH FREQ. INCOHERENCE OF EMPIRICAL SOURCE FUNCTIONS

PATH

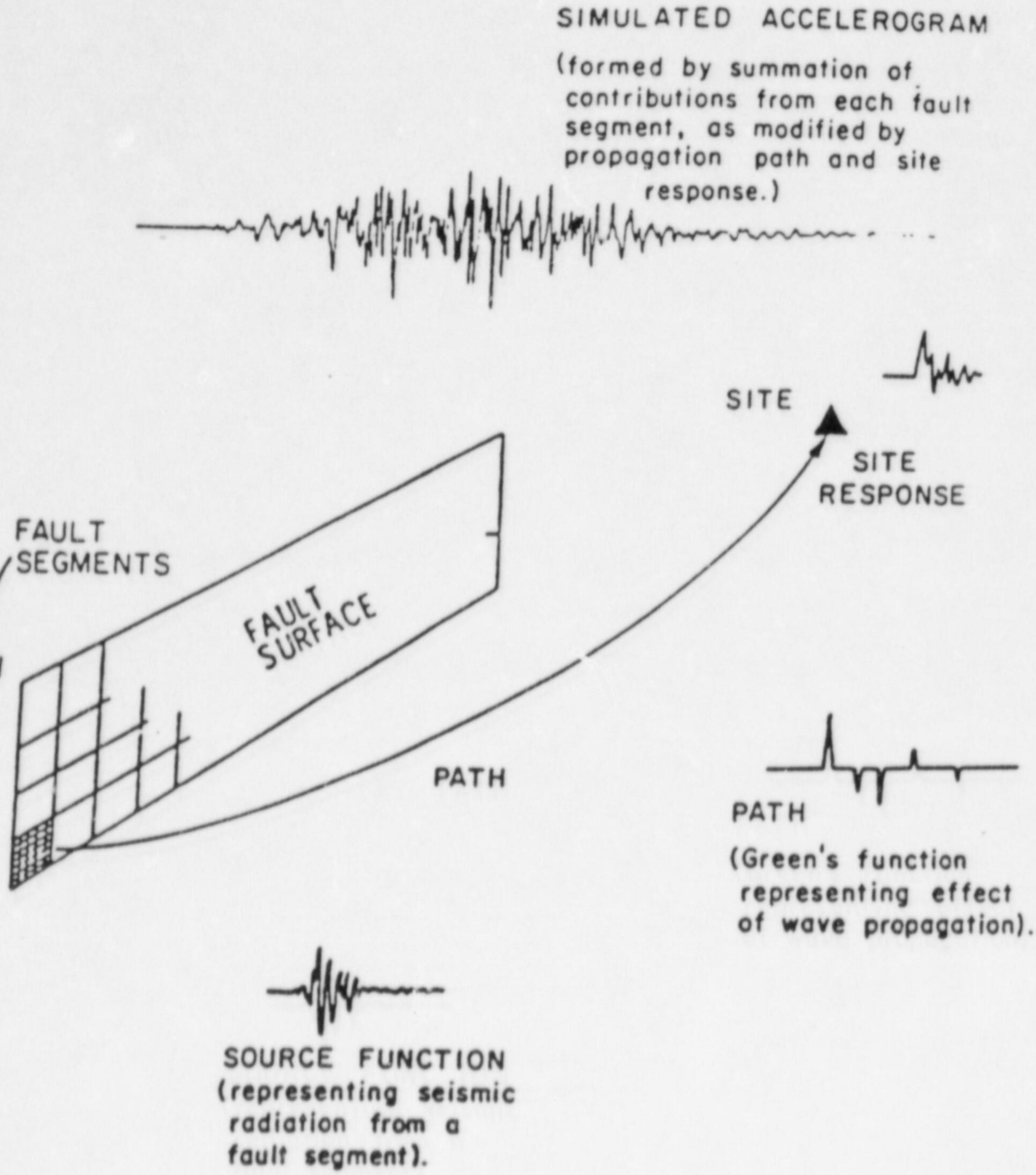
PRELIMINARY STUDY - EMPIRICAL GREEN'S FUNCTIONS REPRESENT PATH

REFINEMENT - INCLUDE SPECIFIC PROPAGATION CHARACTERISTICS IN THE SITE VICINITY
(CALCULATE GREEN'S FUNCTIONS FROM STRUCTURE MODELS DEVELOPED USING GSG SITE EXPERIMENTS)

SITE

PRELIMINARY STUDY - SITE TRANSFER TECHNIQUE

REFINEMENT - INCLUDE SPECIFIC SITE RESPONSE CHARACTERISTICS
(CALCULATE GREEN'S FUNCTIONS FROM SITE MODELS DEVELOPED USING GSG SITE EXPERIMENTS)


SIMULATED ACCELEROGRAM
(formed by summation of contributions from each fault segment, as modified by propagation path and site response.)
SITE
SITE RESPONSE
FAULT SEGMENTS
FAULT SURFACE
PATH
PATH
(Green's function representing effect of wave propagation).
SOURCE FUNCTION
(representing seismic radiation from a fault segment).

SOURCE CHARACTERISTICS

LARGE EARTHQUAKE SOURCE CHARACTERISTICS

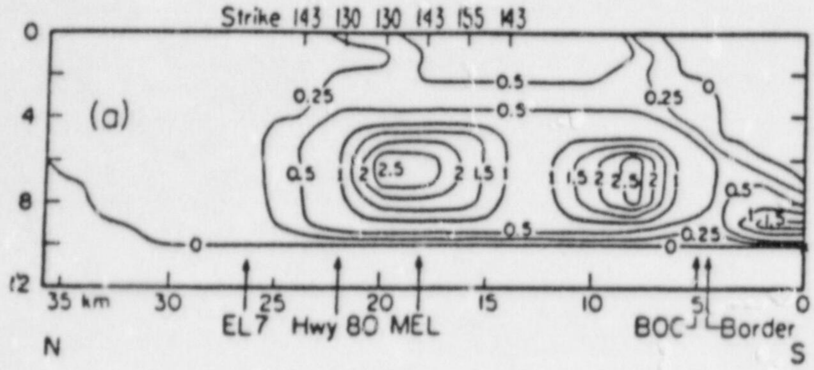
- HOW TO MODEL THEM

SMALL EARTHQUAKE SOURCE CHARACTERISTICS

- HOW TO USE THEM AS EMPIRICAL SOURCE FUNCTIONS

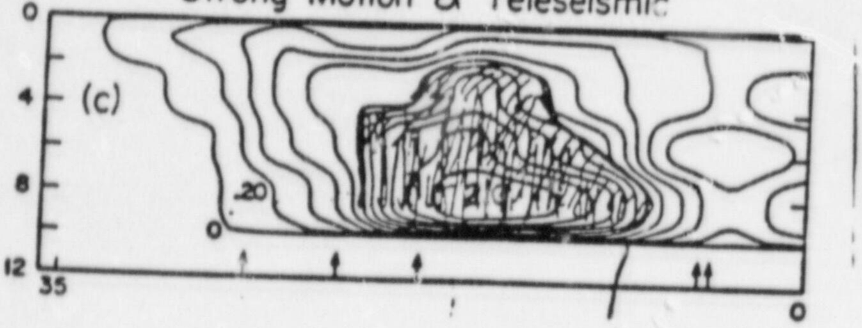
IMPERIAL VALLEY MAIN SHOCK

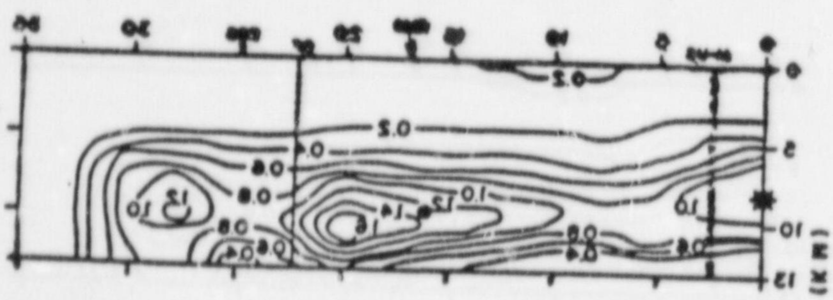
Model 9WM



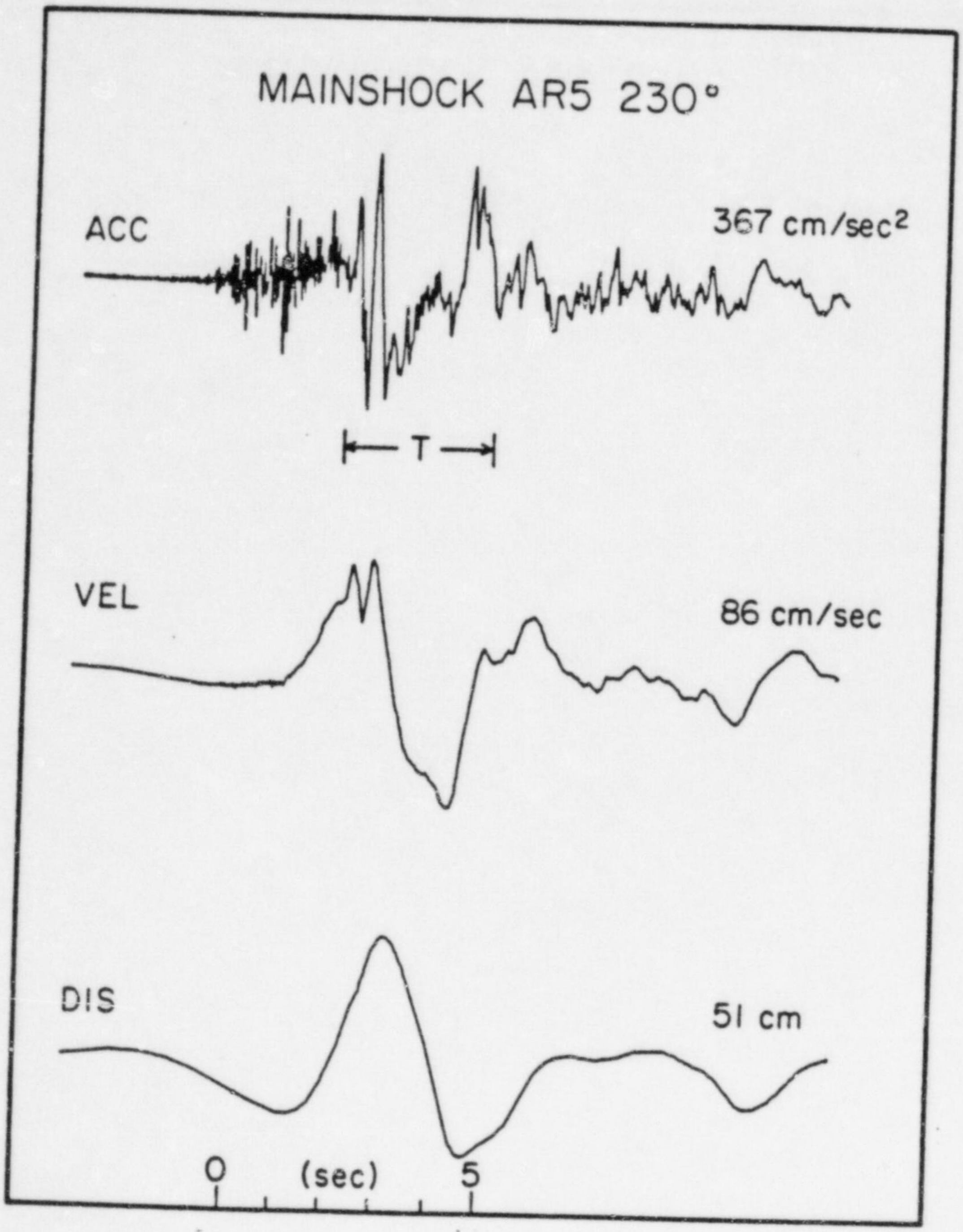
HARTZELL AND HELMBERGER

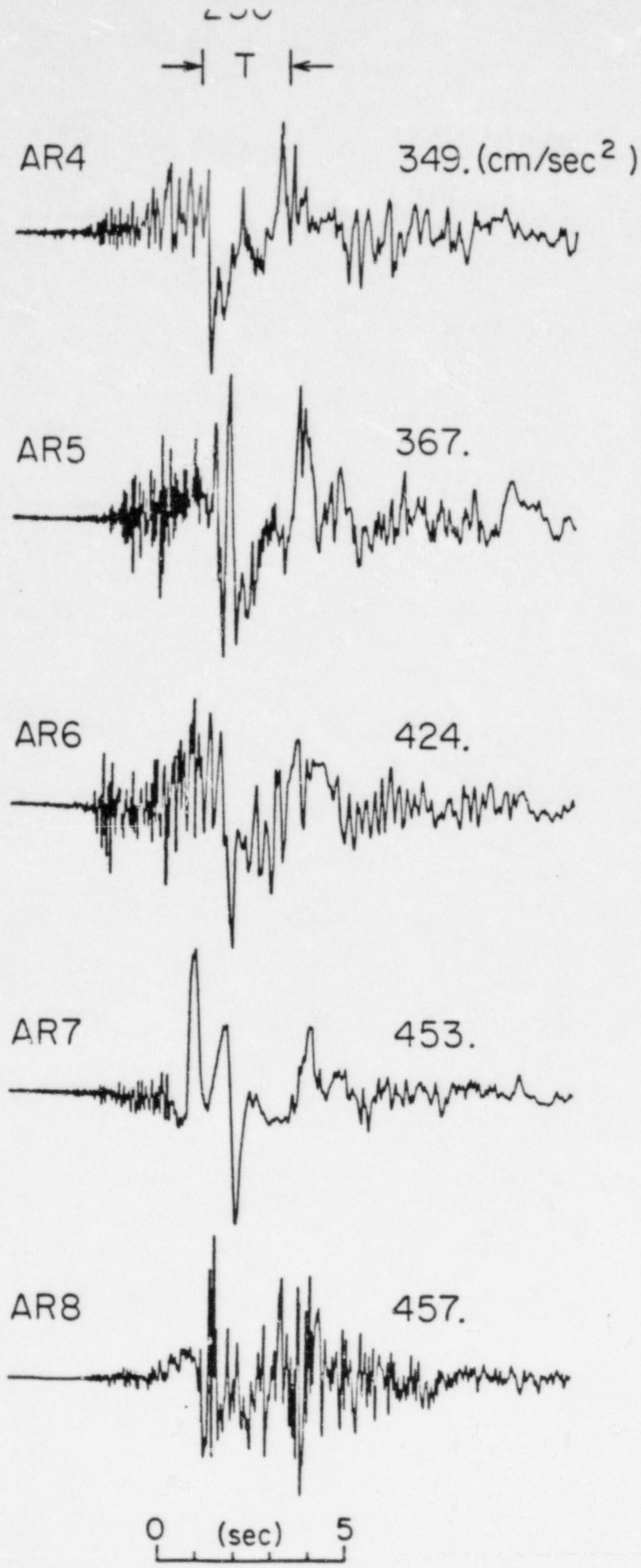
Strong Motion & Teleseismic





ARCHULETA


MAINSHOCK AR5 230°
ACC
367 cm/sec2
T
VEL
86 cm/sec
DIS
51 cm
0
(sec)
5



6

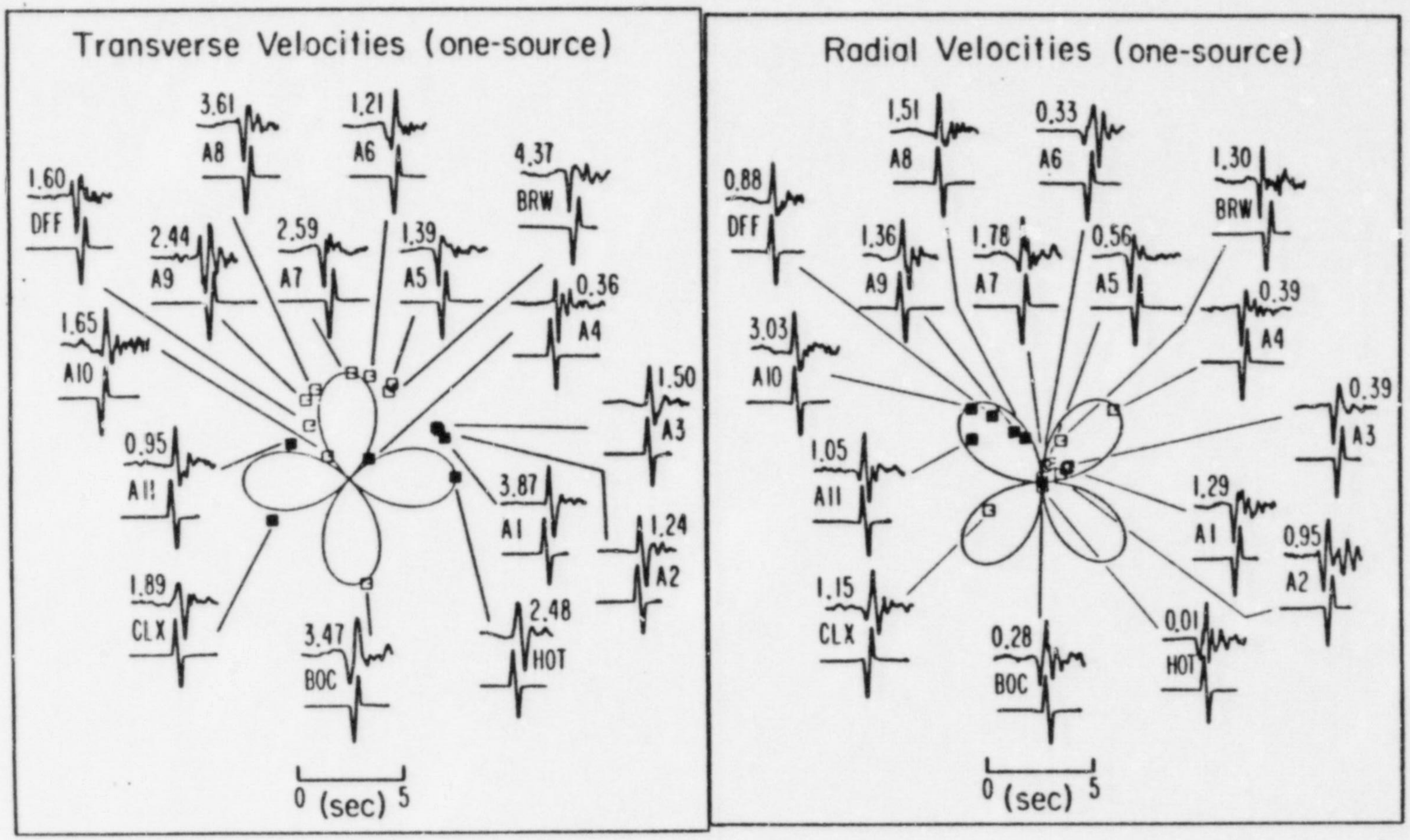
FAULT SURFACE WEIGHTING FACTORS

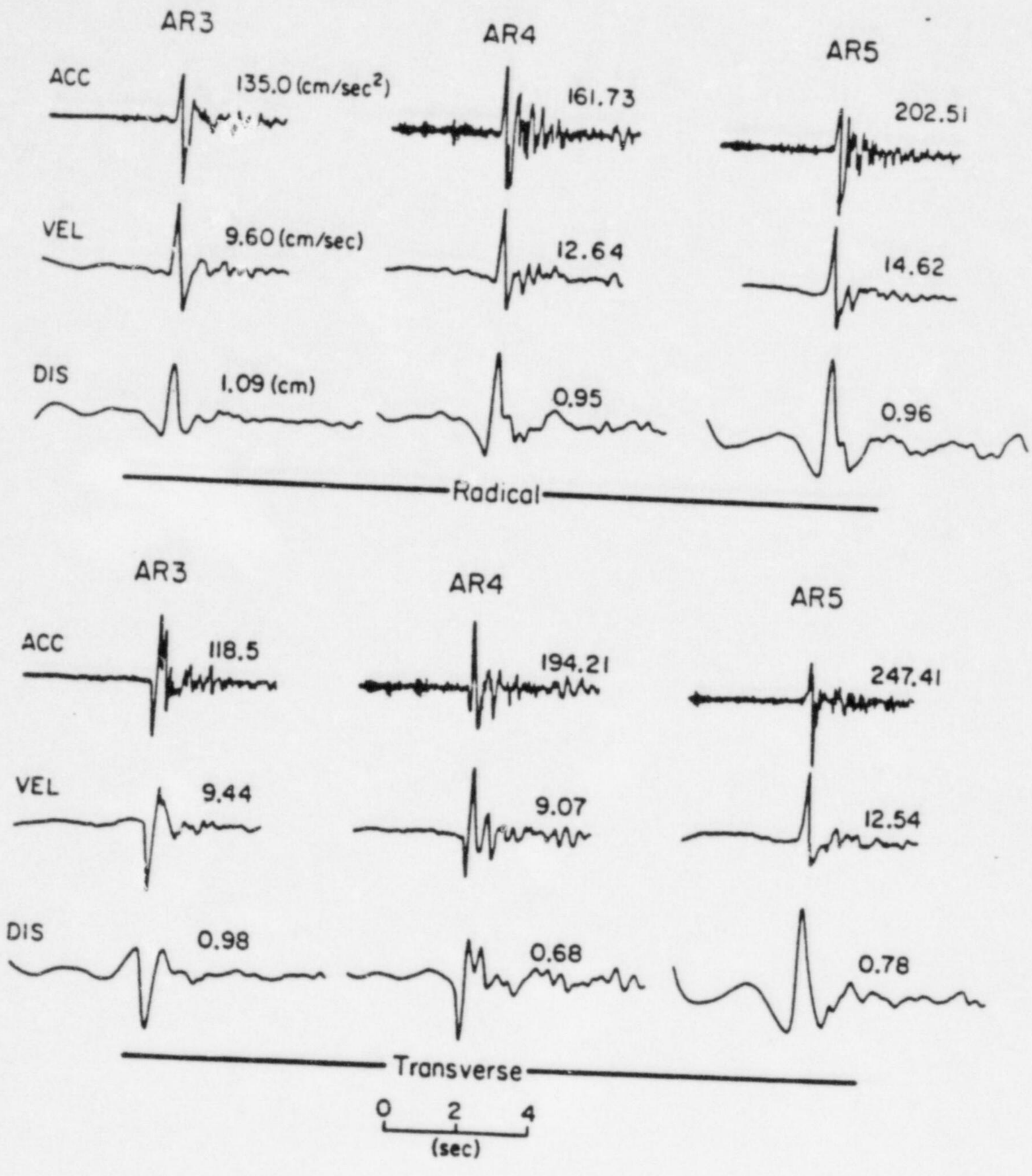
M = 6.5 Simulation

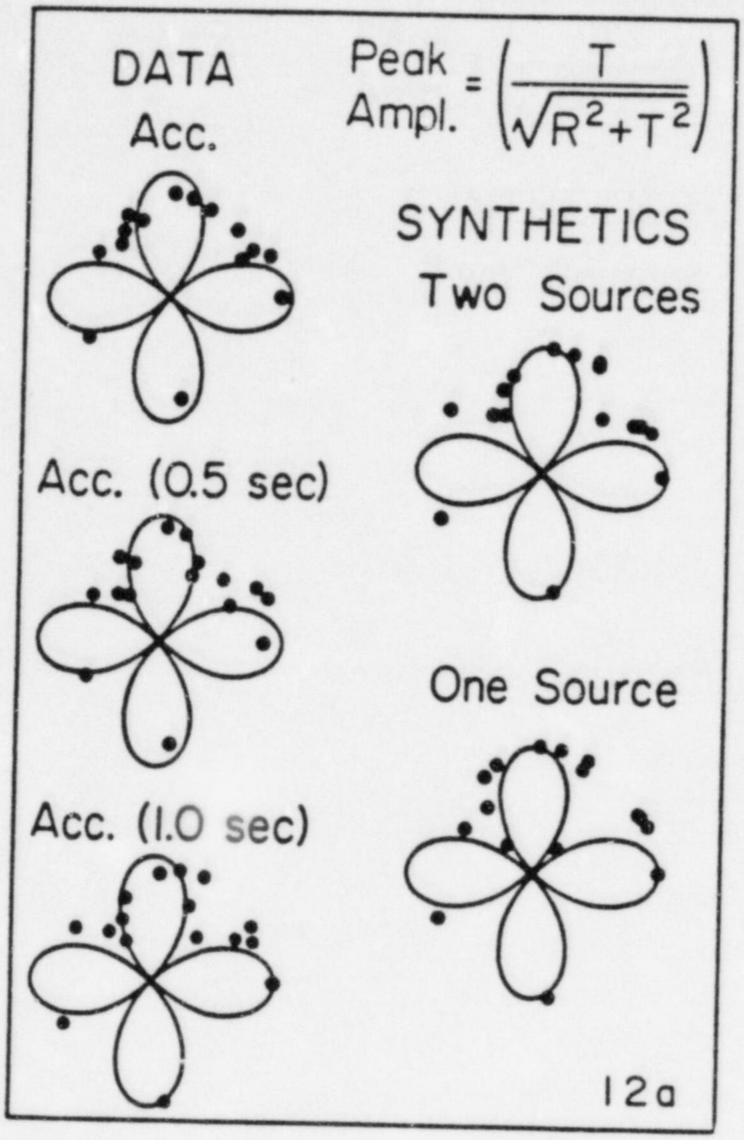
-.356	1.87	1.87	-.356
-.270	.985	.985	-.270
-.198	.512	.512	-.198
-.200	.354	.354	-.200

depth 12 km

length 16 km

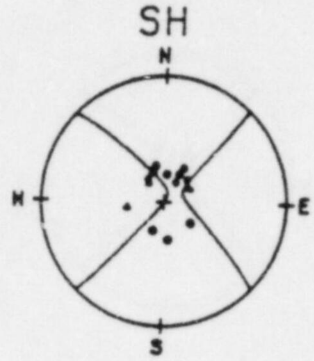

Transverse Velocities (one-source)
1.60 DFF
3.61 A8
1.21 A6
4.37 BRW
2.44 A9
2.59 A7
1.39 A5
0.36 A4
1.65 A10
1.50 A3
0.95 A11
3.87 A1
1.24 A2
1.89 CLX
3.47 BOC
2.48 HOT
0 (sec) 5
Radial Velocities (one-source)
0.88 DFF
1.51 A8
0.33 A6
1.30 BRW
1.36 A9
1.78 A7
0.56 A5
0.39 A4
3.03 A10
0.39 A3
1.05 A11
1.29 A1
0.95 A2
1.15 CLX
0.28 BOC
0.01 HOT
0 (sec) 5


AR3
AR4
AR5
ACC
135.0 (cm/sec²)
161.73
202.51
VEL
9.60 (cm/sec)
12.64
14.62
DIS
1.09 (cm)
0.95
0.96
Radical
AR3
AR4
AR5
ACC
118.5
194.21
247.41
VEL
9.44
9.07
12.54
DIS
0.98
0.68
0.78
Transverse
0 2 4
(sec)

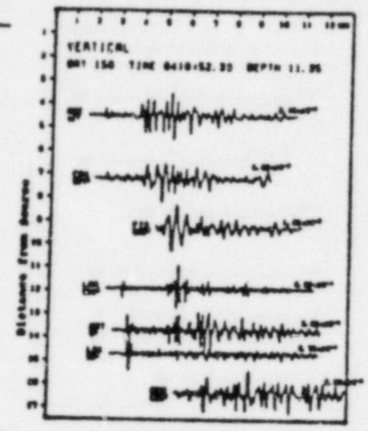

DATA
Acc.
Peak Ampl. = $\left(\frac{T}{\sqrt{R^2+T^2}}\right)$
SYNTHETICS
Two Sources
Acc. (0.5 sec)
One Source
Acc. (1.0 sec)
12a

THEORETICAL RADIATION PATTERN CORRECTION - PRELIMINARY STUDY

1. Correct small event records for estimated S wave radiation pattern.



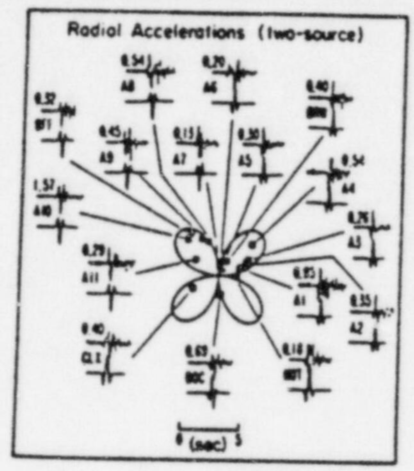
2. Construct radiation-corrected distance section of Green's Functions.



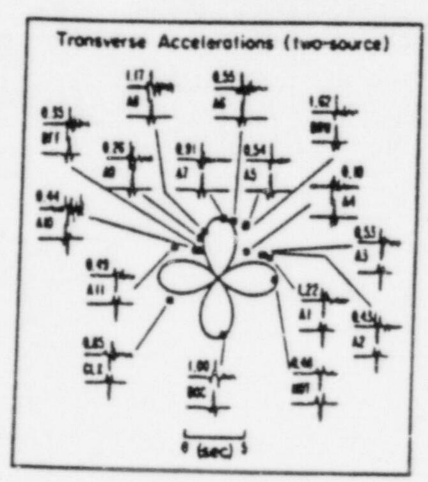
3. Select records for simulation <u>purely</u> on the basis of range and theoretically correct for radiation pattern of the large event.

SEMI-EMPIRICAL RADIATION PATTERN CORRECTION - REFINED STUDY

1. Back-project observed records through the crustal structure to the SV and SH focal spheres.



2. Select records for simulation on the basis of <u>location on the focal sphere.</u> Project them through the new structure and simulate the large event. Make no theoretical radiation pattern correction.



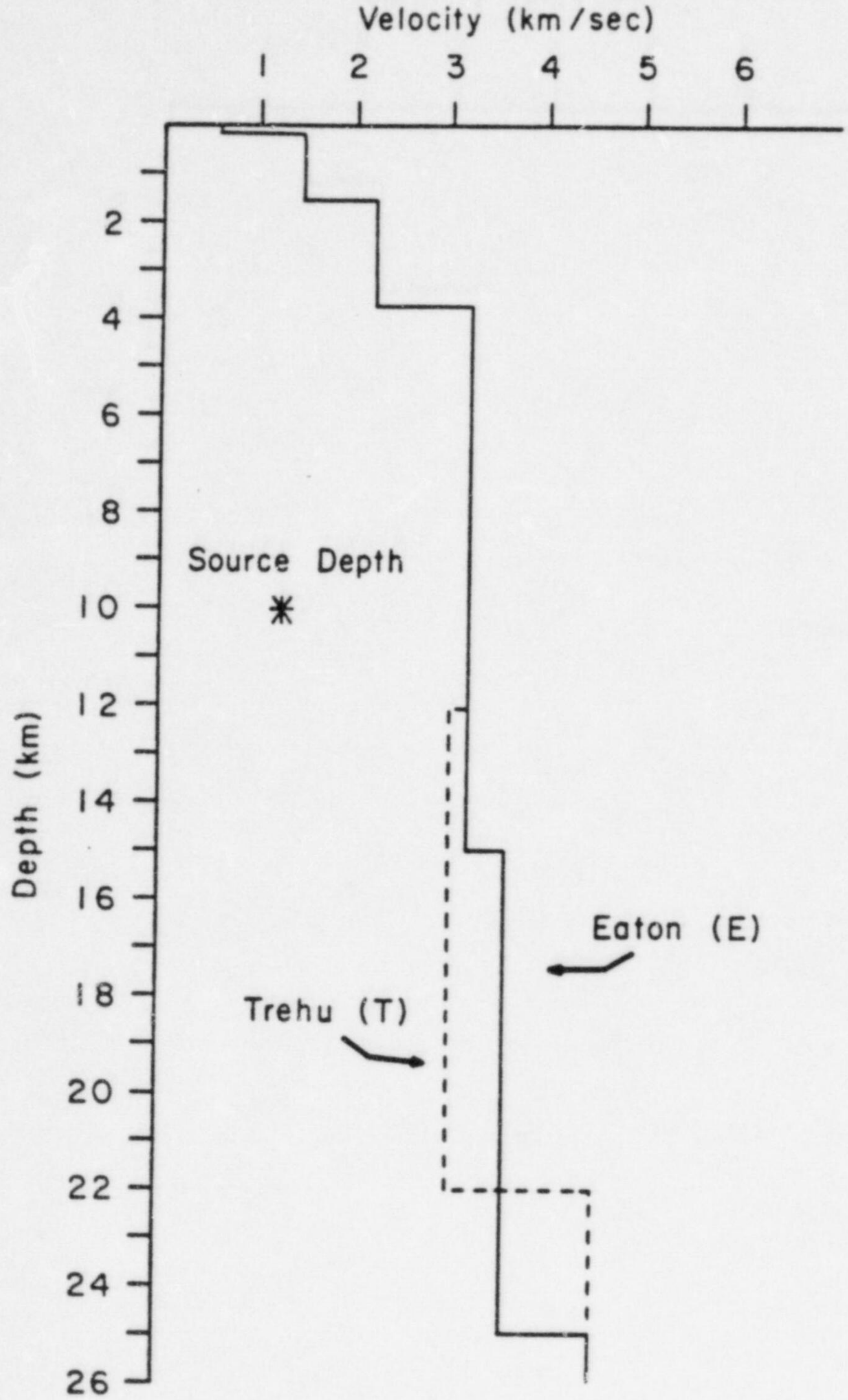
PATH CHARACTERISTICS

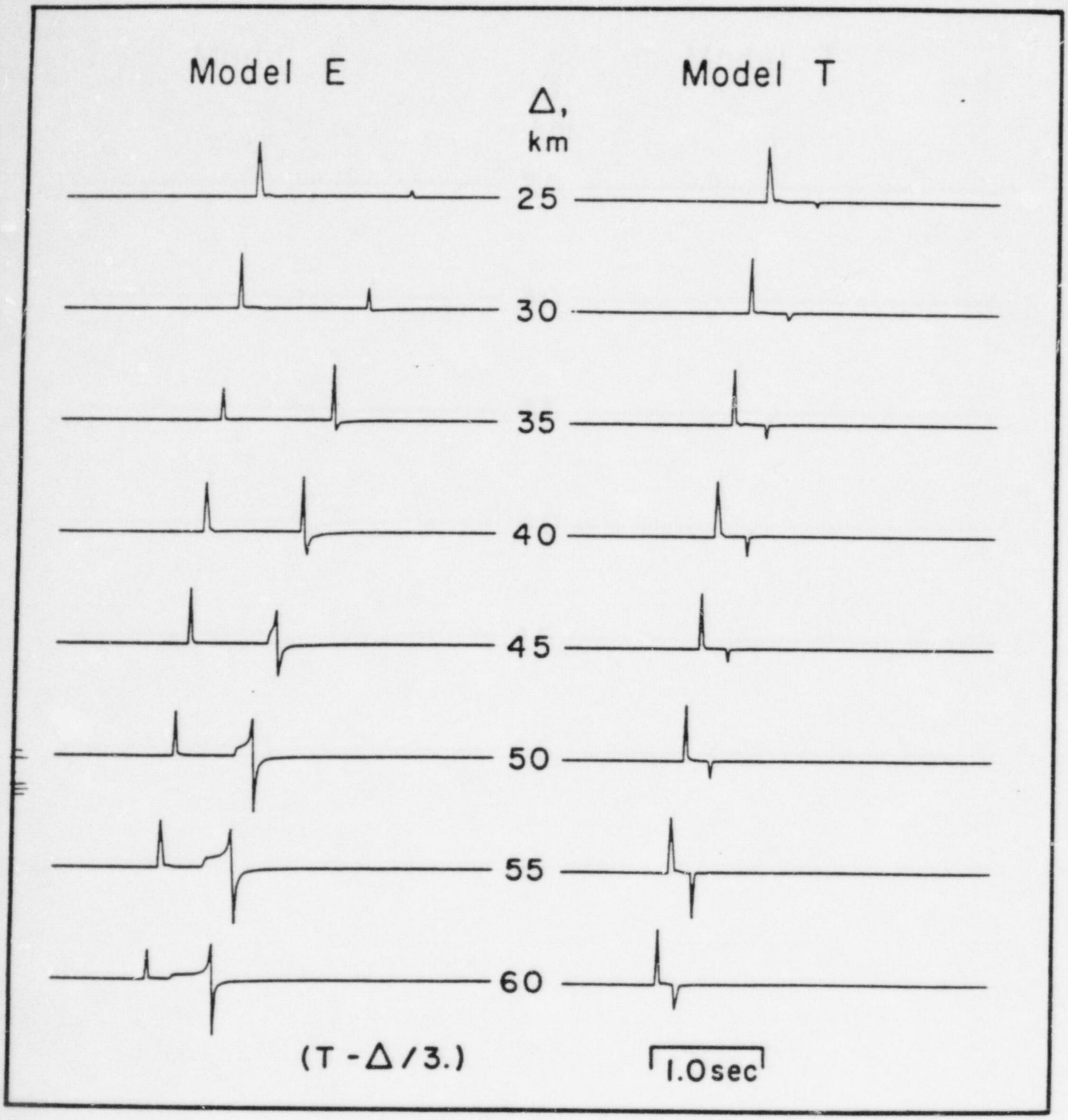
INFLUENCE OF CRUSTAL STRUCTURE ON GROUND MOTION CHARACTERISTICS

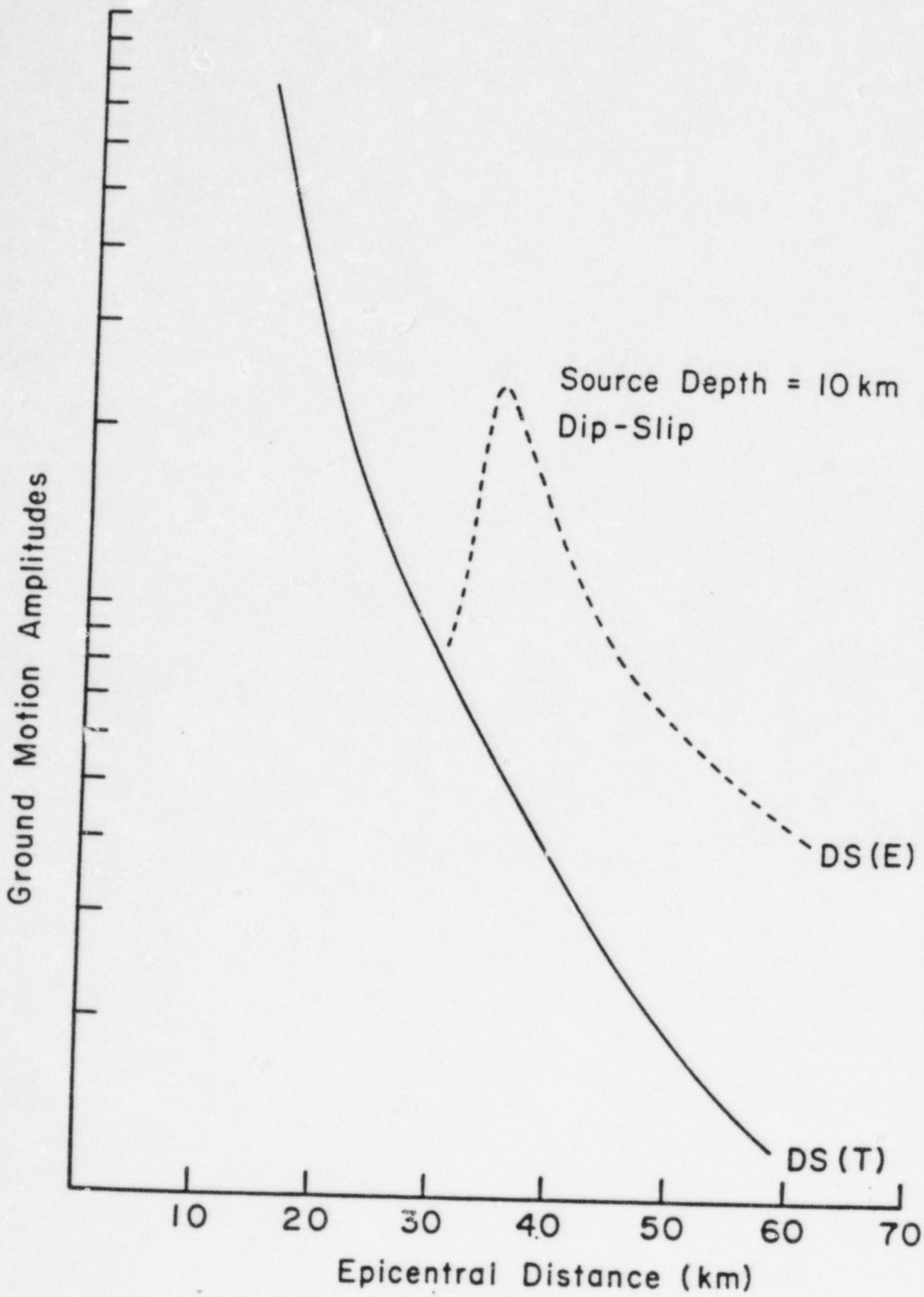
- SHADOW ZONE FROM PROPOSED LOW VELOCITY LAYER
- POST-CRITICAL REFLECTIONS FROM THE MOHO

PATH MODELS

- PLANE HORIZONTAL LAYERS
- PLANE DIPPING LAYERS
- LAYERS HAVING IRREGULAR BOUNDARIES


Velocity (km/sec)
1
2
3
4
5
6
Depth (km)
2
4
6
8
10
12
14
16
18
20
22
24
26
Source Depth
Eaton (E)
Trehu (T)


Model E
Model T
Δ, km
25
30
35
40
45
50
55
60
(T - Δ/3.)
1.0sec



Source Depth = 10 km
Dip-Slip
DS(E)
DS(T)
Ground Motion Amplitudes
10
20
30
40
50
60
70
Epicentral Distance (km)

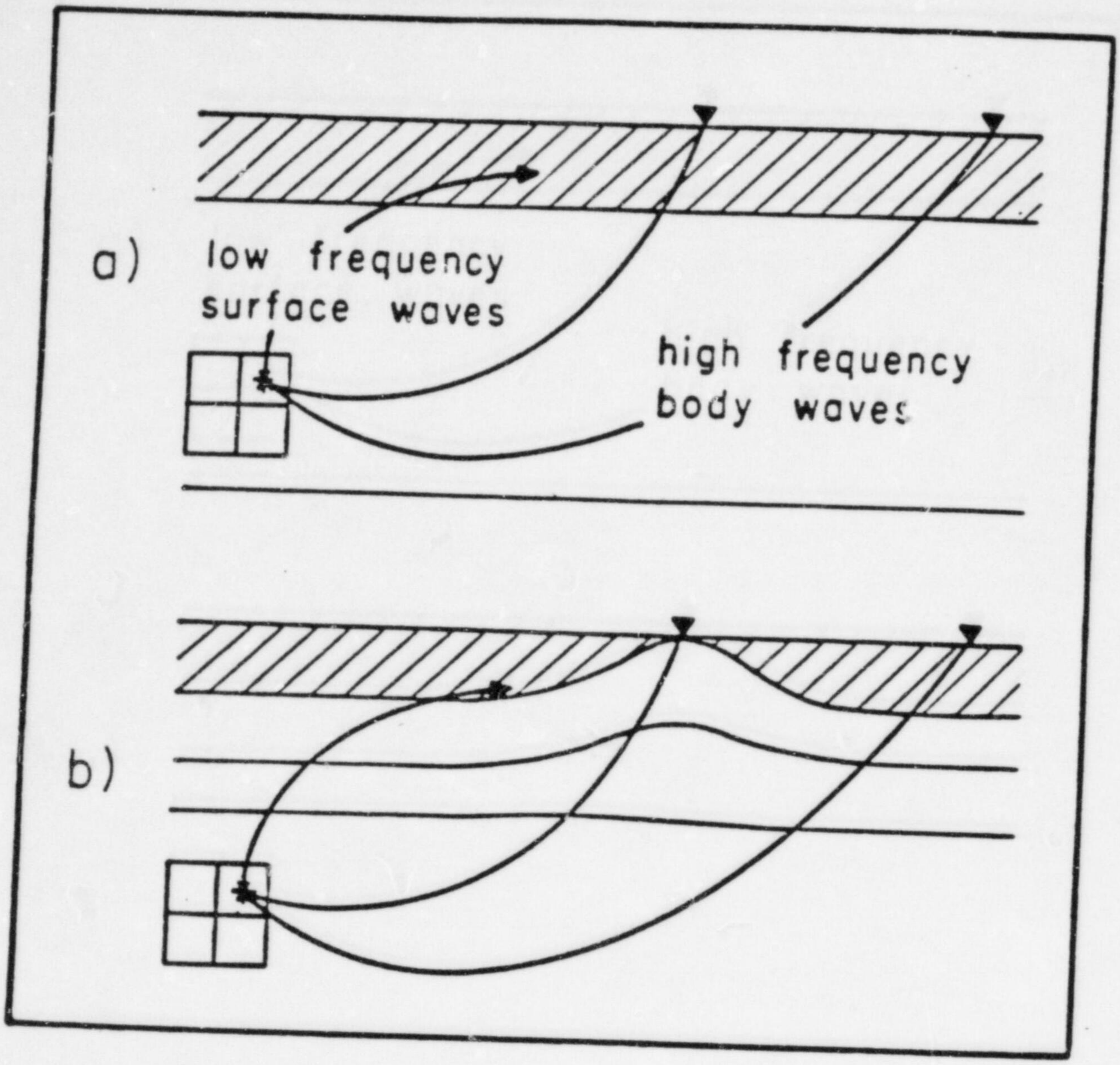
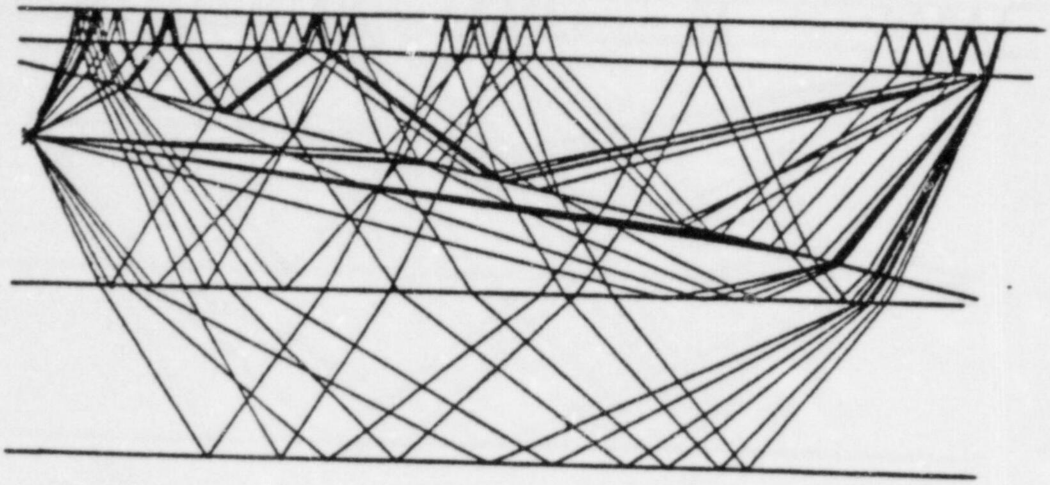
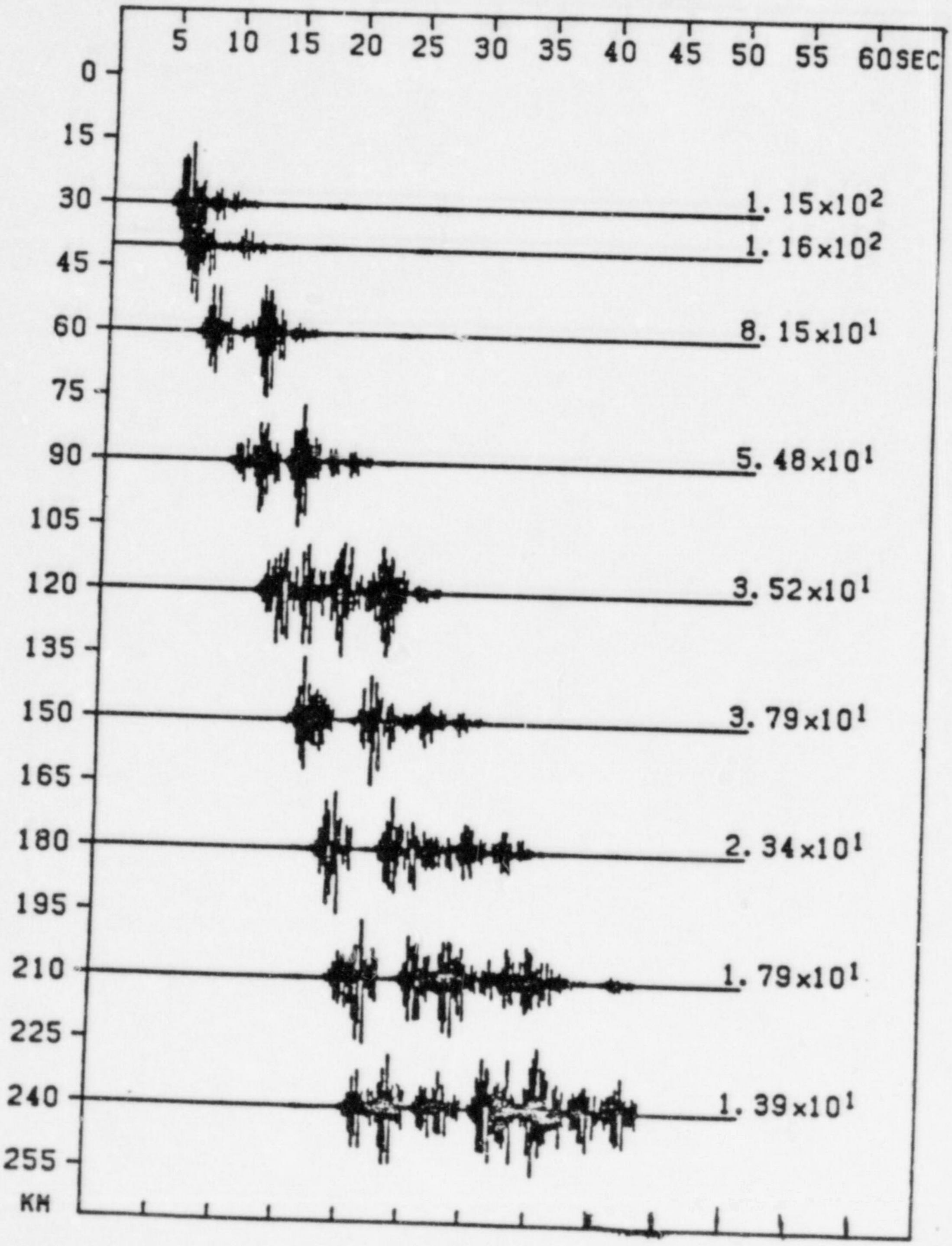
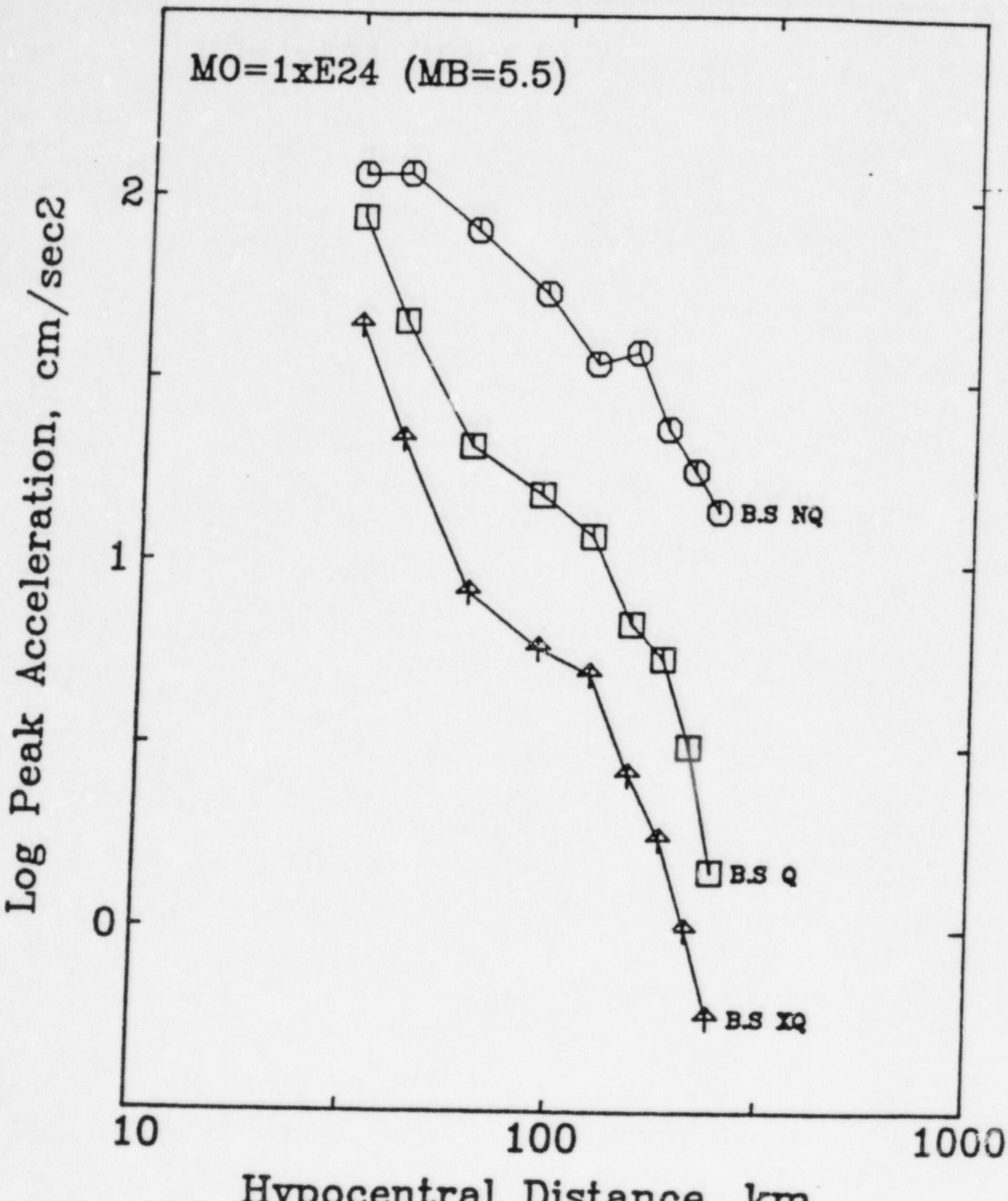


Figure 2: Schematic diagram displaying energy paths for a) flat-layered model versus b) laterally varying structure. The model is two-dimensional or constant properties into and out of the plane of the paper.




5 10 15 20 25 30 35 40 45 50 55 60 SEC
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
255
KM
1.15×10^2
1.16×10^2
8.15×10^1
5.48×10^1
3.52×10^1
3.79×10^1
2.34×10^1
1.79×10^1
1.39×10^1

SH VSS AZ=30 N.H.SRC



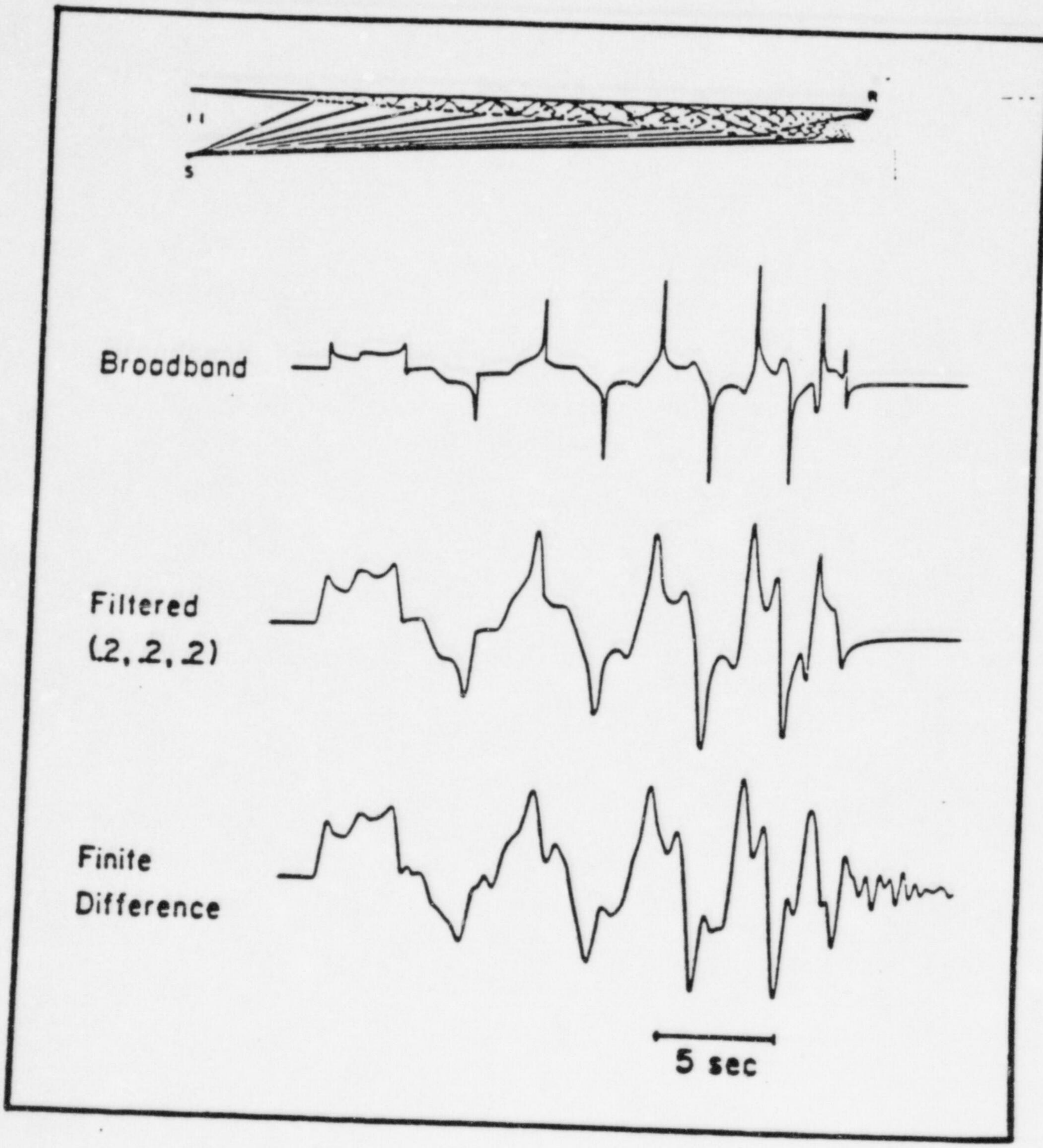
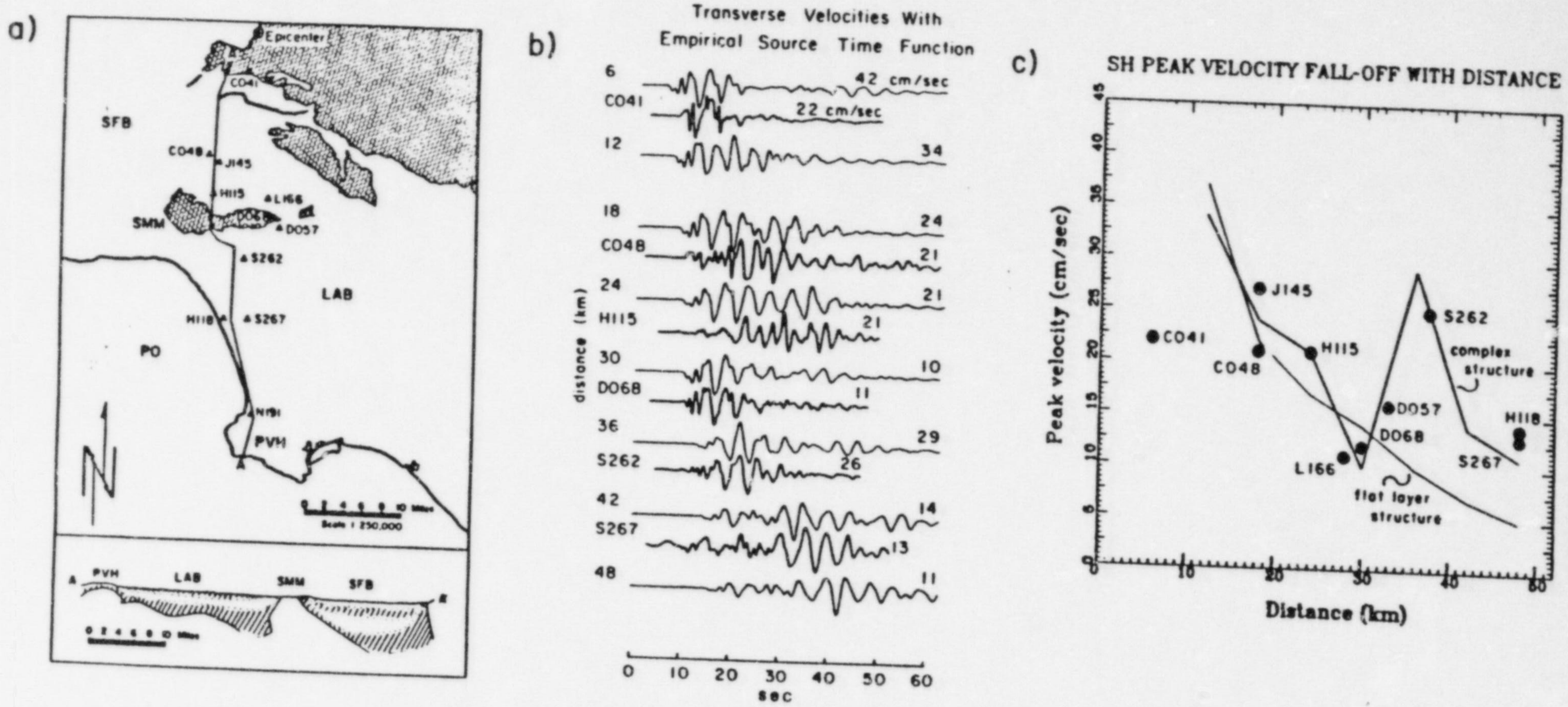


Figure 26 Comparison of GRT results with finite difference calculations (after Vidale et al., 1985).

III · 11



a)
Epicenter
SFB
C041
C048
J145
H115
L166
SMM
D068
D057
S262
LAB
H118
S267
PO
N191
PVH
Scale 1:250,000
A
PVH
LAB
SMM
SFB
B
b)
Transverse Velocities With
Empirical Source Time Function
distance (km)
6
C041
12
18
C048
24
H115
30
D068
36
S262
42
S267
48
42 cm/sec
22 cm/sec
34
24
21
21
21
10
11
29
26
14
13
11
0 10 20 30 40 50 60
sec
c)
SH PEAK VELOCITY FALL-OFF WITH DISTANCE
Peak velocity (cm/sec)
Distance (km)
C041
J145
C048
H115
S262
complex structure
D057
D068
L166
flat layer structure
H118
S267

20

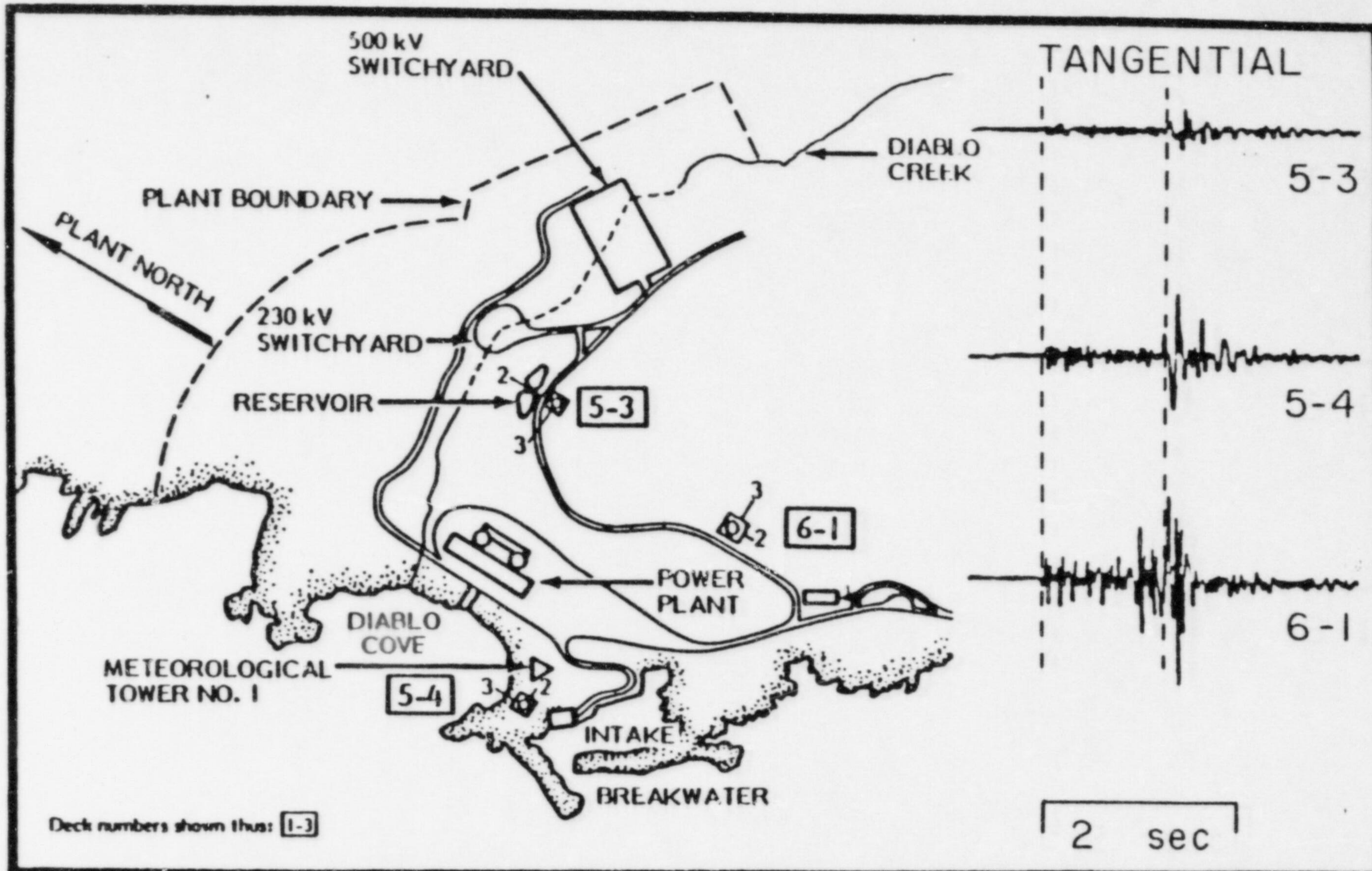
SITE CHARACTERISTICS

EFFECTS OF SITE ON STRONG GROUND MOTIONS

- COHERENT EFFECTS - FOCUSING / DEFOCUSING
- INCOHERENT EFFECTS - SCATTERING
- SPATIAL INCOHERENCE

METHODS FOR MODELING SITE EFFECTS

- KIRCHHOFF
- 3-D WKBJ
- FINITE DIFFERENCE


500 kV
SWITCHYARD
TANGENTIAL
DIABLO
CREEK
PLANT BOUNDARY
PLANT NORTH
230 kV
SWITCHYARD
RESERVOIR
5-3
6-1
POWER
PLANT
DIABLO
COVE
METEOROLOGICAL
TOWER NO. 1
5-4
INTAKE
BREAKWATER
Deck numbers shown thus: 1-3
5-3
5-4
6-1
2 sec

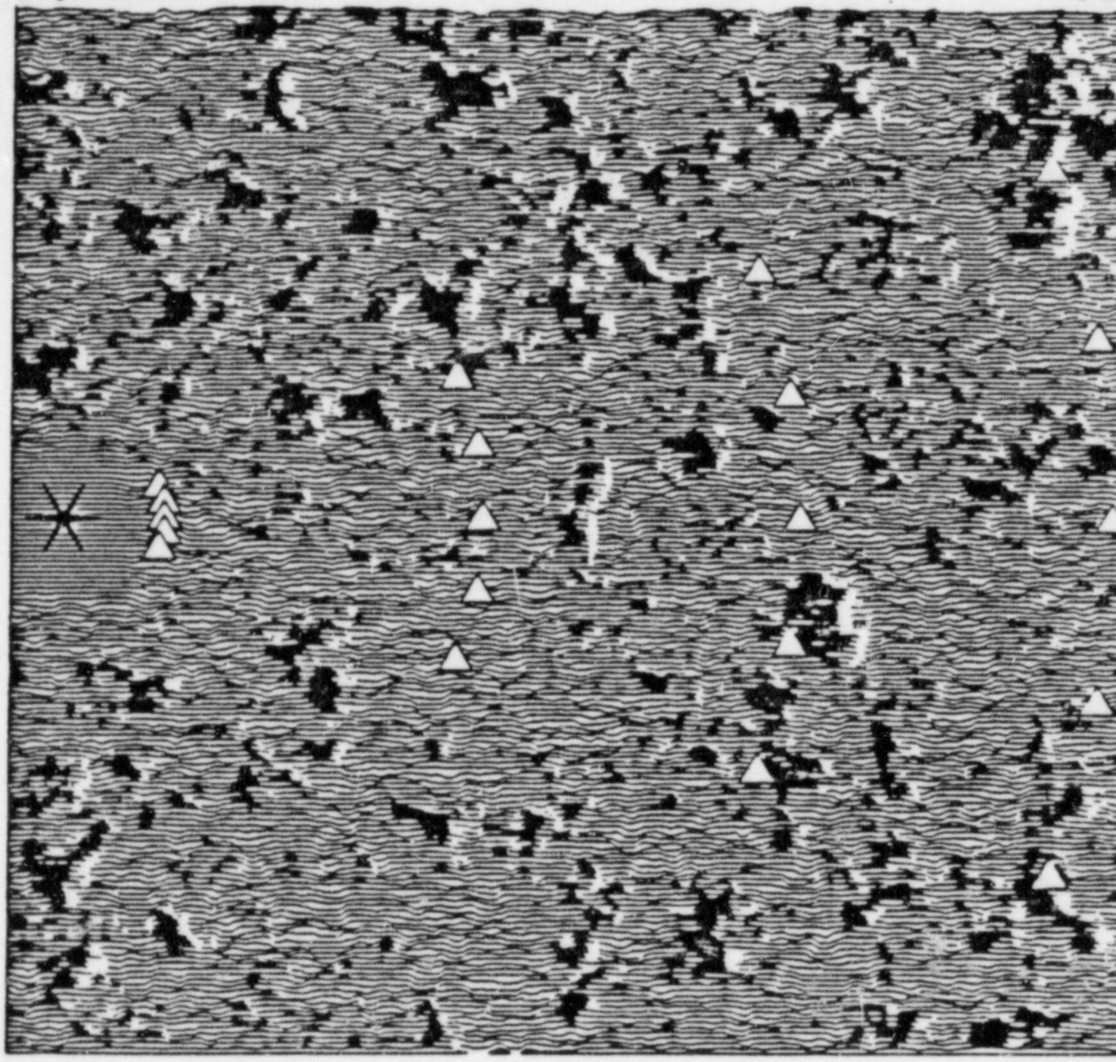


Figure 6: Typical velocity model used for random media studies. The star denotes the location of the explosion source and the triangles are the receivers. The medium has an exponential correlation function with a correlation distance of 80 m. The velocity variation are 10%.

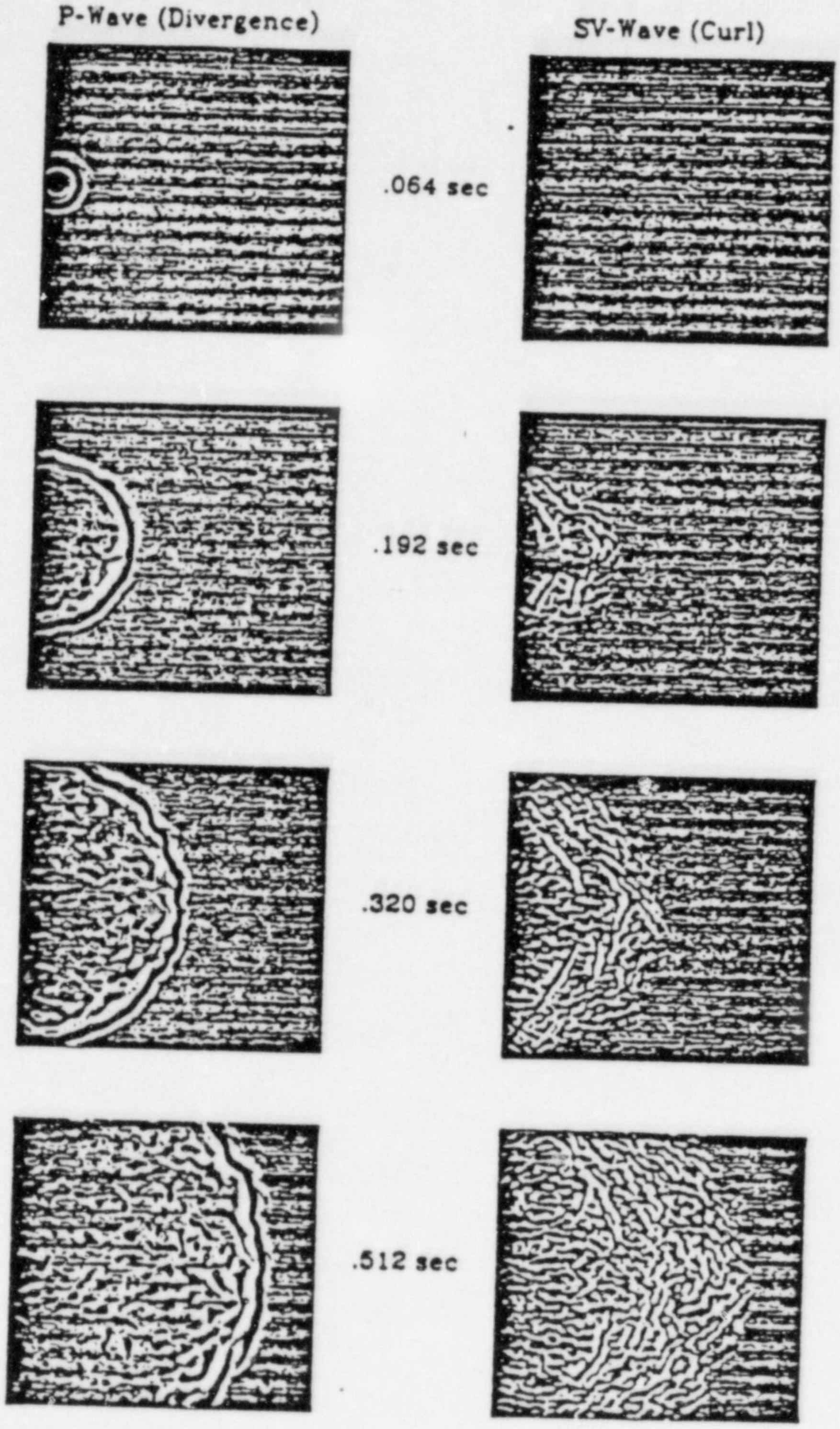
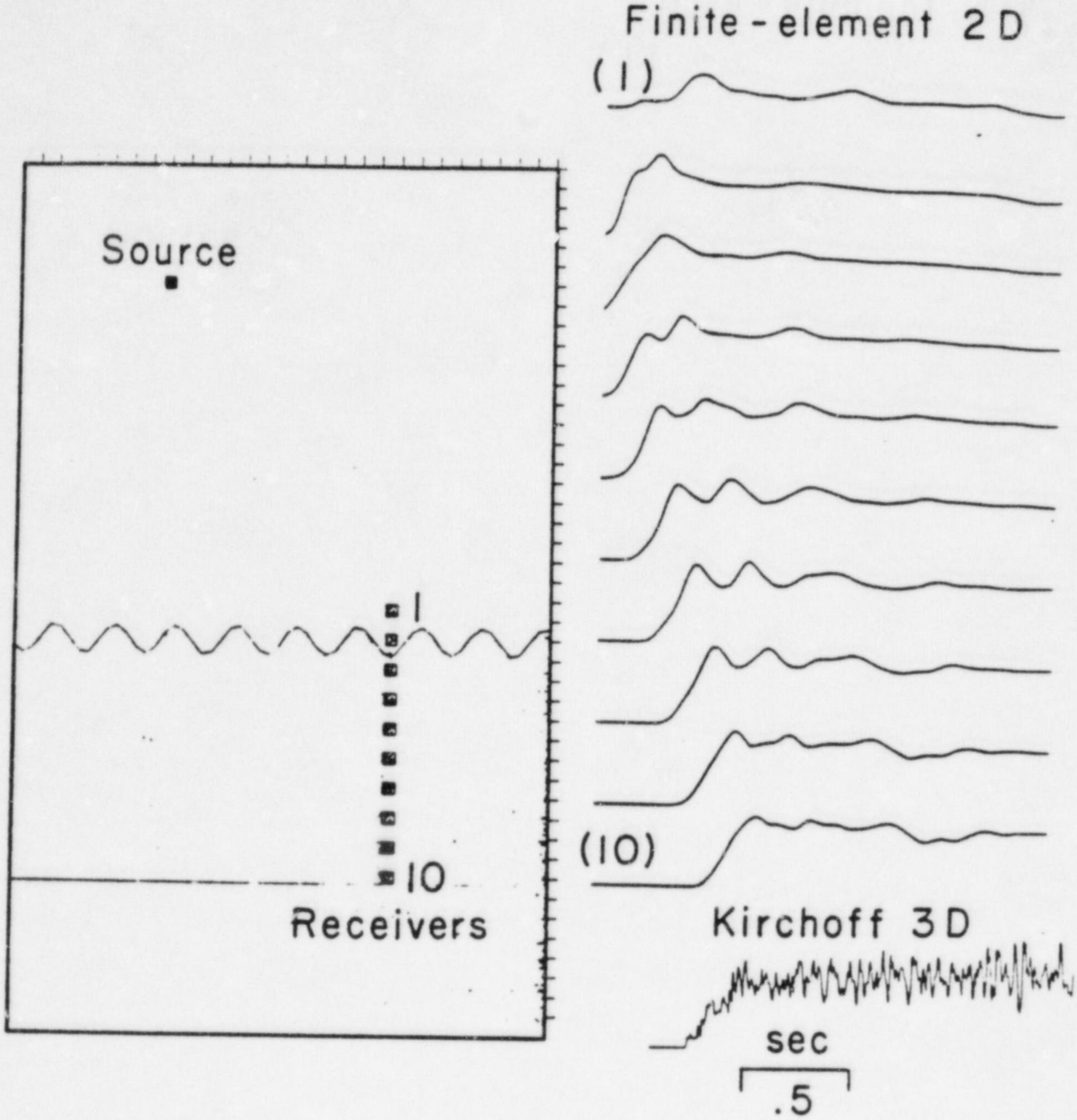


Figure 7: Time slices of the divergence (P waves) and curl (SV waves) for a wavefield propagating through the medium shown in Figure 6.


Finite - element 2D
(1)
(10)
Source
1
10
Receivers
Kirchoff 3D
sec
.5

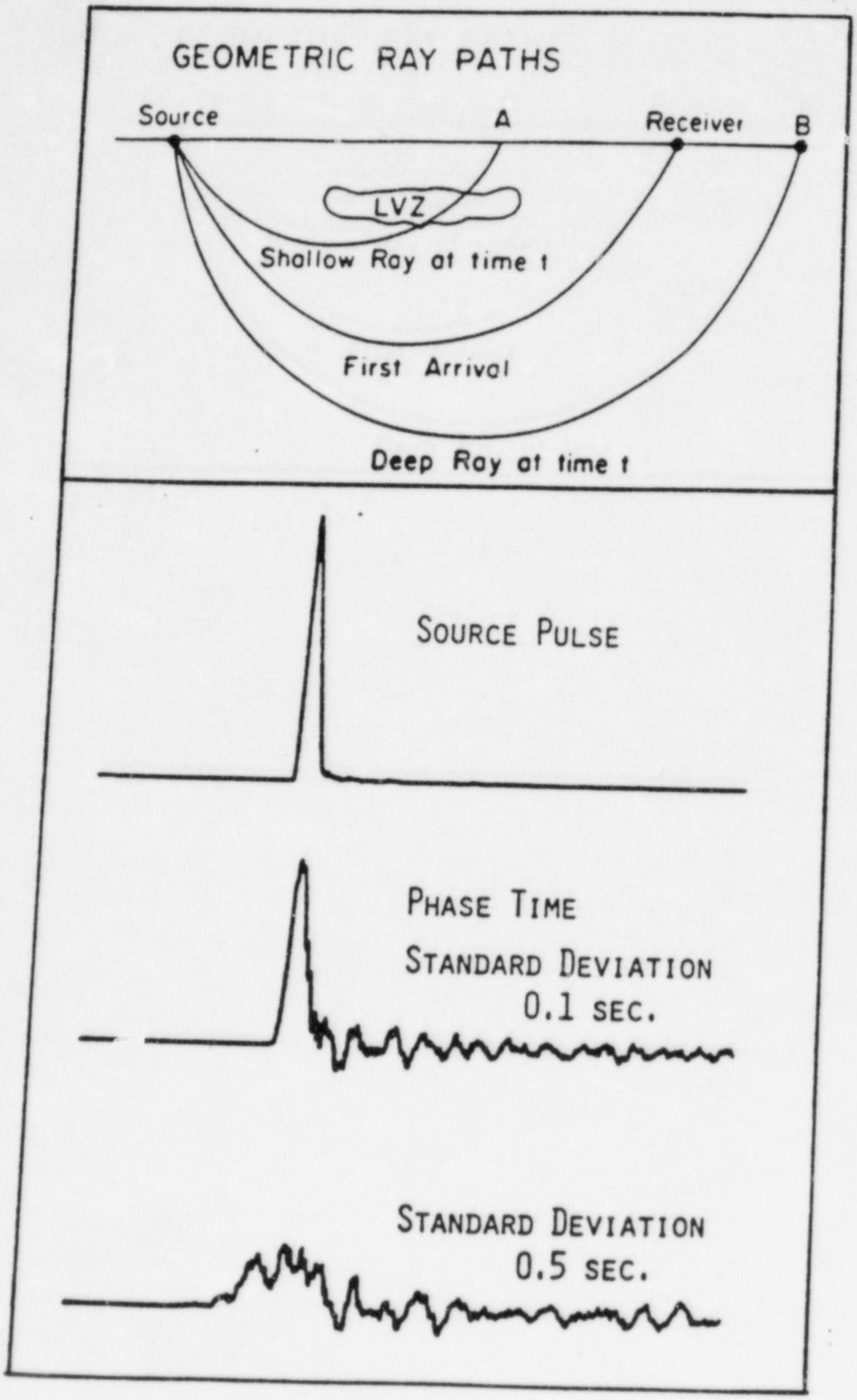


Figure 2. Degradation of a pulse by scattering of the phase.

SUMMARY

SOURCE

- INCLUDE ASPERITIES, BARRIERS, DEPTH DEPENDENCE
- RETAIN LOW FREQ. COHERENCE/ HIGH FREQ. INCOHERENCE OF EMPIRICAL SOURCE FUNCTIONS

PATH

- INCLUDE SPECIFIC PROPAGATION CHARACTERISTICS IN THE SITE VICINITY - CALCULATE GREEN'S FUNCTIONS FROM STRUCTURE MODELS DEVELOPED USING GSG SITE EXPERIMENTS

SITE

- INCLUDE SPECIFIC SITE RESPONSE CHARACTERISTICS CALCULATE GREEN'S FUNCTIONS FROM SITE MODELS DEVELOPED USING GSG SITE EXPERIMENTS

ENCLOSURE 4

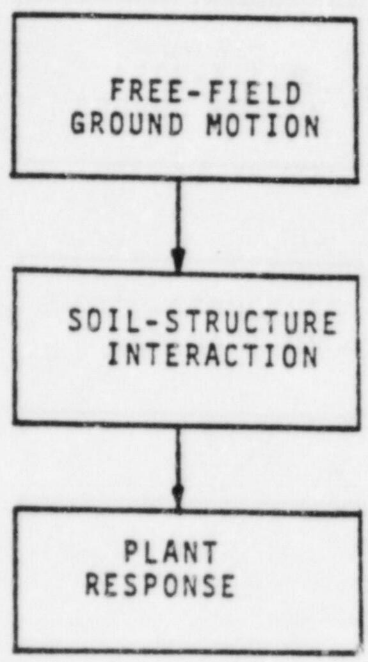
SECTION 13

PACIFIC GAS AND ELECTRIC COMPANY

DIABLO CANYON

LONG TERM SEISMIC PROGRAM

EVALUATION OF SOIL-STRUCTURE INTERACTION EFFECTS



OUTLINE OF ANALYTICAL APPROACH

- THREE-DIMENSIONAL (3-D) SOIL-STRUCTURE INTERACTION ANALYSIS METHODS WILL BE EMPLOYED.

- ALL COMPONENTS OF NEAR-FIELD STRONG GROUND MOTION WILL BE INCLUDED IN THE ANALYSIS SIMULTANEOUSLY.

- ANALYSES WILL CONSIDER SEISMIC WAVE INCIDENCE CHARACTERISTICS INCLUDING INCLINED BODY WAVES AND SURFACE WAVES.

- ANALYSES WILL CONSIDER THE EFFECT OF INELASTIC RESPONSE, IF SIGNIFICANT, OF THE PLANT STRUCTURES UNDER THE STRONG EARTHQUAKE GROUND MOTION.

- AVAILABLE RECORDED EARTHQUAKE DATA AT THE DIABLO CANYON PLANT SITE WILL BE UTILIZED TO ASSIST IN CALIBRATING THE LOW AMPLITUDE DYNAMIC CHARACTERISTICS OF THE SOIL-STRUCTURE DYNAMIC MODEL.

- PARAMETRIC STUDIES WILL BE MADE BY APPLYING SIMULTANEOUSLY THE HALF-SPACE APPROACH USING THE "CLASSI" COMPUTER PROGRAM AND THE FINITE-ELEMENT APPROACH USING THE "SASSI" COMPUTER PROGRAM.

SOIL-STRUCTURE INTERACTION

WORK PLAN

TASK 1. ASSEMBLAGE AND REVIEW OF SITE ROCK DATA

TASK 2. DEVELOPMENT OF FREE-FIELD INPUT MOTIONS FOR SSI ANALYSIS

- 2.1 EVALUATION OF LITERATURE ON SPATIAL COHERENCY OF GROUND MOTIONS
- 2.2 REVIEW OF RESULTS OF GROUND MOTION STUDIES
- 2.3 DEVELOPMENT OF FREE-FIELD INPUT MOTIONS FOR SSI ANALYSES

TASK 3. IMPLEMENTATION OF CLASSI AND SASSI COMPUTER PROGRAMS

- 3.1 IMPLEMENTATION AND TESTING OF CLASSI AND SASSI PROGRAMS
- 3.2 VERIFICATION AND DOCUMENTATION OF CLASSI AND SASSI PROGRAMS

TASK 4. DEVELOPMENT OF SSI ANALYTICAL MODELS

- 4.1 REVIEW OF EXISTING DYNAMIC MODELS OF POWER BLOCK STRUCTURES
- 4.2 DEVELOPMENT OF 3-D STRUCTURAL DYNAMIC MODELS
- 4.3 DEVELOPMENT OF 3-D FOUNDATION MODELS

TASK 5. CORRELATION WITH RECORDED DATA

- 5.1 ANALYSES OF RECORDED DATA
- 5.2 CORRELATION BETWEEN ANALYTICAL MODELS AND RECORDED DATA

TASK 6. PARAMETRIC STUDIES

6.1 RECONCILIATION OF CLASSI AND SASSI SOLUTIONS

6.2 BASEMAT FLEXIBILITIES

6.3 FOUNDATION EMBEDMENT

6.4 VARIATIONS OF SOIL/STRUCTURE PROPERTIES

6.5 VARIATIONS OF INPUT MOTIONS

6.6 SOIL/STRUCTURE NONLINEARITIES

TASK 7. GENERATION OF SSI RESPONSES

TASK 8. DOCUMENTATION AND PREPARATION OF REPORTS

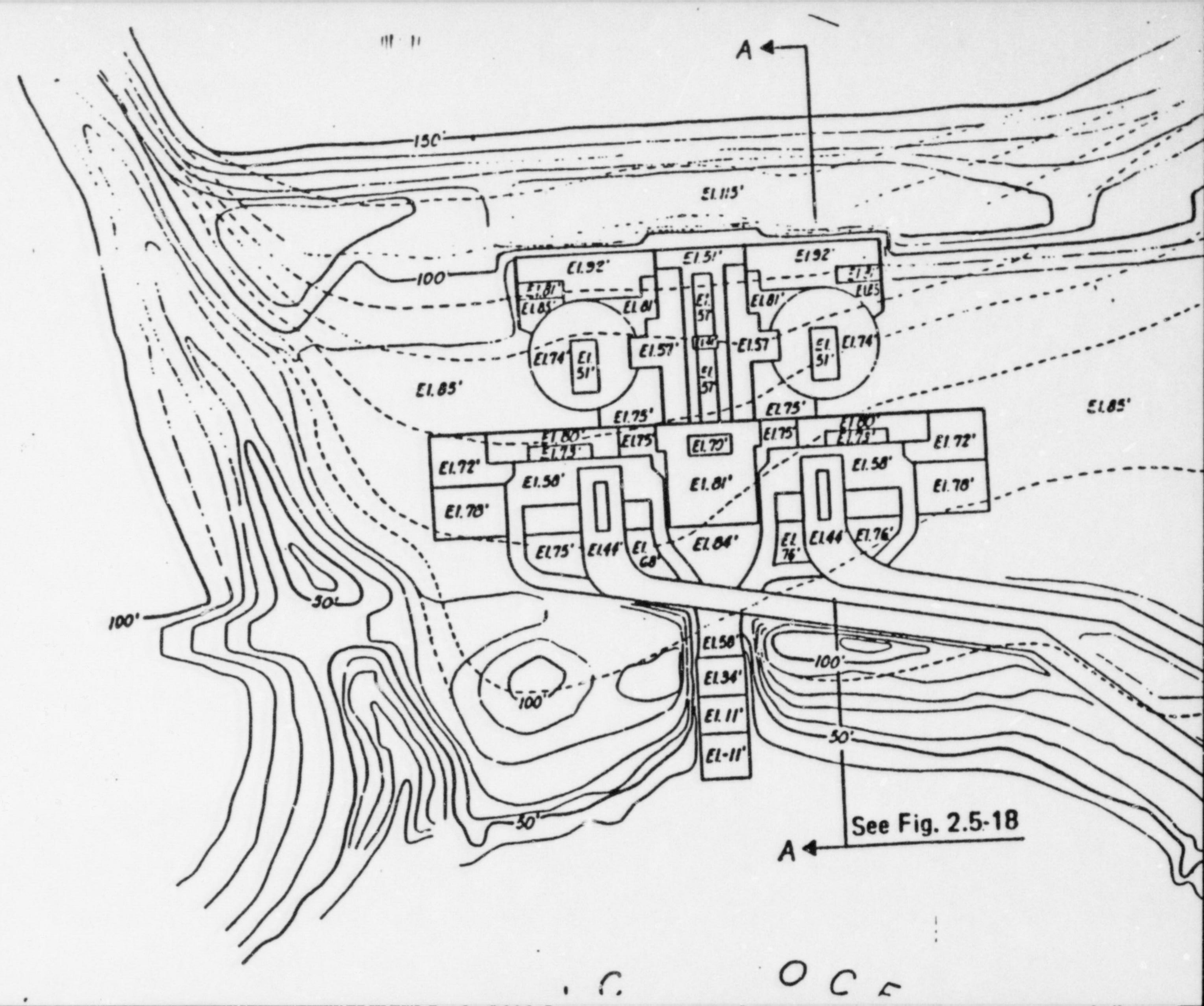
TASK 1: ASSEMBLAGE AND REVIEW OF SITE ROCK DATA

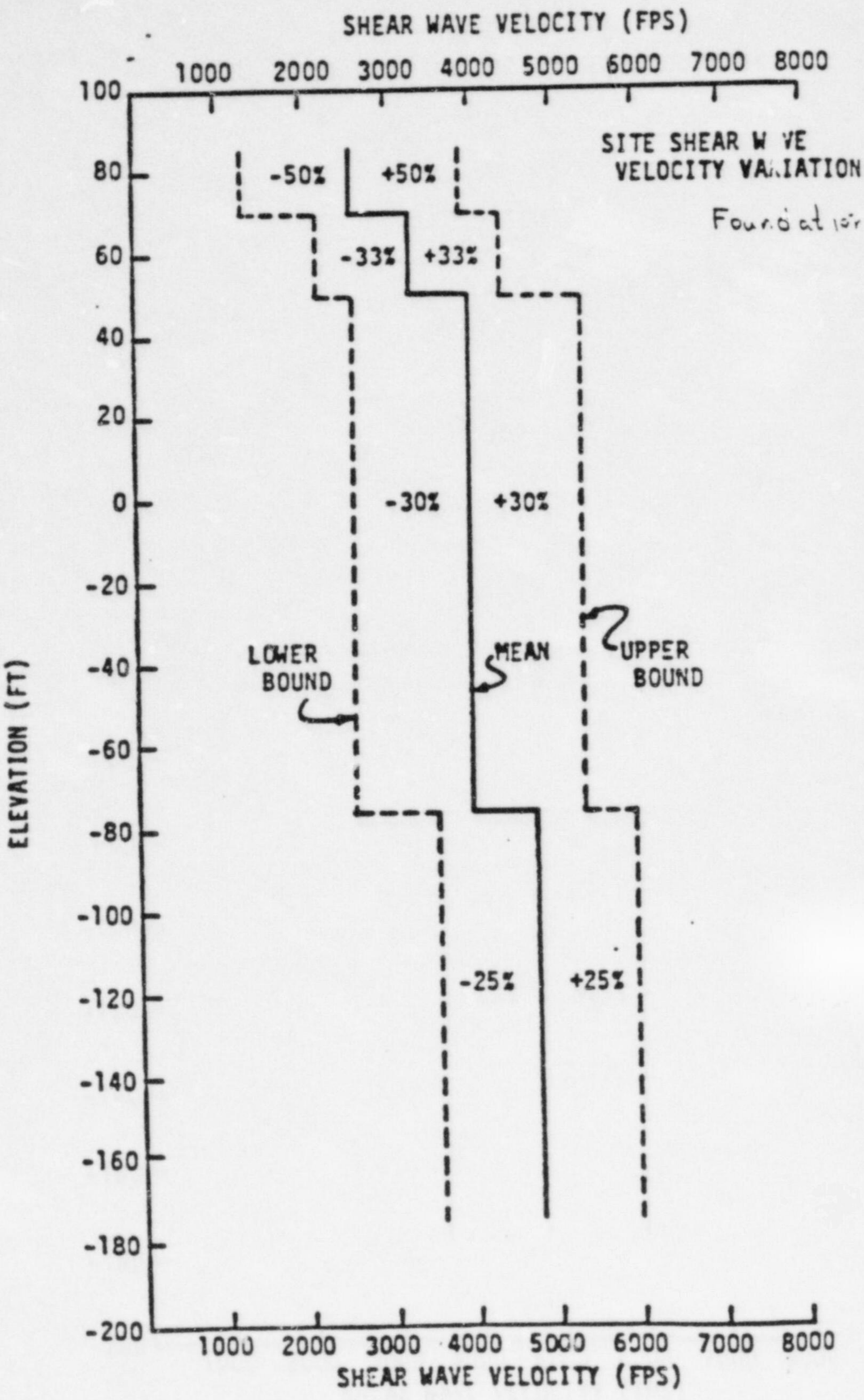
(1) ASSEMBLAGE OF THE EXISTING SITE ROCK DATA.

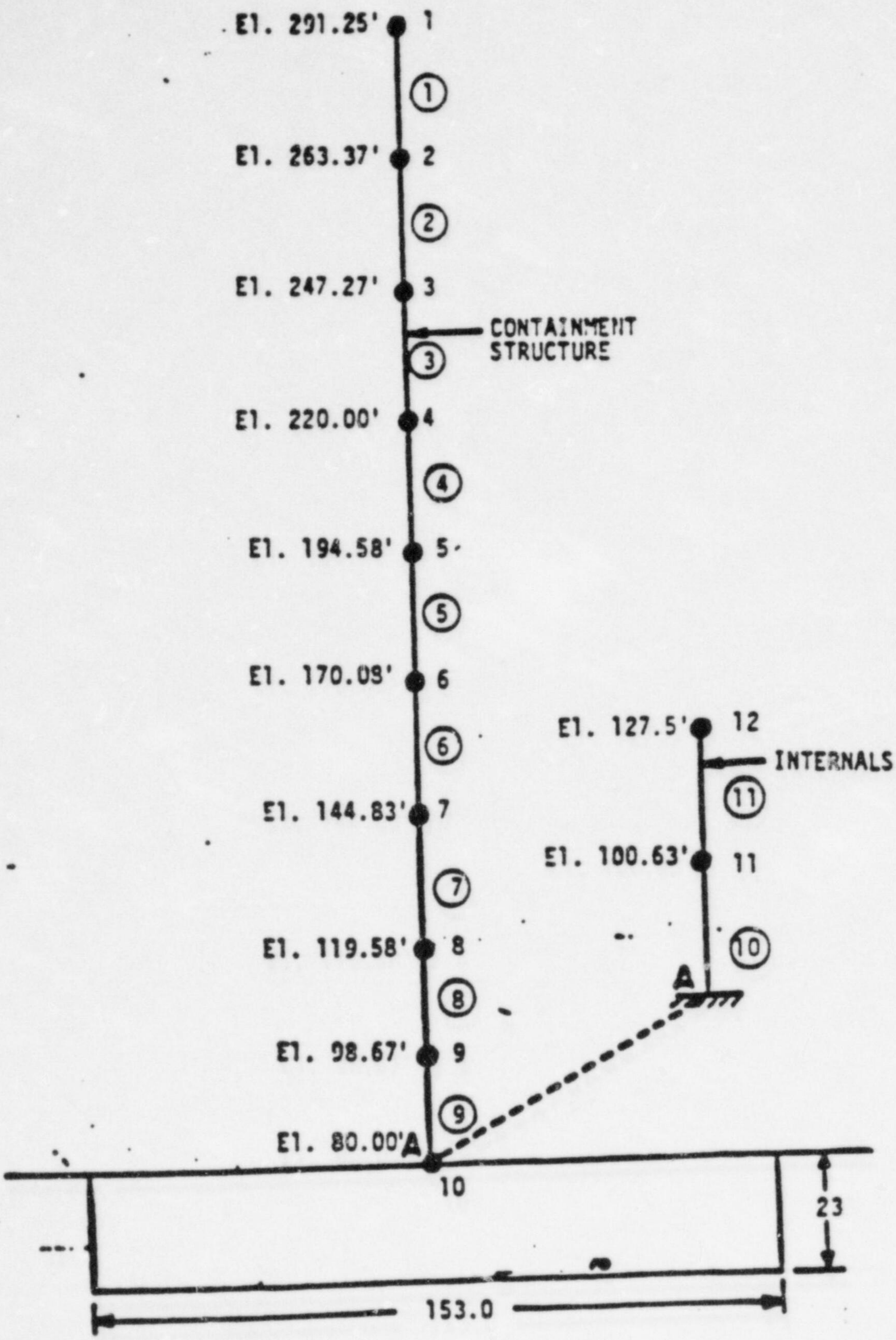
(2) DEVELOPMENT OF SITE ROCK PROPERTY PROFILES AND RANGE OF VARIATIONS.

(3) SSI RESPONSE SENSITIVITY STUDY.

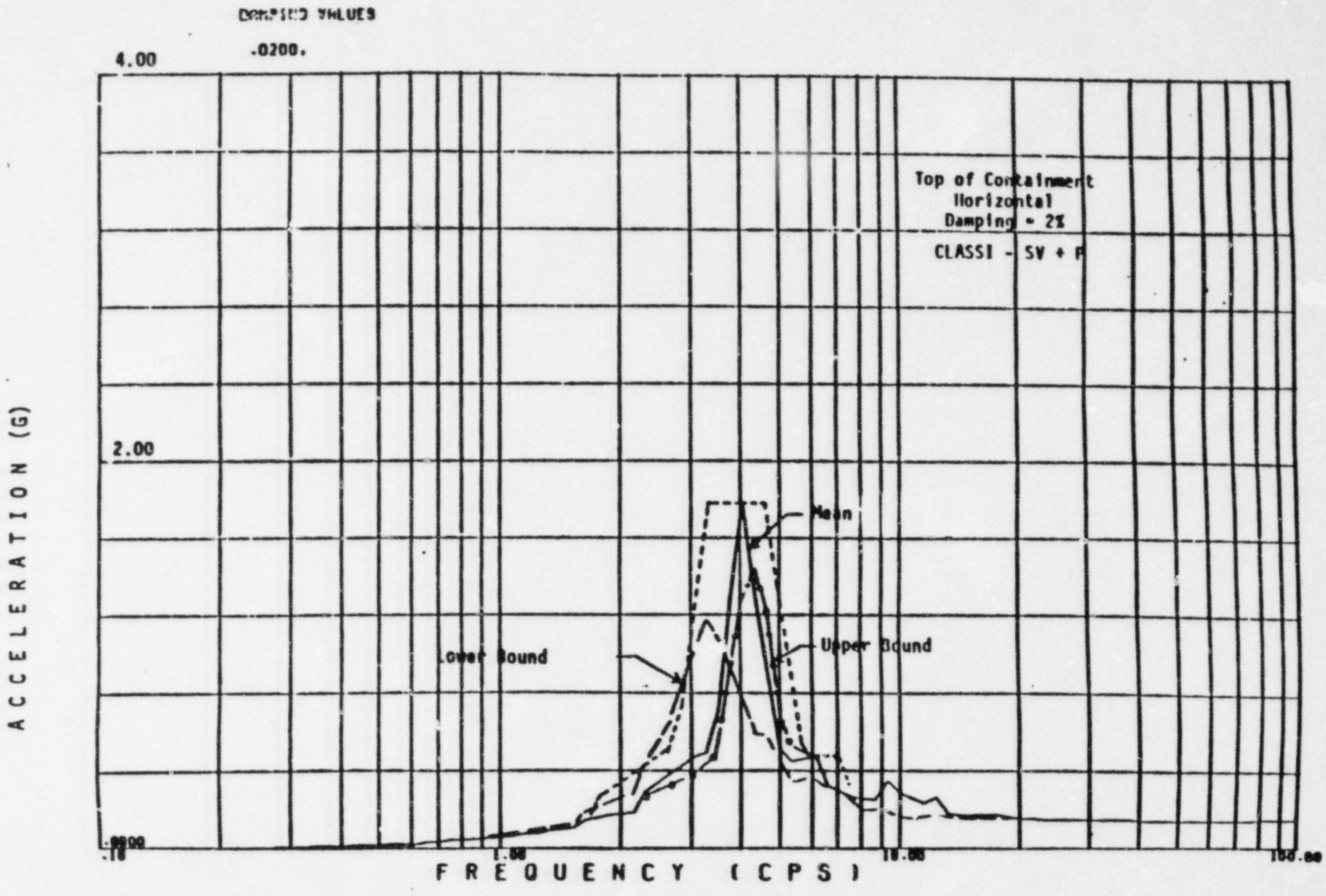
(4) CONFIRMATION USING EARTHQUAKE DATA RECORDED AT THE SITE.


A
150'
El.115'
100
El.92'
El.51'
El.81'
El.61'
El.57'
El.74'
El.85'
El.75'
El.80'
El.72'
El.79'
El.58'
El.81'
El.78'
El.84'
El.44'
El.76'
El.68'
50'
100'
El.34'
El.11'
El-11'
See Fig. 2.5-18
A


SHEAR WAVE VELOCITY (FPS)
1000
2000
3000
4000
5000
6000
7000
8000
SITE SHEAR W VE
VELOCITY VA.IATION
Foundations
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-50%
+50%
-33%
+33%
-30%
+30%
-25%
+25%
LOWER
BOUND
MEAN
UPPER
BOUND
ELEVATION (FT)
SHEAR WAVE VELOCITY (FPS)



SSI ANALYSIS MODEL USED IN CLASSI AND SASSI ANALYSES AND IN SITE ROCK SENSITIVITY STUDIES



DAMPING VALUES
.0200,
4.00
2.00
.0000
ACCELERATION (G)
Top of Containment
Horizontal
Damping = 2%
CLASSI - SV + P
Mean
Upper Bound
Lower Bound
.10
1.00
10.00
100.00
FREQUENCY (CPS)

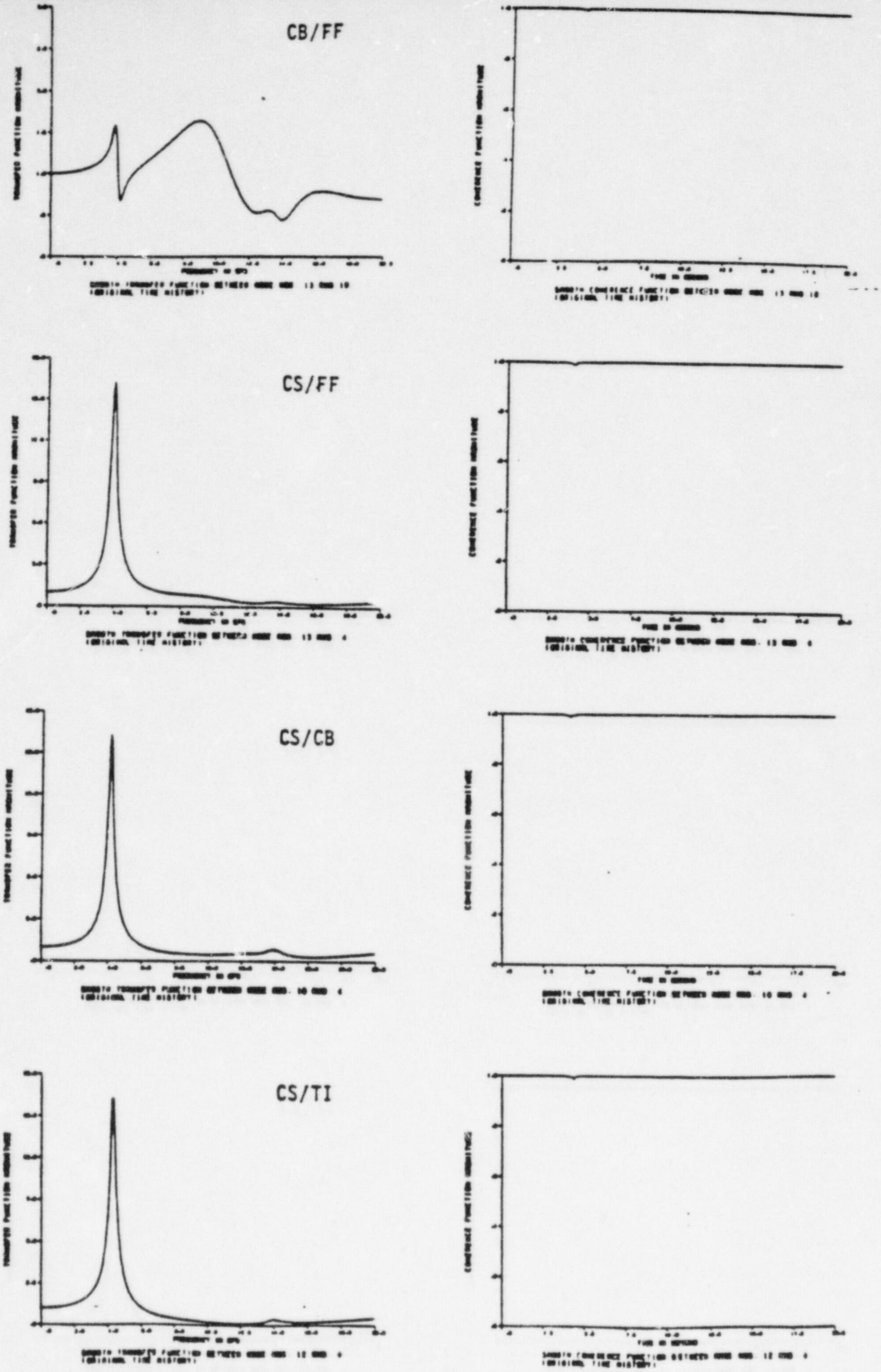
NODE 1 H

EARTHQUAKES FOR WHICH RECORDED DATA ANALYSED:

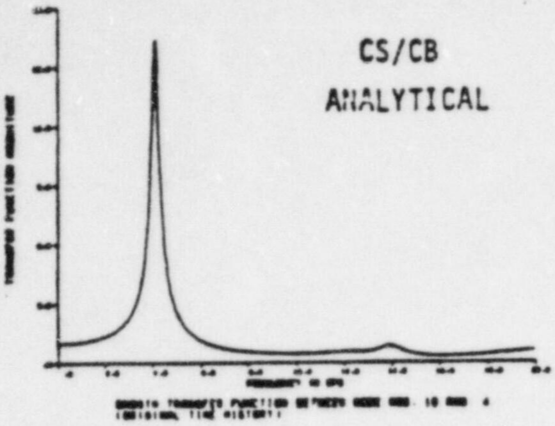
1. SANTA MARIA OFFSHORE EARTHQUAKE OF JUNE 20, 1984
   $M_L = 4.3$
   MAXIMUM HORIZONTAL GROUND ACCELERATION = 0.011G

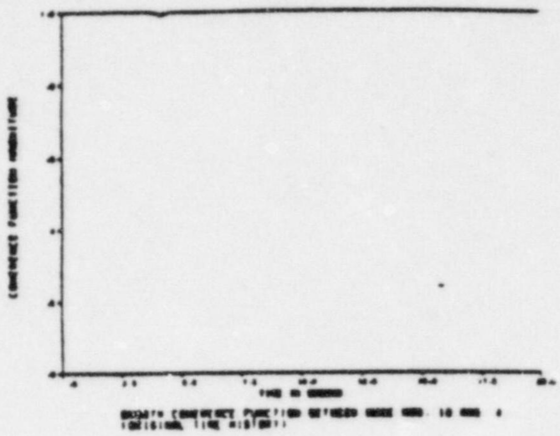
2. COALINGA EARTHQUAKE OF MAY 2, 1983
   $M_L = 6.5$
   MAXIMUM HORIZONTAL GROUND ACCELERATION = 0.012G

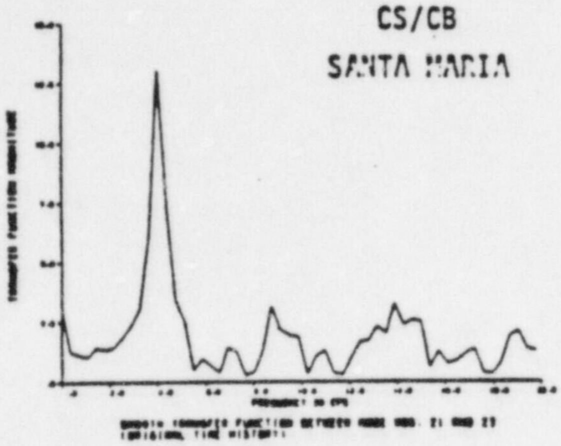
3. POINT SAL EARTHQUAKE OF MAY 28, 1980
   $M_L = 4.6$
   MAXIMUM HORIZONTAL GROUND ACCELERATION = 0.012G

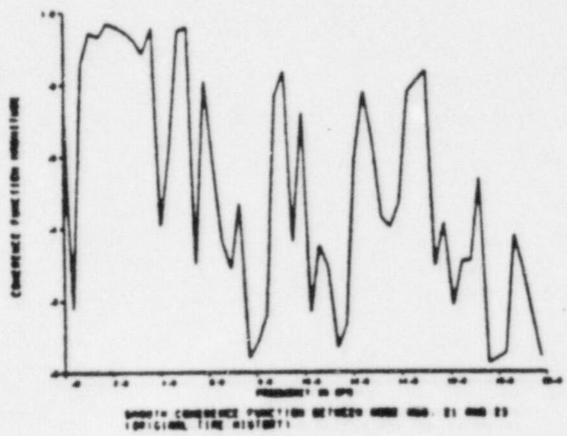


CS:Containment @ Springline   CB:Containment Base   FF:Free-field

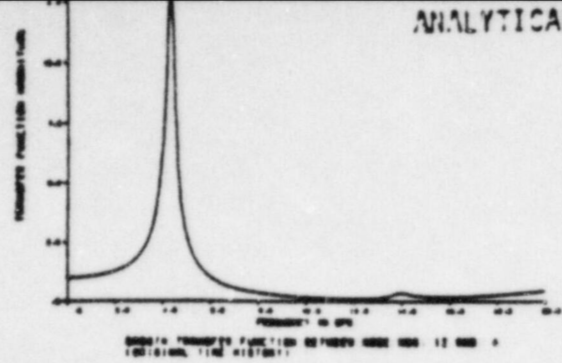

CS/CB
ANALYTICAL

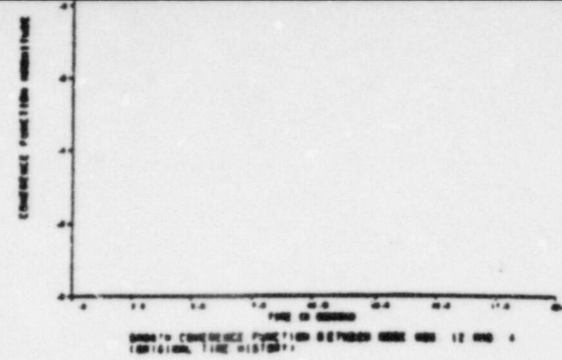



CS/CB
SANTA MARIA

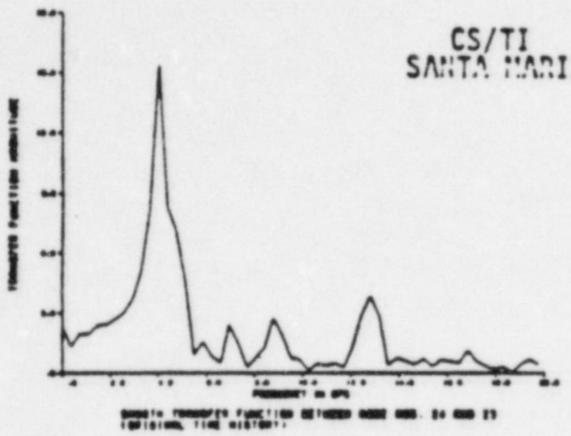


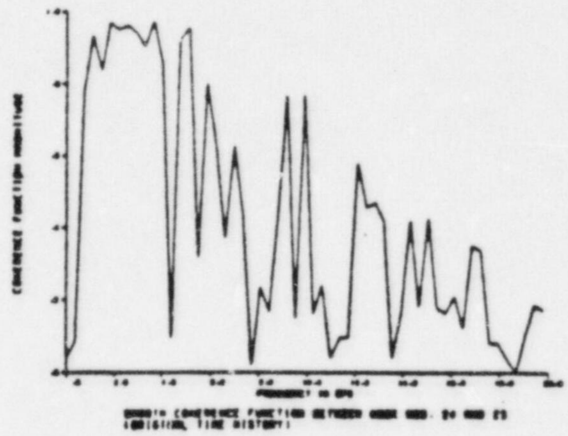
ANALYTICAL



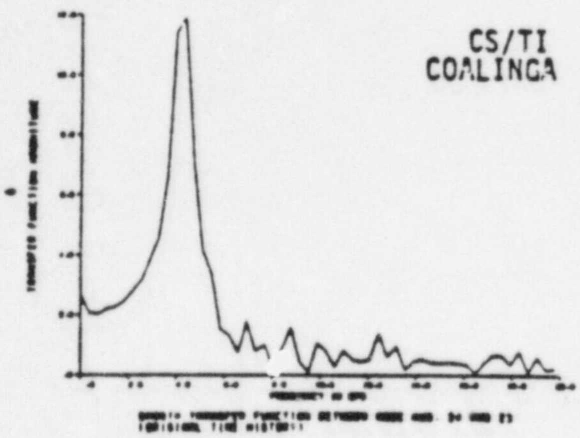


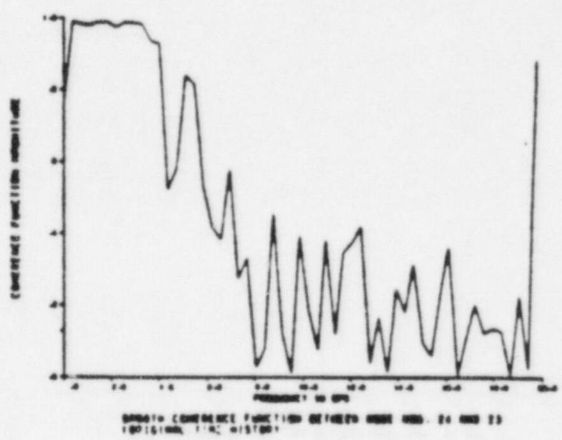
CS/TI
SANTA MARIA



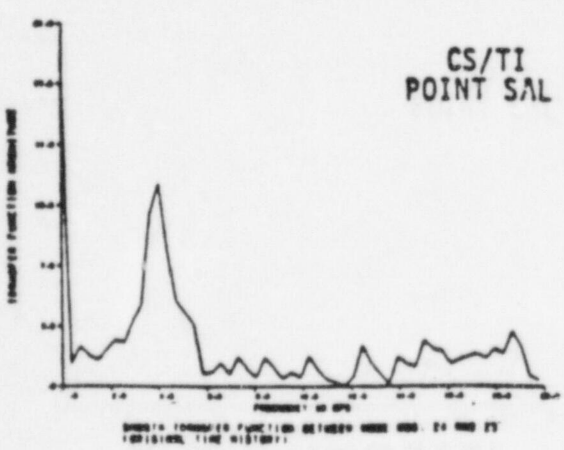


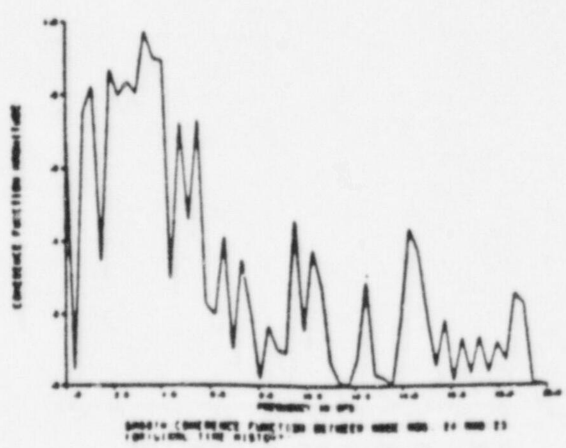
CS/TI
COALINGA





CS/TI
POINT SAL





TASK 2.1 EVALUATION OF LITERATURE ON SPATIAL COHERENCY OF GROUND MOTIONS

(1) SURVEY AND REVIEW OF LITERATURE

- o EL CENTRO DIFFERENTIAL ARRAY (SMITH, KING)
- o TAIWAN SMART-1 ARRAY (PENZIEN, BOLT, VANMARCKE, HARADA)
- o CHUSAL DIFFERENTIAL ARRAY (KING)

(2) CHARACTERIZATION OF SPATIAL COHERENCY OF RECORDED MOTIONS

- o RESPONSE RATIO METHOD (SMITH, KING, PENZIEN, BOLT)
- o CROSS-CORRELATION METHOD (SMITH, KING, PENZIEN, BOLT, VANMARCKE)

(3) MODELS FOR CHARACTERIZATION OF SPATIAL COHERENCY

- o COVARIANCE MODEL (LOH, HARADA)
- o COHERENCY MODEL (LOH, VANMARCKE, LUCO)

(4) INCORPORATION OF SPATIAL COHERENCY OF INPUT MOTIONS FOR SSI ANALYSES

- o DETERMINISTIC - TIME-HISTORY ANALYSIS WITH MULTIPLE GROUND MOTION INPUTS (CLASSI)
- o PROBABILISTIC - RANDOM VIBRATION ANALYSIS WITH COVARIANCE MATRIX INPUT (LUCO)

TASK 3.1 IMPLEMENTATION AND TESTING OF CLASSI AND SASSI PROGRAMS

(1) ACQUISITION AND INSTALLATION OF THE CODES

- o CLASSI - NEW VERSION ON UNIVAC-1110 AND VAX-780
- o SASSI - NEW PROGRAM ON UNIVAC-1110 AND CDC/UIS CRAY

(2) ARRANGEMENT OF TECHNICAL SUPPORTS TO THE CODES

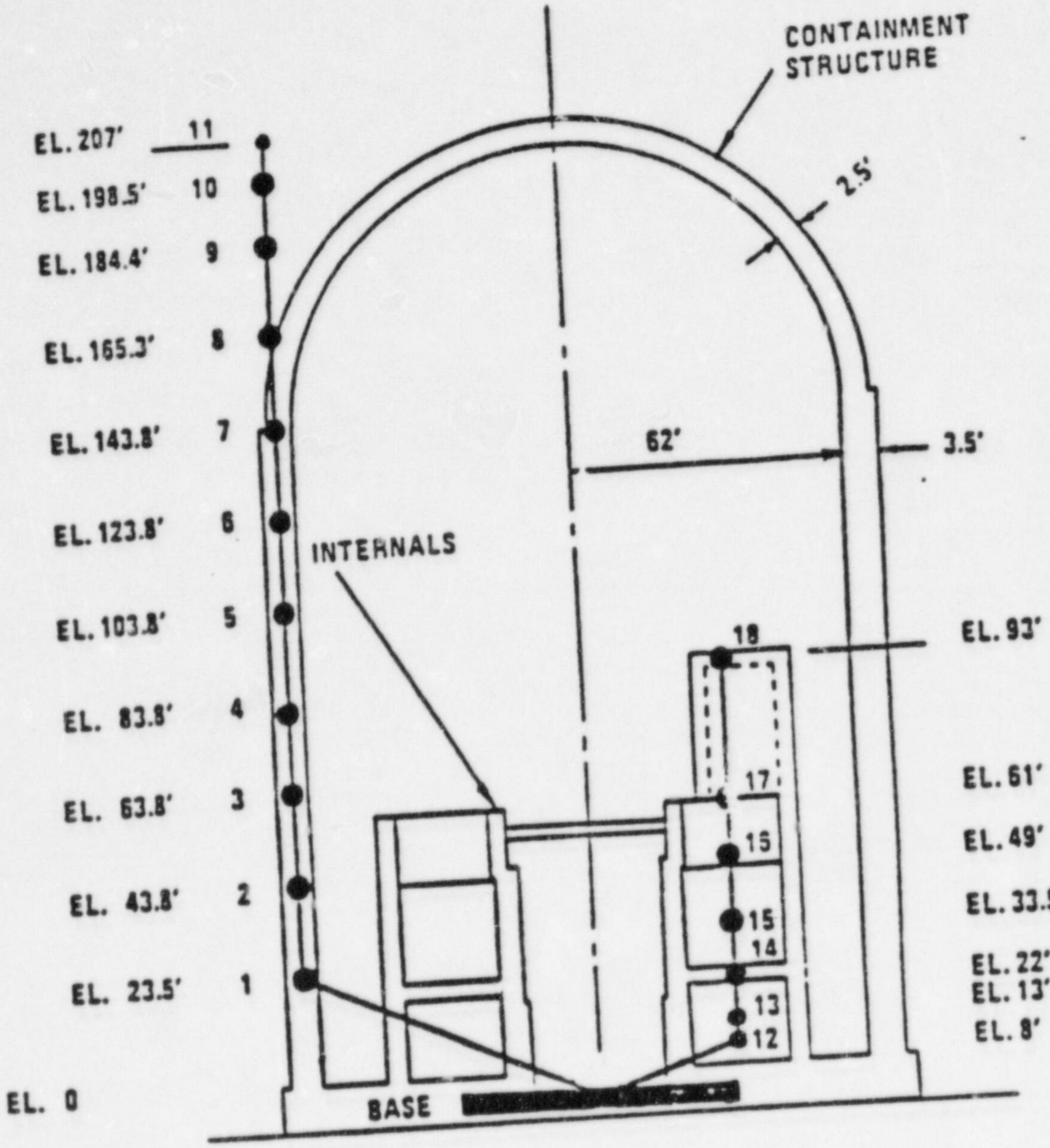
- o CLASSI - PROFS. J. E. LUCO AND H. L. WONG
- o SASSI - PROF. JOHN LYSMER

(3) BENCHMARK TESTING OF THE CODES

- o CLASSI - 6 TEST PROBLE[illegible]OMPARING WITH 7 BENCHMARK SOLUTIONS
- o SASSI - 9 TEST PROBLEMS COMPARING WITH 12 BENCHMARK SOLUTIONS

LIST OF TEST PROBLEMS FOR CLASSI AND SASSI COMPUTER PROGRAMS

Capabilities to be Tested	Test Problem No. CLASSI	Test Problem No. SASSI	Benchmark Solution Reference
1. Impedance Analysis			
1.1 Surface foundation on uniform halfspace	1	7	7(a)
1.2 Surface foundation on two-layered system	2	3	2
1.3 Rigid-flexible surface foundation	-	5	5
1.4 Multiple surface foundation	5	8	-
2. Scattering Analysis			
2.1 Vertically propagating body waves			
2.1.1 Free-field motions	-	1	1
2.1.2 Embedded Foundation	-	4	4
2.2 Inclined body waves			
2.2.1 Surface foundation	3	6	6
2.2.2 Embedded foundation	-	4	-
2.3 Surface Waves	6	9	-
3. SSI Analysis			
3.1 Seismic response	1, 4	7, 10	7(b)
3.2 Forced excitation response	-	3	3



Soil $\begin{cases} V_s = 2000 \text{ ft/sec} \\ V_p = 4000 \text{ ft/sec} \\ \gamma = .130 \text{ Kcf} \\ \beta = .05 \end{cases}$

Fig. 7.7(a) SSI Analysis Model of the Containment and Internal Structure (SASSI Test Problem No. 7)

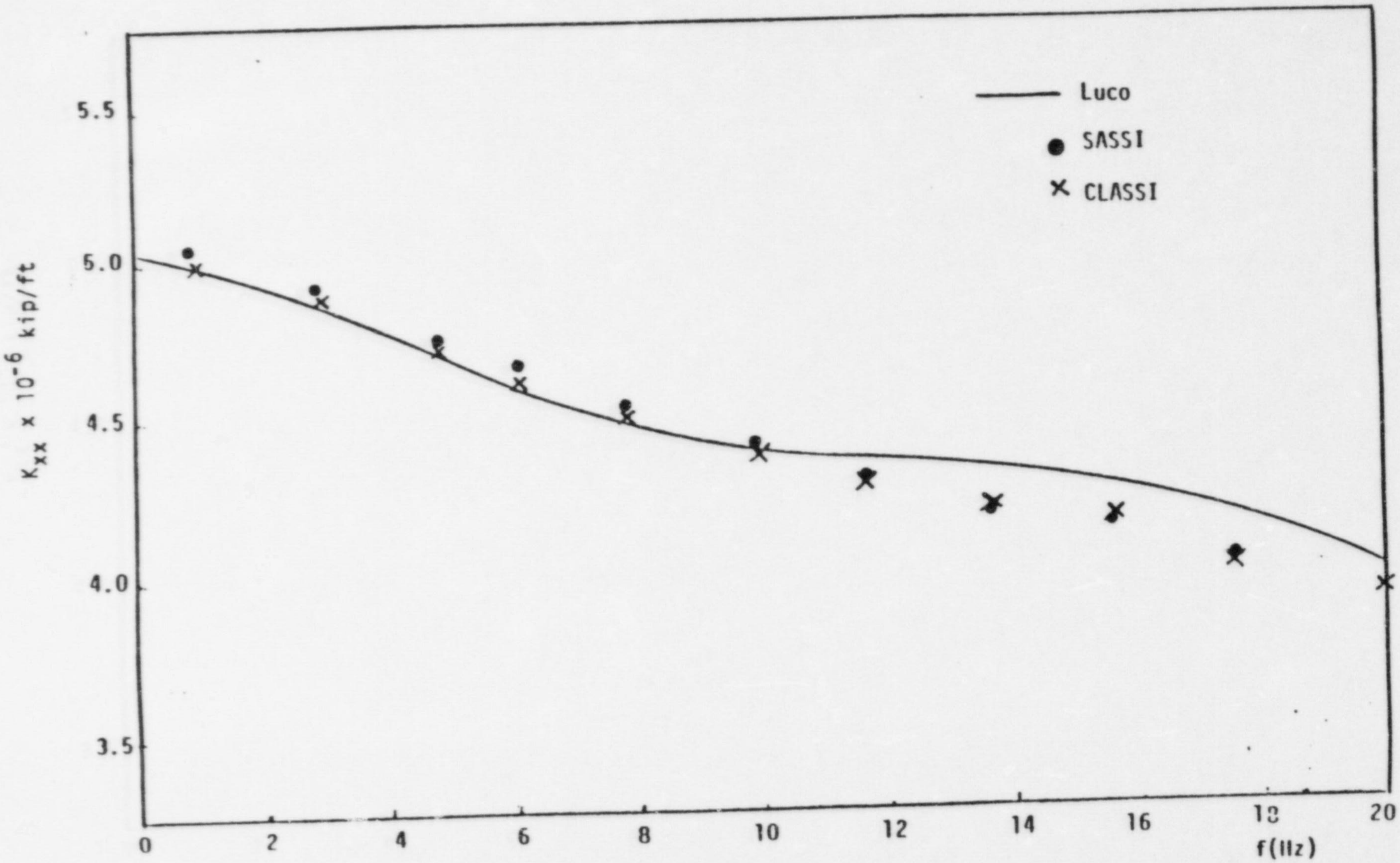


Fig. 7-7(b) Horizontal Stiffness Coefficient (Luco, 1976)
(SASSI Test Problem No. 7)

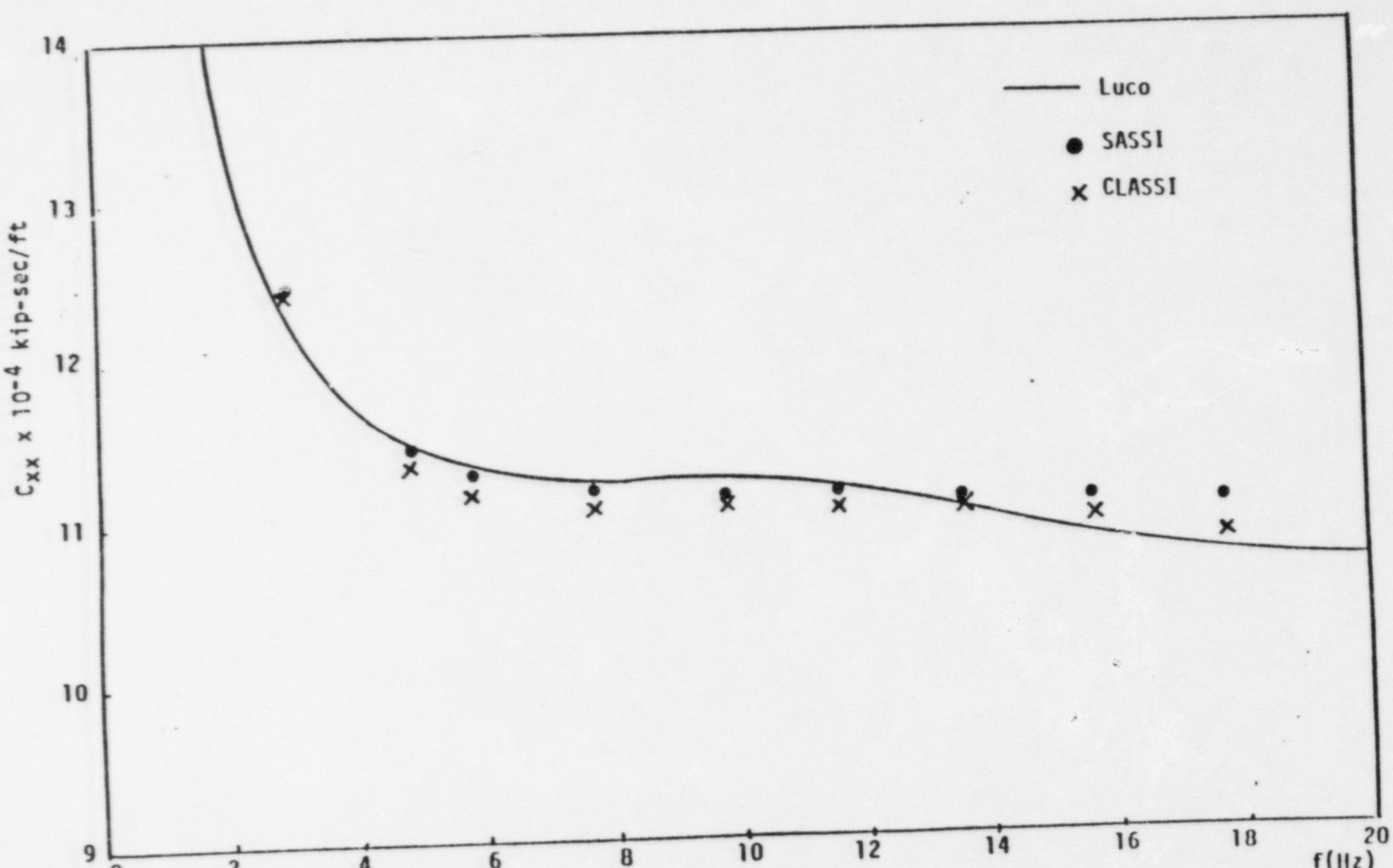


Fig. 7-7(c) Horizontal Damping Coefficient (Luco, 1976)
(SASSI Test Problem No. 7)

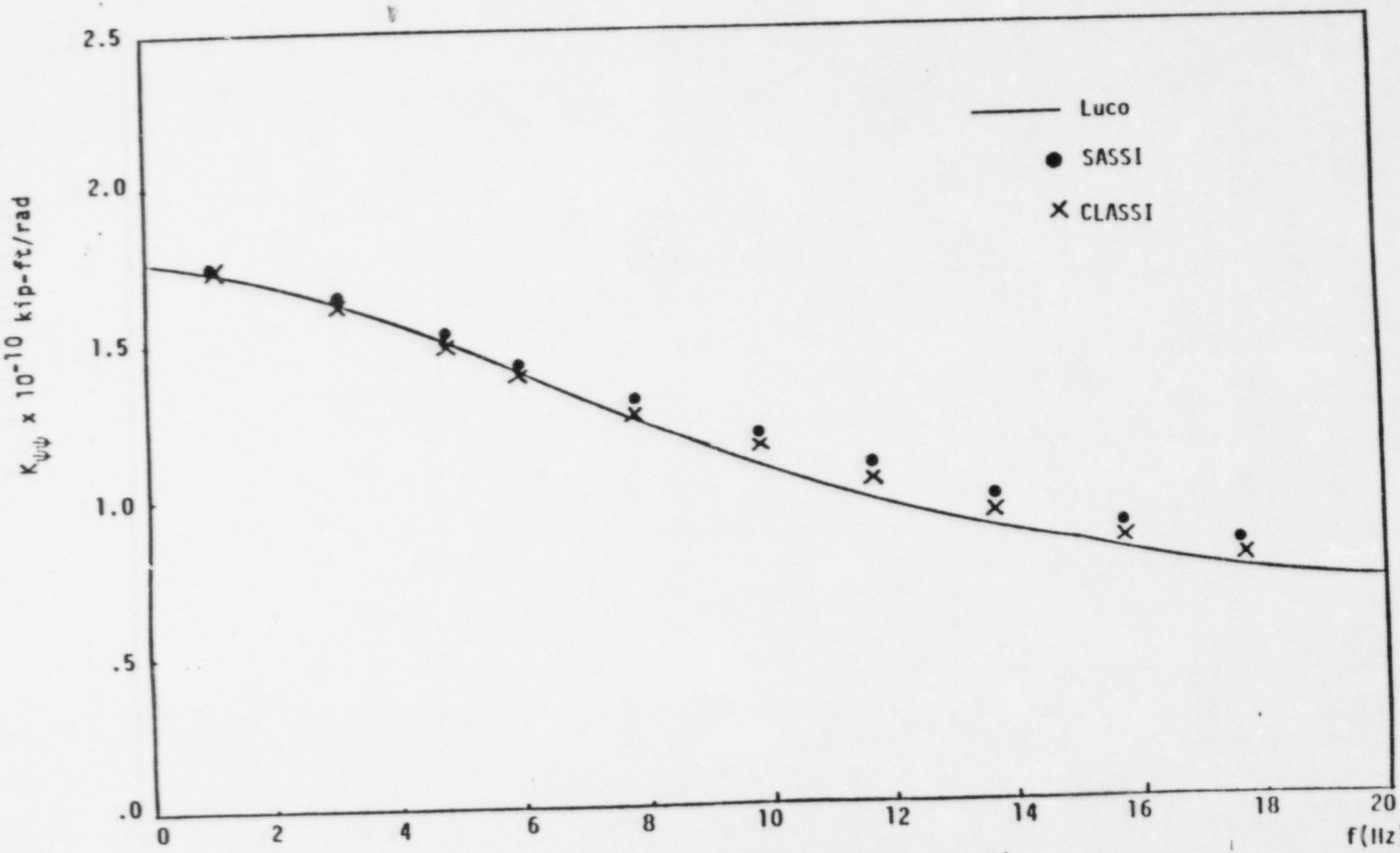


Fig. 7-7(d) Rocking Stiffness Coefficient (Luco, 1976)
(SASSI Test Problem No. 7)

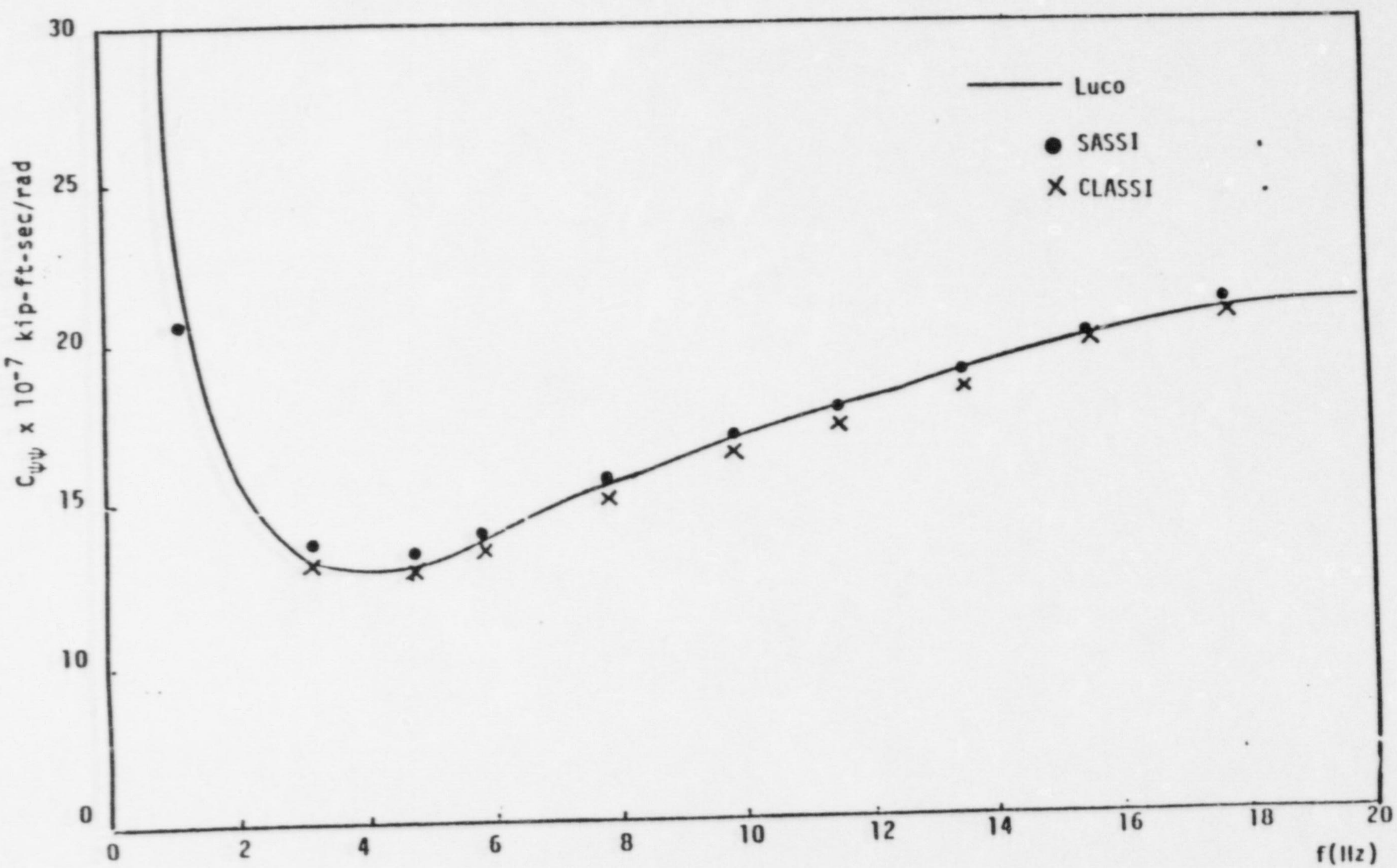


Fig. 7-7(e) Rocking Damping Coefficient (Luco, 1976)
(SASSI Test Problem No. 7)

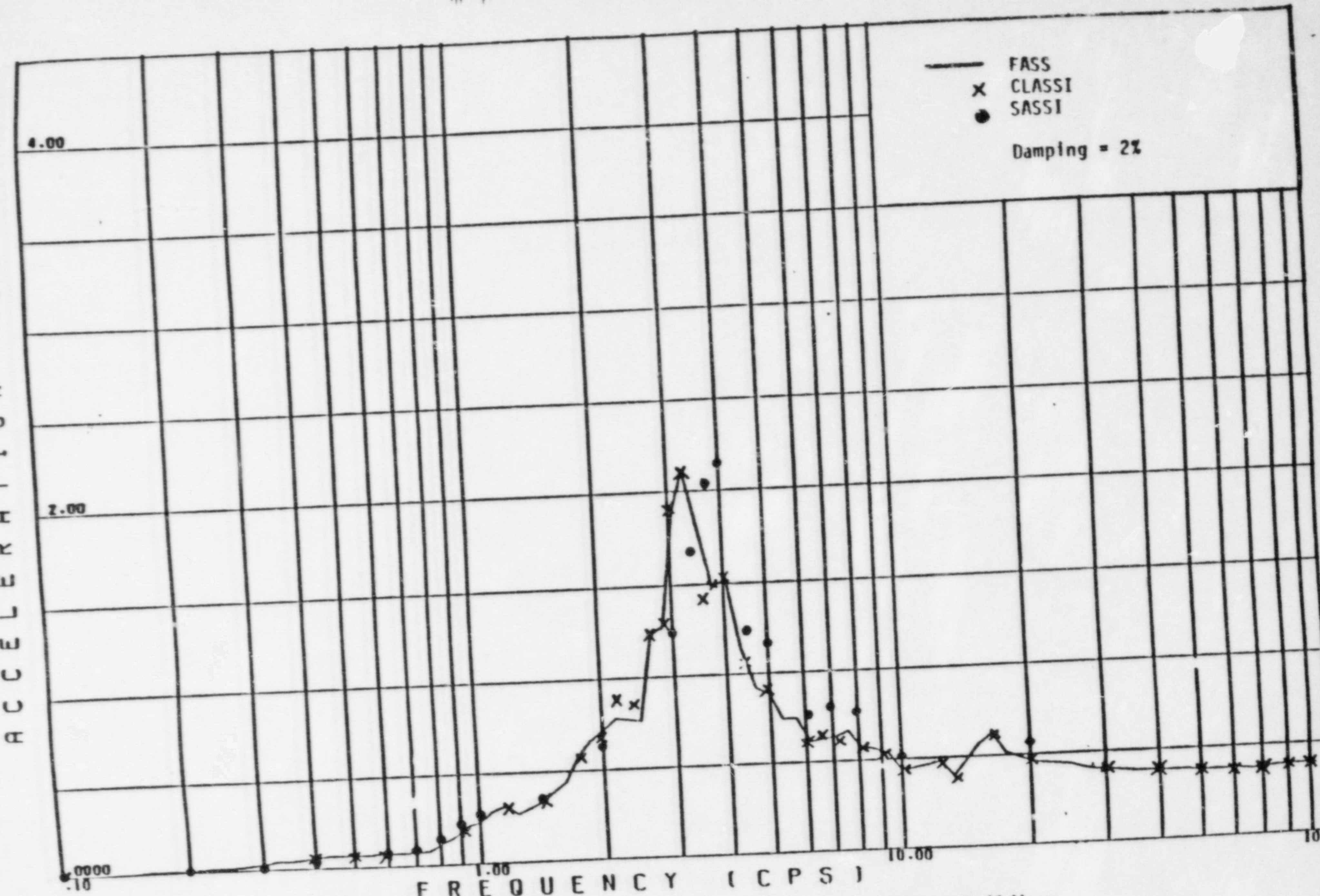


Fig. 7-7(h) Absolute Acceleration Response Spectrum at the Top of Containment Building (SASSI Test Problem No. 7)

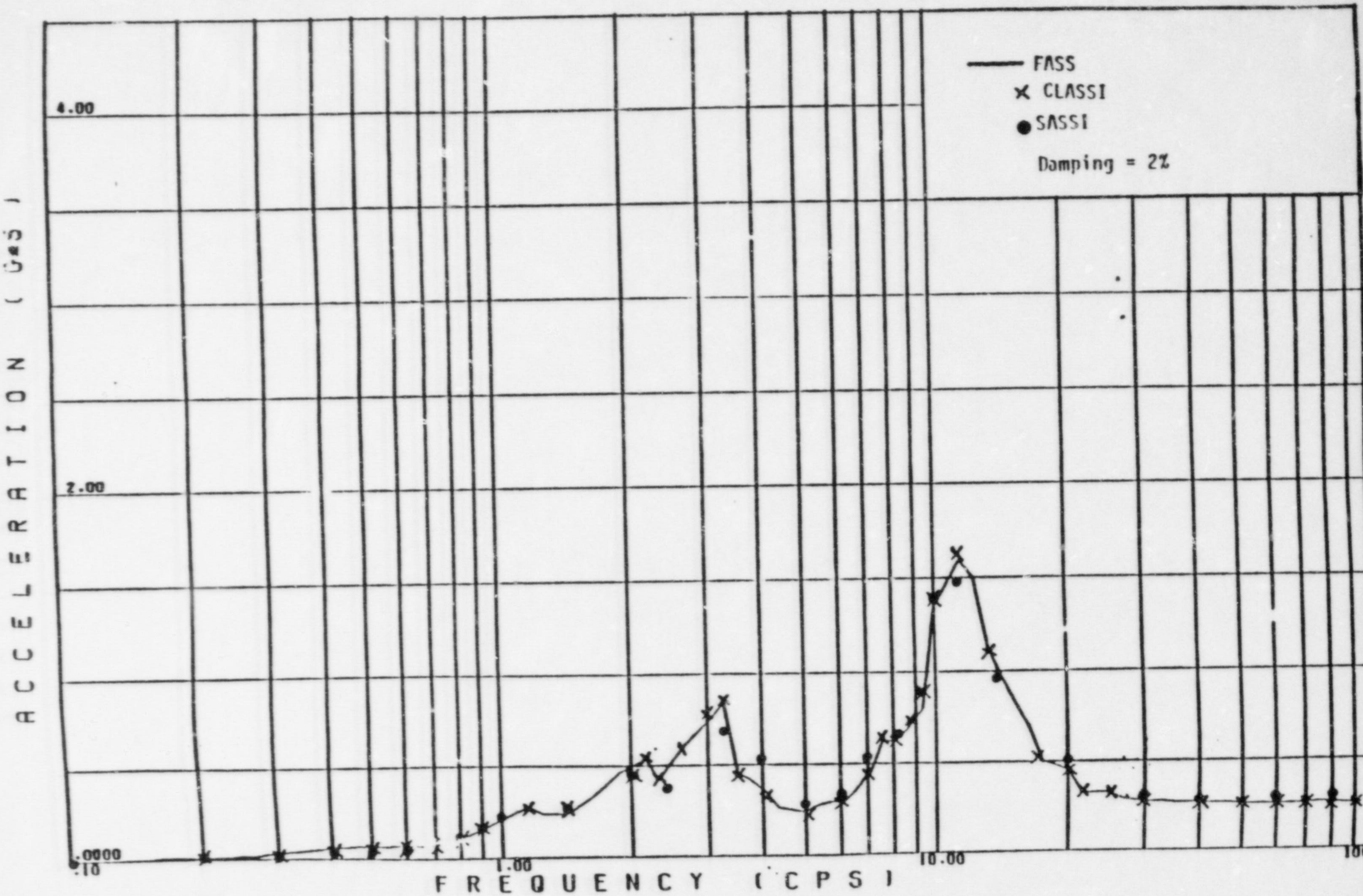


Fig. 7-7(i) Absolute Acceleration Response Spectrum at the Top of Internal Structure
(SASSI Test Problem No. 7)

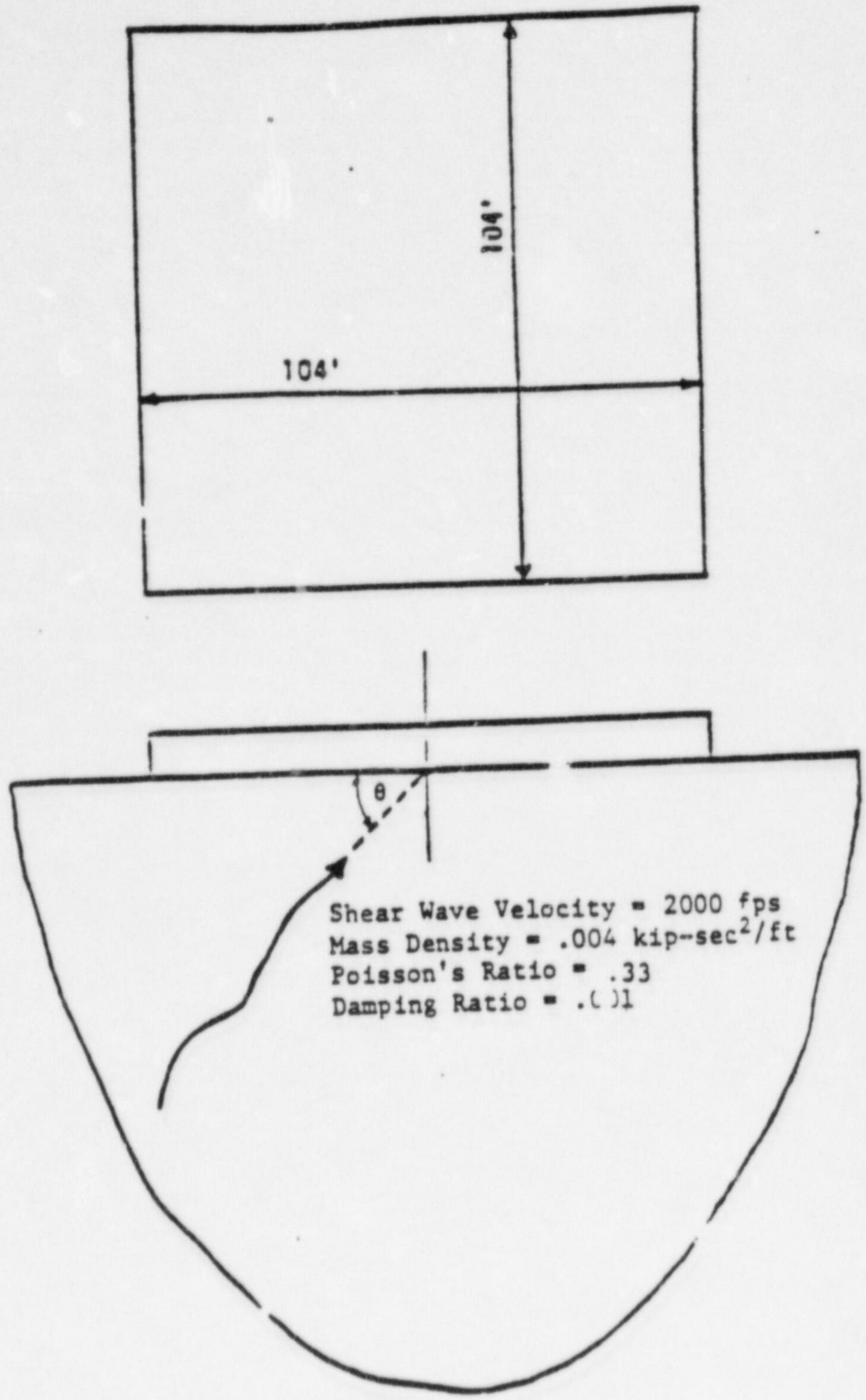


Fig. 4.2-3.1 Square Foundation on Elastic Half-space

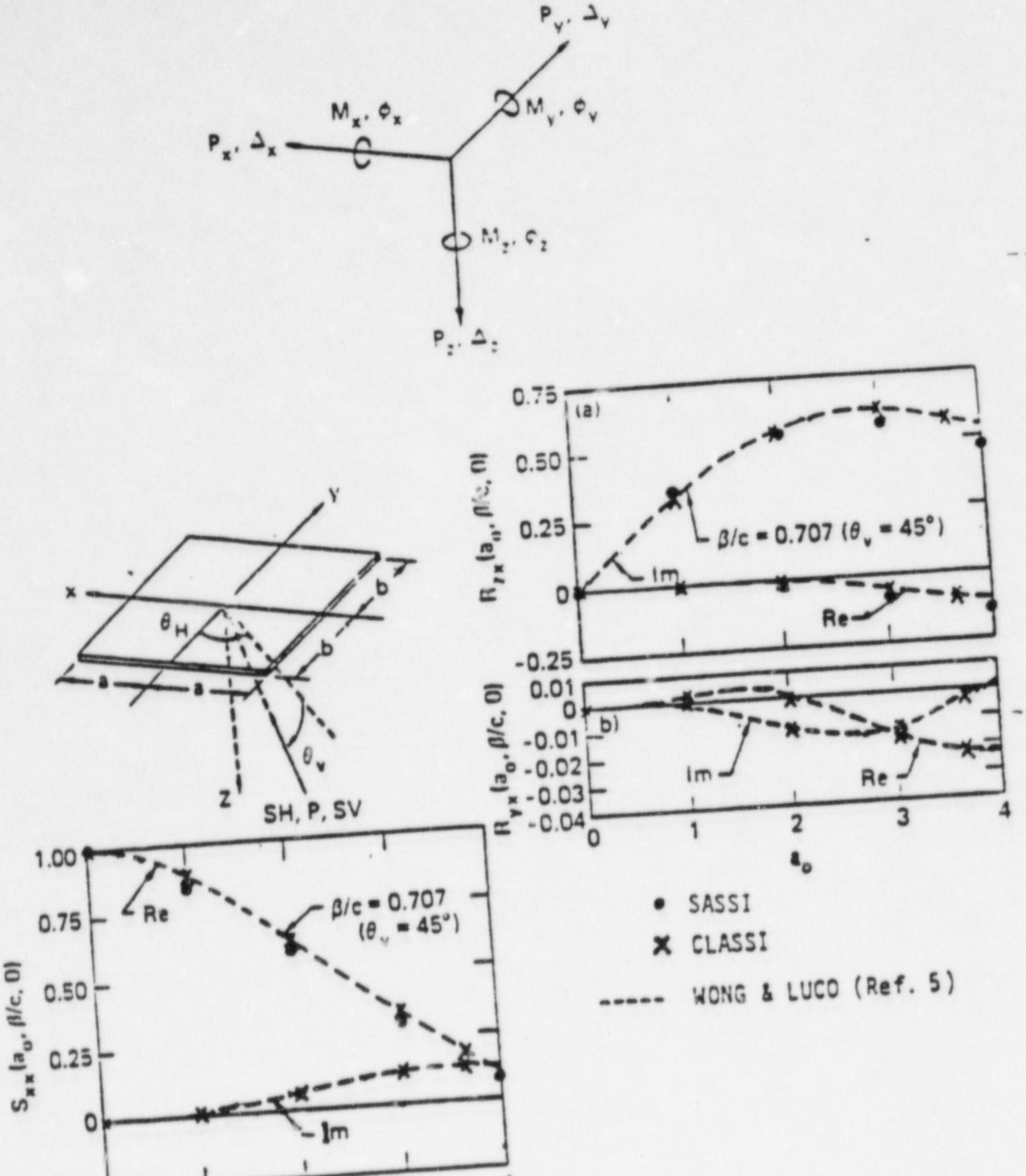


Fig. 4.2-3.2 Scattering Elements for Inclined SH-Wave

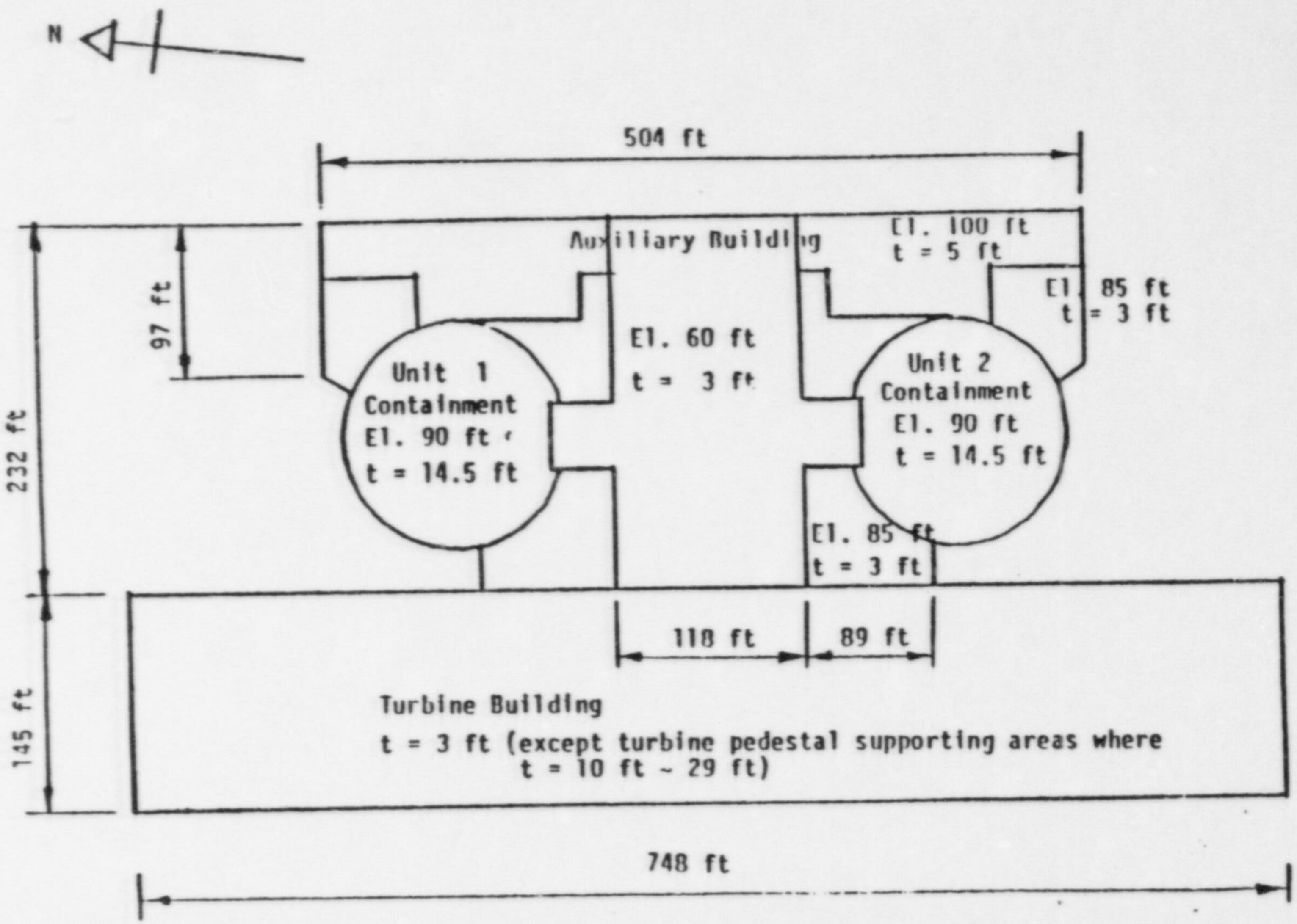
TASK 4.1 REVIEW OF EXISTING DYNAMIC MODELS OF POWER BLOCK STRUCTURES

(1) REVIEW OF EXISTING DCPP STRUCTURAL MODELS OF POWER BLOCK STRUCTURES

(2) DEVELOPMENT OF CONCEPTUAL MODELS

(3) IDENTIFICATION OF WORK REQUIRED TO COMPLETE THE MODEL DEVELOPMENT

- o CONTAINMENT MODEL
- o AUXILIARY BUILDING
- o TURBINE BUILDING AND TURBINE PEDESTAL



Note: All elevations are at top of mat.

Fig. 1.1 Foundation Mats of Power Block Structures

WORK REQUIRED TO COMPLETE THE MODEL DEVELOPMENT

CONTAINMENT STRUCTURES

(1) RECONSTRUCT THE AXISYMMETRIC DOME MODEL FOR THE DOME PORTION OF CONTAINMENT AND CALCULATE THE MODAL PROPERTIES.

(2) CALCULATE THE 3-D 9-MASS MODEL PROPERTIES FROM THE EXISTING MODEL AND THE DOME MODEL.

(3) CONSTRUCT A 3-D MULTIPLE-STICK MODEL FOR THE INTERNAL STRUCTURE FROM THE EXISTING MODEL.

(4) EVALUATE THE ECCENTRICITIES OF THE INTERNAL STRUCTURE.

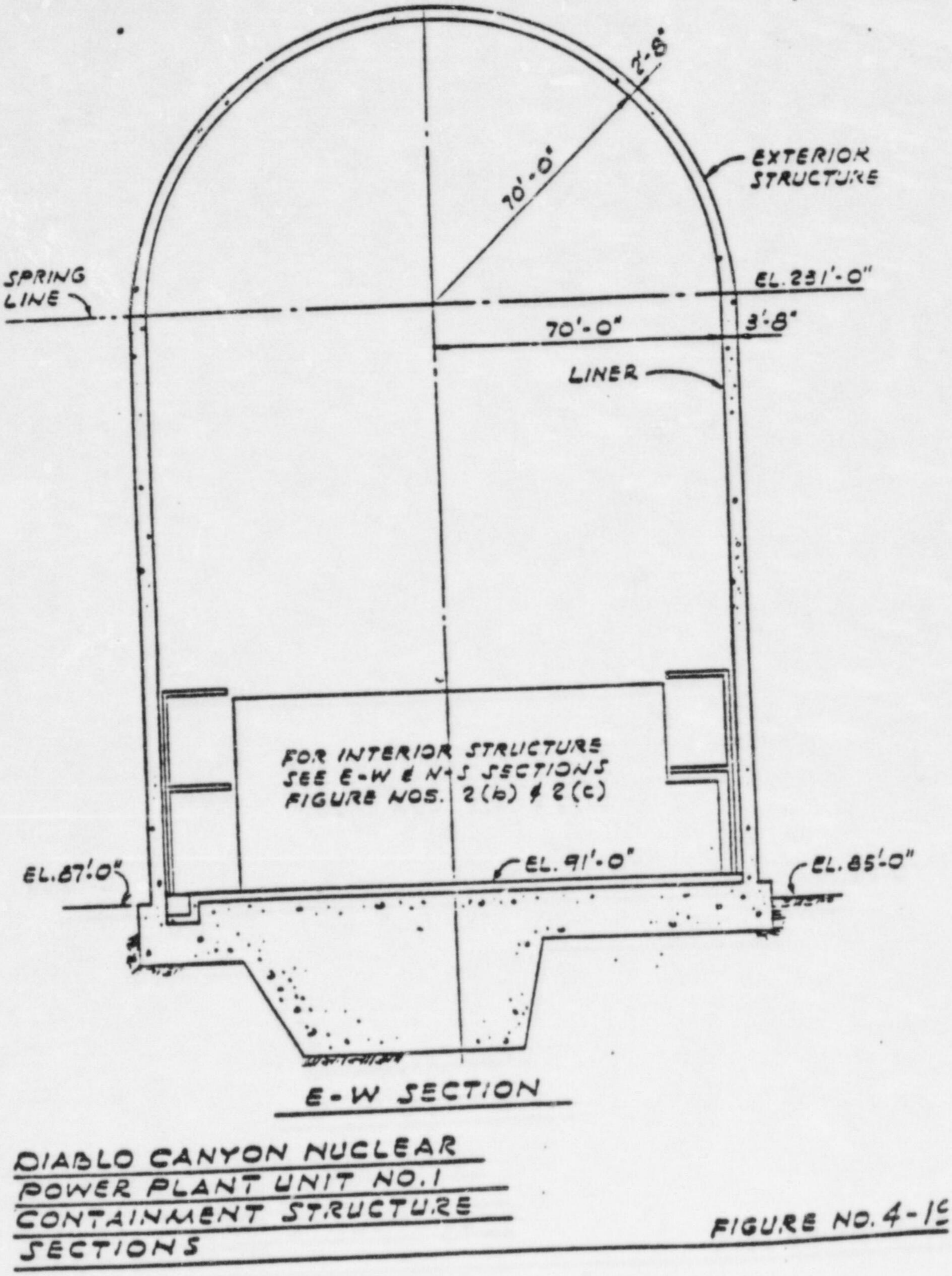


Fig. 2.1 E-W Section of Containment Structure (Ref. 1)

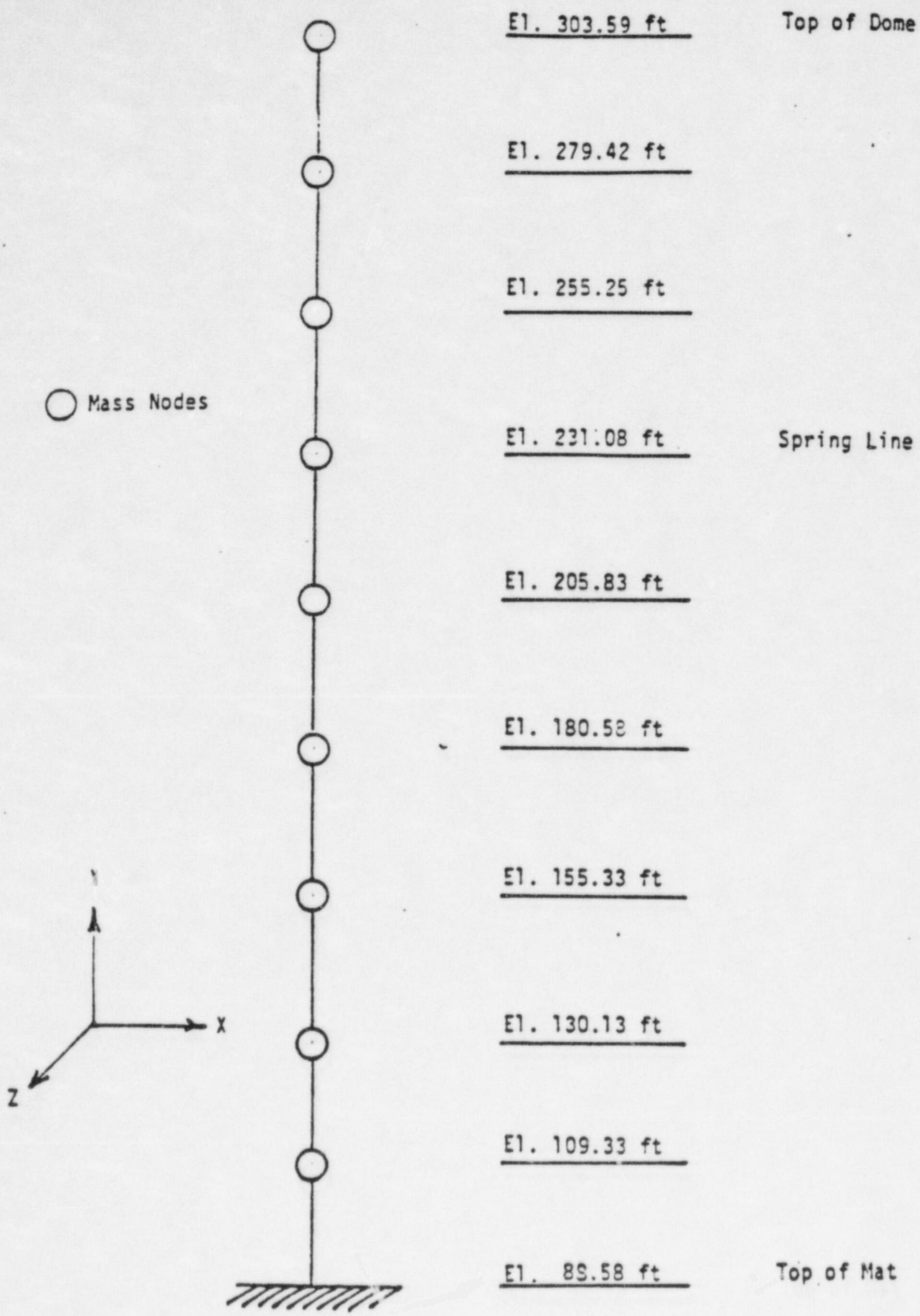


Fig. 2.7 9-Mass Stick Model for Exterior Shell (Ref. 2)

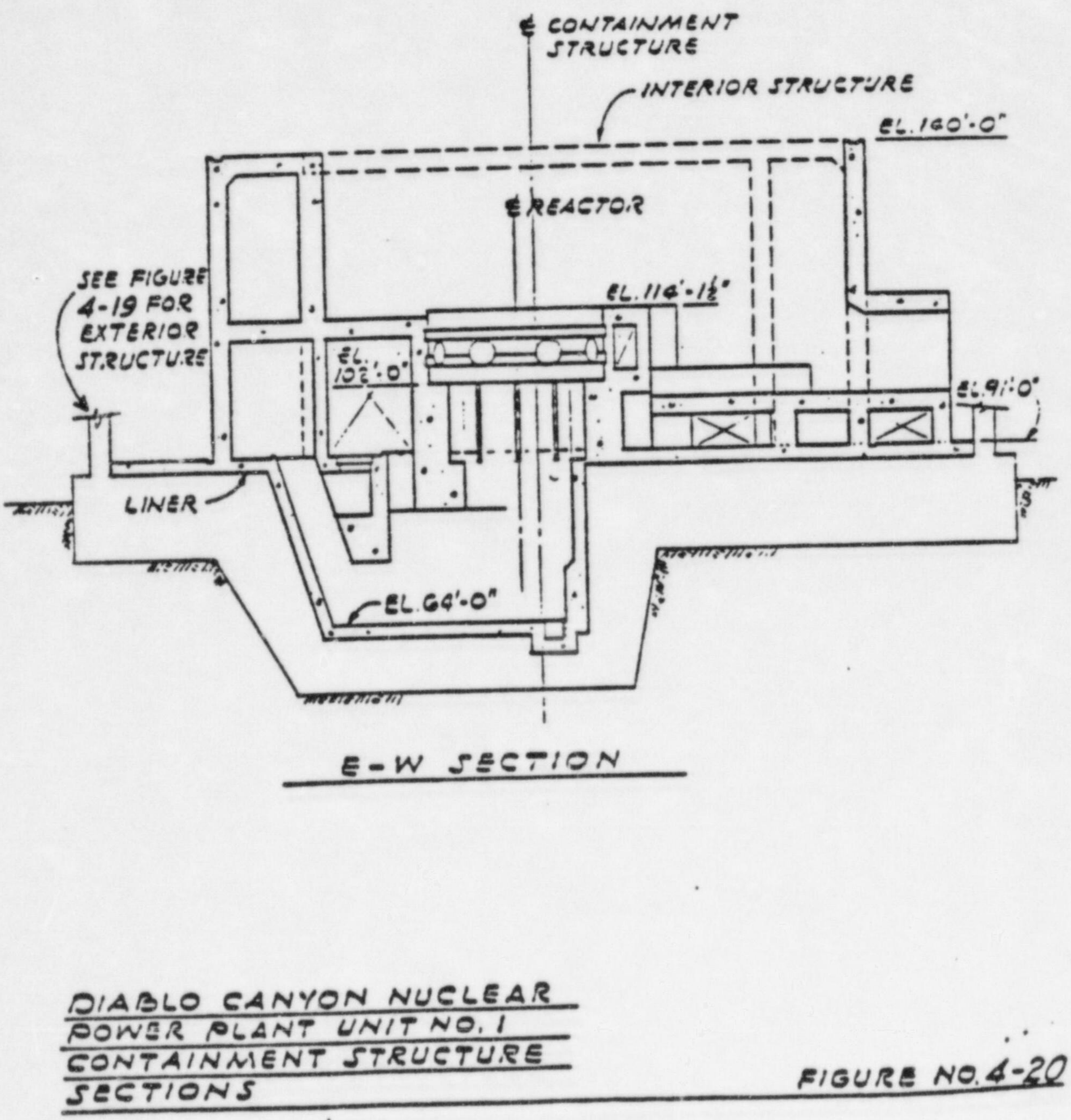


Fig. 2.2 E-W Section of Internal Structure (Ref. 1)

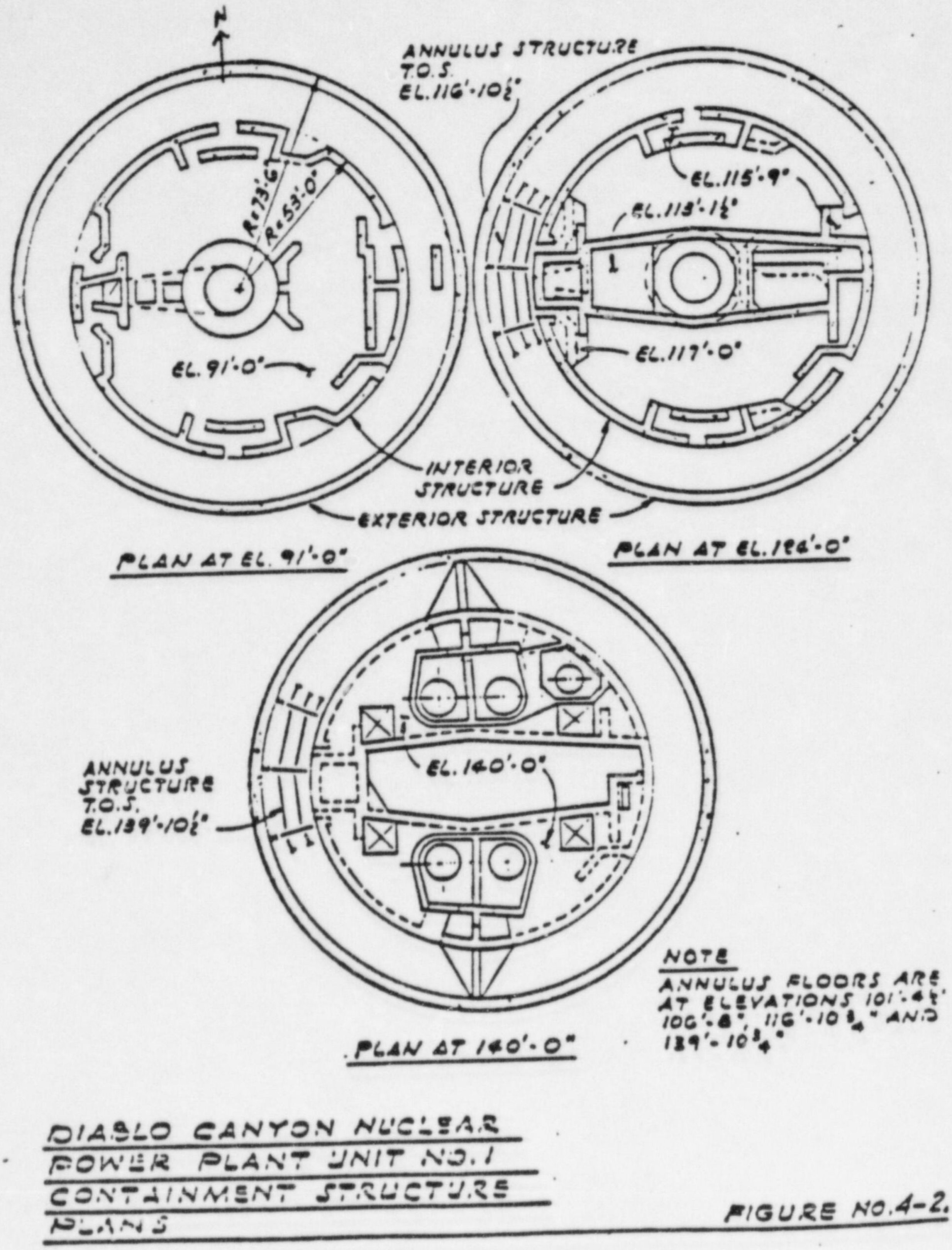


Fig. 2.4 Plan View of Containment Structure (Ref. 1)

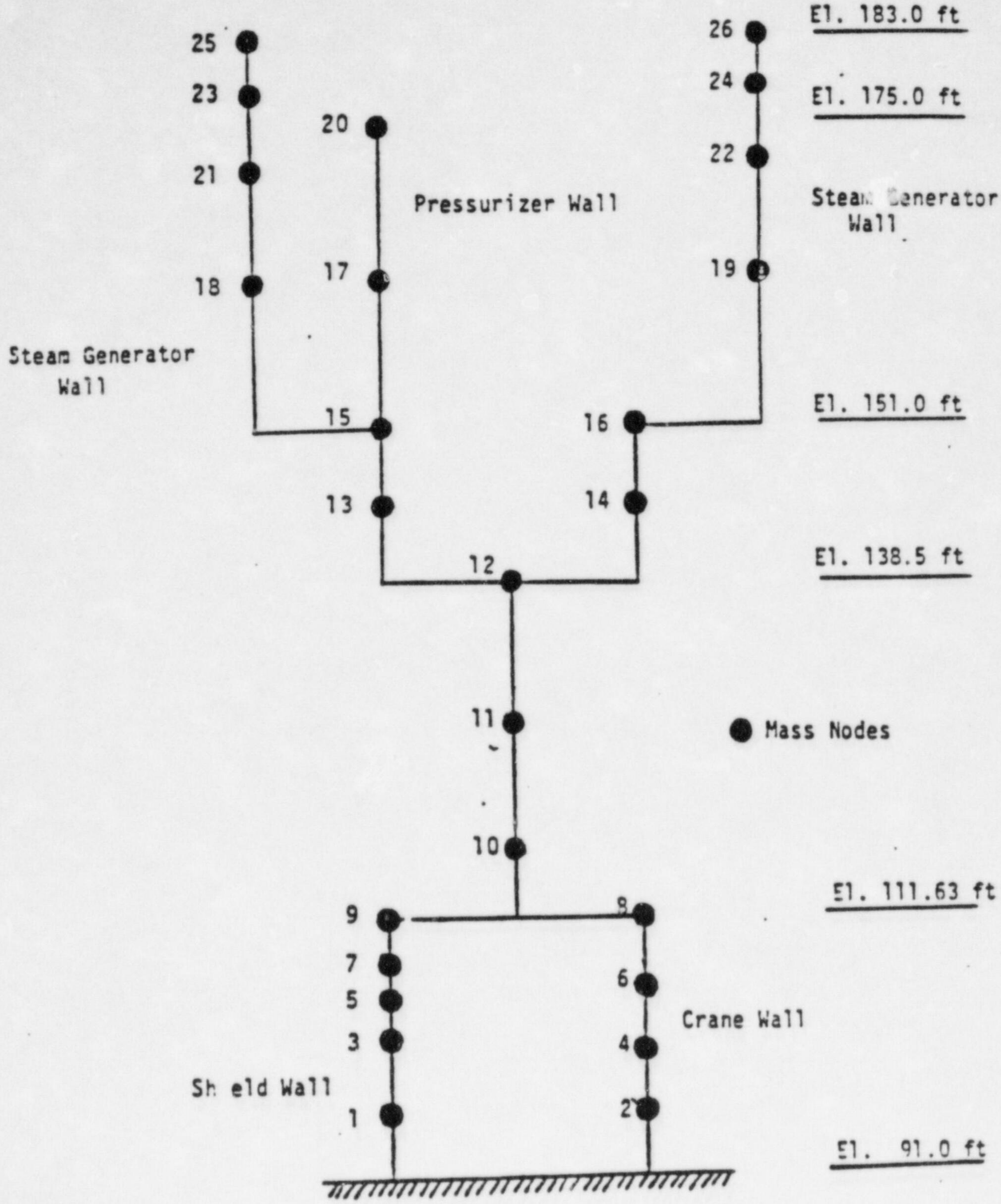


Fig. 2.8 2-D 26-Mass Multiple-Stick Model for Internal Structure (Ref. 3)

WORK REQUIRED TO COMPLETE THE MODEL DEVELOPMENT

AUXILIARY BUILDING

(1) EVALUATE THE MODEL PROPERTIES FOR THE N-S DIRECTION USING THE EXISTING 3-D FEM MODEL RESULTS.

(2) CALCULATE THE IN-PLANE DIAPHRAGM STIFFNESSES FROM THE EXISTING 3-D FEM MODEL RESULTS.

(3) EVALUATE THE ECCENTRICITIES.

(4) CALCULATE THE EFFECTIVE MASS-AND-SPRING SYSTEMS FOR THE VERTICAL FLOOR FLEXIBILITIES FROM THE EXISTING FLOOR MODELS.

(5) DEVELOP A 3-D LUMPED-MASS MULTIPLE-STICK MODEL.

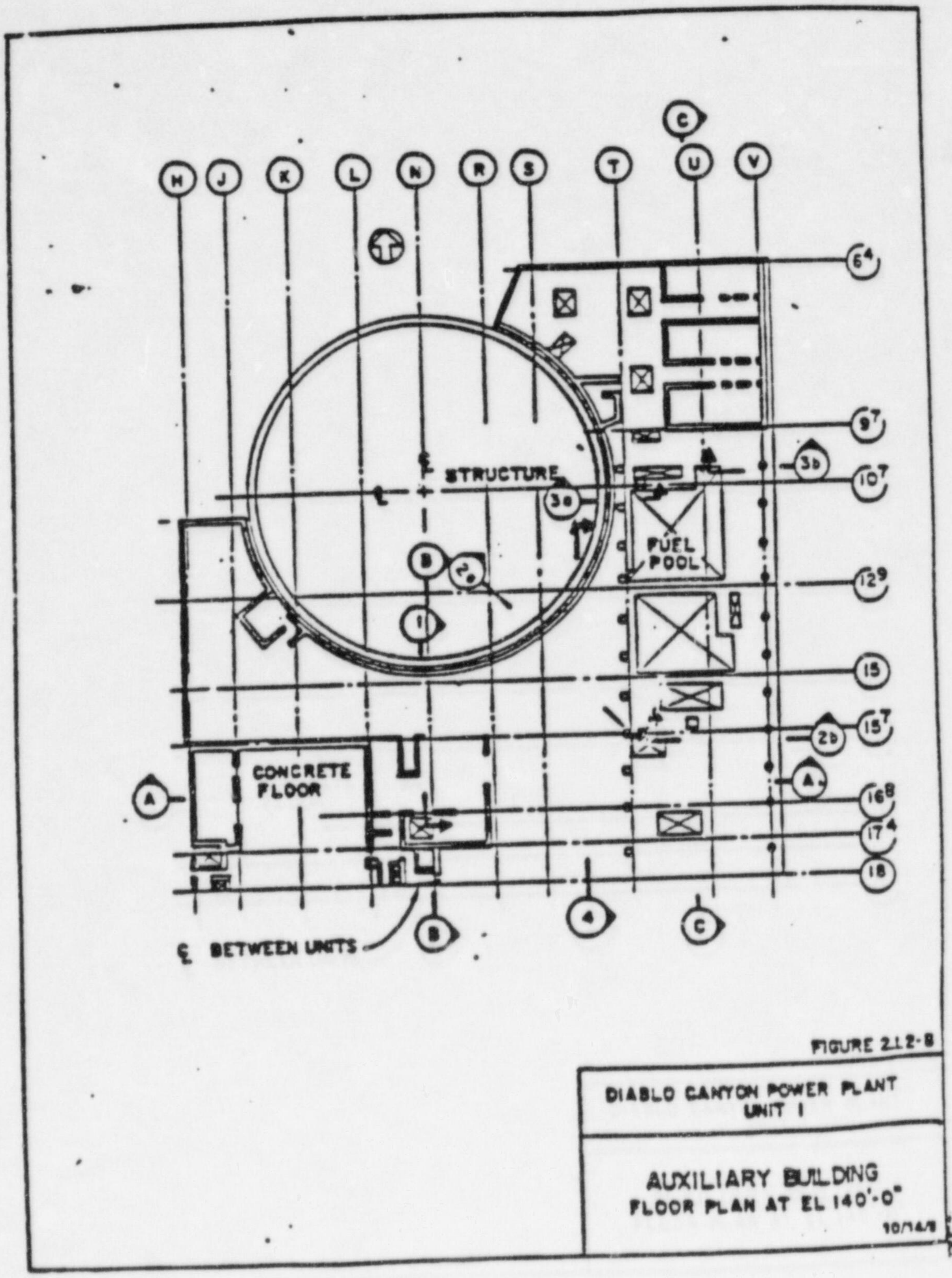


Fig. 3.1 Auxiliary Building, Floor Plan at El. 140 ft (Ref. 4)

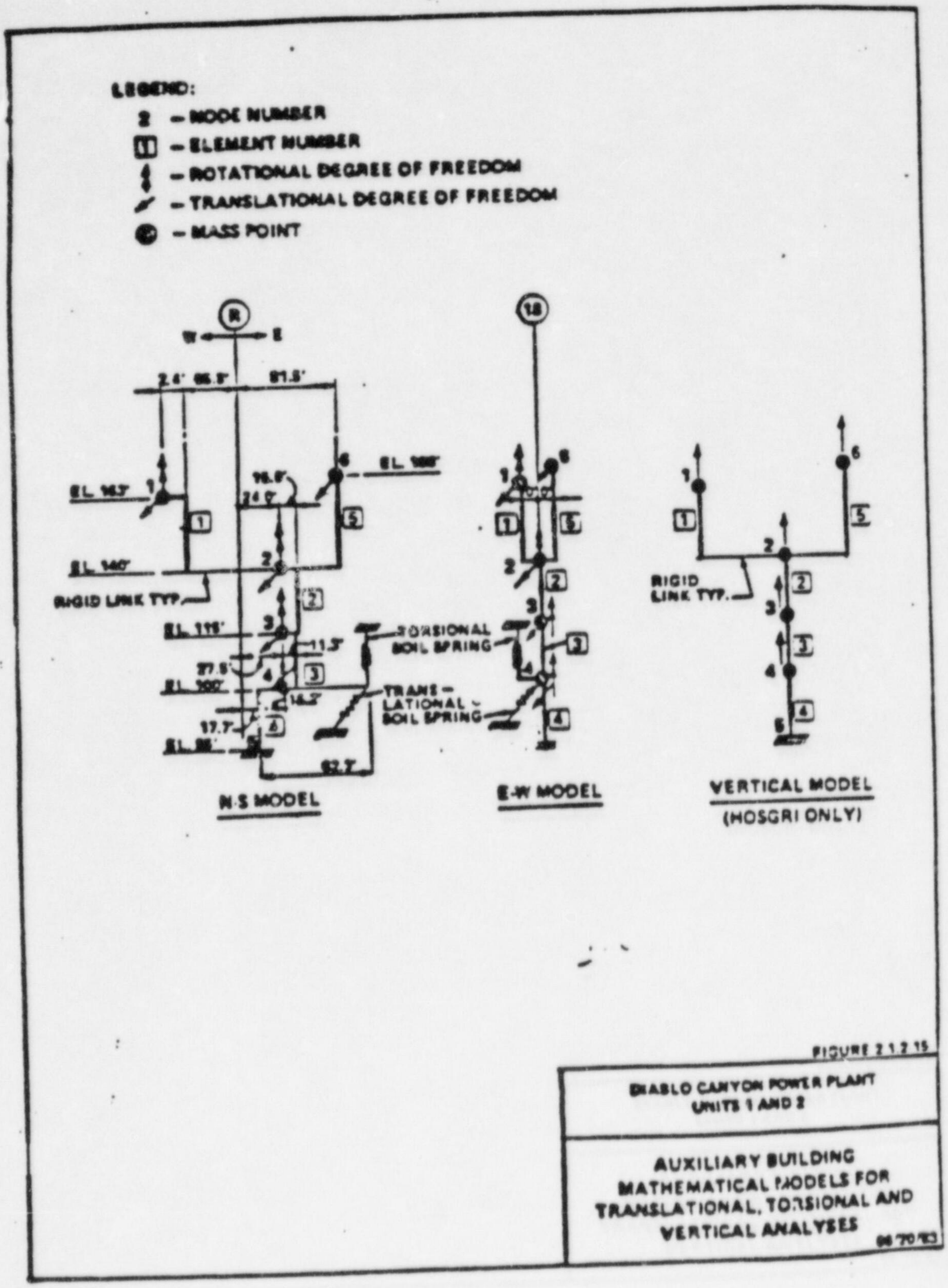


Fig. 3.8 5-Mass Stick Models for Auxiliary Building (Ref. 4)

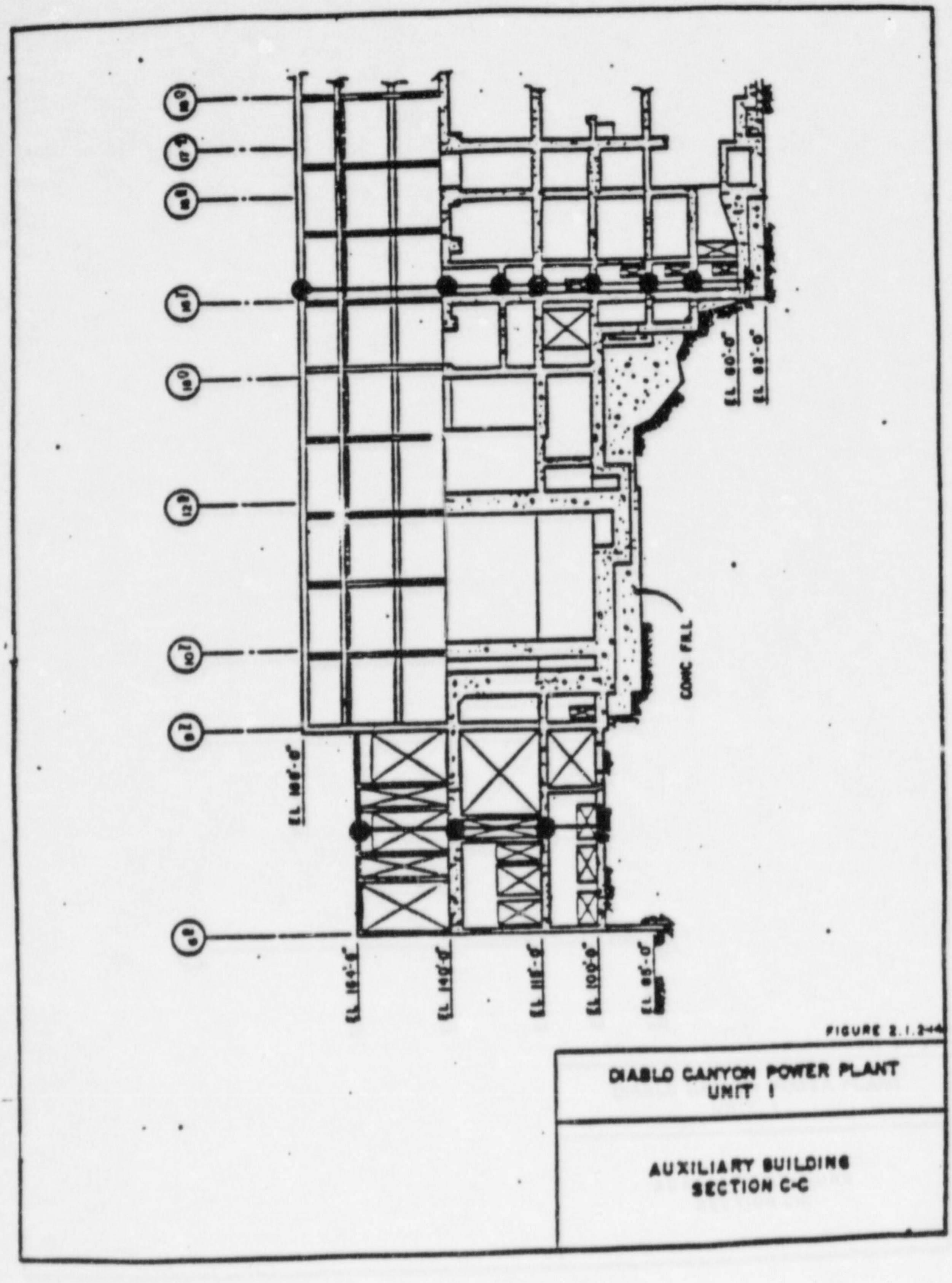


Fig. 3.7 Auxiliary Building, Section C-C (Ref. 4)

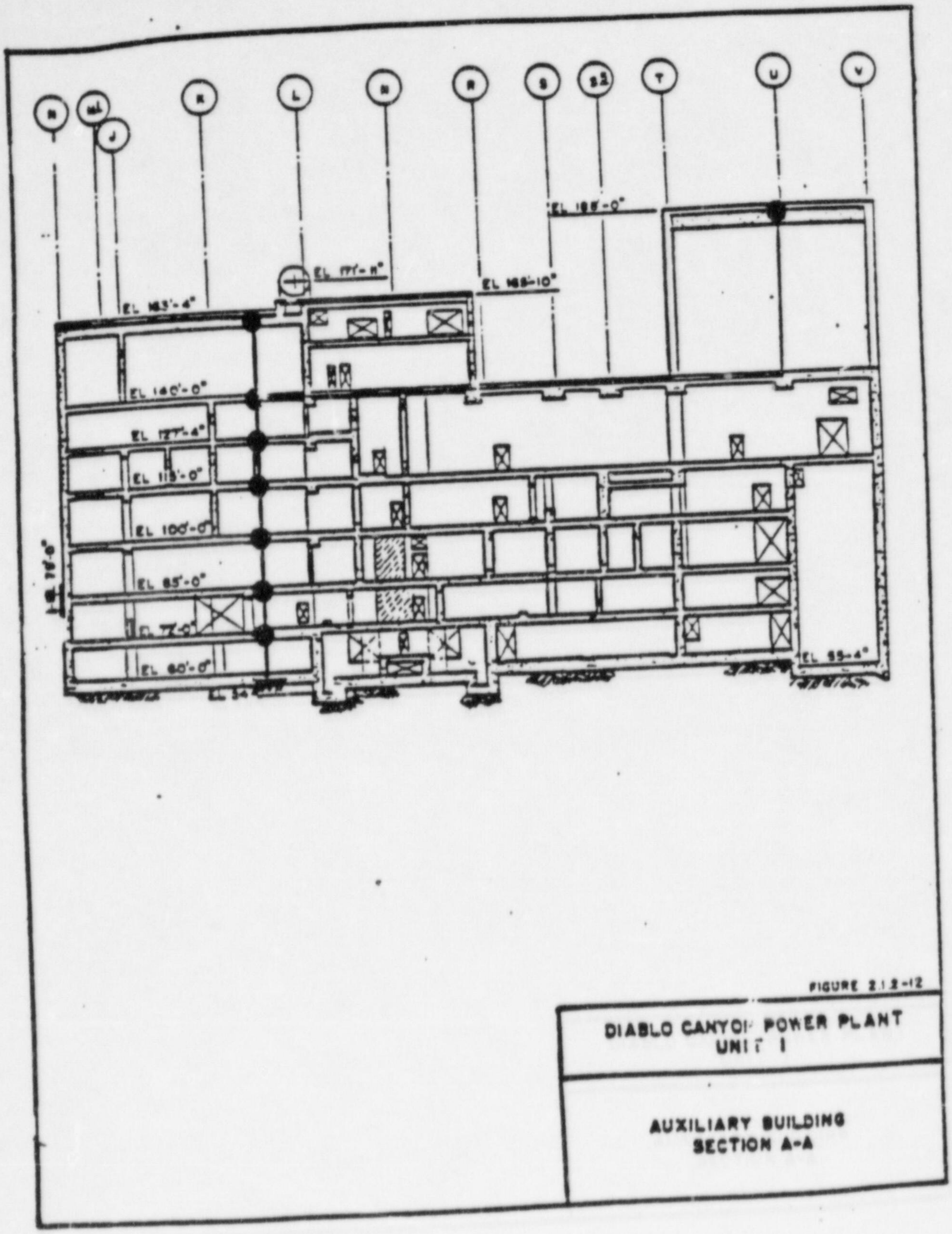


Fig. 3.5 Auxiliary Building, Section A-A (Ref. 4)

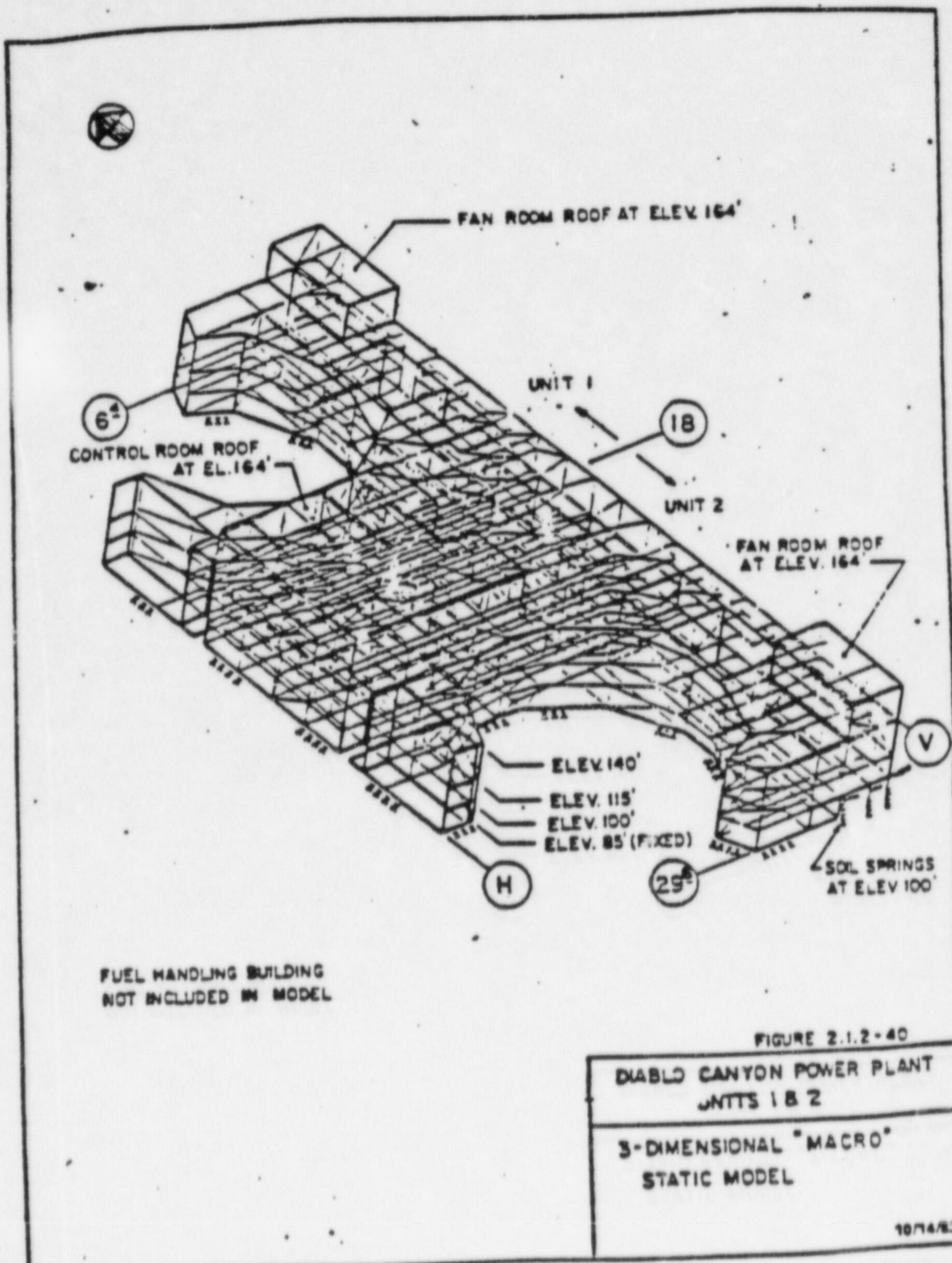


Fig. 3.9 3-D Detailed FEM Model for Auxiliary Building (Ref. 4)

WORK REQUIRED TO COMPLETE THE MODEL DEVELOPMENT

TURBINE BUILDING

(1) DEVELOP APPROPRIATE STICK MODEL REPRESENTATIONS FROM THE STATIC DISPLACEMENTS OF THE EXISTING 3-D MODELS.

(2) DETERMINE THE STRUCTURAL PROPERTIES OF STICKS AND CONNECTING BEAMS.

(3) CALCULATE THE LUMPED MASSES FROM THE EXISTING MODELS.

(4) EVALUATE THE ECCENTRICITIES

(5) CALCULATE THE EFFECTIVE MASS-AND-SPRING SYSTEMS FOR THE VERTICAL FLOOR FLEXIBILITIES FROM THE EXISTING FLOOR MODELS.

(6) DEVELOP A 3-D LUMPED-MASS MULTIPLE-STICK MODEL.

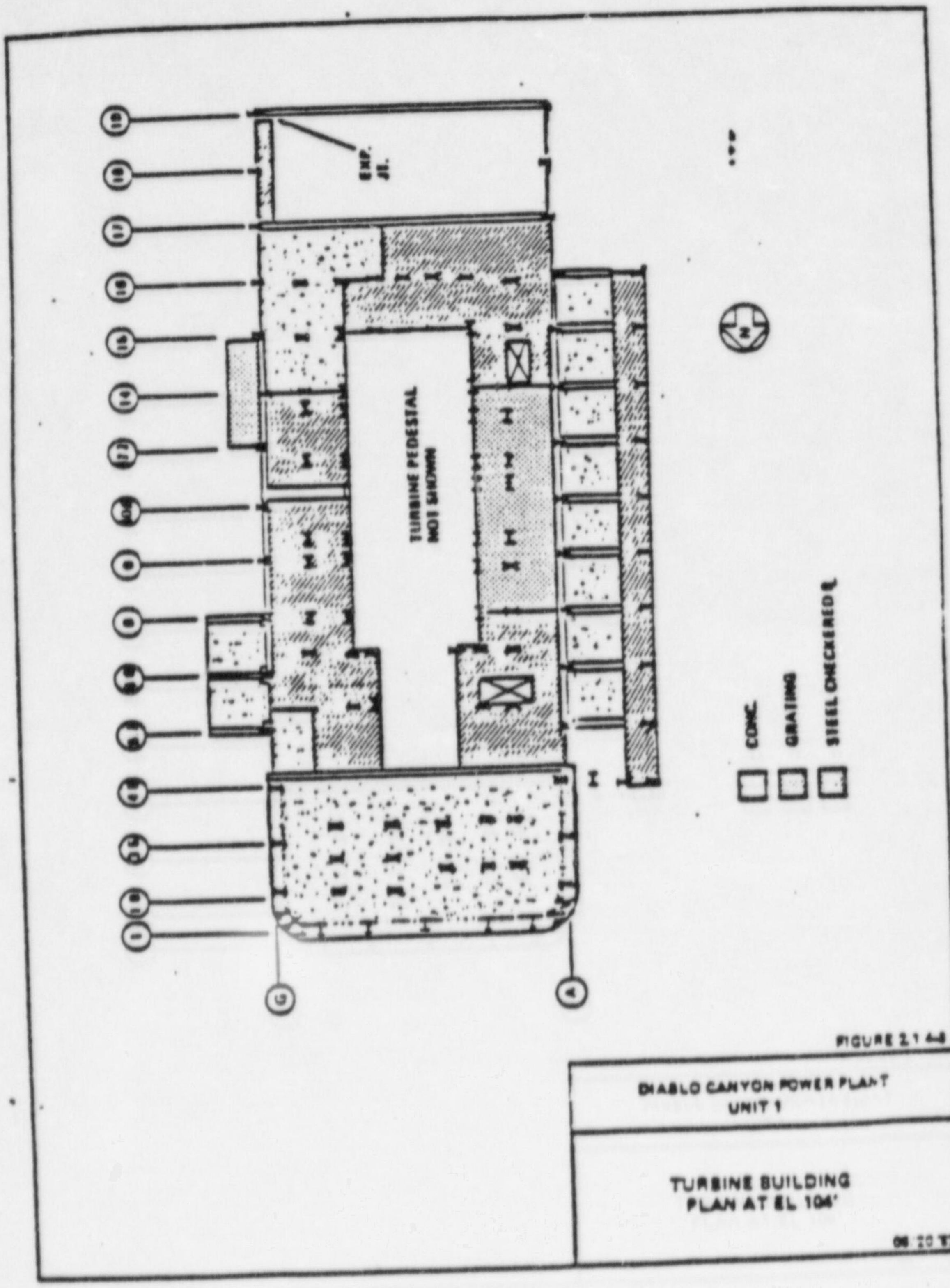


Fig. 4.2 Unit 1 Turbine Building, Floor Plant at El. 104 ft (Ref. 4)

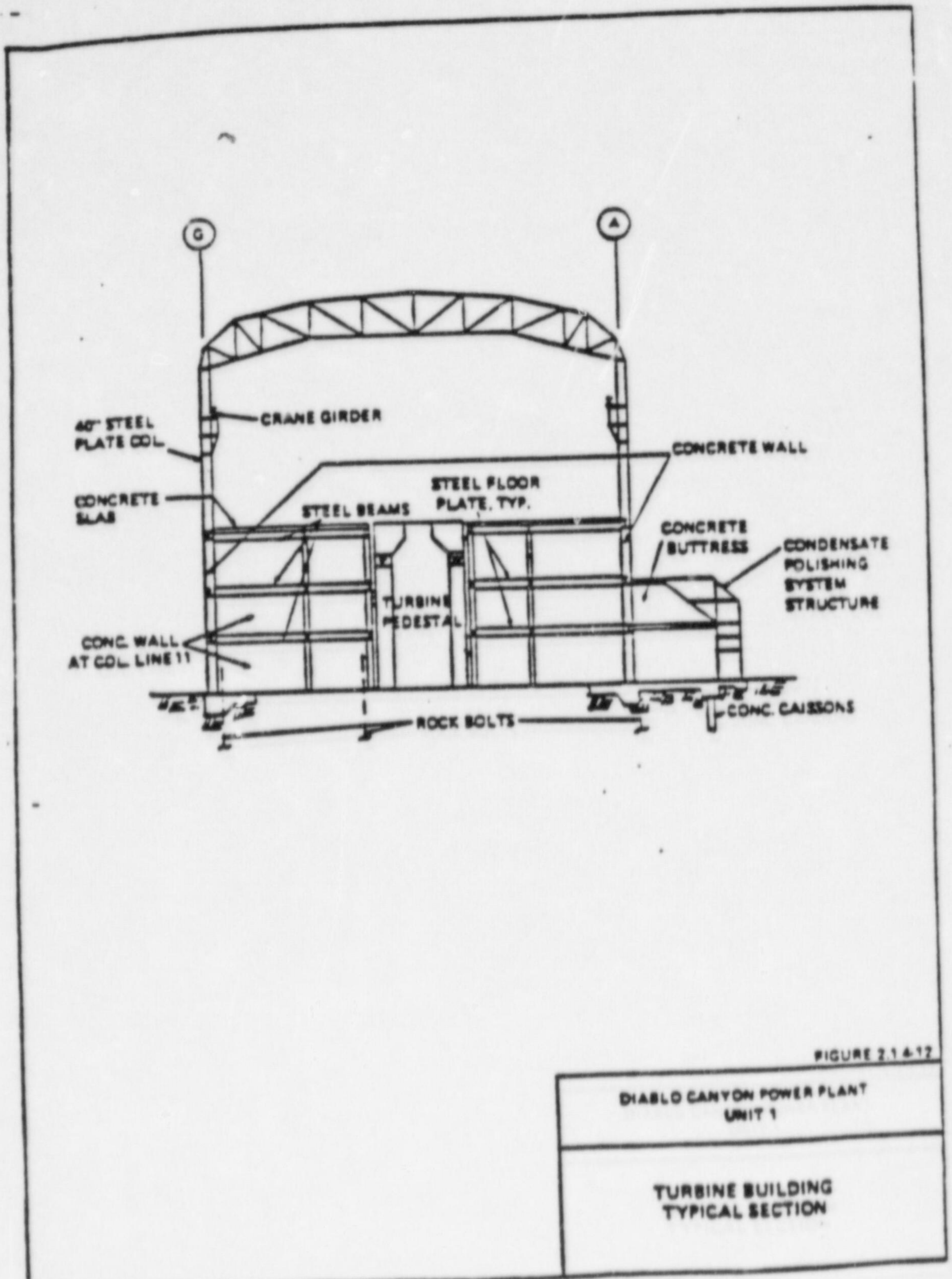


Fig. 4.6 Unit 1 Turbine Building, Transverse Section (Ref. 4)

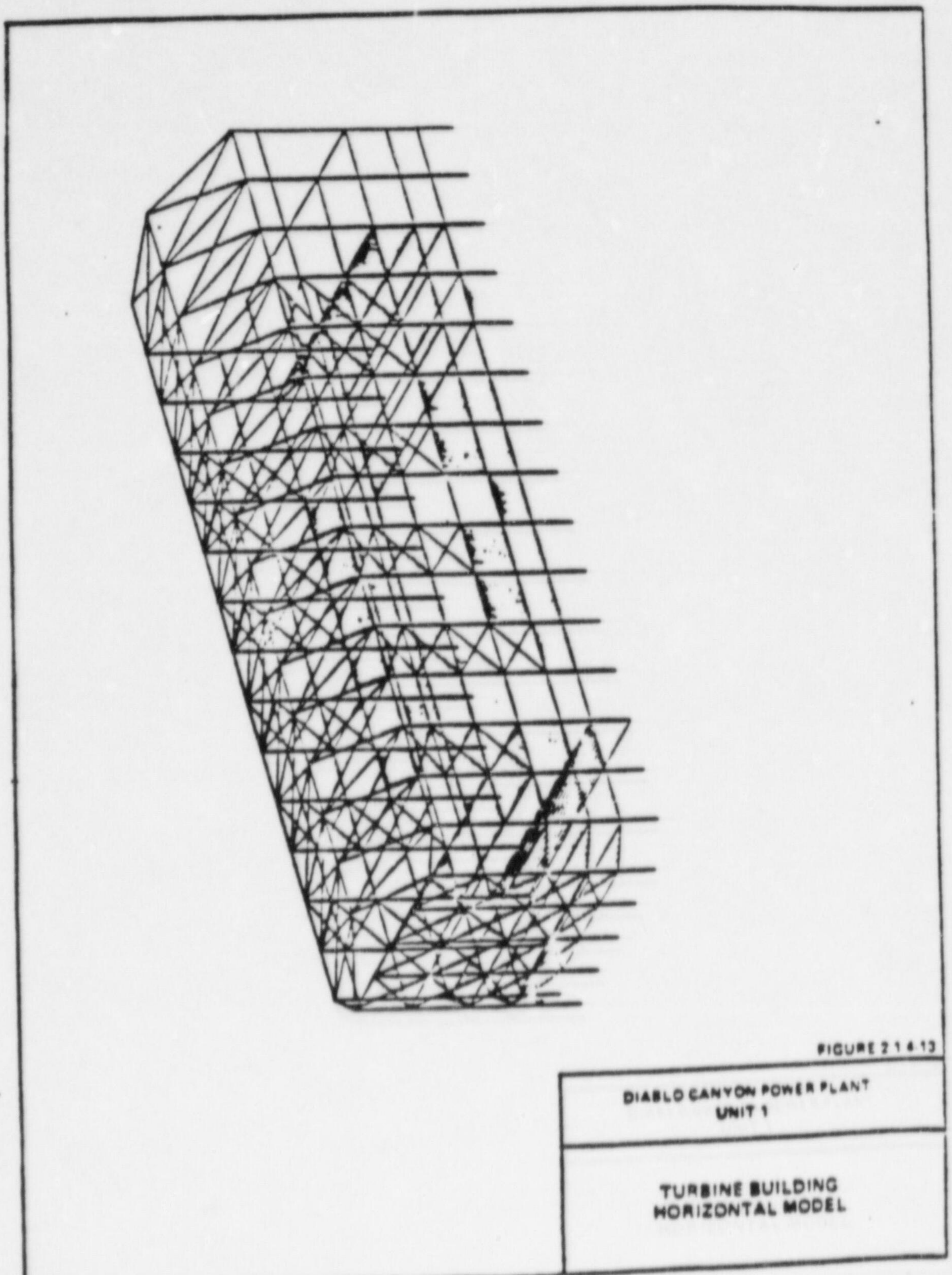


Fig. 4.7 3-D Detailed FEM Model for Unit 1 Turbine Building (Ref. 4)

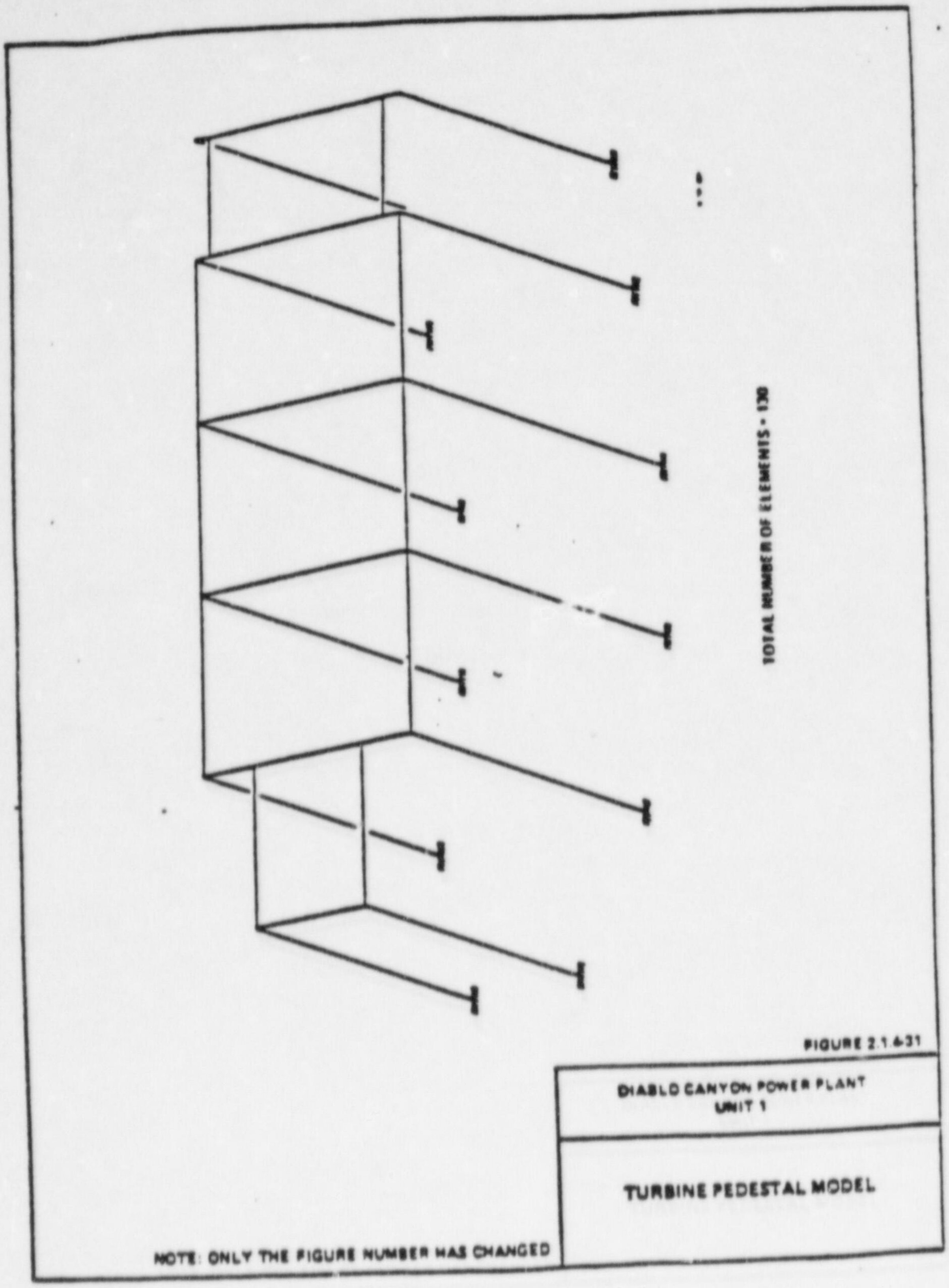


Fig. 4.19 Turbine Pedestal Model (Ref. 4)