Enclosure 3d

George A. Thompson
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October 25, 1986

To: ACRS, via Richard Savio
From: George A. Thompson
Subject: The NRC/PG&E Workshop on the Diablo Canyon Long Term Seismic Program, held in San Francisco October 21-24

I was in attendance on the first three of the four days, although I had to leave in mid-afternoon on the 22nd and 23rd to teach classes. The Geology/Geophysics aspects were covered during the first two days and Ground Motions on the last two days. The workshop was important in bringing to light important new evidence on the seismotectonics of a large region around the Diablo Canyon site and in outlining the plans for continued studies.

The Hosgri fault, which lies a few km seaward of the plant, is a major focus of investigations. Northward the Hosgri zone projects on land at San Simeon (although some branches may detour seaward), and the San Simeon studies are meeting with great success. There the fault strands that have been trenched are vertical and have nearly horizontal slickensides. This is a strike-slip fault with all of the usual characteristics of California strike-slip faults. Offset shoreline angles (base of ancient seacliff) on uplifted marine terraces yield a right-lateral rate of about 5mm/yr. for about 200,000 years. Ongoing age dating and soil studies will refine and test this preliminary conclusion. It seems certain, however, that the San Simeon part of the Hosgri zone is a strike-slip fault with a rate about one order of magnitude less than the San Andreas zone.

PG&E is in the process of obtaining (or has obtained) major sets of seismic reflection and deep refraction images of the crust both inland and seaward of the plant. This program brings to bear the best modern technology and is certain to shed much new light on the structural complexities of the region. The seaward part is aimed especially at problems of the nature of the Hosgri fault.

Attention is also directed to a vague zone composed of the Santa Maria River fault, the Oceano monocline, the Pismo fault, and the San Miguelito fault. This zone assumes special significance because one element of it, the San Miguelito fault, projects close to the plant. A variety of studies is in progress. The Edna, San Miguelito, Casmalia and other faults are oblique to the coastline and project toward, and seem to be truncated by, the Hosgri fault. No similar oblique faults are known to the west of the Hosgri. It is hoped that the existing and to-be-acquired seismic reflection data will clarify the inter-relationships of these faults.

PG&E's extensive earthquake monitoring network is partly in place, with additional instruments to be delivered soon. Meanwhile, studies of focal mechanisms, locations, and depths, and a thorough re-study of the 1927 Lompoc earthquake are excellent. The moment magnitude of the Lompoc is about 6.8, compared to 6.6 for the Coalinga earthquake. The Lompoc earthquake was generated on a northerly striking reverse fault, dip 66°, at a depth of about 10km. Smaller earthquakes throughout the region do not cluster closely on faults. Seismicity cuts out at a depth of 10-14km, below which presumably the rocks are hot enough to be ductile. Maximum compressive stress is N-S to NNE. The larger earthquakes are compressional (strike-slip or reverse).

To summarize the Geology/Geophysics studies, a central objective is to define the geometry and rates of movement of both faults and folds (which may be the surface expressions of underlying faults). Most of the faults in the region are classified as having late Quaternary displacement rates of 0.1 to 1mm/yr. A few (the Rinconada, San Simeon-Hosgri, and in the Transverse Ranges, the Santa Ynez) have rates of 1.1 to 10mm/yr. Only the San Andreas has a rate in excess of 10mm/yr.

The Geology/Geophysics studies summarized above provide inputs to the Ground Motion studies, in which both deterministic and probabalistic studies are going on in parallel. The NRC staff was effective in challenging and exploring the methodology and assumptions of the analyses. The Ground Motion studies, like the Geophysical studies, are pushing the scientific frontiers.

Clearly PG&E is conducting the most intensive, well-integrated study that I have seen in connection with any site. The personnel involved on all sides are the most knowledgable available. However, we must be alert for overlooked details.

George Thompson

George A. Thompson
Geophysicist

Enclosure 4a

NRC Staff Comments
Diablo Canyon LTSP Ground Motion
Workshop on October 23 and 24, 1986

1. Selection of records based on whether the recording site is a "rock" site or a "soil" site requires close scrutiny and should reflect proper identification with respect to the Diablo Canyon Plant site conditions. In addition, the duration of strong ground motion has a significant influence on structural response. Consequently, this factor requires proper attention also.

2. The use of empirical Green's functions appears to be promising. However, using the Imperial Valley earthquake records alone may not be sufficient to determine uncertainties associated with site conditions.

3. The establishment of a seismometer array to estimate earthquake wave coherency/incoherency is a commendable move on the part of the licensee. It can be expected to provide valuable information to verify the use of incoherency in the soil-structure-interaction (SSI) analysis.

4. The use of data from small earthquakes to estimate local site conditions by comparing them to USGS data available for other locations appears to be very useful.

5. The estimation and use of angles of incidence of seismic waves should be approached with caution.

6. Communication between the earth scientists and the engineers, engaged in the LTSP, should be emphasized to make both parties aware of the manner in which geophysical data are utilized to obtain engineering parameters. For instance, the procedure for evaluating effects of spatial incoherency of ground motion on the SSI analysis was not presented in sufficient detail.

7. Based on the questions posed at the meeting, it is imperative that at certain milestones in the LTSP program, the assumptions made to facilitate analysis and the uncertainties associated with the entire process are discussed in detail and properly documented.

8. Additional comments received from the staff's consultants since the October meeting identify several issues which, in their opinion, may significantly impact of the LTSP results; for example, the use of the Imperial Valley Earthquake records as discussed above, the definition of f-max (maximum frequency in the acceleration spectra), and departure from the ω^2 - scaling model. These concerns need to be addressed by the licensee.

Enclosure 4b

DEPARTMENT OF GEOLOGICAL SCIENCES
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28 October 1986

Dr. Jean Savy
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Dear Jean:

This is my letter report on the Diablo Canyon LTSP ground motion workshop held on 23 & 24 October in San Francisco. At the end of the workshop, Leon Reiter summarized the general feeling of NRC representatives and consultants as "considerable progress has been made in the right direction". The more I think about the presentations at the workshop, the more I become concerned about the approach they have been taking.

There are several important issues we should have brought out and addressed more clearly. They are:

(1) The use of an aftershock of the Imperial Valley earthquake as the empirical Green's function is inappropriate for the Diablo Canyon site, because the deep sediment site in the Imperial Valley attenuates high-frequency while the rock site of the Diablo Canyon does not. In other words, f_{max} (the maximum frequency in the acceleration spectra) will be higher for the Diablo Canyon site than the Imperial Valley site evident in casual comparison of spectra of small earthquakes recorded at Diablo Canyon and the Imperial Valley presented in the workshop. This issue of f_{max} is extremely important for the Diablo Canyon, because we are concerned here with high-frequency ground motions. This key parameter of strong motion was never mentioned in the 2-day presentation by PG and E. There are numerous works by USGS and other groups that demonstrate higher f_{max} for rock sites than for sediment sites. An extensive study of site effect by Phillips and myself (1986, BSSA) also showed that for frequencies higher than about 5Hz, the site effect is dominated by absorption in sediment, while for lower frequencies it is dominated by amplification in sediment due to low impedance. Thus, the rock site can have higher amplitude than the sediment site for frequencies higher than about 5Hz.

I cannot think of any more important issue than the possible high f_{max} at the Diablo Canyon much higher than observed in the Imperial Valley, in view of the vulnerability of the structure to high frequency accelerations.

(2) For small earthquakes, the f_{max} has been attributed primarily to the site effect as mentioned above. The f_{max} of major earthquakes such as the Kern County earthquake of 1952, the San Fernando earthquake of 1971, the Parkfield earthquake of 1966, the Borrego Mountain earthquake of 1968, and the Long Beach earthquake of 1933 has been attributed to the source effect by Papageorgiou and myself (1983, BSSA). As far as these major earthquakes are concerned, I have never seen any

study attributing the f_{max} to the site effect. Since we are concerned with a major earthquake near the Diablo Canyon, it is extremely important to examine the possibility that f_{max} may be determined by the source effect. The f_{max} of major earthquakes mentioned earlier ranges from 3 to 5Hz, which is much lower than the f_{max} of small earthquakes measured at rock sites. Lower f_{max} of course gives lower acceleration. It is, therefore, extremely important to evaluate f_{max} due to the source effect for the earthquake affecting the Diablo Canyon site. Detailed geological, geophysical, and seismological studies may be helpful here, because the f_{max} of a major earthquake appears to be related to the constant corner frequency of small earthquakes, the kink in frequency magnitude relation, the critical weakening slip of fault friction law, and the width of fault zone.

(3) The ω^2-scaling law assumed by the PG and E is a single parameter model (except for the distribution of slip in the case of asperity model). Namely, the seismic moment is the only parameter, and it allows to construct the seismogram of a large earthquake from that of a small one by knowing the moment ratio only. This is a robust approach, because no other parameter than moment is needed for calculating synthetic seismogram. Papageorgiou and myself, in a paper mentioned earlier, however, showed that major California earthquakes did not follow the ω^2 model. They showed that seismic moment alone cannot predict acceleration, but the crucial parameters are the characteristic slip and the fault area. For example, the Parkfield earthquake and the Long Beach earthquake had a similar slip of 30-50 cm, while the Kern County and San Fernando earthquake had slip of several meters although their fault areas are not much different. The information available from geological studies on characteristic slip can be directly used in estimating the parameters of specific barrier model used by Papageorgiou and myself, assuming that the local stress drop is about the same for all earthquakes. This assumption is supported by observations. Thus, with additional geologic information, we can use a multiple parameter model rather than a single-parameter ω^2-model, thereby increasing the accuracy of prediction.

(4) The particular method of randomly synthesising ω^2-model used by PG and E can satisfy the requirement at the lowest and highest frequencies, but underestimate the spectra in between as can be seen in the figures of the paper by Joyner and Boore.

There are other issues, but judging from discussions we had at the workshop they will be addressed adequately by the other consultants. I strongly believe that the issue of f_{max} and the issue of departure from the ω^2-model must be addressed immediately and explicitly by PG and E. They should not be concealed now, because they will eventually come out.

Sincerely yours,

Kei

Keiiti Aki

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Enclosure 4c

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Nov. 17, 1986

Dr. Jean Savy,
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Dear Jean,

Enclosed is my report on the meeting of October 24 and 25 with PG&E concerning the Diablo Canyon Nuclear Power Plant. It took longer than I expected to write it. Also I am including a voucher for five days of consulting, two days for the meeting and three days for the writing the report.

I hope to see you at the AGU meeting in San Francisco. Also, is it possible to get a copy of the reports written by Steve and Kei?

Sincerely,

Ralph J. Archuleta

Ralph J. Archuleta

DCNPP Meeting
Oct. 24, 25 1986

Ralph J. Archuleta

The following are my comments pertaining to the information and strategies presented at the meeting between PG&E with its consultants and the Nuclear Regulatory Commission with its consultants concerning the Long Term Seismic Plan (LTSP) for relicensing Diablo Canyon Nuclear Power Plant (DCNPP). The meetings which I attended were held Oct. 24 and 25, 1986, in the PG&E building in San Francisco.

These comments fall into three categories: (1) the numerical modeling representation of a propagating rupture, (2) the empirical methods for deciding on representative time histories and (3) generalities.

Numerical Modeling

There were two different approaches presented, presumably the latter being the method favored by PG&E. The basic method depends on subdividing the expected faulting area into a number of smaller elements. The ground motion is computed by summing the contribution from each of the elements. Thus the continuous integral (over the fault plane) in the representation theorem [see, for example, *Aki and Richards*, 1980] is replaced by a discrete sum. In the form presented by PG&E there are three factors which are convolved for each element: (1) the source function, (2) the Green's function and (3) the receiver function. Normally one would have the receiver function included within the Green's function. However, because PG&E has been using earthquakes in the Imperial Valley for the source function and for the Green's function, there is a mismatch between the material description at DCNPP and Imperial Valley. This entire mismatch is assumed by PG&E to be resolved by modifying the receiver function to be appropriate for DCNPP. In PG&E's first approach, referred to as the empirical method, the source function is taken to be an M_L 5.0 aftershock that occurred at 23 hr 19 min Oct. 15, 1979 on the Imperial fault [see *Archuleta, 1984, JGR* or *Liu and Helmberger, 1985, BSSA*]. PG&E uses the horizontal ground motion recorded at Holtville and the vertical ground motion recorded at El Centro Array 9 (E09) from this aftershock as the empirical Green's functions. In order to compute synthetic seismograms PG&E must make certain assumptions about the fault plane and the dynamics of the rupture. Three representative fault planes were chosen such that each plane was centered on the DCNPP site. The rupture initiates either at the center or at one end of the fault an propagates with a mean rupture velocity. The time at which any subelement ruptures is given by the mean rupture velocity and a random number with a uniform PDF. The slip that occurs in each subelement has been divided into n_T parts. The time at which any part might occur is also given by a random number with a uniform PDF.

I have some serious reservations about this approach which might be cleared up by a written report as to the details of this method. First, one of the most important features of a rupture is the rupture velocity. There has been no investigation of this effect. I strongly contend that this parameter must be investigated more systematically. The random element practically guarantees that the effects due to rupture velocity are suppressed. Considering the emphasis placed by PG&E on the Imperial Valley earthquake of Oct. 15, 1979, I can hardly see how they could ignore the rupture velocity. It is the primary difference among the various models and has been demonstrated [*Olson and Apsel,* 1982; *Archuleta,* 1984] to be a major effect in modeling the strong motion records. There are also the theoretical results of *Day* [1982] which suggests the relationship that where the rupture velocity is high the slip velocity is high. The region of high slip velocity is the region of the broad asperity, by definition. These results are corroborated to some degree by models of the Imperial Valley earthquake. Any coherence of seismic waves leaving the fault due to the rupture velocity is probably destroyed entirely by the manner in which the slip is randomized.

The investigators have implied that slip is a random function. My interpretation of what has been done is different. A given moment m_0 is prescribed for each subelement of the faulting area. A particular subregion will radiate seismic waves N_T times at random intervals. However, each subregion can have only a moment of m_o. Thus at each *i*th time (i=1,N_T), with *i* being chosen according to a uniform random number PDF, the amount of radiation is $1/N_T\ m_o$ so that after N_T times the subelement has a total moment of m_o. Thus, in addition to the randomness introduced for the rupture velocity, there is a randomness in the time at which the waves are radiated due to activation of the moment m_o function. This randomness in m_o is equivalent to adding randomness in the rupture velocity. I strongly object to this. The radiated wave field is guaranteed to being a random function. I would like to point out the obvious. While it is true that white noise has a flat acceleration amplitude spectrum, it is equally true that a delta function has a flat acceleration amplitude spectrum. The difference between the two is in the phase spectrum. Anything that affects the time variable affects the phase spectrum. I think that the randomness for m_o should be on the percentage of m_o that could occur in a given time period T. Thus in some cases the subelement would release all of its seismic moment at one time while there would be other subelements that would release their moment at different rates. There would be no constant N_T applicable to every subelement. N_T would be a result of the calculation and not an *a priori* constraint. This approach seems a more reasonable approximation when the PDF is Gaussian because the moment rate would be peaked near the time of the rupture front.

The semi-empirical method differed from the wholly empirical one in several ways: the PDF was changed to Gaussian from uniform for both the rupture arrival time and the weights applied to the time interval for m_o, and the Green's functions are computed using generalized ray theory instead of being included in the time function of a small shock. It should be noted that the Green's functions are not complete; only specified rays are used, e.g., direct P, direct S, pP, sP. The incompleteness of the Green's function could lead to problems if the rupture breaks through to the free surface and generates high frequency surface waves. This semi-empirical method is more easily viewed as an empirical source representation with a numerical Green's function. This method was very unclear in some very important aspects. First, how does one calibrate the source? The recorded ground motion already has the effects due to the path included. If one were to use another Green's function on the recorded motion, it would be like running the rays through a second medium. The question is how does one deconvolve the numerical Green's function from the recorded motion to produce the empirical.source? The statement was made by PG&E that a magnitude 2.5 earthquake would produce "too small" a Green's function for the subelement size. A true Green's function should be as small as possible such that it should have the smallest amount of source complexity. Why not simply reduce the subelement size? Do the numerical results depend on the subelement size? Discussion during the meeting indicated that the results did depend on the characteristics of the event chosen as the generic empirical source.

Although PG&E tried to show the validity of this method, I question the comparisons between the synthetics and the data. First, any comparison between a random number series and the data in which only one number, the peak value, is used is not enough of a test. The question is whether or not the peaks in the two series occurred at approximately the same time. For example, it is clear from Figures IX-9 (particle velocity data at E05) and IX-10 (synthetics for E05) that the peak values in the synthetics are associated with motion in the opposite direction to that in the data. The claim that the semi-empirical method with an asperity is better than a smooth rupture with a uniform distribution of slip is moot. The Hartzell and Heaton asperity model was derived for the Imperial Valley earthquake because it was their best fit to the data. In fact the comparisons, using peak values of acceleration and velocity, between the "smooth" (uniform slip distribution on the fault) and the apserity model indicate the poorness of such comparisons. If the peak amplitudes of the smooth rupture are multiplied by 2, they agree as well as those from the asperity model. However, it is well known by those who have tried to model the Imperial Valley earthquake that a smooth rupture produces a poor fit to the data.

Summary

I think that the semi-empirical modeling shows a lot of promise. Conceptually there are a number of good points. There are also a number of aspects that need closer scrutiny. The effects of a variable rupture velocity has to be considered. I do not understand the randomness of the slip function introduced into the subelements. Of course, if one knows where to place the asperities the ground motion can be computed. The question is what to do when the location is not known. Given all the randomness the issue of quantifiable uncertainty in the ground motion parameters becomes another unknown. In fact, PG&E has (unknowingly, perhaps) taken an approach that might provide a resolution tothe issues of randomness in the slip function, quantification of the uncertainty and the distribution of asperities. The basis of the summation of empirical sources is based on the ω^2 model. In order to adhere to this model the stress drop must be a constant which implies that $M_o f_c^3$ is a constant. As *Andrews* (1980, 1981) has shown, this implies that the wavenumber spectrum of roughness of stress on the fault (distribution of stress drops $\Delta\sigma$) must have a power law distribution $\Delta\sigma(\kappa) \propto \kappa^{-1}$ where κ is wavenumber. Thus the distribution of asperities is specified, the amplitude of stress drop which is directly proportional to slip rate is specified and the uncertainty can be computed based on the form of the stress drop distribution. This might not work, but something more physical has to be considered. It is difficult to visualize how one subregion of a fault would break and rebreak 8 (N_T=8) times.

The other major concern is the choice of the generic empirical source. Will any magnitude 5 earthquake do? The final results for faulting near the DCNPP site should not depend on the choice of the empirical source function. It was fairly clear that the spectrum of the synthetics depended on the spectrum of the empirical source function.

Empirical Methods

My greatest concern in this area is the subjective winnowing of data. This entire approach is based on the data set being used. It is too early to exclude data. The basic criterion for accepting or not accepting data seems to depend on the local site condition. There is no definition of what constitutes a "rock" or "rock-like" site. Except for the Imperial Valley, it would seem that just about every site falls into the category "rock" or "stiff alluvium." I do not think that any data should be excluded unless it can be demonstrated unequivocally that a site condition affects the regression results.

The magnitude scale should be uniform. Since PG&E has the accelerograms, why not convert them to a Wood-Anderson M_L? The Moment Magnitude M is all right also provided that the seismic moment M_0 for each earthquake has been computed. It is hard to imagine that M_0 has not been computed for the earthquakes under consideration. M_0 should be listed as well as magnitude for all earthquakes being used.

The recorded accelerograms were scaled for magnitude, distance and site condition. Yet, there was no explanation for any of these procedures. After the meeting in April 1986, I raised questions about the scaling being used for site condition. For some reason it is simply assumed that this scaling for any of these factors is a well-accepted procedure. Moreover, it is assumed that the scaling for each of these factors produces an accelerogram with an equal amount of uncertainty in the scaled accelerogram , i.e., scaling for magnitude is supposed to be a precise as scaling for site condition. There is little justification for any of these assumptions. I for one would insist that I see a written document showing the justification for using these scale factors. For example, scaling for magnitude seems to give an increase in amplitude with no increase in duration. As pointed out at the meeting, the scaling relation for magnitude, Figure II-13, did not have the correct limit for the curves at 20 second period. Scaling the amplitude with distance is not straightforward. First the S-waves and P-waves become more separated with greater distance. One has to know the ray path and follow each ray back to the source, very much like migration in the exploration industry. Unless the material properties of the medium are taken into account, the scaling with distance is incorrect. All of the reflection and transmission coefficients have to be accounted for plus the intrinisic attenuation plus the timing. Of course, the error in scaling with distance becomes greater as the distance becomes greater.

The attenuation relationships are based on a model that includes (1) "near-field distance saturation of ground motion characteristics" and (2) "nonlinear magnitude scaling to allow for saturation of ground motion with magnitude." The first of these implies a $(r + r_o)^{-\gamma}$ relation where r_o is yet to be determined and γ is determined from the regression. The selection process of r_o is important because the value of r_o determines when the curves start to flatten out as r approaches zero. I would certainly like to see the arguments that go into deciding on what value of r_o is appropriate. Clearly the displacement is finite as $r \to 0$ in that the displacement must approach 1/2 the slip on the fault; the particle velocity is finite as $r \to 0$ because its maximum is determined by the stress drop. What limits acceleration as $r \to 0$? At very close distances the effect of attenuation should be small. The ground motion parameters are limited as $r \to 0$, not as $r \to r_o$. The second condition seems physically plausible when the total rupture length is much larger than the distance between fault and receiver.

Thus the difference in amplitudes should become less as the magnitudes become larger. Also this difference should be distance dependent. For example, if the observer is 5 km from the fault, the difference between a M 6.5 and M 7.5 earthquake should not be much. However, if the observer is 100 km from the fault, a difference should be expected. This is the same question raised in the synthetic seismogram technique as to when is the observer in the zone where the Fraunhoffer approximation breaks down. Yet, in comparing figures V-26, V-27, V-28 the scaling for different magnitudes does not show any distance effect.

Summary

First, I do not see the application of these regression analyses to the overall problem. The empirical method tries to reduce the earthquake ground motion to a single parameter. This might be sufficient if one were always at a very large distance from the causative fault. However, that is exactly the major problem. DCNPP is very near faults capable of producing strong ground motion. As a consequence there is a very large uncertainty in the applicability of the method, uncertainty in the extrapolations from far distances to close distances (The regression results are strongly conditioned by data for distances >30 km.), and uncertainty in one's choice of parameterization variables because the ground motion in the near source region is not the result of a radiating point source. The real test of these techniques is not whether the errors on the regression variables are reduced by adding data from the latest earthquake (That's a moot point.), rather it is by taking the current regression curve and seeing how well it would have predicted the ground motion parameters of the latest earthquake.

The scaling of the time histories for magnitude, distance and site condition were not shown to be consistent with the regression analysis. The physical basis for such scaling is not presented in any single document that I could find. There are obvious shortcomings in the scaling methods.

General Comments

The teleseismic record of the 1927 Lompoc earthquake was strong evidence for a thrust mechanism. It certainly had a large P-wave which would not be expected from a strike-slip earthquake. This leads to a major complication. Unless the location can be determined with an accuracy that is much less than the distance between the San Lucia Bank and the Hosgri fault, the possibility of the Hosgri having a significant thrust component will have to be considered in future analyses with respect to the seismic risk at DCNPP.

I am very concerned about the lack of analysis of the only earthquake recorded at the site. There is a tremendous variation in the amplitude from site to site. Perhaps PG&E is waiting for the results from the active refraction experiments. Those records from a M 2.5 earthquake deserve special attention. Even if the amplitude variation cannot be explained precisely, the phases, the relative vertical to horizontal amplitudes, and the relative amplitudes between stations need some explanation. The preliminary analysis of a dipping structure presented during the meeting was quite interesting. That analysis deserves to be continued. The transfer function of the dipping layers will probably have to be used in computing the expected ground motion.

I am concerned about the role of the numerical modeling. Of the thirteen time histories, only two were to be synthetics. I raise this question because it seemed to me that an accelerogram scaled for magnitude, or distance or site effect would be equivalent to a synthetic accelerogram. As mentioned above, these scaling procedures are not well documented and could be invalid. Is the weight given to numerical modeling 2/13? That list of accelerograms might imply the priority being given to the various methods now being used by PG&E. I would agree to emphasizing data provided that the data are well understood. That understanding requires having a model of the earthquake process and material description that generated the data. Otherwise the data are open to lots of question about their applicability when we are dealing with a site specific problem.

Throughout the meeting I felt that there was a definite gap between the engineering interpretation of the accelerograms and their actual interpretation. Specifically the engineers have this misconception that a near-source accelerogram is generated by a point source in space: there is a well-defined point on the fault to which a single distance parameter can be assigned, all of the waves are arriving from one direction, all of the waves are incoherent. If these ideas are being held, there is going to be one big mess. I definitely got the impression that SSI would not be able to incorporate the reality of being in the near-source region into their analysis. It leads me to wonder just how are the accelerograms going to be used.

Now that a great deal of work is being done, there is a pressing need for written reports on precisely how different lines of reasoning are being used to solve the problems. References to abstracts and gray literature are almost useless. Besides I want to know **specifically** how certain approaches are being applied to DCNPP. If a technique is well documented in some report, fine, include it as an appendix to the written report. A lot of my criticism rises from lack of information. I just do not understand, in sufficient detail, how the techniques are being applied. Consequently, I have lots of doubts and questions about the usefulness of such methods.

Although I have criticized some of the things that were presented, there were a number of positive aspects of the meeting. The semi-empirical method for synthesizing strong ground motion is certainly a reasonable approach. It needs more validation, but it certainly has the capability to incorporate the basic physics of an earthquake rupture and the propagation effects. The initial steps toward accounting for the near-surface lateral variations were interesting and potentially very useful in explaining the variations in the amplitude from the M2.5 earthquake and future earthquakes recorded at the site. Examining the angles of incidence in the synthetic seismograms may give the engineers a better idea of a preferred direction. Installing more instruments at the site is excellent. The active experiment should give enough data to quantify the lateral variations expected at the site. It should also give PG&E a very good idea of the velocity structure in the area.

Ralph J. Archuleta

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Enclosure 4d

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4 December, 1986

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Re: Comments on Meeting of 23-24 October, 1986 with Ground Motion 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 at the subject meeting. As you are aware, the meeting was primarily a presentation on the current status of the ground motion studies, with only a rather short summary presentation made of the state of the SSI activity. The meeting was extremely worthwhile for me to attend, however, to obtain information on the ground motion calculations which will be used as input to the SSI work. Some specific comments follow.

(1) As I stated in my comments on the April 1986 meeting, the program presented by the Project Team concerning the empirical ground motion study is a reasonable and well thought out one. Essentially all of the strong motion data available has been evaluated for potential use at the DCNPP site. These evaluations are based upon a study of specific magnitude, distance and site similarities to the Diablo Canyon site. Based upon these evaluations, a suite of thirteen strong motion recordings have been selected as candidate motions to be used as input to the remainder of the program. In addition, although I was not present at the discussions on site geology, it is my understanding that a strong field program is underway to determine local geologic profiles, with investigations being conducted both on and off shore.

(2) In the fragility study, this suite of strong motion seismic records are being modified to yield average spectral amplifications of 2.25g's in the frequency range of 3 to 8.5 hz. This is being done by modifying the time histories by several different scaling methods to arrive at a new suite of artificial accelerograms. These scale factors were developed by the fragility evaluation team members and are apparently arbitrary in nature. This approach leads to several concerns on my part. First, these amplification factors have been chosen independently from the geologic characteristics of the site. Of more concern, however, is the fact that SSI effects are apparently not to be accounted for in the fragility study. If SSI effects are found to be significant, the results of the fragility study will be suspect, due to the fact that kinematic interaction effects are not properly treated. It is not clear to me if and how the results of the SSI program are to be factored into the fragility study in the current program plan.

(3) Relatively detailed presentations were made on the various simulations being used in the numerical modeling area. The purpose of this phase of the program is to provide additional information to the ground motion study that cannot be generated from the empirical program alone. Impact of site specific fault behavior and geologic configuration can be studied to determine the impact of specific site parameters on potential seismic motions. Although some of this work is impressive, it does not appear to me that this phase of the program will lead to significant results, particularly in the frequency range of interest to the structures. It seems to me that the numerical methods being used can lead to potentially significant errors at the higher frequencies of interest. No specific discussion of this point was presented. In addition, it is unclear if the effects of local geologic structure on seismic motions are currently being included in any significant manner. This is required if any progress is to be made on the coherence problem. As you recall, this effect was considered in the original design to reduce the high frequency inputs to long structures, such as the turbine building.

As an additional concern for this aspect of the study, the calculations are being made using rock damping definitions which are different from those used in the SSI program. As I mentioned in my previous report to you, these differences will have a primary effect at the higher frequency range of interest to the SSI program. Again, no discussion of this topic was presented.

(4) The SSI presentation was a short one intended to give the ground motion panel an indication of the use of their output. Thus many specific details were omitted. However, some comments and concerns can still be presented. In the SSI program, eight of the strong motion records selected in the empirical study have been chosen. It is presumed that these records are the original time histories and not the scaled records artificially enhanced by the amplification factors discussed previously.

The records currently considered (Figs. III-4 thru III-15 of the handouts) show significant spectral variations in the horizontal and (in particular) the vertical directions. From these records, only three are to be chosen for use in the specific SSI calculations using the CLASSI/SASSI computer codes. It was not made clear what criteria will be used to select this subset of input motions. It was stated that a "median" record would then be generated, presumably based upon average spectral values. Again, it was not made clear what use would be made of this "median" record. More importantly, it was not made clear how the major differences in spectral values noted above will be evaluated in the SSI studies.

(5) A short presentation was made by the Project Team to try to determine predominant incidence angles from the measured seismic records. Such information is required if the noncoherence problem is to be judged. However, it does not appear that this calculation is a reasonable one.

(6) No specific discussion was held on the impact of potential nonlinearities on the SSI study. If I can recall from the original IDVP study of the project, several significant problem areas were encountered where nonlinearities could play a significant role in the design. Items such as phasing between the horizontal and vertical input motions, the major differences in spectral content of the suite of input motions being considered, and the degree of noncoherence of the input pulses will play a major role in assessing the adequacy of the design. It is not clear to me how or if the SSI program as currently envisioned is going to address these problems. In fact, it is not clear to me how the Project Team plans to compare the results of this seismic reassessment with the original design.

In closing, I would like to reiterate that attendance at the Ground Motion Panel meeting was extremely valuable to me in being able to judge the adequacy of the approaches being used in the calculations of the input seismic motions. Such information is obviously important in evaluating the degree of variability inherent in the SSI calculations currently being performed. I would also like to take this opportunity to thank the members of the Project Team for the effort they made in their presentations.

Respectfully submitted,

Carl J. Costantino

Carl J. Costantino
Professor of
Civil Engineering

Enclosure 4 e

S-CUBED

A Division of Maxwell Laboratories, Inc.

November 6, 1986

Dr. 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 San Francisco meeting of October 23 and 24, 1986, between the NRC staff and P. G. and E. I begin with a summary, followed by my comments on the progress and direction of the ground motion tasks of the Long Term Seismic Program.

Summary

The technical material presented by P.G. and E. falls into four roughly distinct categories: i) selection and construction of ground motion time histories for use in fragility and soil-structure interaction (SSI) analyses, ii) spatial description of ground motion for input to SSI., iii) a comparative study of various empirical distance-attenuation relationships for response spectral ordinates, and iv) site instrumentation and event recordings. The anticipated method of incorporating ground motion time histories into SSI analysis was also briefly summarized.

Time histories. Four types of time histories were discussed: recordings from events of appropriate magnitude, distance, and site condition; recording from other events, scaled to appropriate conditions; theoretical records from the empirical Green's function (EGF) method; and theoretical records using an empirical source function method.

Spatial description of wavefield. Results from three types of analysis were presented: wave-type decompositions from EGF simulations, polarization direction output from the EGF simulations, and empirical analysis of polarization directions from several earthquake recordings.

Attenuation relations. Comparative plots were shown for spectral acceleration versus distance and magnitude. Some attention was given to effects of separating reverse-slip events from strike-slip events in doing the regressions.

P.O. Box 1620, La Jolla, California 92038-1620 3398 Carmel Mountain Road, San Diego, California 92121-1095
Telephone: (619) 453-0060 TWX: 910-337-1253 Telecopier: (619) 755-0474

Site instrumentation and recordings. Dr. Tsai described the anticipated addition, within about a month, of 10 additional accelerographs at the Diablo Canyon site, to supplement the present 3 instruments. He also described plans to record, at the site, airgun and dynamite sources to be shot during a seismic profile in the area. Finally, site recordings of a small (magnitude 2+, I believe) local earthquake were shown and discussed, particularly with respect to amplitude variation across the site.

Comments

General comments. In my May 16, 1986 report, I said that the program was developing a good balance between empirical and theoretical approaches to the engineering objectives. I feel even more strongly now that this is the case. Much progress has been made, the quality of the technical work appears to be very good, and overall the strengths of the program much outweigh the weaknesses. The empirical source function method overcomes the main concerns I expressed in the May report about the EGF approach, e.g., the inappropriateness of the Imperial Valley recordings as Green's functions. The site instrumentation program appears to be very aggressive and well conceived as a vehicle for studying site response and the spatial coherency of ground motion.

I am somewhat concerned that results from the theoretical modeling and coherency array recordings may end up having minimal impact upon the SSI analysis. On the basis of the SSI presentation, it was not clear to me that the analysts are committed to making full use of the seismic data and simulations, in order to conduct a thorough, well-grounded evaluation of the purported tau effect, which I understand to be, roughly speaking, a base-averaging effect. More thought should be given to the problem of defining realistic input motion to the SSI problem, so that the best possible use can be made of the spatial description of ground motion which the seismologists are trying to assemble.

I found it helpful to have the meeting notes distributed ahead of time, and I appreciate the effort that went into doing so. However, there is still a need for an interim technical report, containing written descriptions of the methods, documentation of the numerical tests, and complete references to the literature cited.

Specific comments. The suite of time histories to be used for fragility analysis seems to me to represent empirical and semi-empirical methodologies in a reasonably balanced way. The selection criteria (distance, magnitude, site condition) are appropriate. There was some controversy over the method of scaling soil site recordings for use at Diablo Canyon, and I don't think the scientific issues were dealt with in any completeness at the meeting, but I think there is merit in Ross Sadigh's comment that the procedure being used is the conservative one in light of the uncertainties. I hope that the suite of time histories will be augmented in the future with results from the theoretical modeling studies. These results may help to answer questions about focusing effects very near the fault plane and potential effects of nearby asperities.

My reservations about the EGF method still stand, particularly the use of Imperial Valley recordings as Green's functions for Diablo Canyon site simulations. An inconsistency which stands out is that soil-site recordings were scaled up by several tens of percent for use in fragility analysis, and yet soil-site recordings chosen as empirical Green's functions were not so scaled. I don't know which procedure best represents the physics, but it does appear that the inconsistency carries through to the final product. That is, the EGF time histories are low in peak horizontal acceleration compared to the mean of the site-corrected time histories tabulated on page II-24 of the handout. Peak horizontal accelerations of the two horizontal components of the EGF simulation (page IV-10) fall one standard deviation and one and one-half standard deviations, respectively, below the mean of the corrected recordings.

The empirical source function method proposed at the meeting represents real progress in the theoretical modeling effort. The effort to develop empirical source functions from rock site recordings is worthwhile. A have one concern of a technical nature, and that is the problem of applying an empirical source function at source-receiver ranges at which source-finiteness effects can no longer be rendered accurately under the Fraunhoffer approximation. This approximation is at the heart of the method. Unfortunately, it appears to me that, under the conditions of interest, the approximation may not be valid. For example, assuming sub-event dimension a of 2 km, wavespeed (at source depth) of 3 km/sec, source-receiver separation r of 10 km, and frequency of 10 Hz, the squared source dimension exceeds the product of wavelength λ and receiver distance. Validity of the method formally requires $a^2 \ll \lambda r$. Of course, the criterion is violated even more egregiously at the extremes of the frequency and distance ranges of interest, i.e., 20-30 Hz and 4-6 km. This issue needs to be carefully considered.

I did not find the polarization analyses which were presented to be particularly informative. The attempt to infer angle of incidence information from observed polarization was based on several assumptions which may be faulty, and I think thoses inferences are potentially very misleading. The assumption was introduced that ground motion is predominantly SV in the vertical plane orthogonal to the fault strike. However, if a large SH component is actually present, then the proposed method may systematically bias the angle-of-incidence estimate toward the vertical.

I do not understand the purpose and direction of the comparative study of distance-attenuation relations. How does this work fit in with the other studies presented? The Joyner-Fumal regressions are clearly different from the competing regressions. We were told that this is because they do not incorporate magnitude saturation nor separate soil- from rock-site data. Campbell's work seems to imply that separation by source type also effects the results. It was not possible for me to discern, from the material presented, which variables have significance nor whose parameterization is most appropriate. But I don't know whether to worry about these things or not, since it is not clear to me how the regression results are to be used in conjunction with the other ground motion studies. An interim report could help a great deal, I think.

Sincerely,

Steven M Day

Steven M. Day
Program Manager
Theoretical Geophysics

Enclosure 5a

PACIFIC GAS AND ELECTRIC COMPANY

PG&E

77 BEALE STREET, RM. #2661A • SAN FRANCISCO, CALIFORNIA 94106 • (415) 972-2791 • TWX 910-372-6587

LLOYD S. CLUFF
MANAGER
GEOSCIENCES

October 14, 1986

Dear Workshop Participant:

Diablo Canyon Long Term Seismic Program
NRC/PGandE Geology/Seismology/Geophysics Workshop
October 21 and 22, 1986
Conference Room 2L, Second Floor
of 45 Fremont Street Building
(This Building is Located Directly Across
the Street from 77 Beale Street Building)

As requested by Hans Schierling (NRC), we are sending the enclosed information in advance of the subject workshop so that everyone will be informed of the subject matter to be presented and discussed.

Please note the change in conference room and building for this workshop.

We look forward to a productive two-day workshop.

Sincerely,

LSC:rle

Enclosures

DIABLO CANYON LONG TERM SEISMIC PROGRAM (LTSP)
GEOLOGY/SEISMOLOGY/GEOPHYSICS
NRC/PGandE WORKSHOP
CONFERENCE ROOM 2L, SECOND FLOOR OF
45 FREMONT STREET BUILDING
(BUILDING LOCATION IS DIRECTLY ACROSS STREET FROM 77 BEALE STREET)
SAN FRANCISCO

AGENDA (TENTATIVE)

TUESDAY, OCTOBER 21, 1986

8:00 a.m. - 8:30 a.m.	Introduction • NRC • PGandE
8:30 a.m. - 12:30 p.m.	Characterization of Hosgri Fault Zone • San Simeon Region • Offshore Region from Point Estero to Purisima Point • Discussion
12:30 p.m. - 1:30 p.m.	Lunch
1:30 p.m. - 3:00 p.m.	Characterization of Hosgri Fault Zone (Continued)
3:00 p.m. - 5:00 p.m.	Characterization of San Luis/Pismo Region • UNR Studies • PGandE Studies • Discussion

WEDNESDAY, OCTOBER 22, 1986

8:00 a.m. - 12:30 p.m.	Characterization of San Luis/Pismo Region (Continued)
12:30 p.m. - 1:30 p.m.	Lunch
1:30 p.m. - 3:00 p.m.	Tectonic Framework • Neogene Tectonic Model • Discussion
3:00 p.m. - 5:00 p.m.	NRC Caucus and Discussion

LSC/FWB:rle
10/15/86

DIABLO CANYON LONG TERM SEISMIC PROGRAM (LTSP)
GEOLOGY/SEISMOLOGY/GEOPHYSICS
NRC/PGandE WORKSHOP
OCTOBER 21-22, 1986

Since the workshop of May 1986, work has continued in the G/S/G Tasks 1, 2, 3, 4 and 5 as described in the Scope of Work for Phase III. Significant progress has been accomplished towards completion of Tasks 1, 2, and 3 and field mapping, and detailed planning has been accomplished for Tasks 4 and 5.

To facilitate presentation of data at the NRC/PGandE workshop, we have prepared a preliminary agenda and package of viewgraph materials for your review. Viewgraph materials are separated into the following packages:

Characterization of Hosgri Fault Zone

- Introduction
- Offshore Region
- San Simeon Fault

Characterization of San Luis-Pismo Region

Each package is prefaced by a review of the applicable LTSP Task description and a brief outline of major topics cross referenced to the viewgraphs.

CHARACTERIZATION OF HOSGRI FAULT ZONE

Viewgraph Number

- Review of Geology and Geophysics
- Geologic Studies of Onshore Portions of Trend
- Analysis of Geophysical Data
- Development of Fault Map and Area-Wide Structural Contour/Isopach Maps

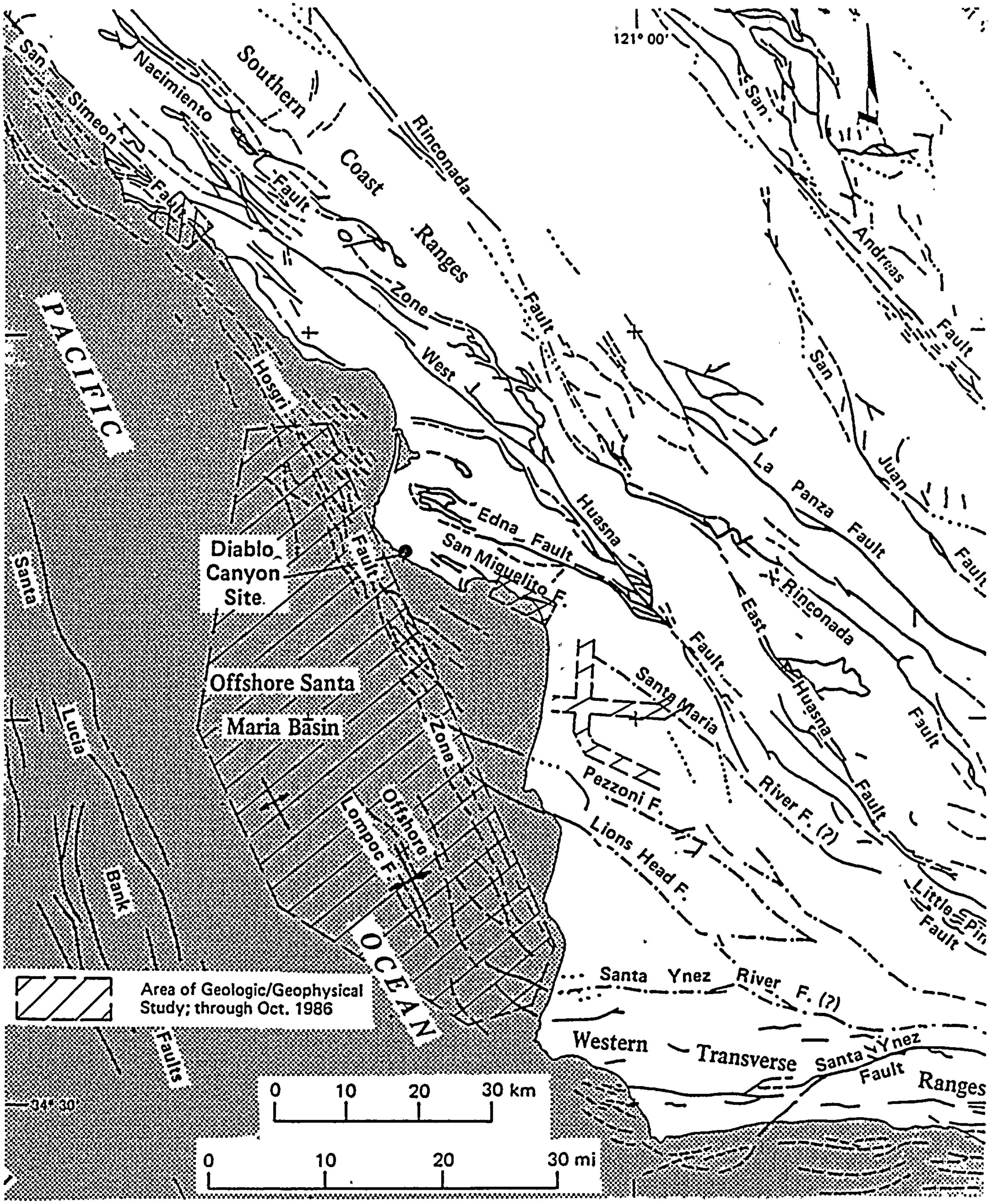
Introduction

- Hosgri Fault in Context of LTSP (I-1)
- Objectives of Task 1 (Review)
- Overview of Hosgri Fault - Geologic and Tectonic Setting of Coastal Central California (I-2)
- Importance of Offshore Hosgri Studies;
  - Introduction to Offshore Geophysics Program

Offshore Region from Point Estero to Purisima Point

- Deep Seismic Studies
  - Data Base: OPI-GSI and Well Data
  - Geological and Geophysical Base Maps (G-1)
  - OPI-GSI Lines and Well Locations (G-2)
  - Recent Seismic Line Acquisitions
    - . Western (G-3)
    - . Nekton
  - OPI-GSI Reprocessing (G-2)
- Results and Interpretations to Date
  - Structural Trend Map
  - Selected Seismic Sections
  - Structural Contour Maps
    - . Top of Monterey Formation
    - . Top of Sisquoc Formation
- Shallow and High Resolution Surveys
  - Data Base: MMS Fairfield Survey
  - Interpretation of Selected Lines
  - Acquisition of Additional High Resolution Data
    - . Objectives
    - . Comap Seismic Line Specifications
  - Structure Contours on Plio-Pleistocene "green reflector"

Geologic Studies of San Simeon Fault



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

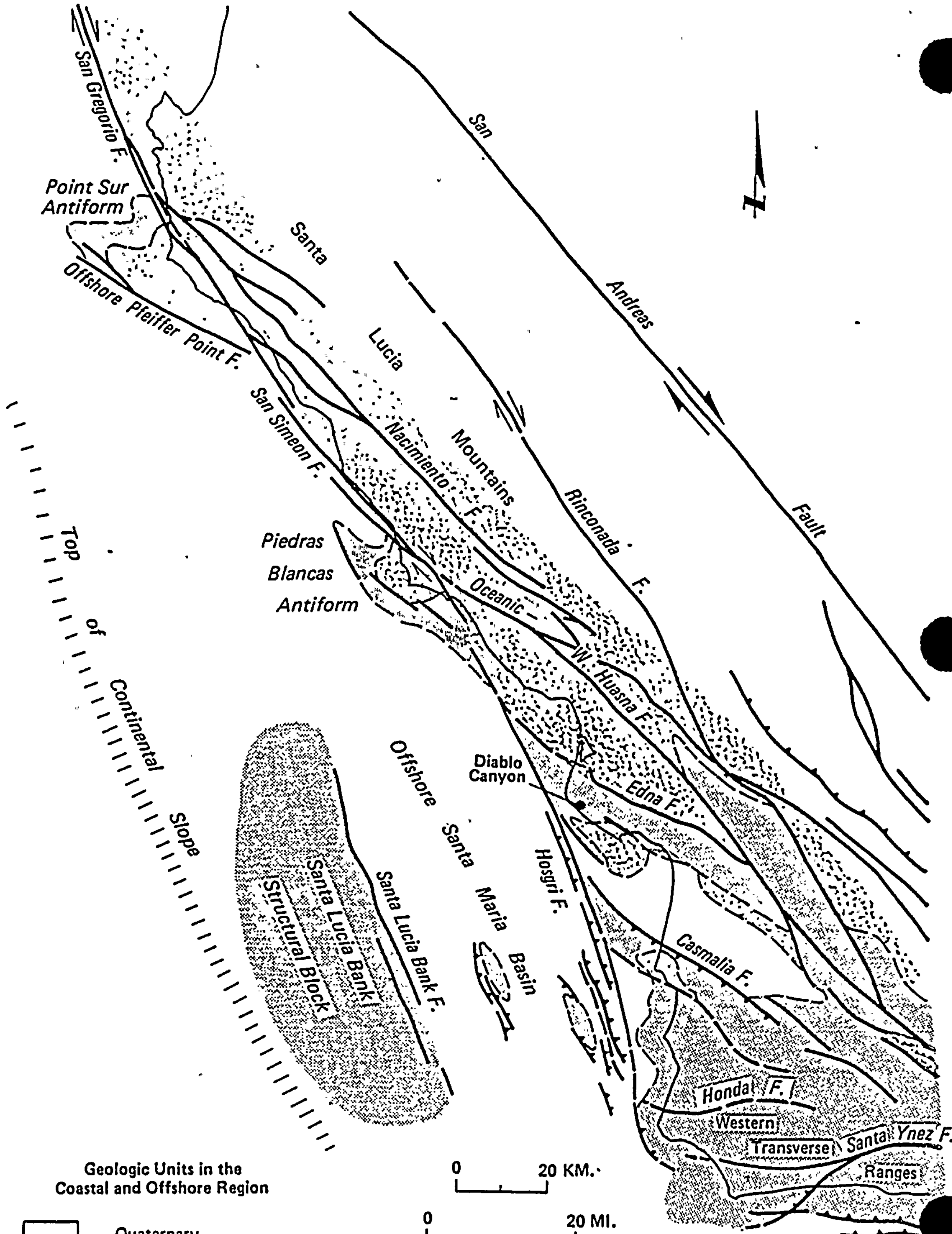
McCulloch et. al. (USGS), 1980 (Santa Lucia Bank area)

Ogle, 1985 (Southern Offshore Santa Maria Basin)

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

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

SANTA MARIA BASIN REGION



Geologic Units in the Coastal and Offshore Region

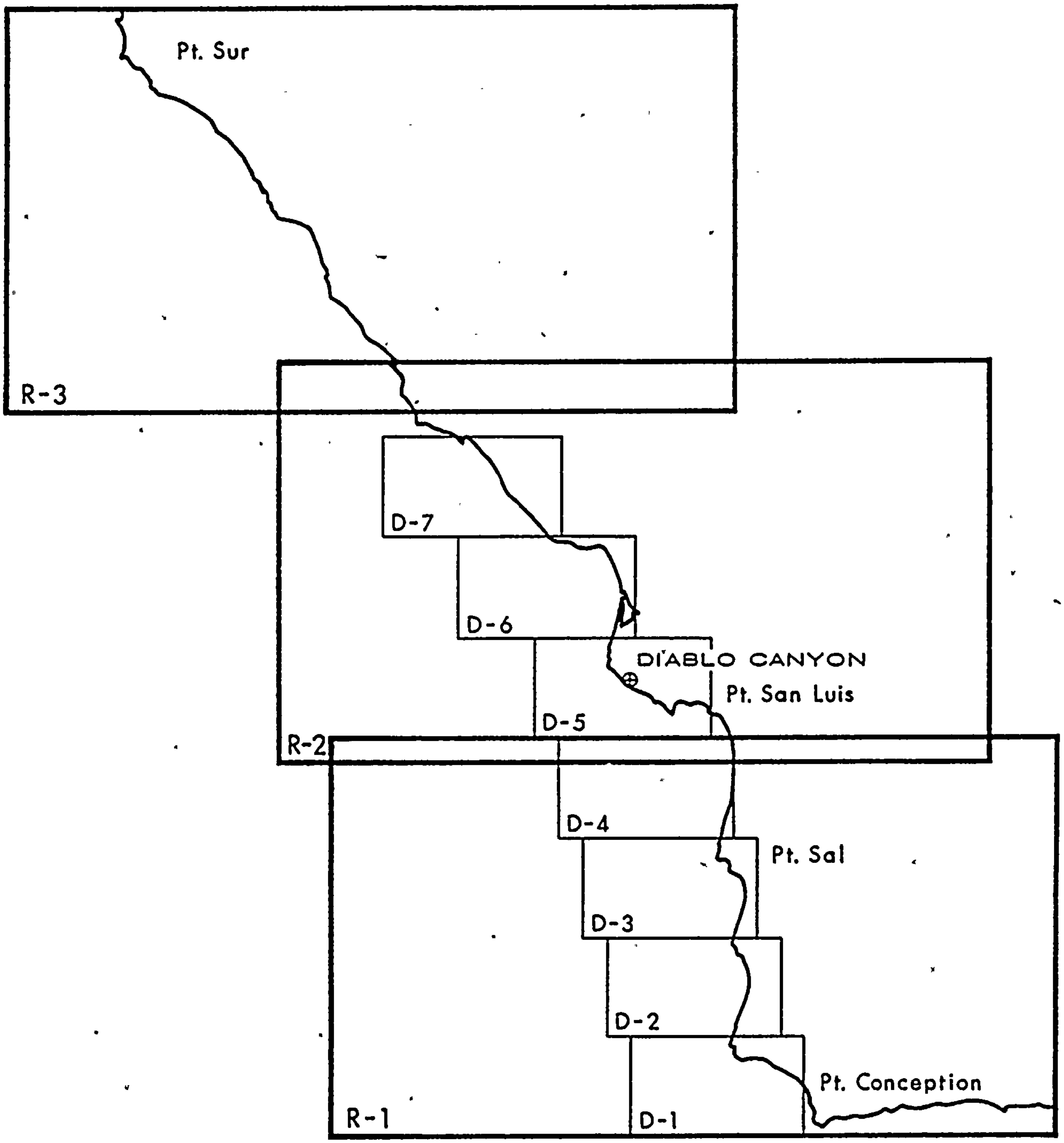
Quaternary

Mid - late Tertiary

Mesozoic - early Tertiary

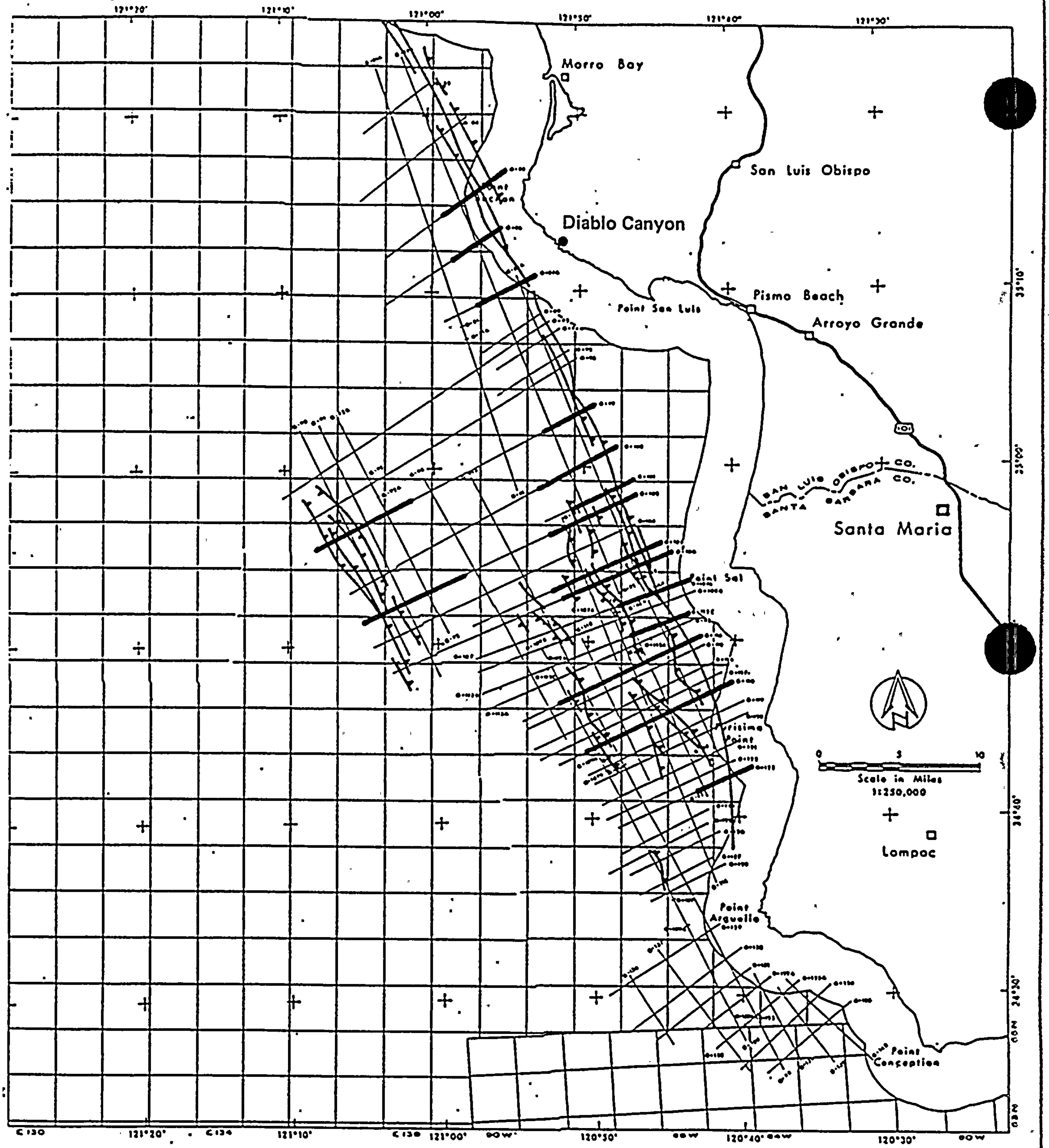
GEOLOGIC AND TECTONIC SETTING, COASTAL CENTRAL CALIFORNIA

Index Map for LTSP Geological and Geophysical Basemap Series



R-1	Regional Basemaps, Scale 1:96,000
D-1	Detail or Work Map Series, Scale 1:24,000

G-1



LTSP GSI-80 MARINE SEISMIC SURVEY

OFFSHORE SANTA MARIA BAS

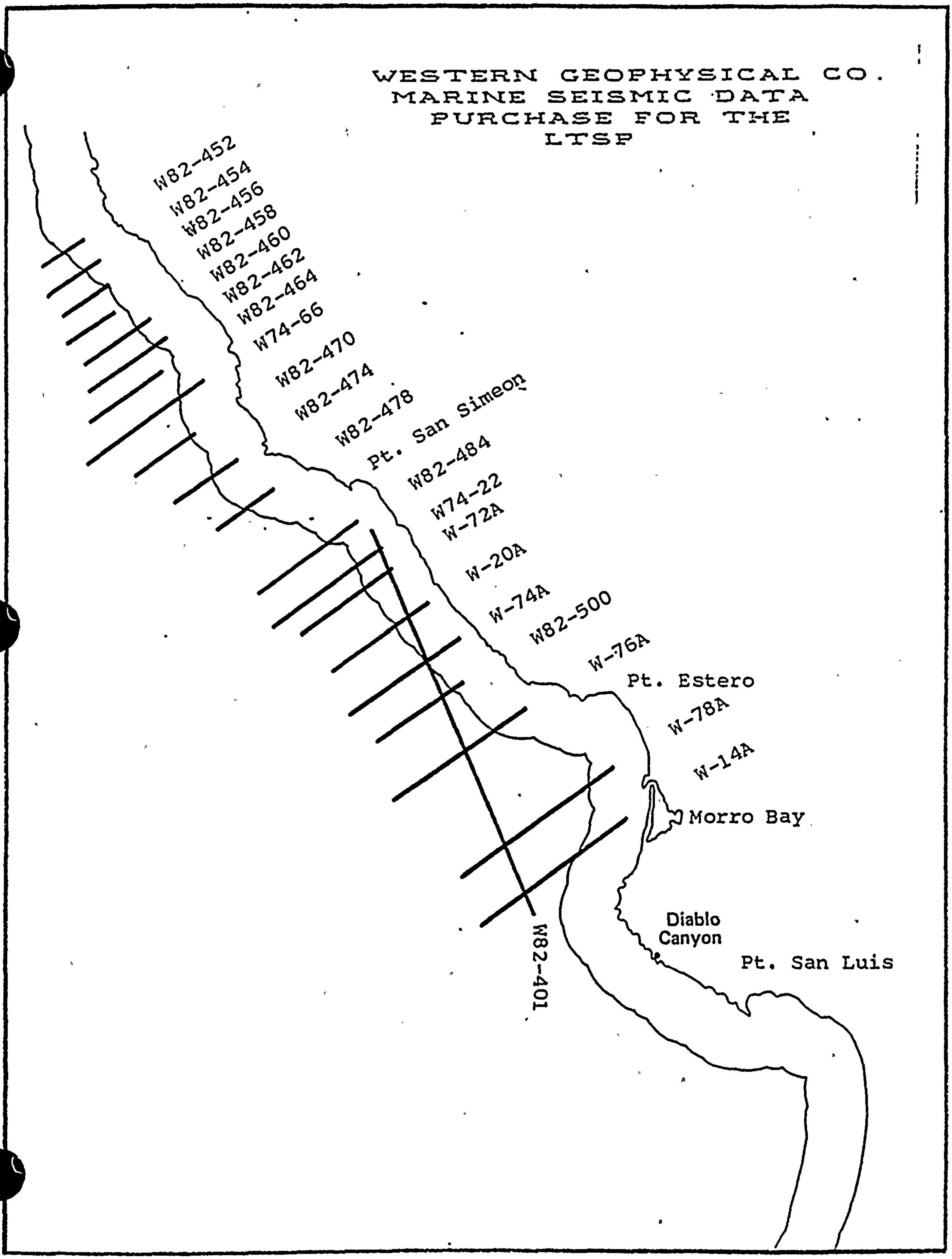
PROPRIETARY SEISMIC DATA

INDEX MAP

GEOPHYSICAL SERVICES INC.

1980

G-2



WESTERN GEOPHYSICAL CO.
MARINE SEISMIC DATA
PURCHASE FOR THE
LTSP
W82-452
W82-454
W82-456
W82-458
W82-460
W82-462
W82-464
W74-66
W82-470
W82-474
W82-478
Pt. San Simeon
W82-484
W74-22
W-72A
W-20A
W-74A
W82-500
W-76A
Pt. Estero
W-78A
W-14A
Morro Bay
Diablo
Canyon
Pt. San Luis
W82-401

PG&E DIABLO CANYON POWER PLANT
LONG TERM SEISMIC PROGRAM (LTSP)

Neotectonic and Quaternary Studies

SAN SIMEON FAULT ZONE

SS-1

NEOTECTONIC AND QUATERNARY STUDIES IN SAN SIMEON AREA

Objectives:

- Location of active fault traces and other tectonic deformation
- Relationship of Quaternary tectonics to pre-existing structure
- Sense of slip and style of deformation
- Timing of deformation along various parts of zone
- Most recent rates of slip in lateral and vertical components

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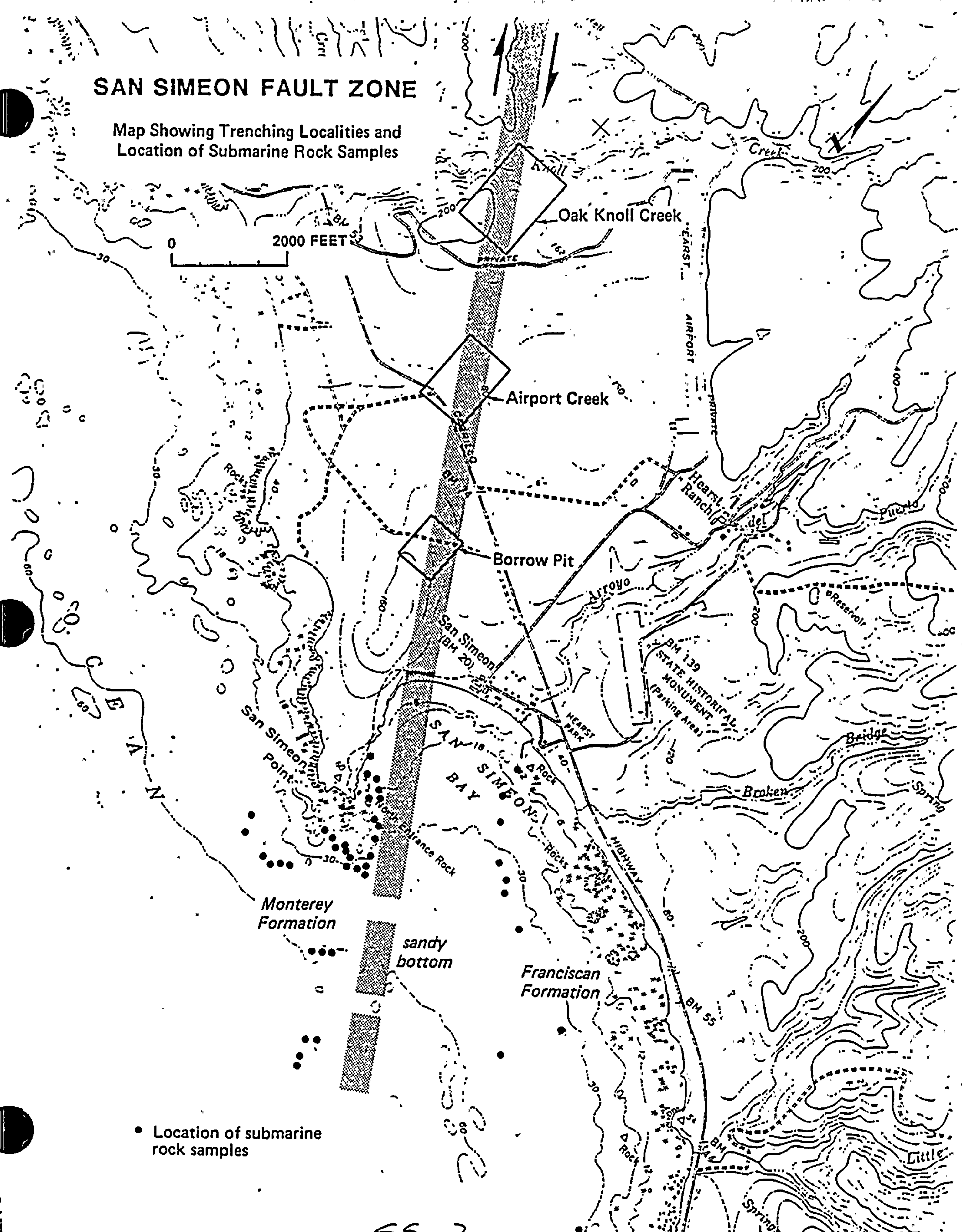
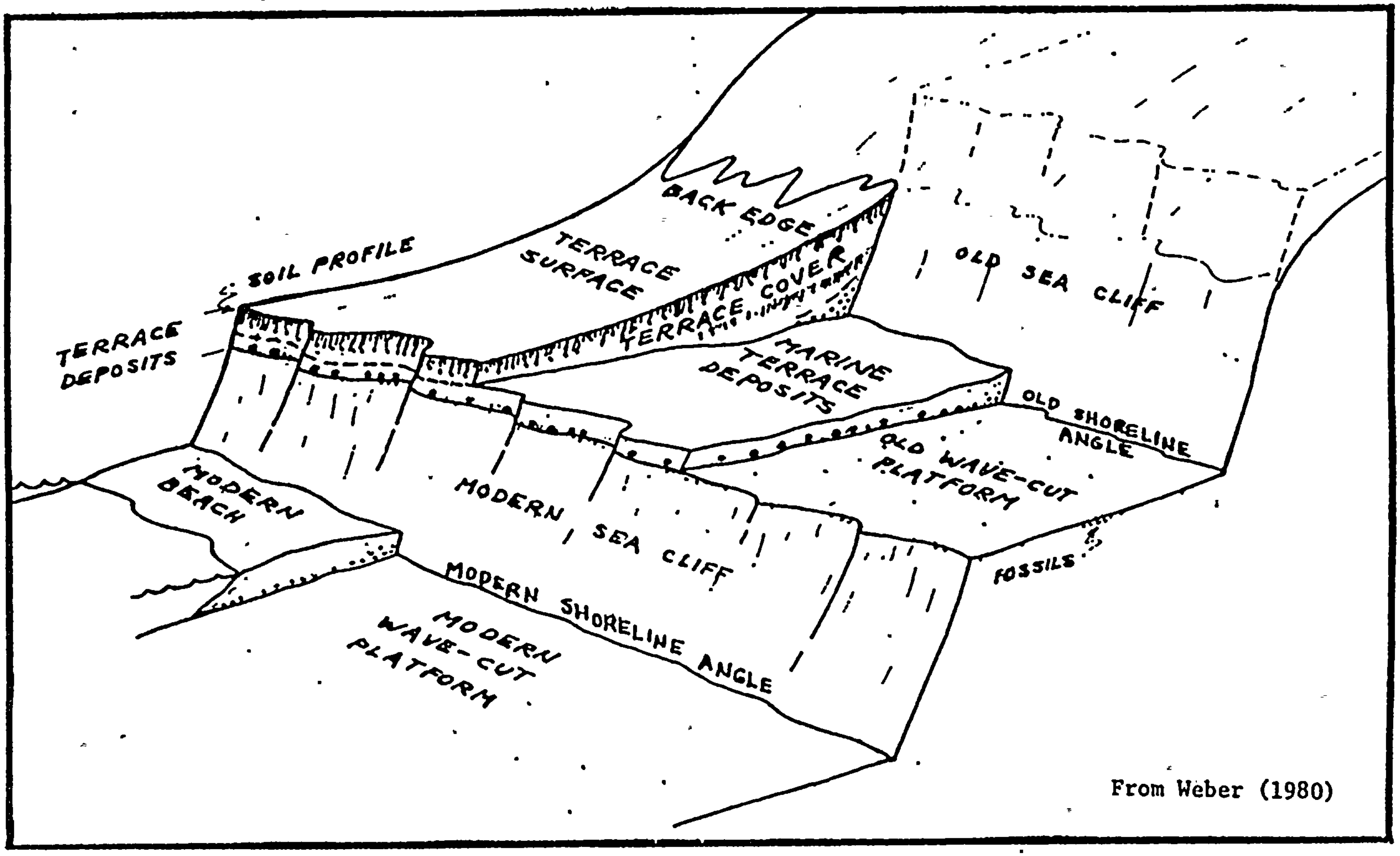
Accomplished as part of GSG Tasks 1.3, 2.1, and 2.3

SAN SIMEON FAULT ZONE

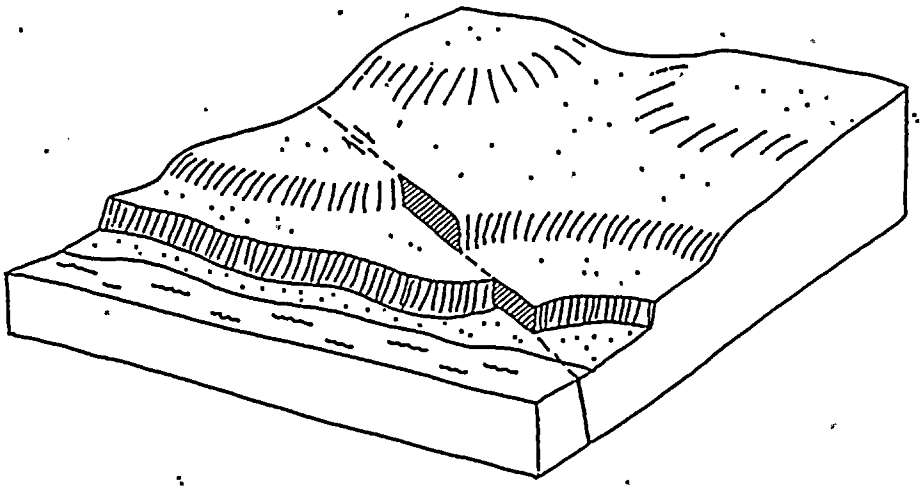
Map Showing Trenching Localities and Location of Submarine Rock Samples



SS-3

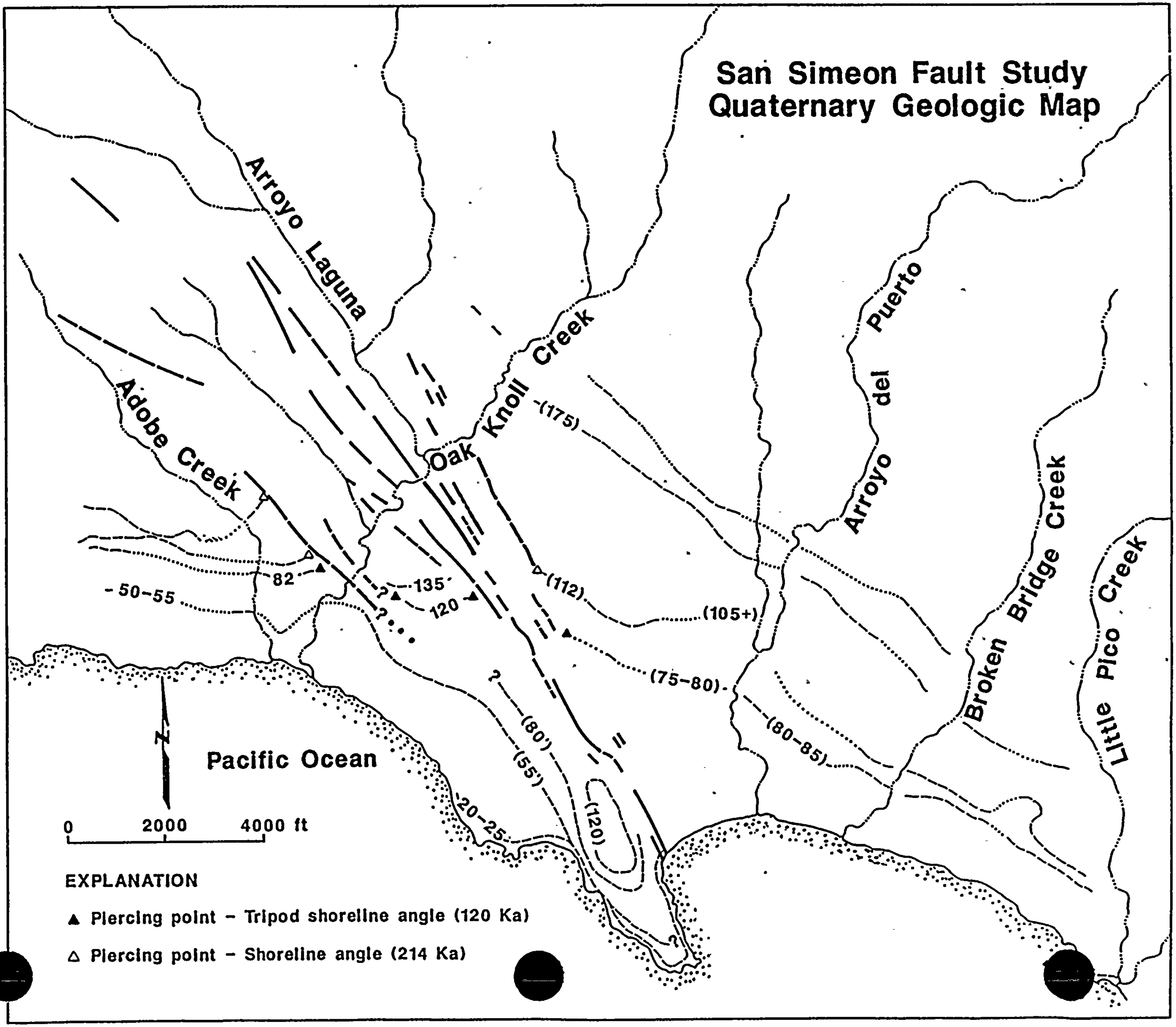


From Weber (1980)

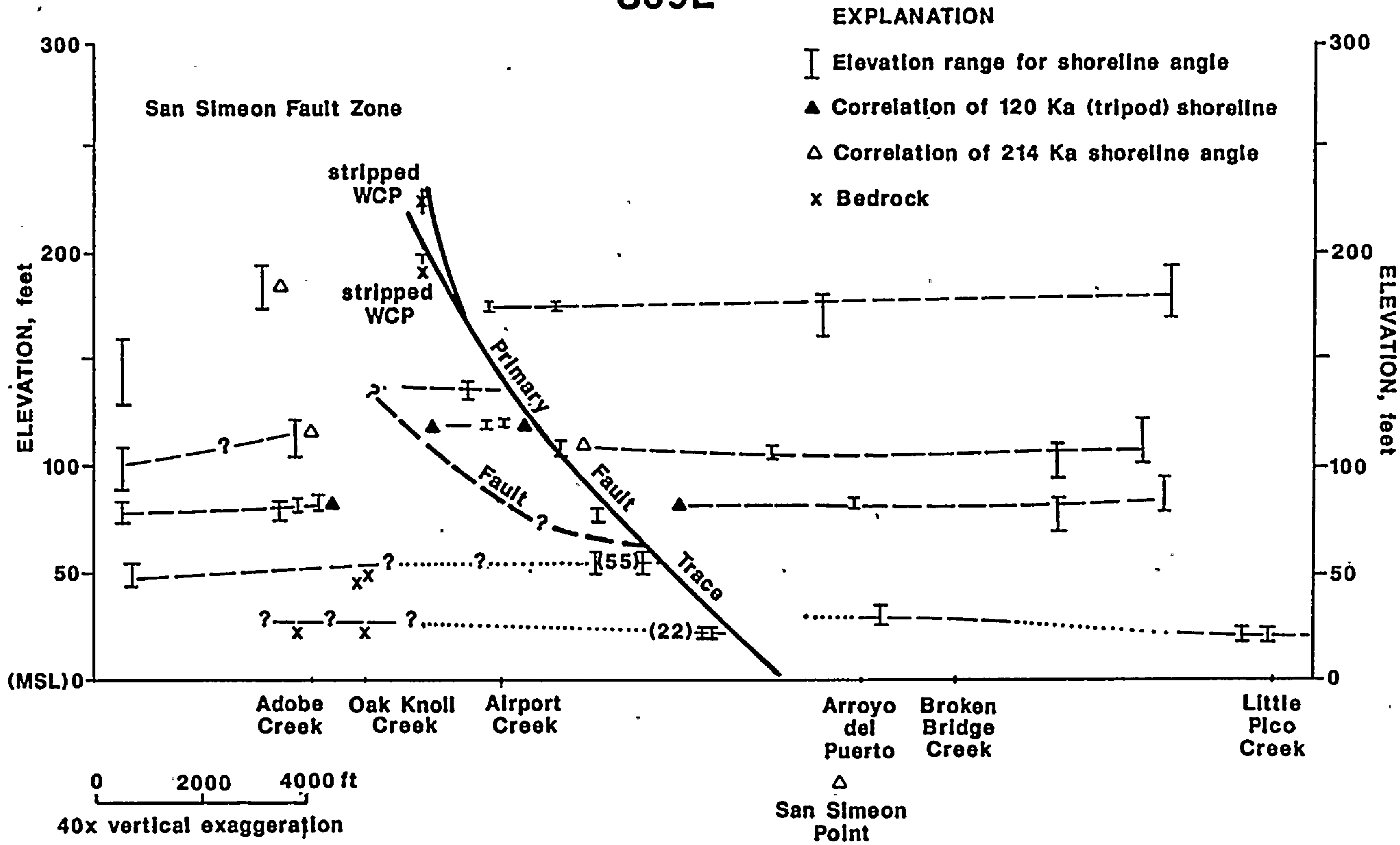


Sketch Illustration of the Development of Offset
Shoreline Angle Strandlines across
a Right Lateral Fault

SS-6


San Simeon Fault Study
Quaternary Geologic Map
Arroyo Laguna
Oak Knoll Creek
Adobe Creek
Arroyo del Puerto
Broken Bridge Creek
Little Pico Creek
Pacific Ocean
N
(175)
(112)
(105+)
(75-80)
(80-85)
82
50-55
135
120
(80')
(55')
(120)
20-25
0 2000 4000 ft
EXPLANATION
▲ Piercing point - Tripod shoreline angle (120 Ka)
△ Piercing point - Shoreline angle (214 Ka)

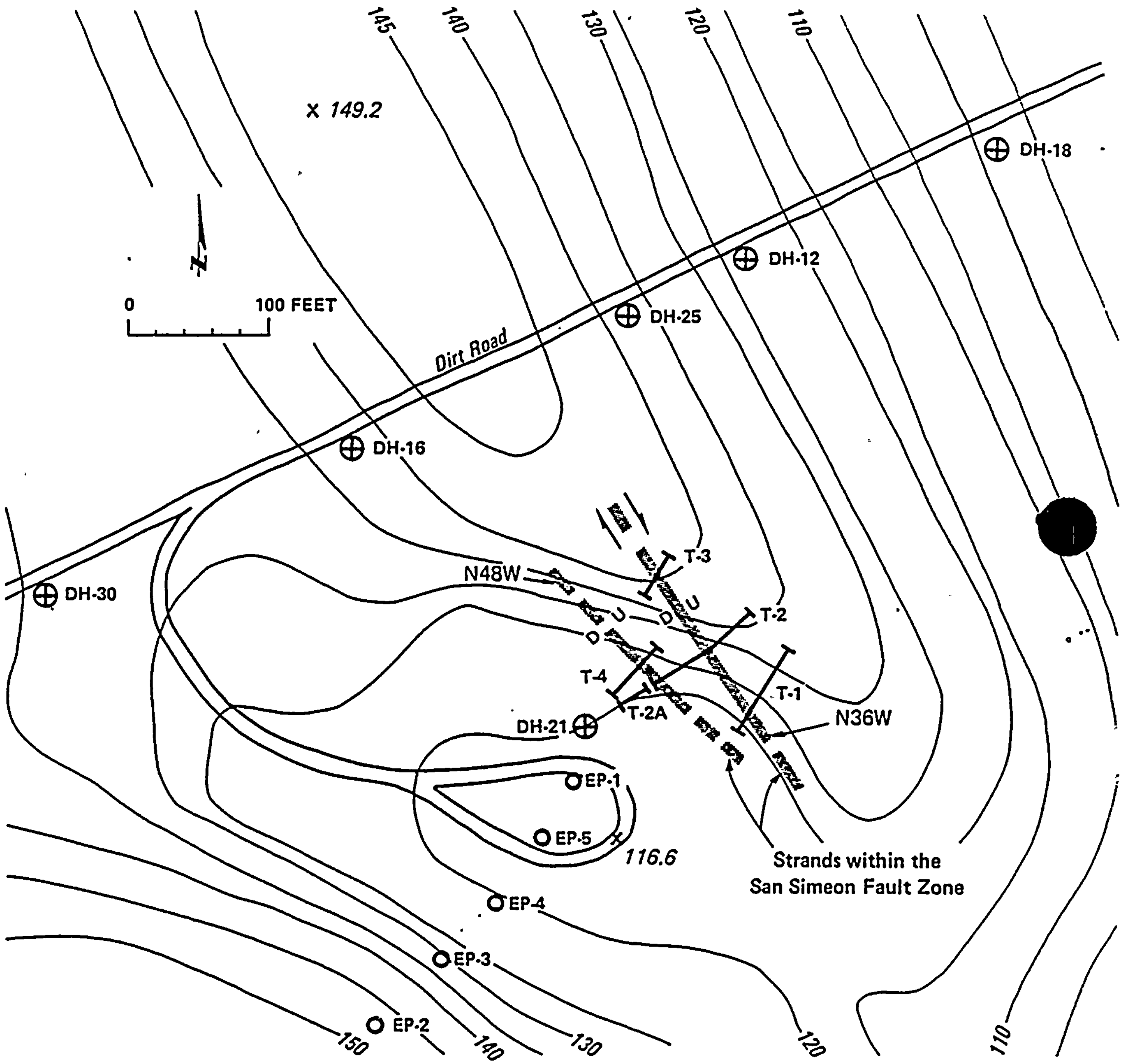
San Simeon Study Area
Shoreline Angle Elevations of Marine Terraces
S69E ⟶



SS-7

SAN SIMEON FAULT — BORROW PIT LOCALITY

Subsurface Exploration



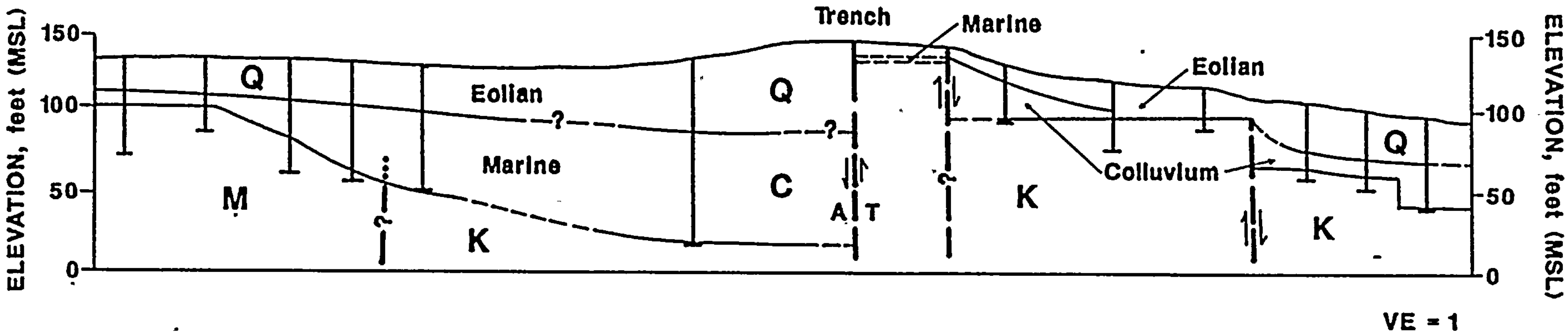
30" wide backhoe trench. (T-1)

5" diameter auger hole. (DH-12)

30" wide backhoe exploratory pit. (EP-1)

SS-8

Cross Section Along Borrow Pit Road, N64E →

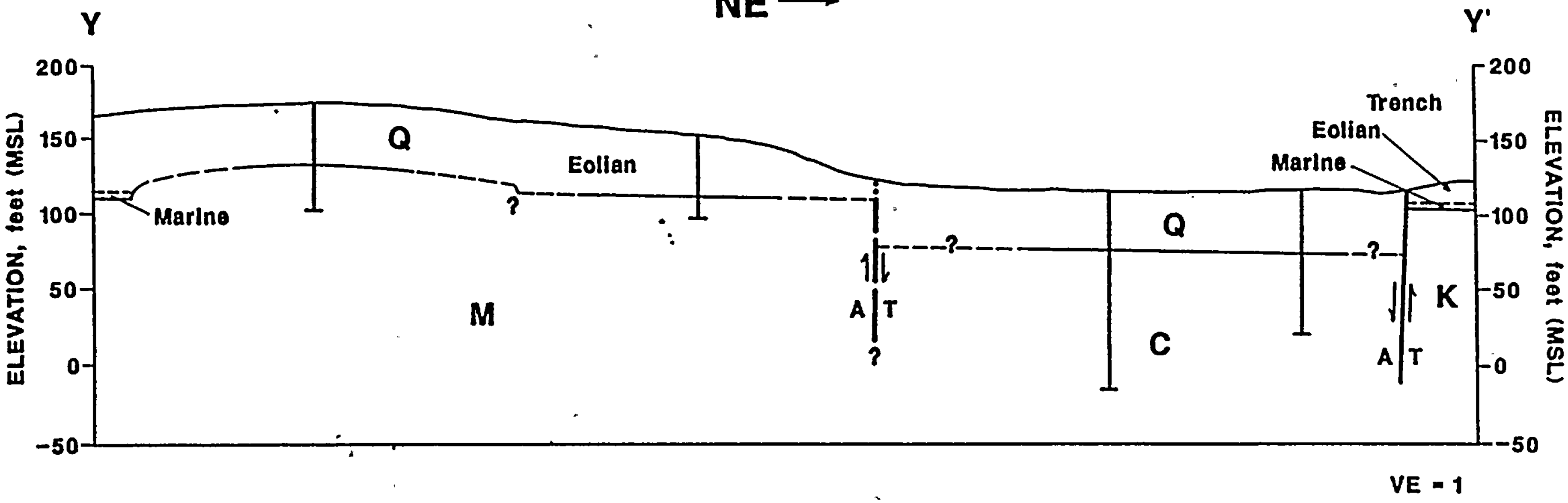


EXPLANATION

- **Q** Quaternary
- **C** Careaga
- **M** Monterey
- **K** Franciscan

55-9

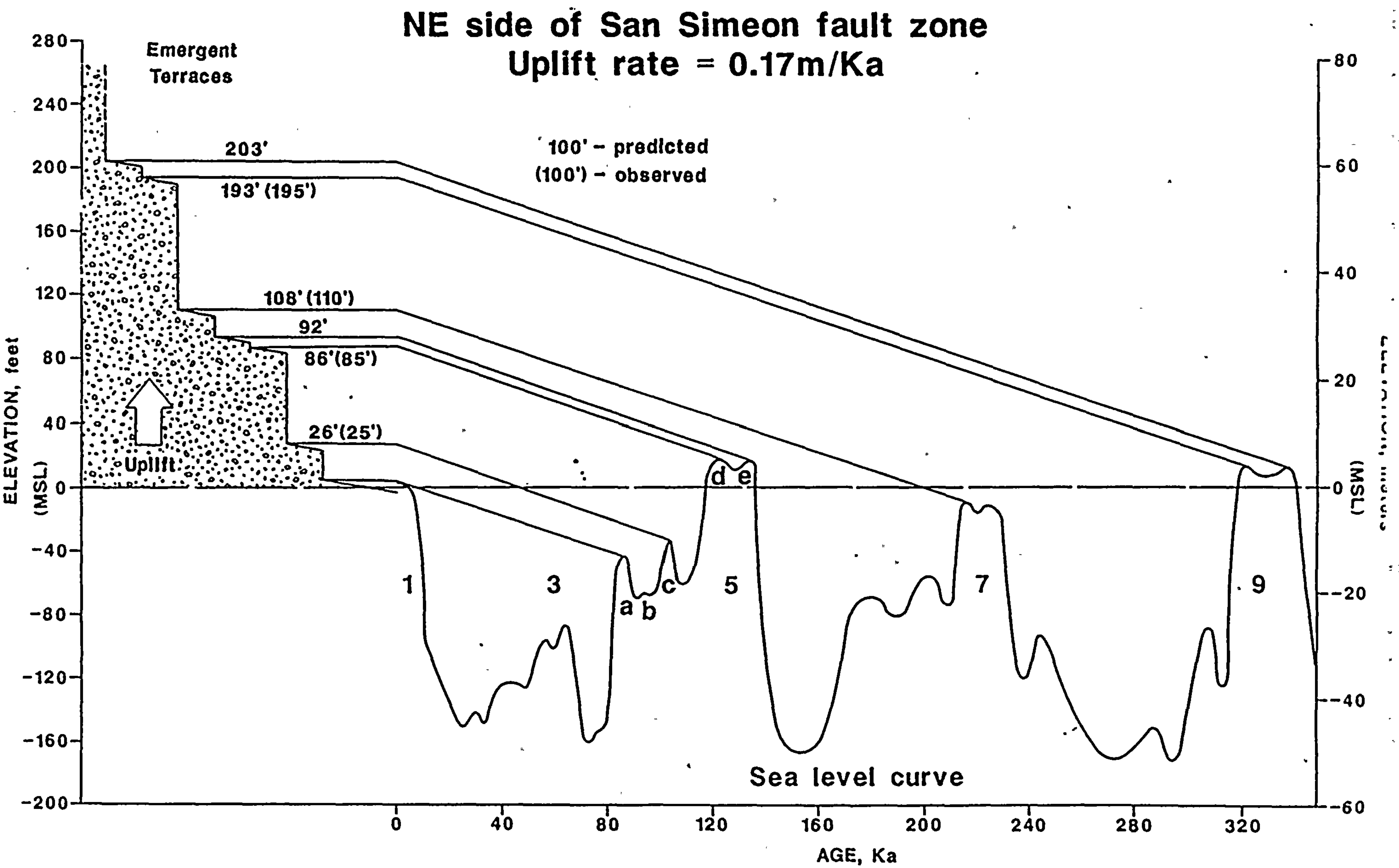
Cross Section Along Borrow Pit, NE →



55-10

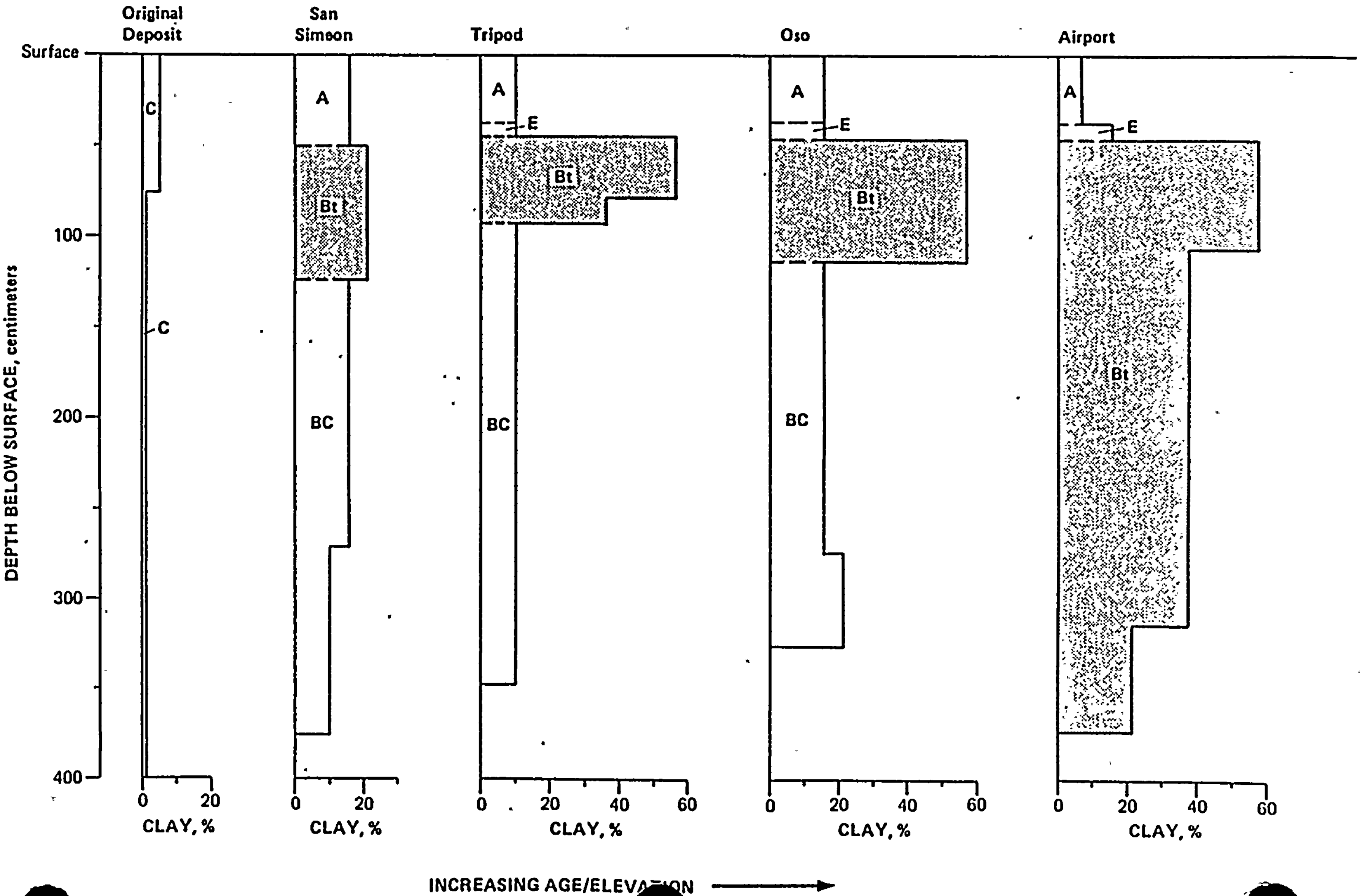
EXPLANATION

- Q — Quaternary
- C — Careaga
- M — Monterey
- K — Franciscan


NE side of San Simeon fault zone
Uplift rate = 0.17m/Ka
Emergent Terraces
100' – predicted
(100') – observed
203'
193' (195')
108' (110')
92'
86' (85')
26' (25')
Uplift
ELEVATION, feet
(MSL)
280
240
200
160
120
80
40
0
-40
-80
-120
-160
-200
80
60
40
20
0
-20
-40
-60
(MSL)
1
3
5
7
9
a
b
c
d
e
Sea level curve
0
40
80
120
160
200
240
280
320
AGE, Ka

SS-11

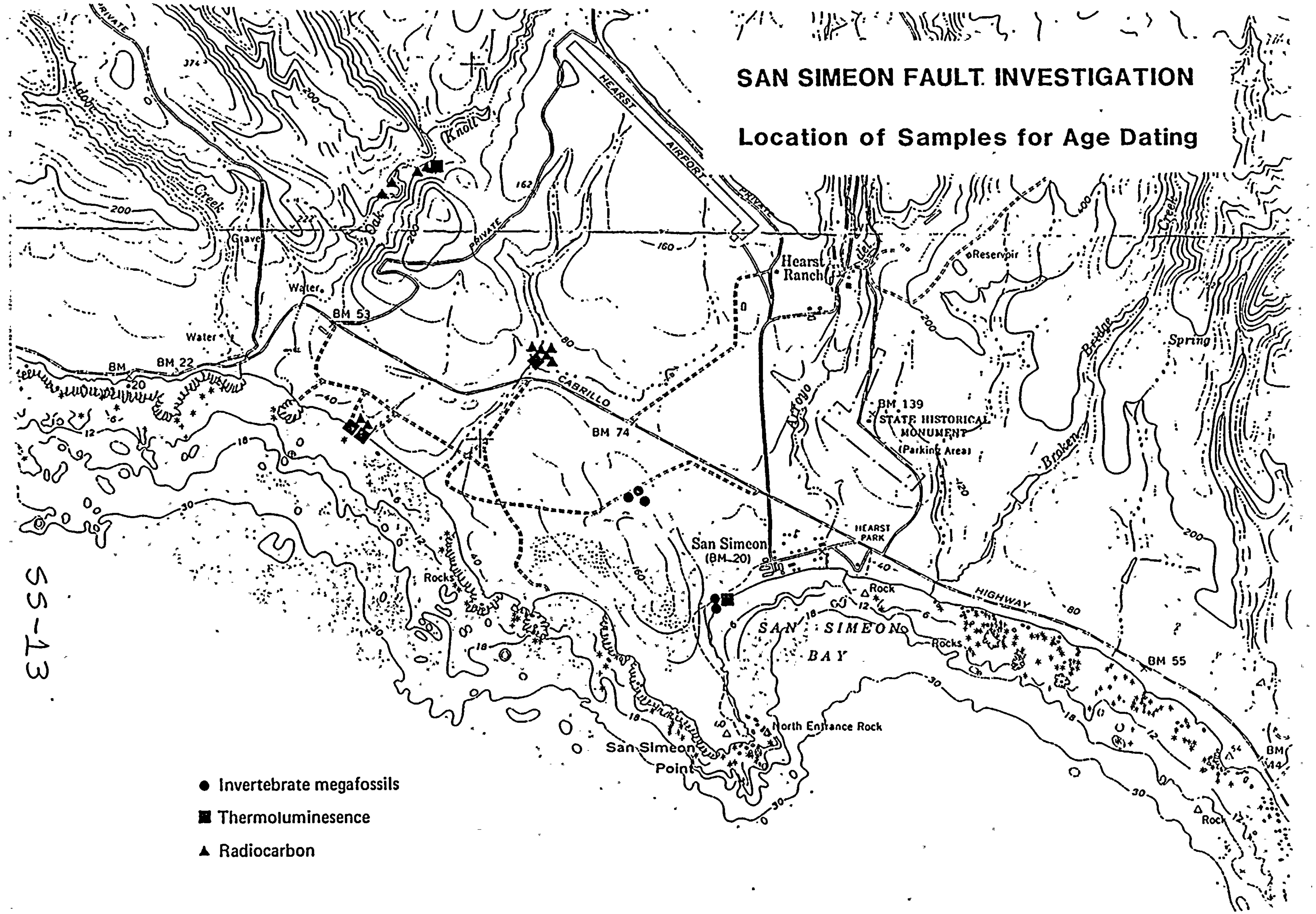
RELATIVE SOIL DEVELOPMENT ON MARINE PLATFORMS



55-12

SAN SIMEON FAULT INVESTIGATION

Location of Samples for Age Dating



● Invertebrate megafossils

■ Thermoluminesence

▲ Radiocarbon

55-13

[1]Preliminary Estimates of Slip Rate Across San Simeon Fault Zone

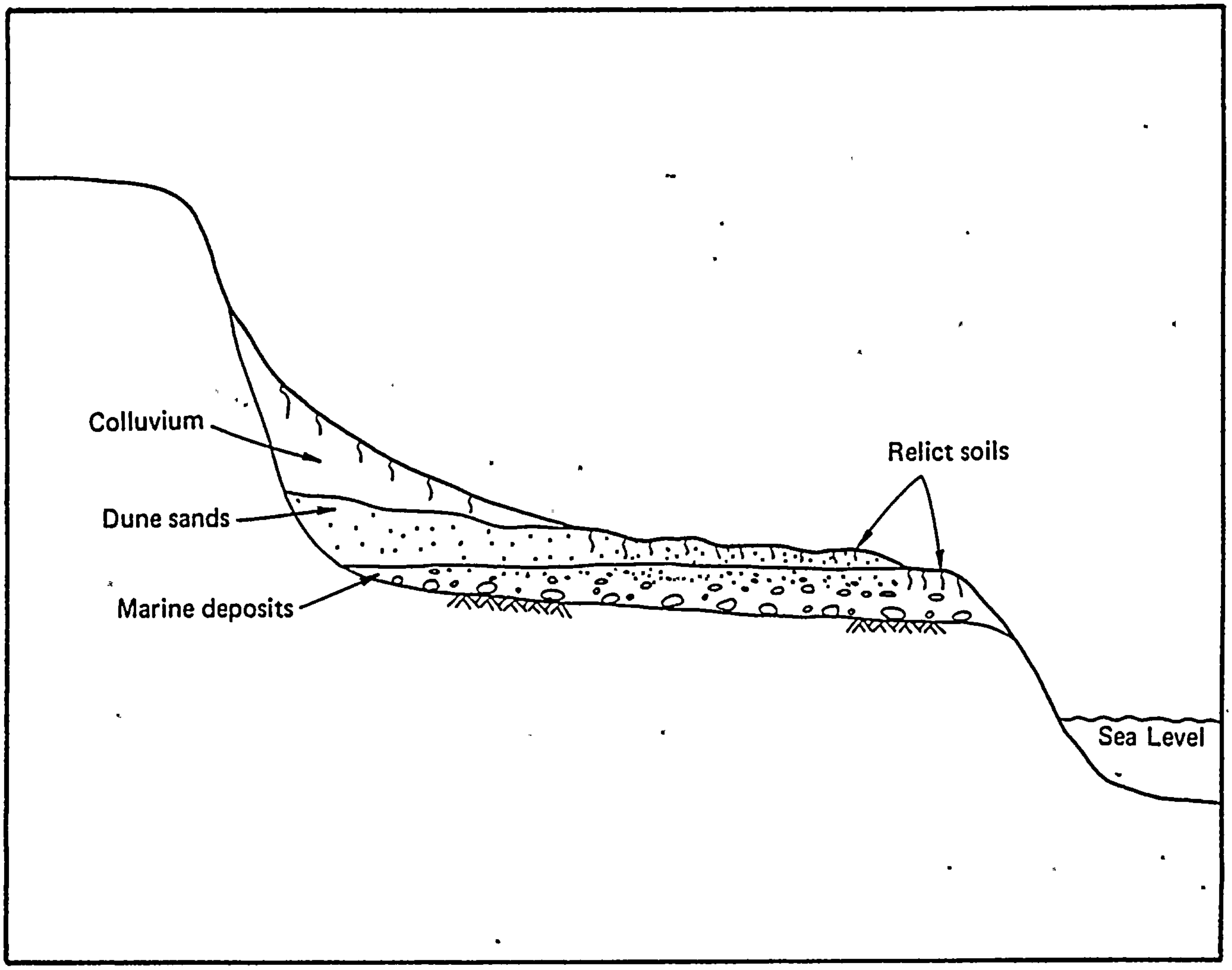
Feature	Age (Ka)	Net Displacement(m)[2]		Net Slip Rate (mm/y)	
		Primary Fault	Total Fault Zone	Primary Fault	Total Fault Zone
Shoreline angle	124^{+9}_{-21}	350 ± 150	725 ± 275	$2.8^{+2.1}_{-1.3}$	$5.8^{+3.9}_{-2.4}$
Shoreline angle	214	--	990 ± 230	--	4.6 ± 1

[1]These estimates are preliminary pending age dating and final mapping results.

[2]Horizontal component =>90% net displacement.

55-14

SCHEMATIC RELATIONSHIP OF RELICT SOILS ON MARINE ABRASION PLATFORMS

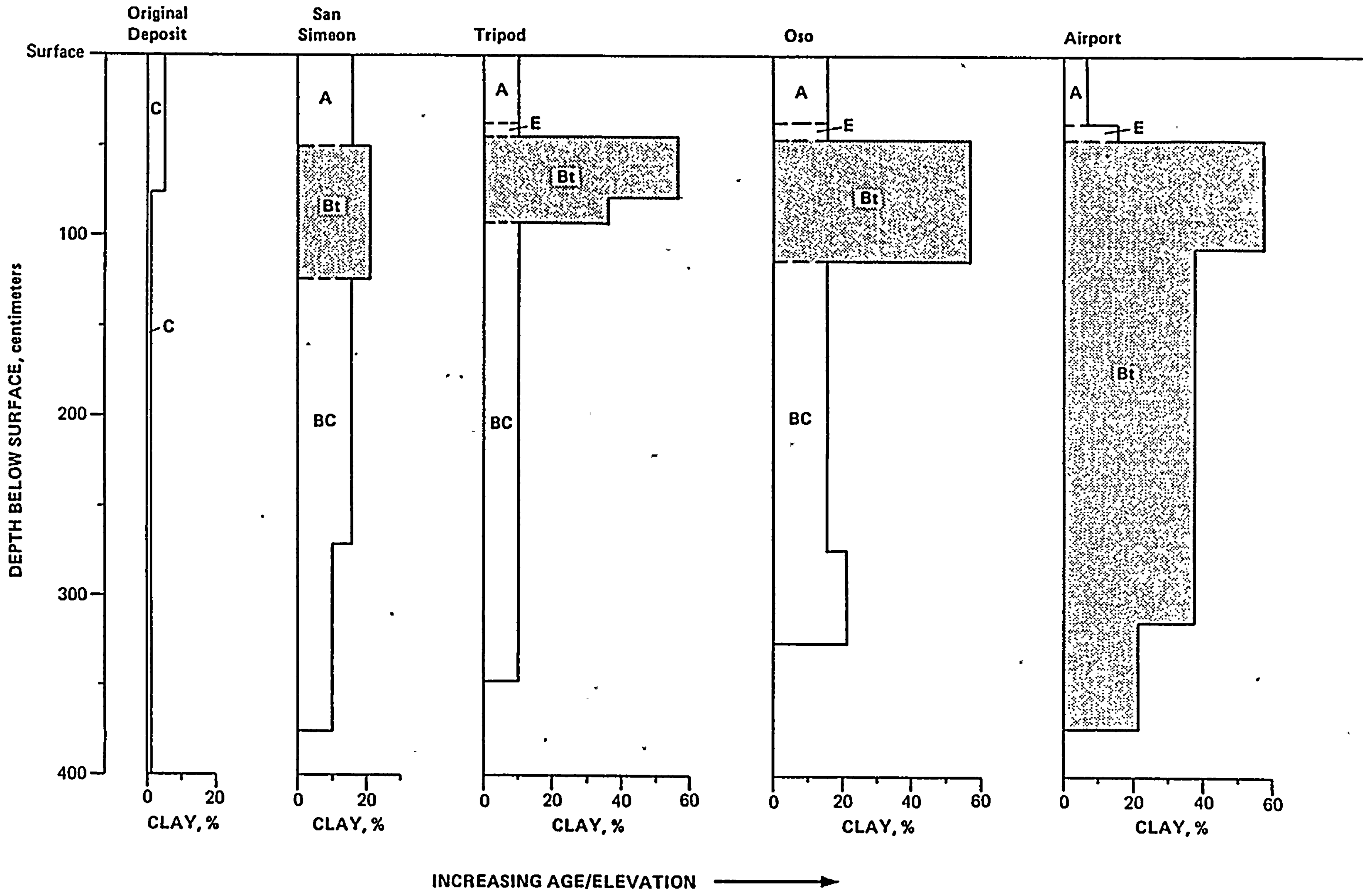


HYPOTHETICAL PEDOGENIC SOIL HORIZONS

PEDOGENIC SOIL	**O** Organic debris		O1*	Original form of most vegetative matter visible to eye
			O2	Original form of most vegetative matter cannot be recognized with eye
	THE SOLUM Genetic soil formed by the soil forming processes	**A** Horizons of maximum biological activity, eluviation, or both	A1	Dark colored horizon with high content of organic matter mixed with mineral matter
			E	Light colored horizon of maximum eluviation typified by loss of iron, aluminum or clay with concentration of resistant materials such as quartz
			AB	Transitional to B but more like A than B
		B Horizons of illuviation, residual concentration, coloring and certain structure	BA	Transitional to B but more like B than A
			Bt	Accumulation of clay, iron, aluminum, humus or in combination; residual concentration of sesquioxides or mixed; sesquioxide coatings giving darker, stronger redder colors, or has granular, blocky, or prismatic structure
			BC	Transitional to C
	C Parent material from which soil is presumed to have formed; lacks soil structure; weathered; may be gleyed, cemented, and have accumulation of soluble salts		g	Gleyed layer with base colors near neutral
			Beta	Beta horizon, accumulation of clay, iron, sesquioxides above bedrock; oxidized or reduced
				Unweathered parent material (typically bedrock)

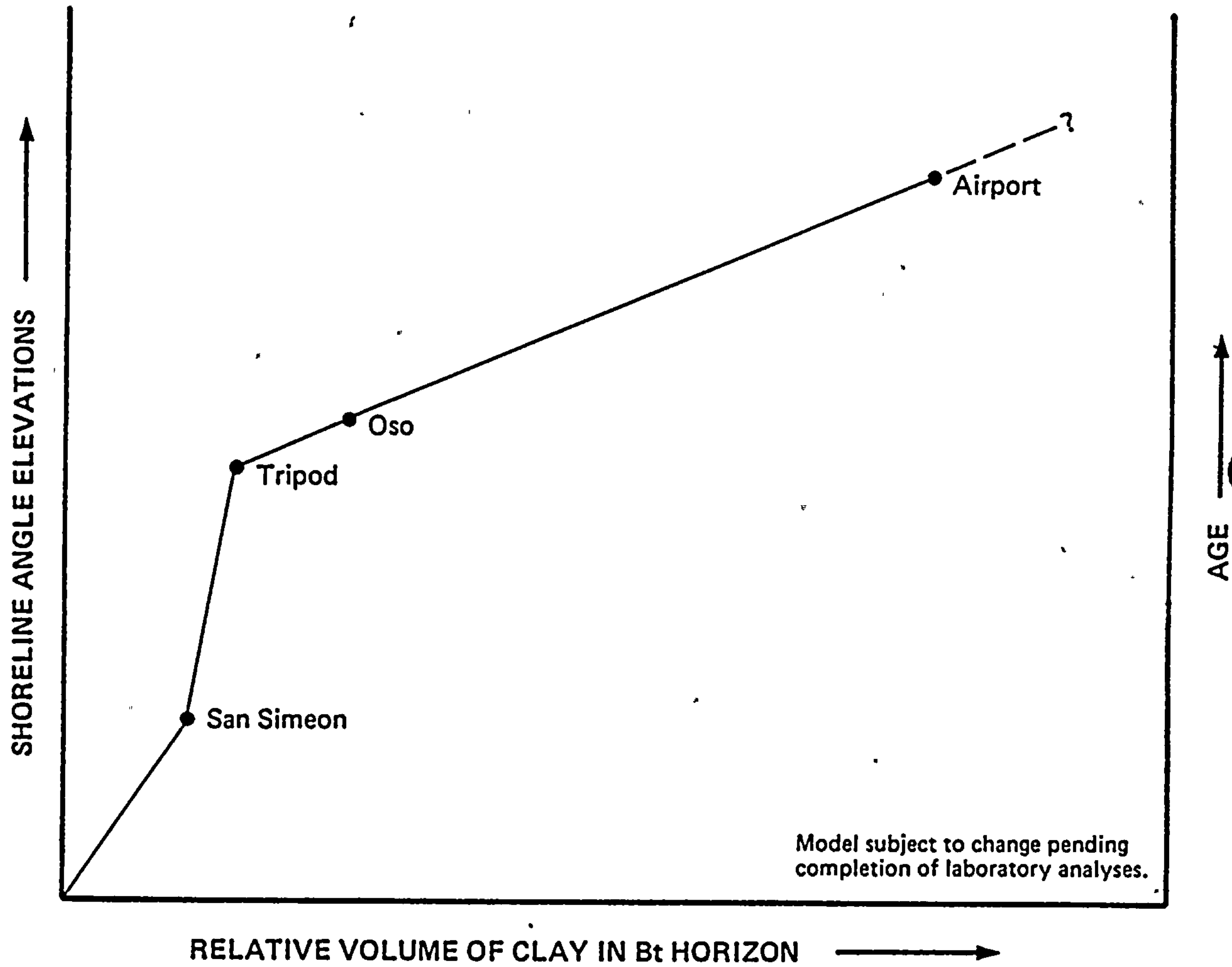
*All of these horizons will not be present in any profile, but every profile has some of them. The pedologic soil consists of the O, the A, the B and the C horizons.

RELATIVE SOIL DEVELOPMENT ON MARINE PLATFORMS



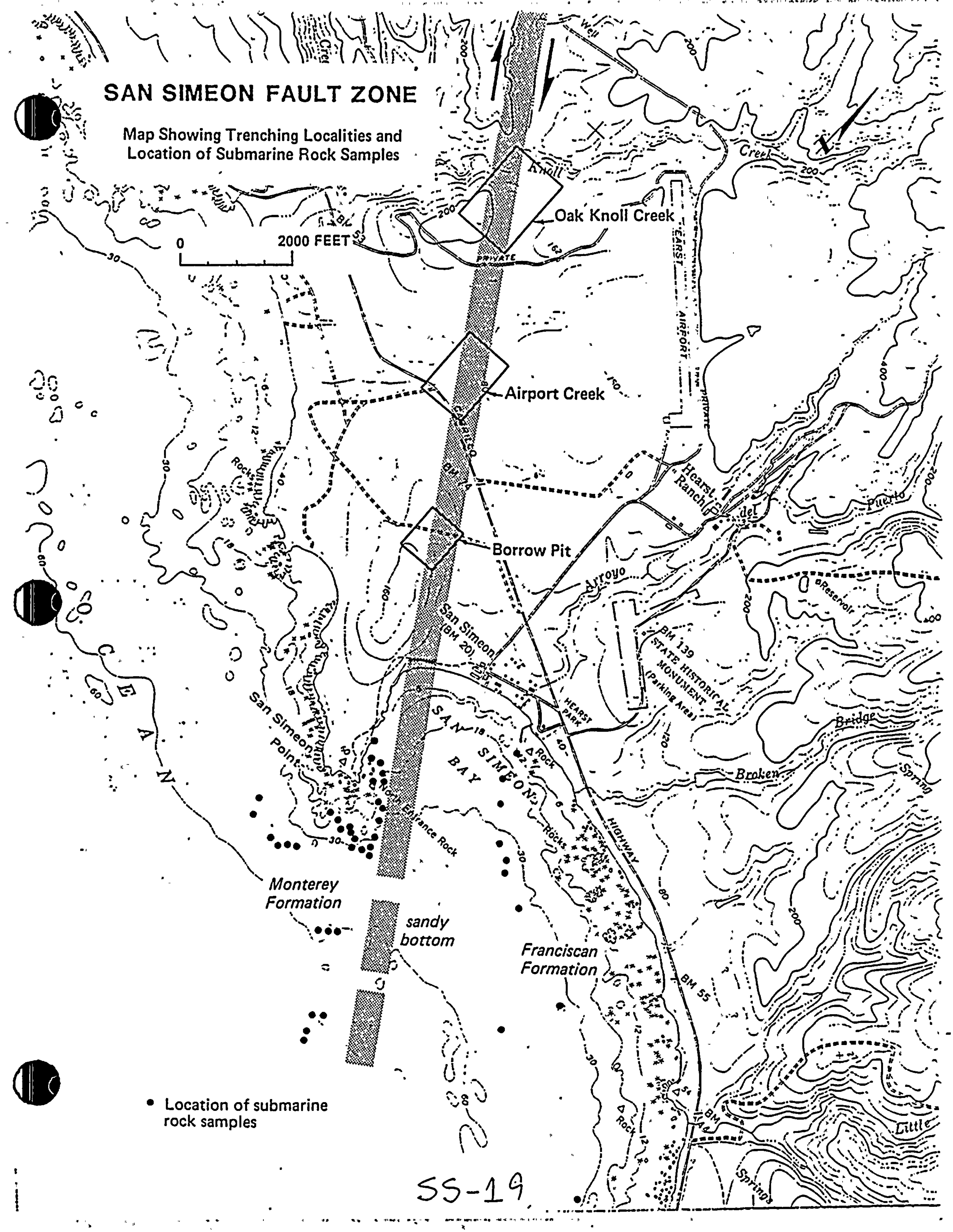
55-17

GENERALIZED MODEL OF SOIL DEVELOPMENT FOR SAN SIMEON REGION MARINE TERRACES



SAN SIMEON FAULT ZONE

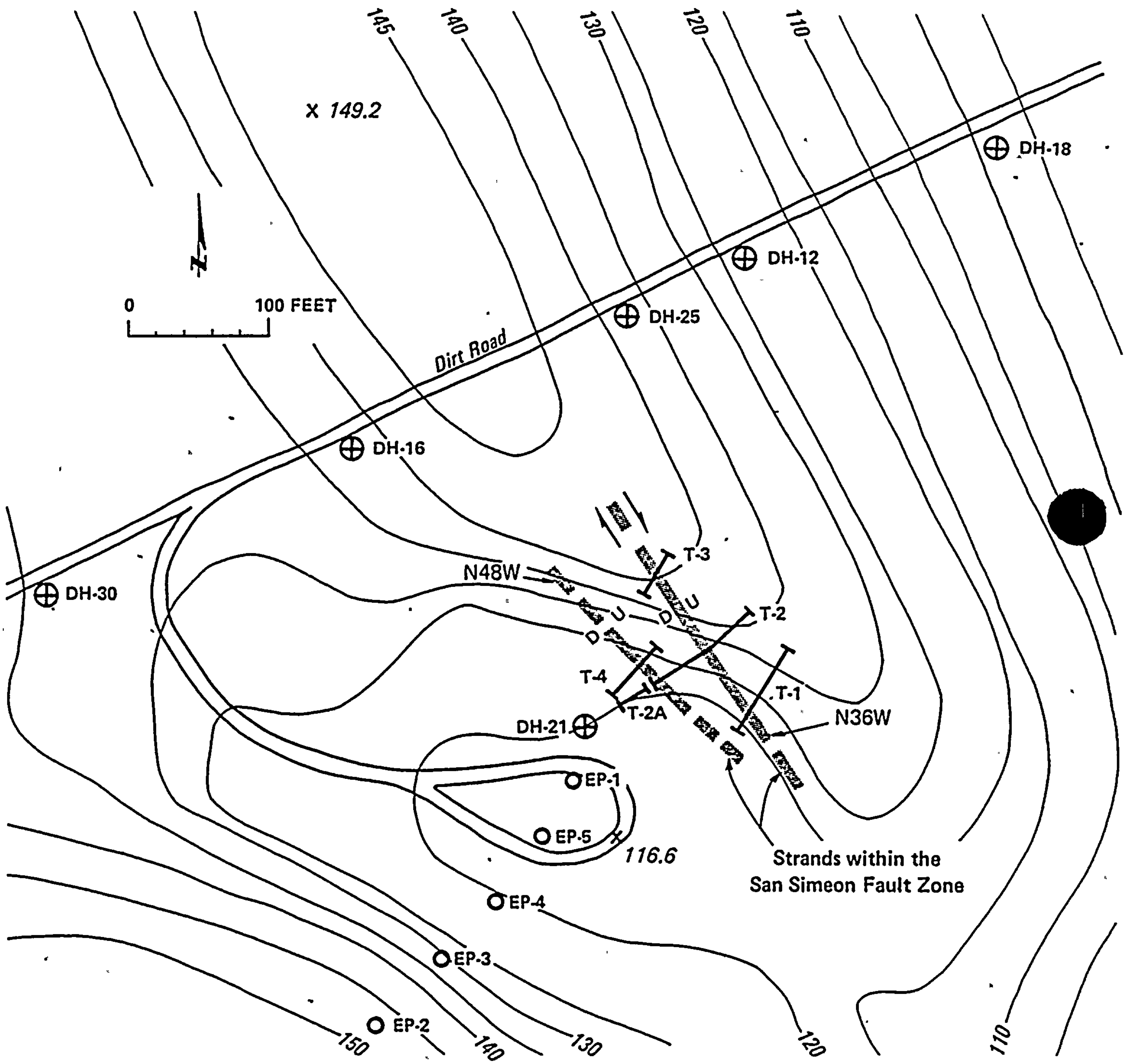
Map Showing Trenching Localities and Location of Submarine Rock Samples



SS-19

SAN SIMEON FAULT — BORROW PIT LOCALITY

Subsurface Exploration



30" wide backhoe trench. (T-1)

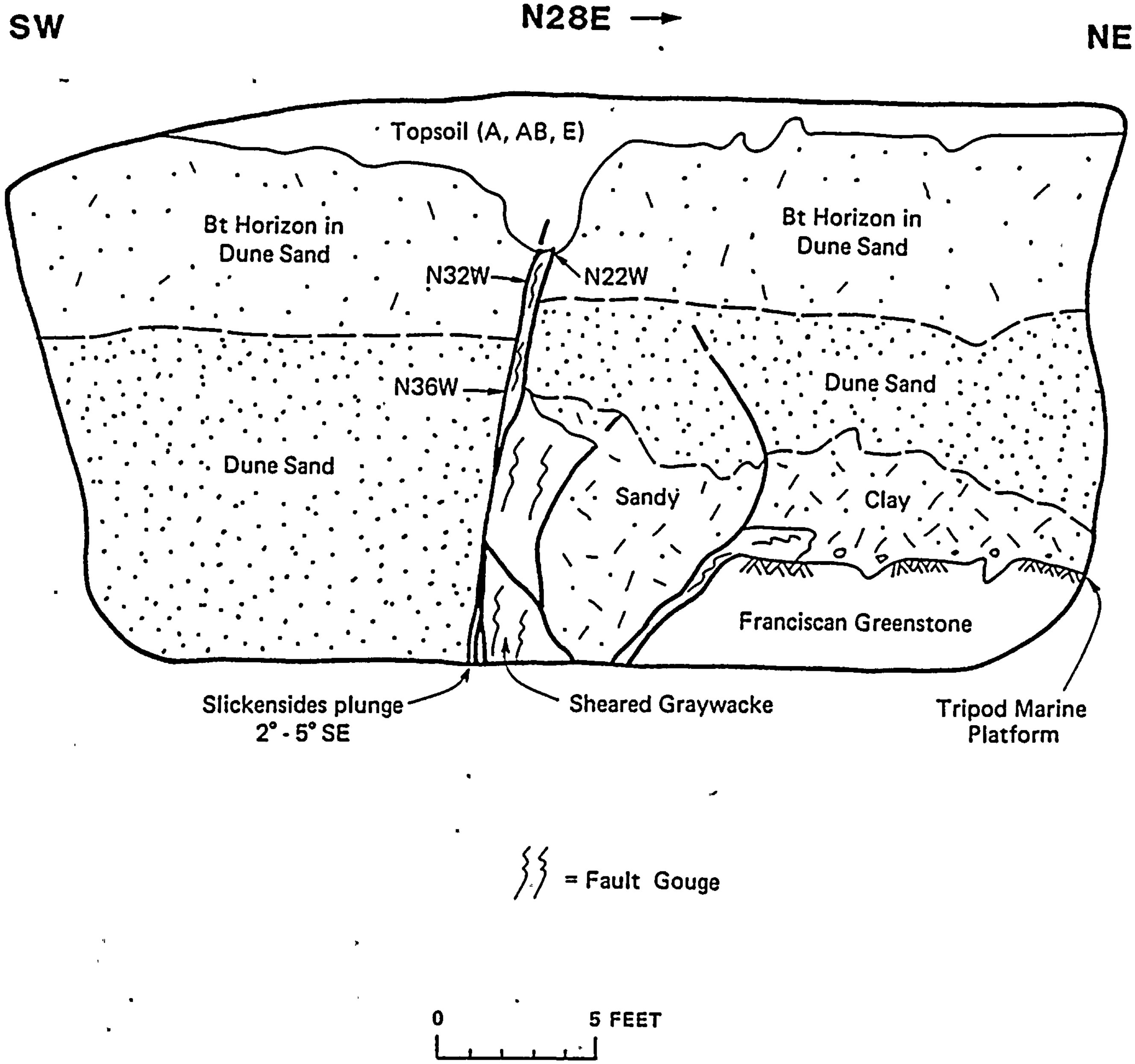
5" diameter auger hole. (DH-12)

30" wide backhoe exploratory pit. (EP-1)

SS-20

SAN SIMEON FAULT

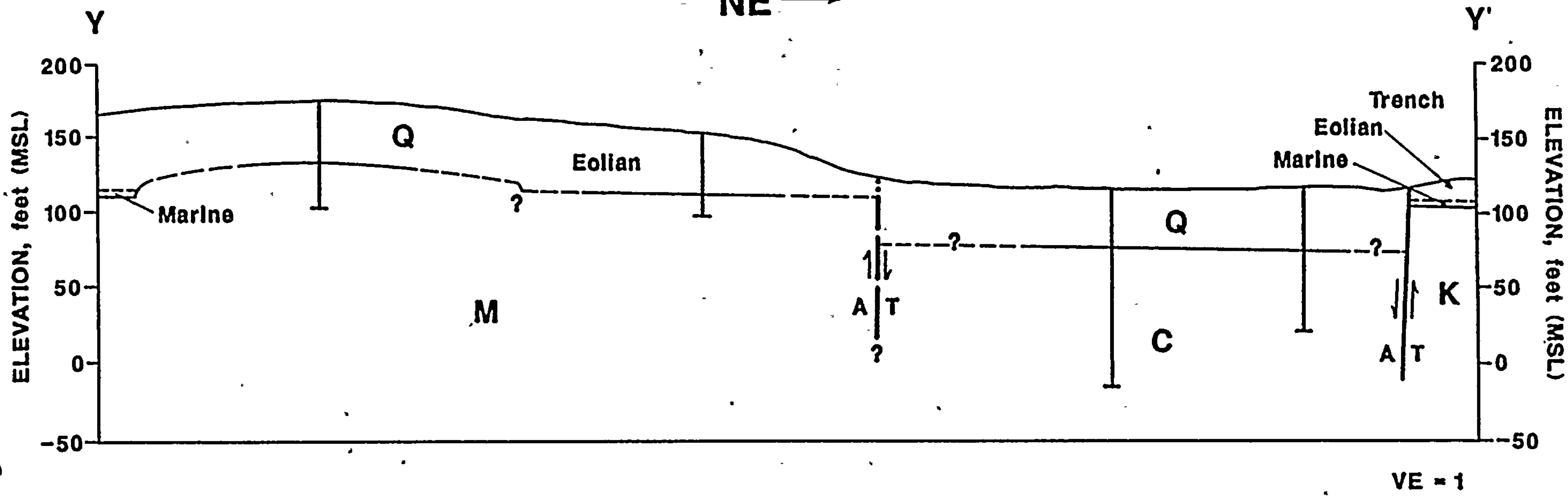
Borrow Pit Trench 3



SS-21

Cross Section Along Borrow Pit,

NE ⟶



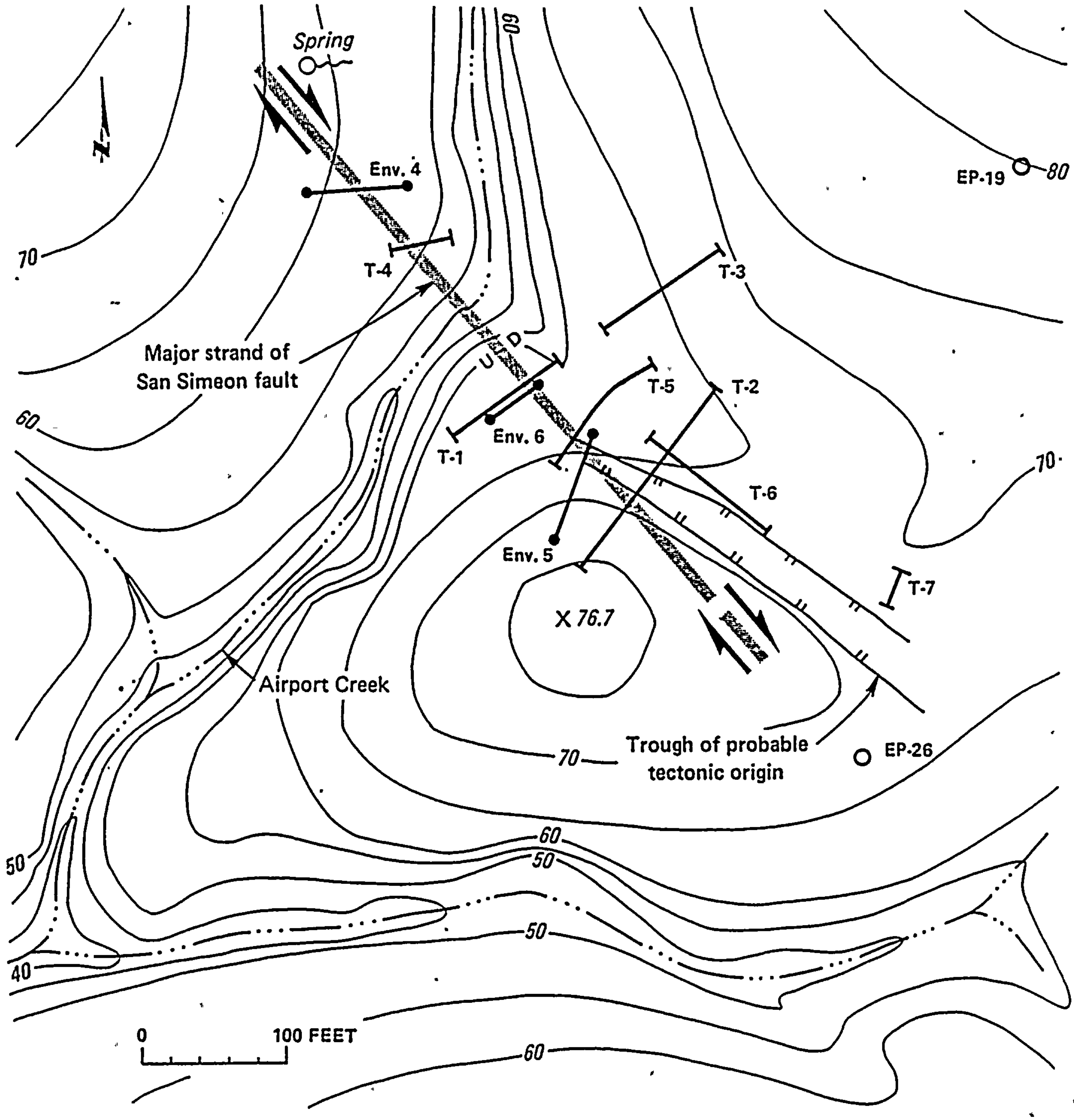
55-22

EXPLANATION

- Q — Quaternary
- C — Careaga
- M — Monterey
- K — Franciscan

SAN SIMEON FAULT - AIRPORT CREEK LOCALITY

Subsurface Exploration



30" wide backhoe trench excavated by ESA. (T-1)

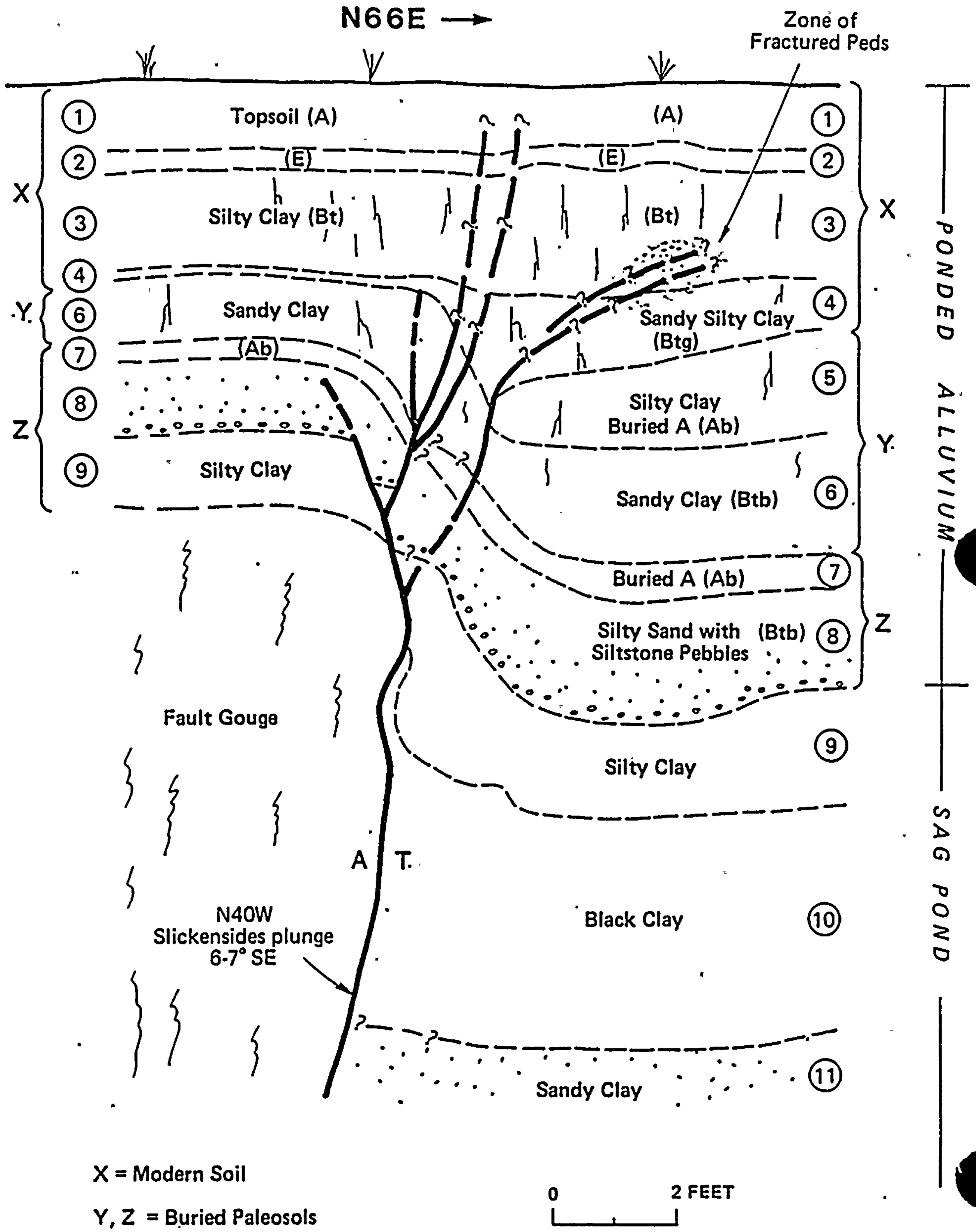
Backhoe trench excavated by Envicom. (Env. 4)

30" wide backhoe exploratory pit. (EP-1)

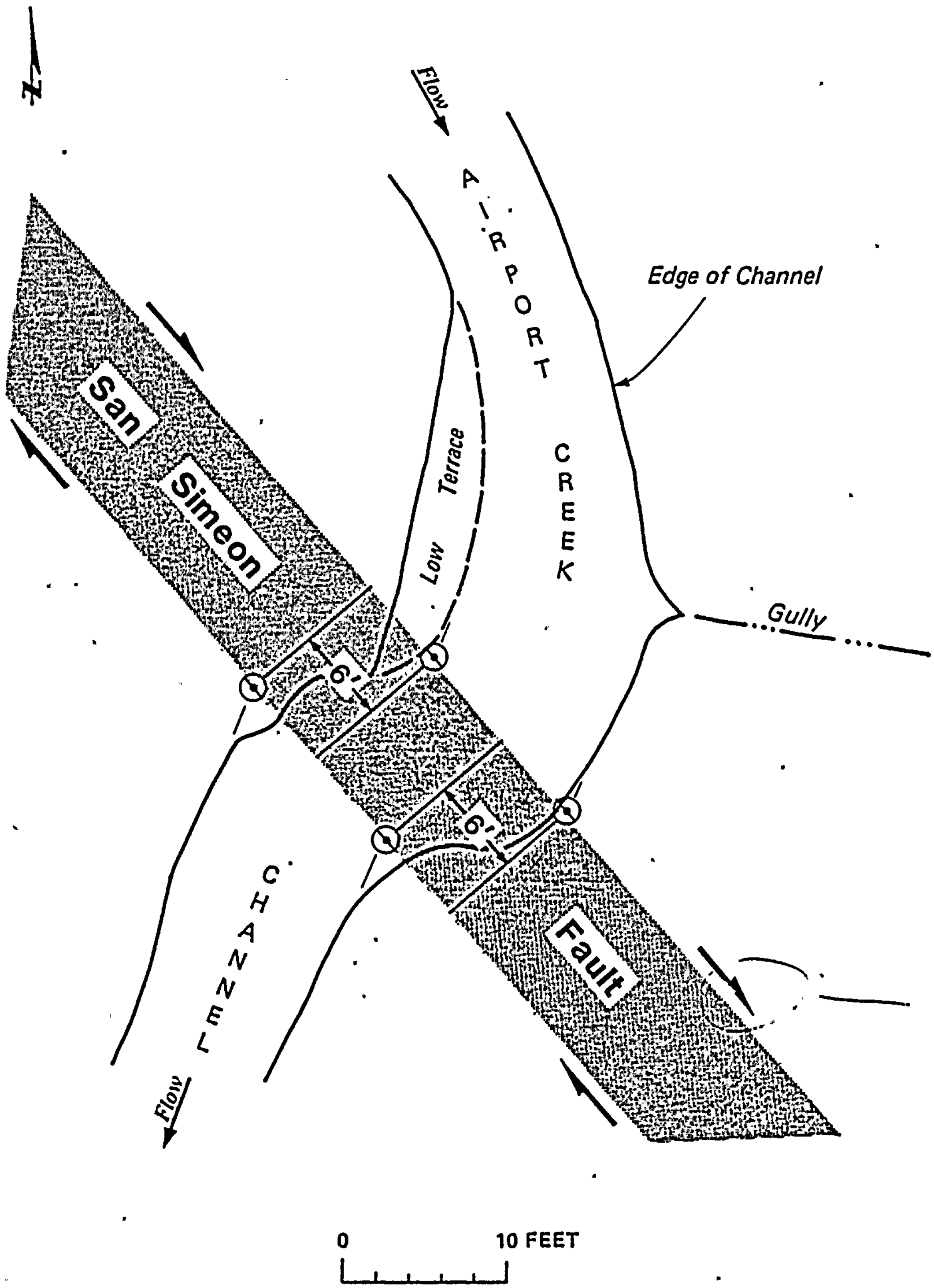
55-23

SAN SIMEON FAULT

Airport Creek Trench 1



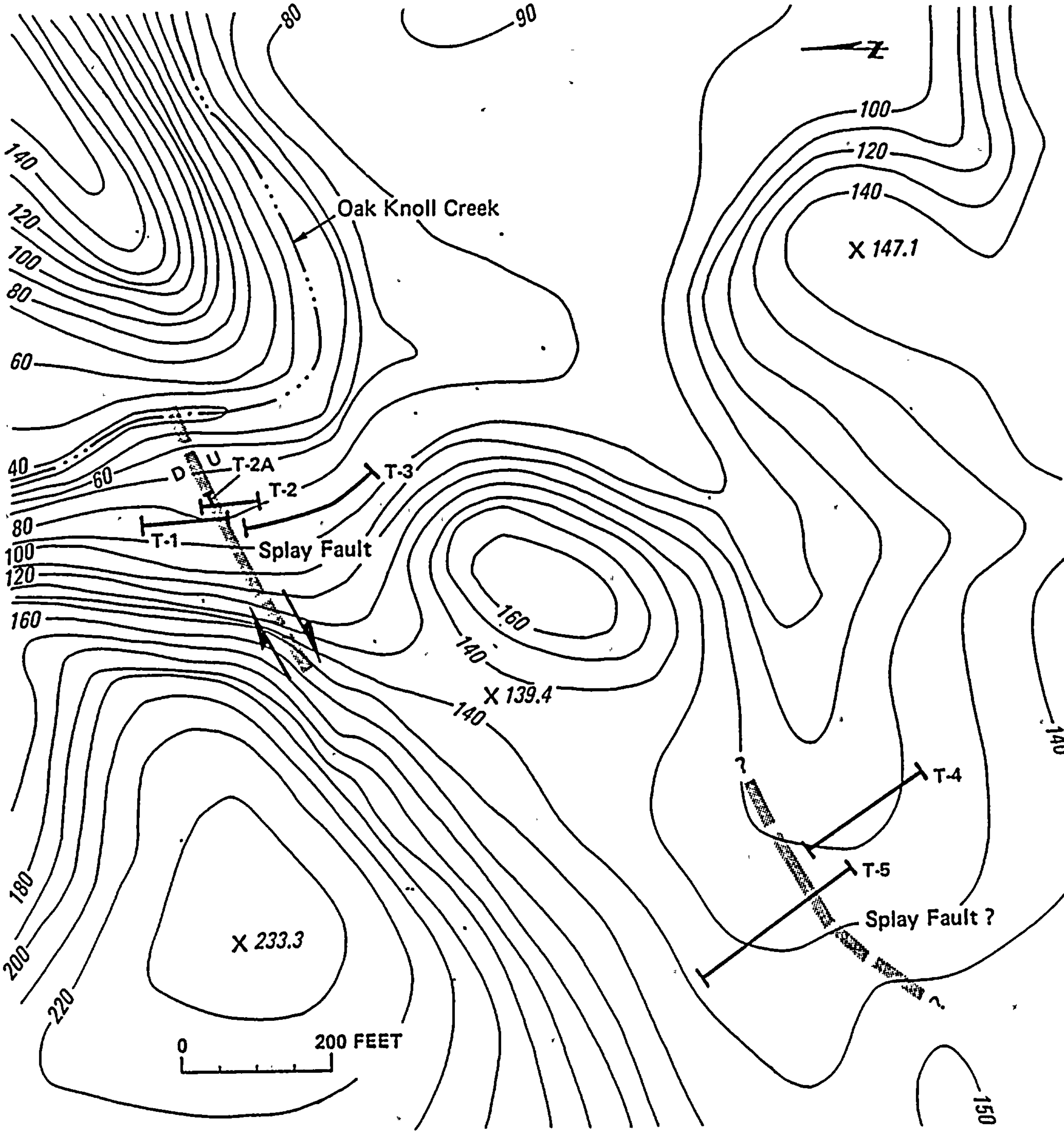
AIRPORT CREEK DEFLECTED CHANNEL



55-25

SAN SIMEON FAULT - OAK KNOLL CREEK LOCALITY

Subsurface Exploration

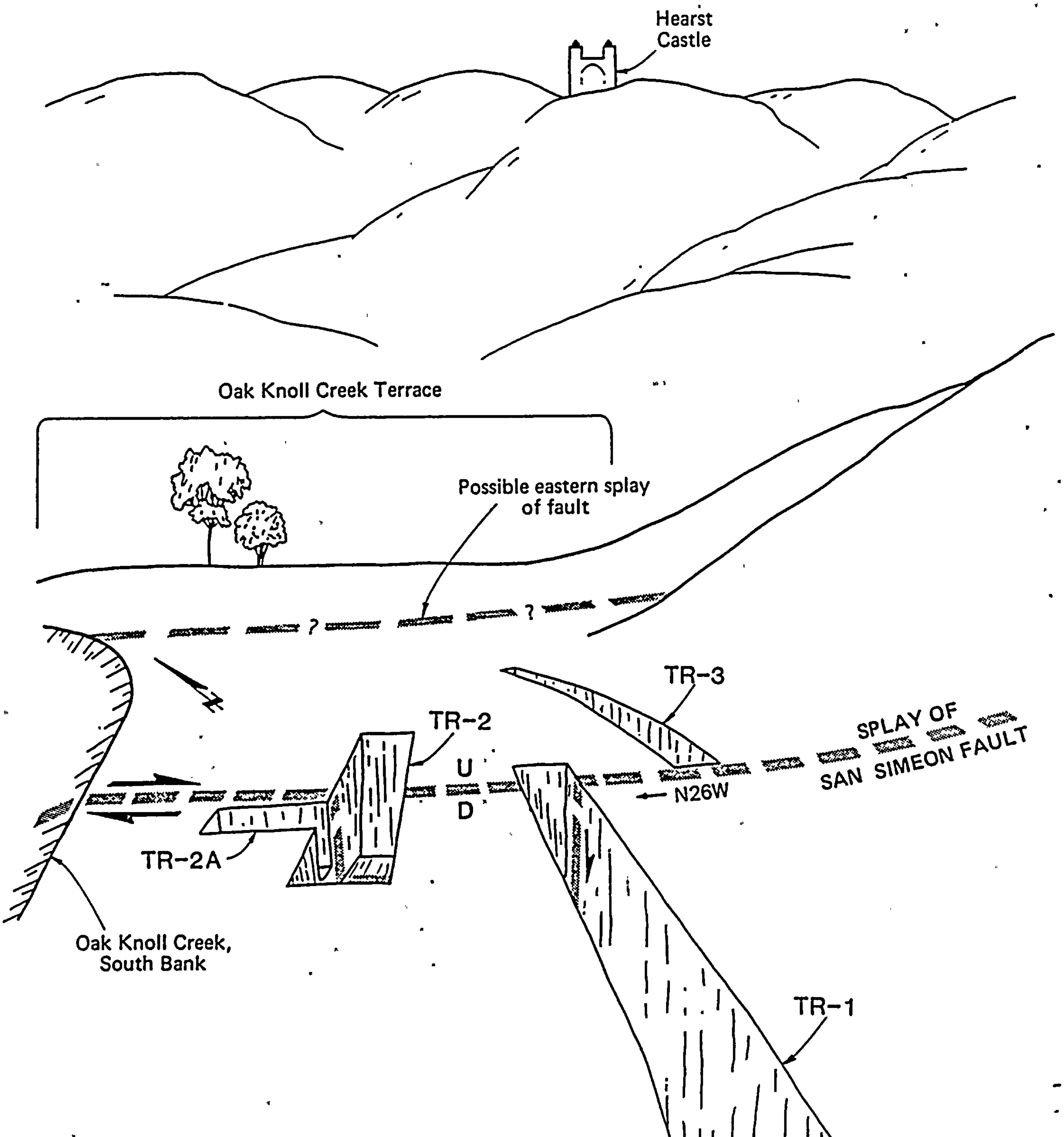


30" wide backhoe trench. (T-1)

SS-26

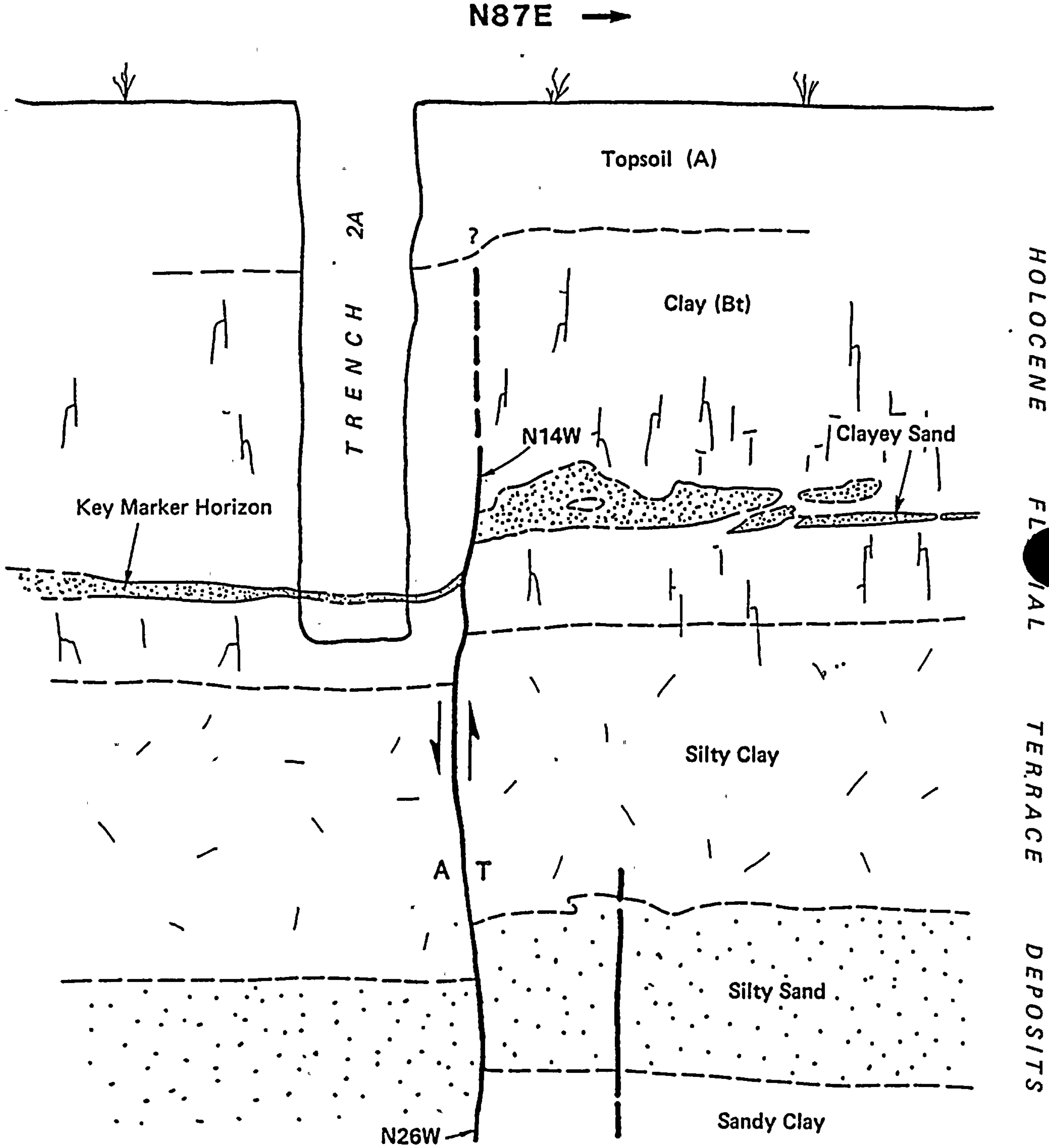
SAN SIMEON FAULT — OAK KNOLL CREEK

Sketch Showing Backhoe Trenches and Splay Fault



SAN SIMEON FAULT ZONE — OAK KNOLL CREEK

Log of North Wall of Trench 2 Showing Splay Fault



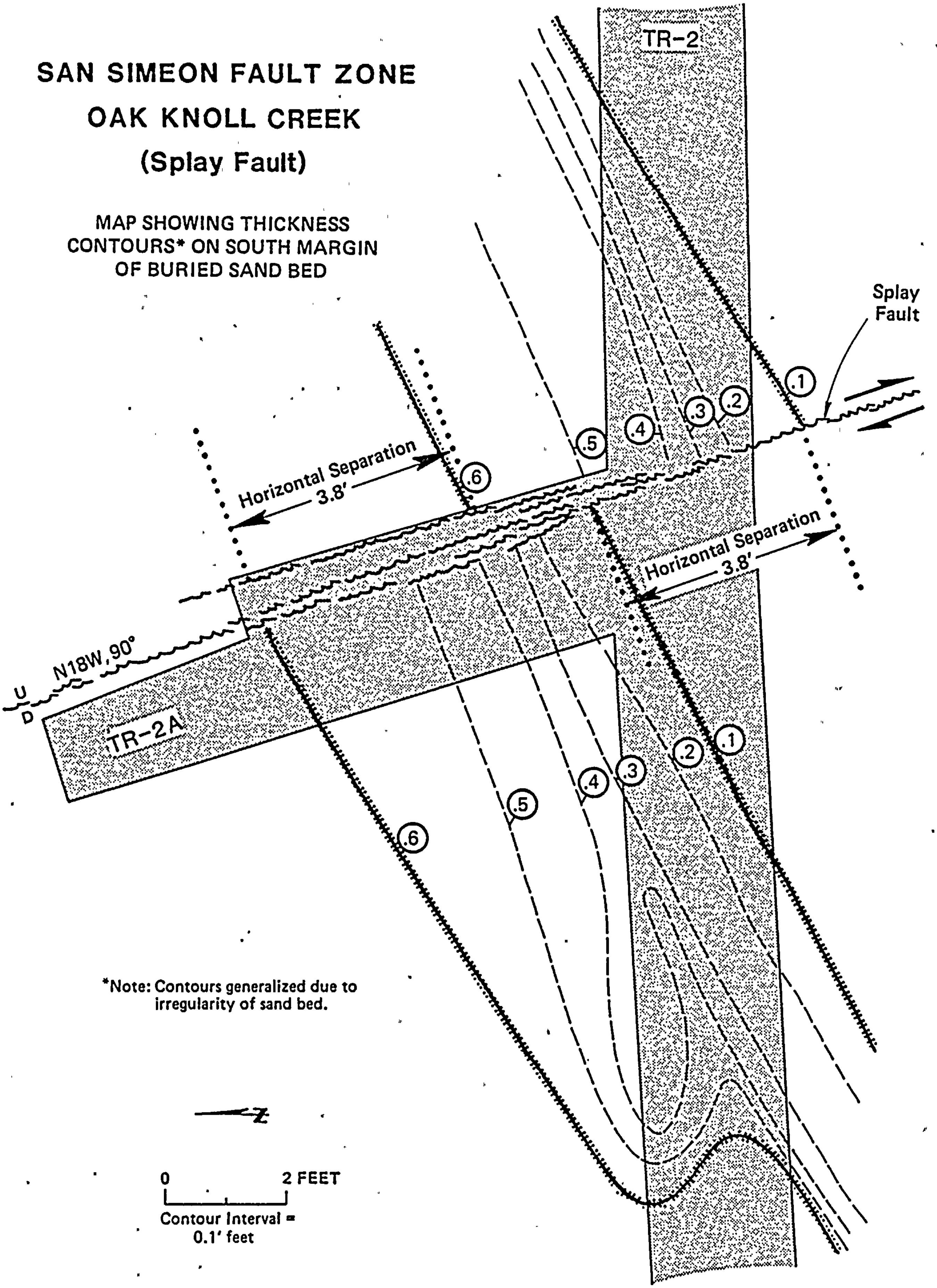
Characteristics of most recent slip event on splay fault:

1) Horizontal right slip = 3.8±0.1'
2) Vertical slip (east side up) = 0.7-0.8'
3) Net slip approximately 3.9' (1.2 m)
4) Poorly defined slickensides plunge 10-15° N

SS-28

SAN SIMEON FAULT ZONE
OAK KNOLL CREEK
(Splay Fault)

MAP SHOWING THICKNESS
CONTOURS* ON SOUTH MARGIN
OF BURIED SAND BED



NEOTECTONIC AND QUATERNARY STUDIES
SAN SIMEON AREA

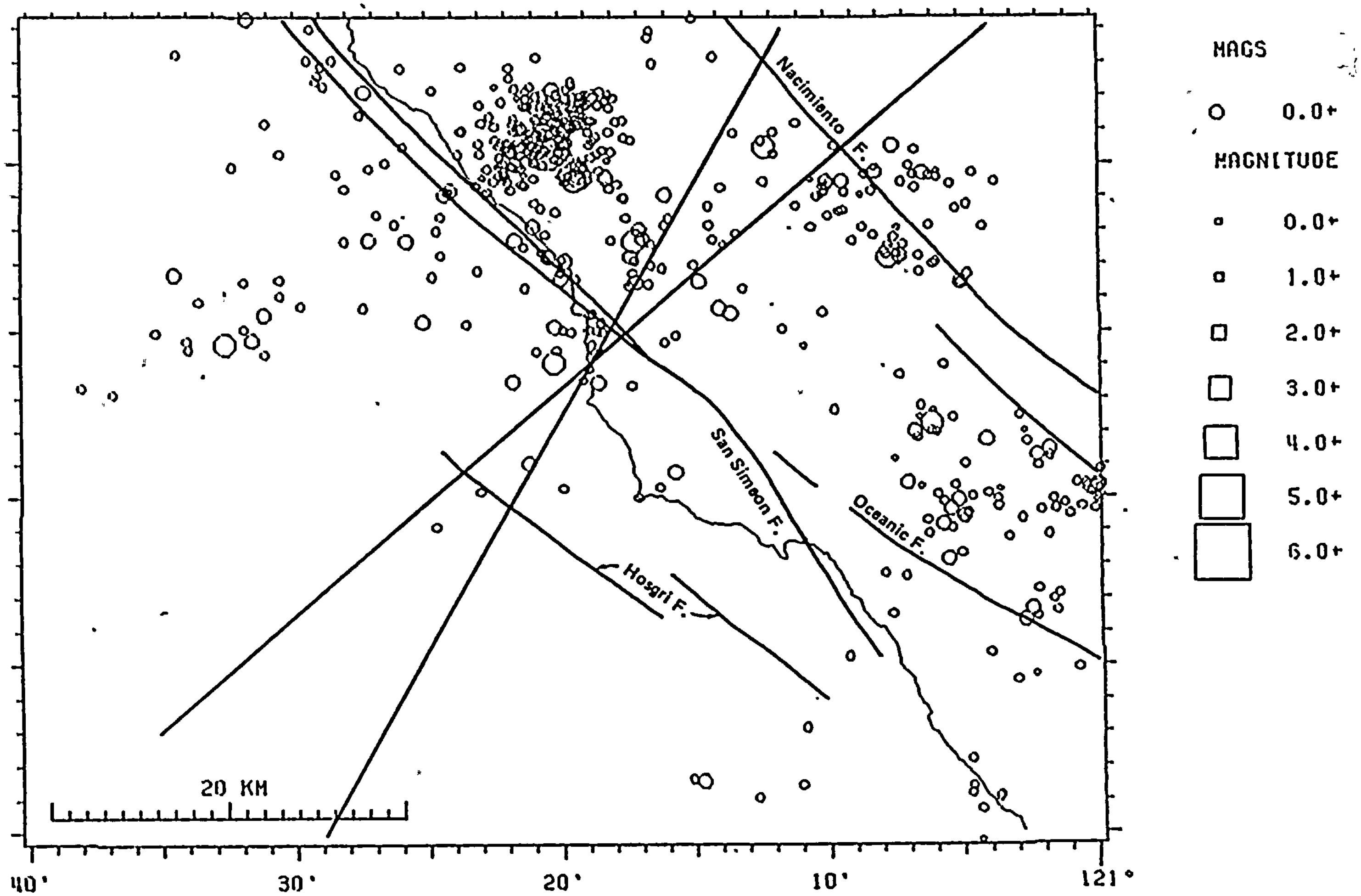
Preliminary Conclusions

- San Simeon fault is major zone of right lateral displacement.
- Zone of faulting is 2000 feet to greater than several miles wide. Zone consists of several primary traces and numerous subsidiary splays.
- Contrast in bedrock lithologies across large shear zones suggest continuing displacement along pre-existing faults.
- Sense of slip is primarily right lateral along steeply dipping to vertical shear planes.
- Primary fault traces show multiple displacement of Holocene deposits. Subsidiary fault splays displace late Pleistocene to Holocene deposits.
- Late Pleistocene rates of slip range from 1.5 to 9.7 mm/yr with a preferred range of 2.8 to 5.8 mm/yr.
- Holocene alluvium containing datable charcoal is displaced ∿1.8 m.

*Subject to change pending completion of field investigations.

SAN SIMEON REGION

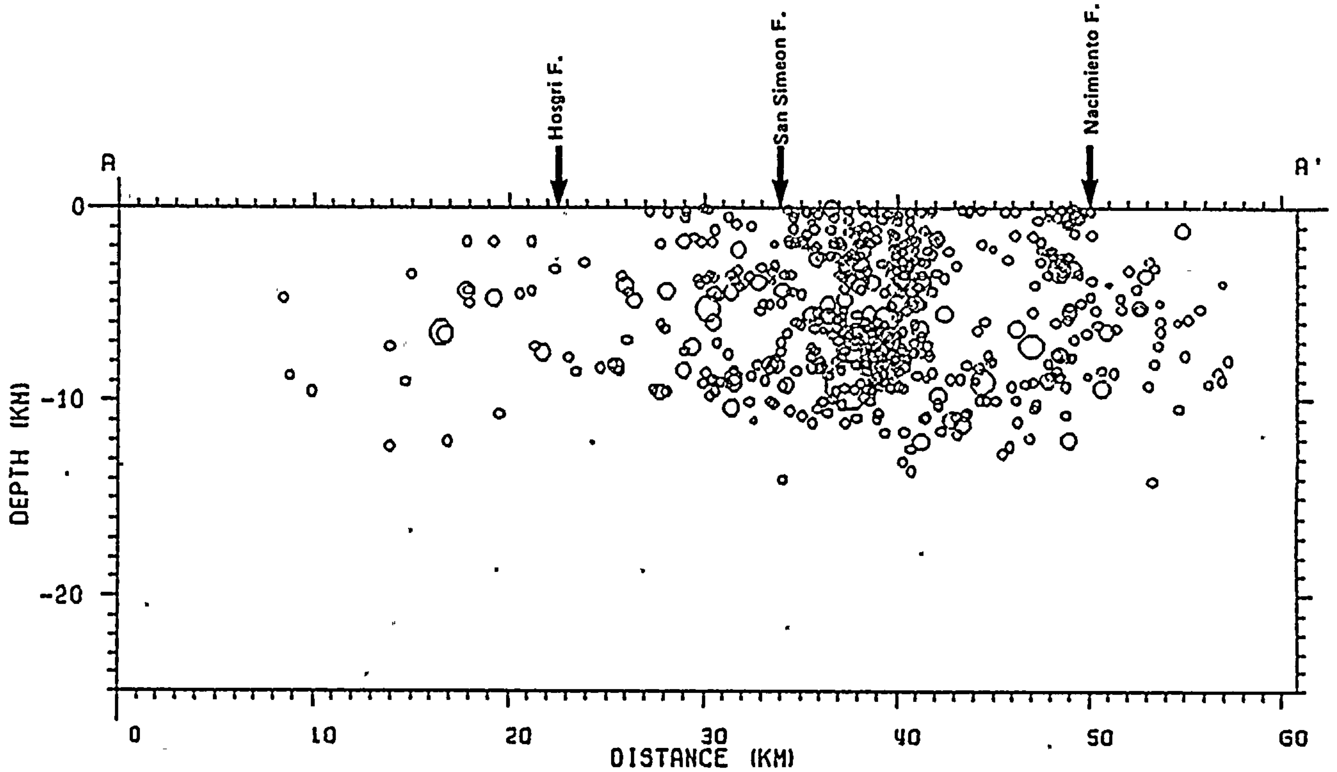
1980-7/23/1986 CALNET EARTHQUAKES, ERZ<5

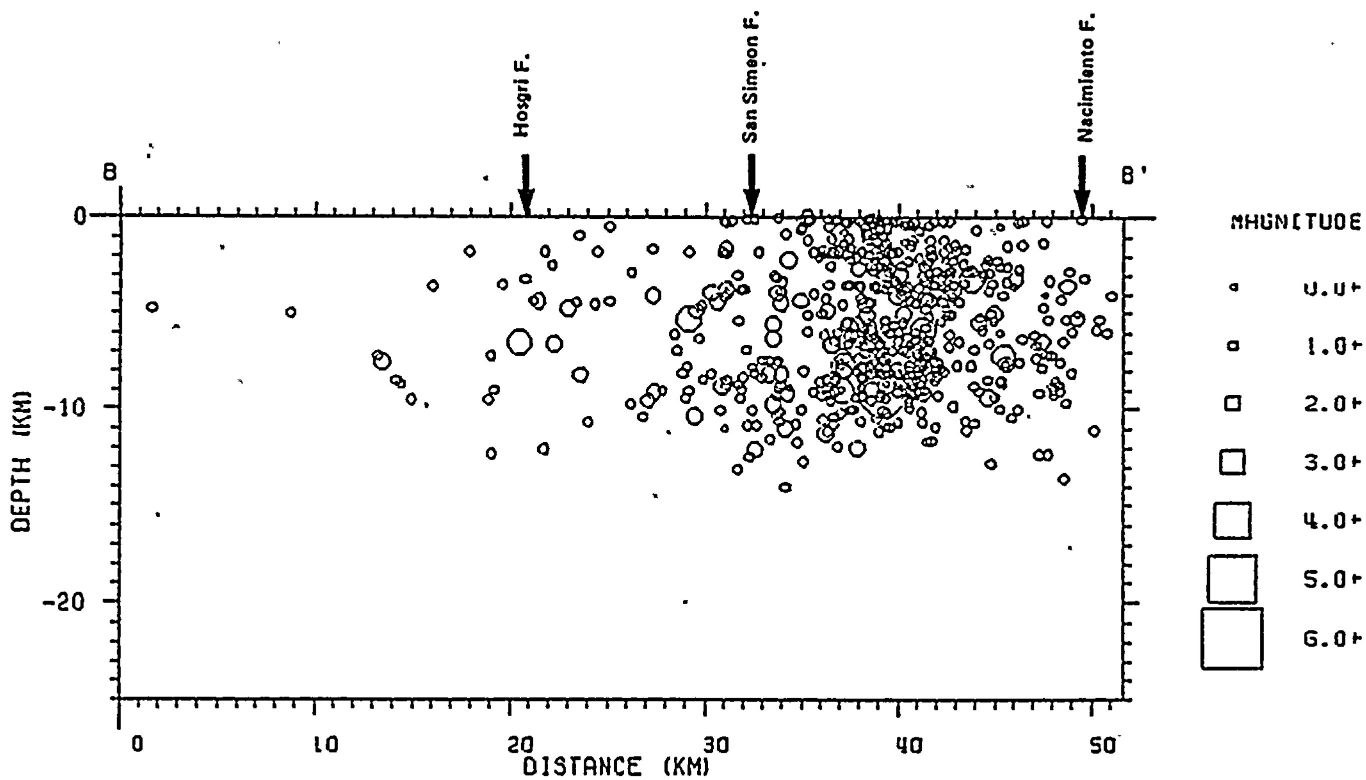


SS-31

SAN SIMEON REGION/ CALNET EARTHQUAKES

1980-JULY, 1986; ERZ<5, ERH<20





SS-32

CHARACTERIZATION OF THE SAN LUIS-PISMO REGION

The objectives of Tasks 4 and 5 are to:

- Review and characterize the Edna and San Miguelito Faults.
- Develop an understanding of the structural evolution of the San Luis-Pismo fold trend.
- Evaluate the local site area for evidence of late Quaternary tectonic deformation.
- Review and characterize the Little Pine-Foxen Canyon fault trend.
- Review and characterize major structural features in the Santa Maria Valley-Santa Ynez Valley Region.

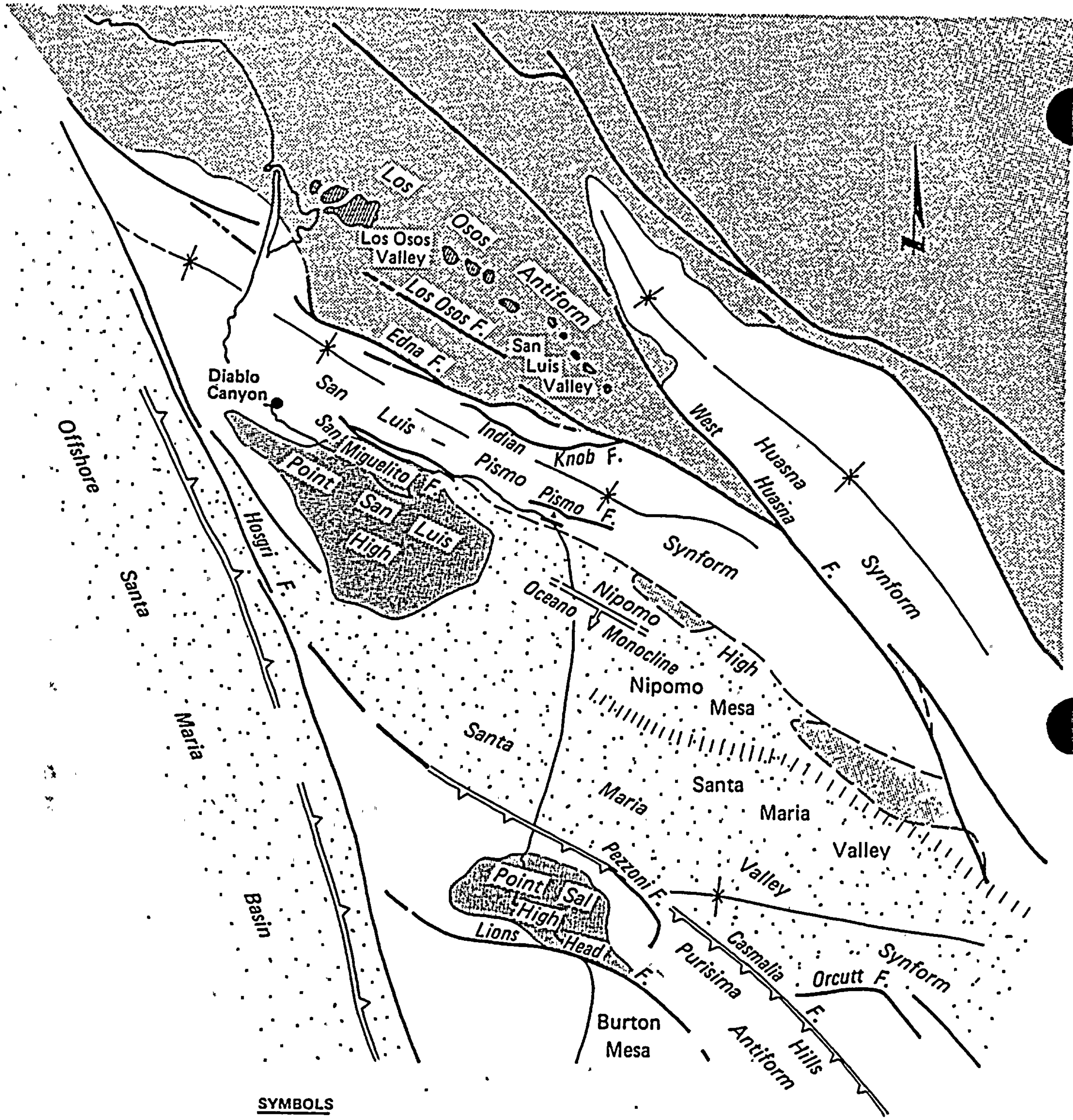
As part of Tasks 4 and 5, geologic studies have been initiated in the San Luis-Pismo region to investigate: 1) the San Miguelito fault; 2) areas of potential late Quaternary tectonic deformation; and 3) the northwestern extent of the Little Pine-Foxen Canyon fault trend (hypothesized Santa Maria River Fault trend, Hall, 1984). Initial geologic studies have included Quaternary geologic mapping (accomplished as part of Task 2), geophysical profiling, offshore geologic mapping, age dating, and detailed evaluation of natural exposures.

PG&E DIABLO CANYON POWER PLANT
LONG TERM SEISMIC PROGRAM (LTSP)

Neotectonic and Quaternary Studies

PISMO BEACH AREA

P-1



SYMBOLS

- Fault.
- Buried reverse/thrust fault.
- Axis of synform.
- Buried monocline.

0 10 KM.

0 10 MILES

GEOLOGIC UNITS

- Quaternary deposits.
- Intrusive volcanic rocks of the Morro Rock-Islay Hill Complex.
- Mid-late Tertiary sedimentary and volcanic rocks.
- Mesozoic and early Tertiary metamorphic and sedimentary rocks.

GEOLOGIC AND TECTONIC SETTING OF THE SAN LUIS OBISPO — PISMO — SANTA MARIA VALLEY REGION

P-2

NEOTECTONIC AND QUATERNARY STUDIES
PISMO BEACH AREA

Objective:

- Locate active fault traces and other potential seismogenic structures

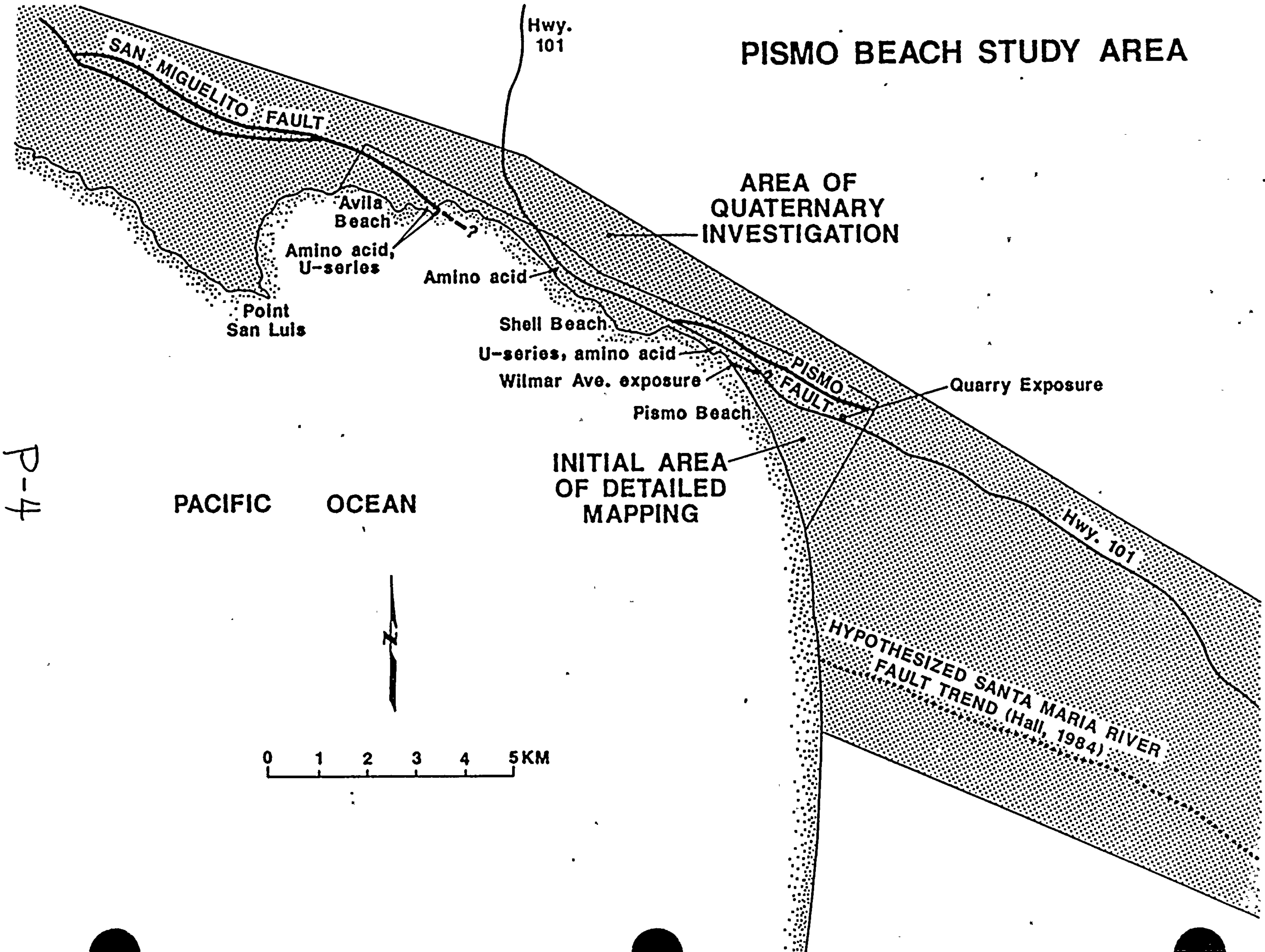
- Determine lateral continuity and spatial relationship of observed faults

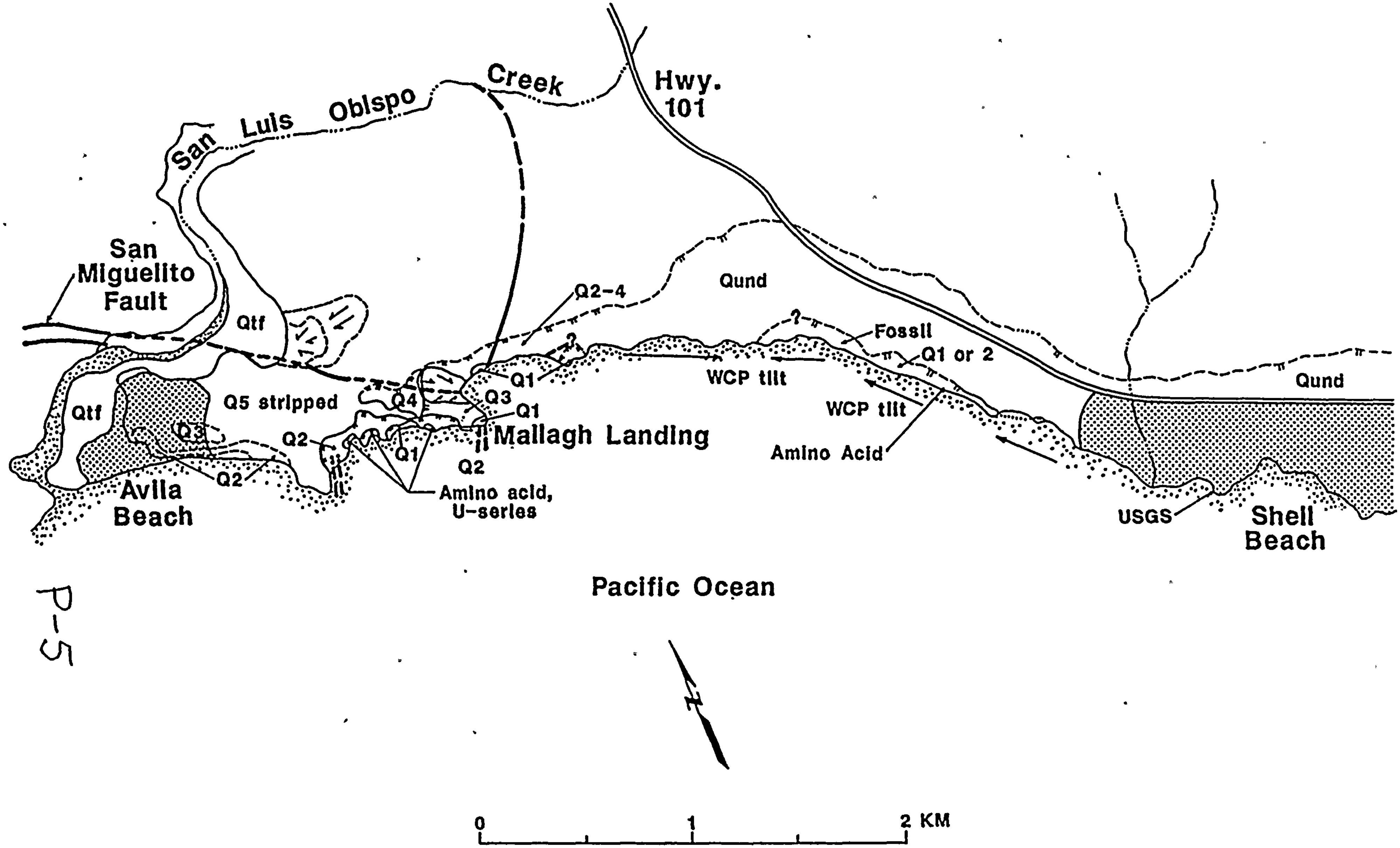
- Assess recency of fault movement

- Assess late Pleistocene and Holocene rates of slip in vertical and lateral components

- Assess sense of slip and style of deformation

P-4


PISMO BEACH STUDY AREA
Hwy. 101
SAN MIGUELITO FAULT
AREA OF QUATERNARY INVESTIGATION
Avila Beach
Amino acid, U-series
Amino acid
Point San Luis
Shell Beach
U-series, amino acid
Wilmar Ave. exposure
PISMO FAULT
Quarry Exposure
Pismo Beach
INITIAL AREA OF DETAILED MAPPING
PACIFIC OCEAN
Hwy. 101
N
HYPOTHESIZED SANTA MARIA RIVER FAULT TREND (Hall, 1984)
0 1 2 3 4 5KM

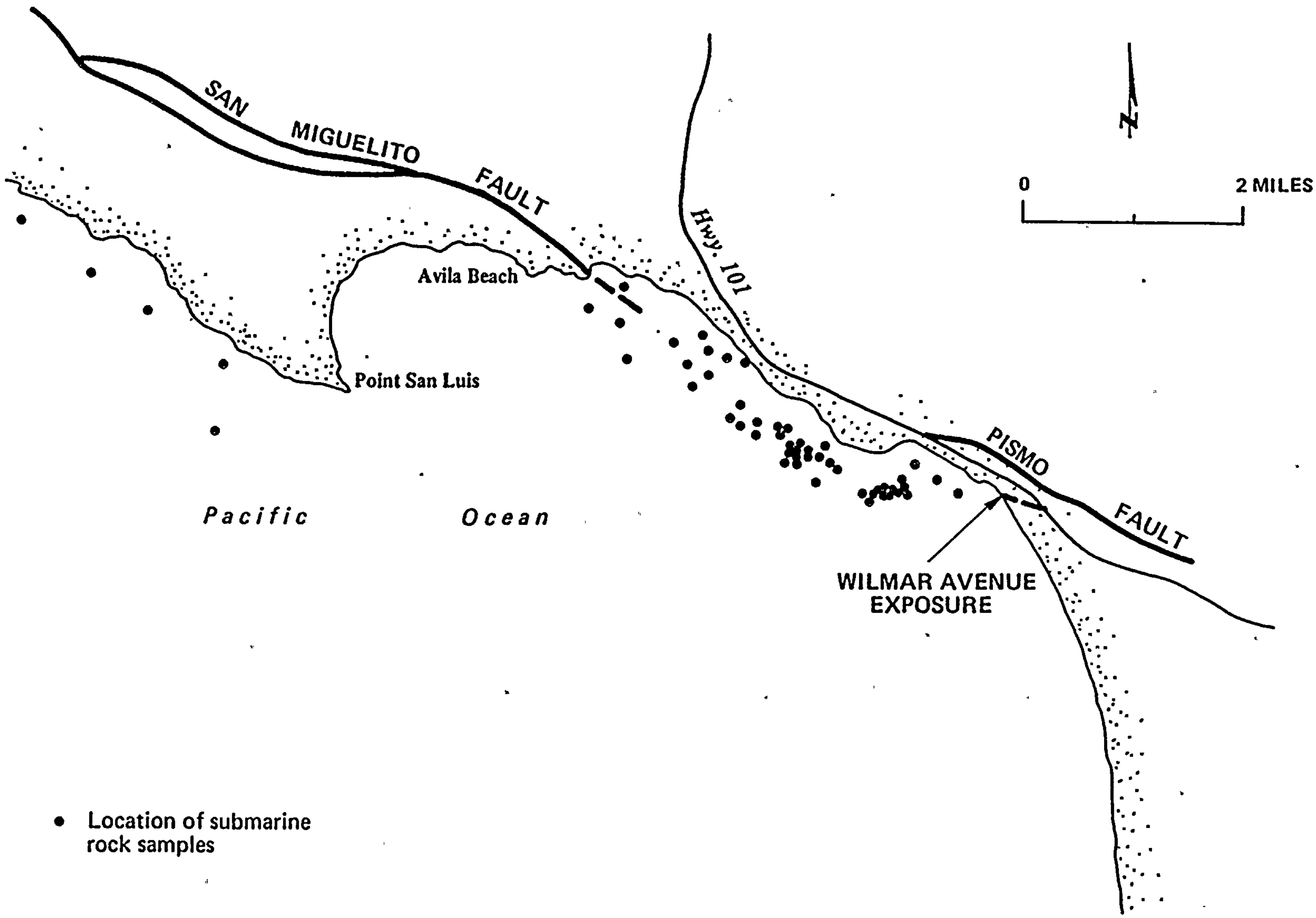

San Luis Obispo Creek
Hwy. 101
San Miguelito Fault
Qtf
Qtf
Q5 stripped
Q2-4
Qund
Qund
Fossil
Q1 or 2
Q1
Q3
Q1
Q4
Q3
Q2
Q2
Q1
Q2
Mallagh Landing
WCP tilt
WCP tilt
Amino Acid
Amino acid, U-series
Avila Beach
USGS
Shell Beach
Pacific Ocean
0
1
2 KM

P-5

P-6

PISMO BEACH STUDY AREA

Submarine Geologic Mapping



NEOTECTONIC AND QUATERNARY STUDIES
PISMO BEACH AREA

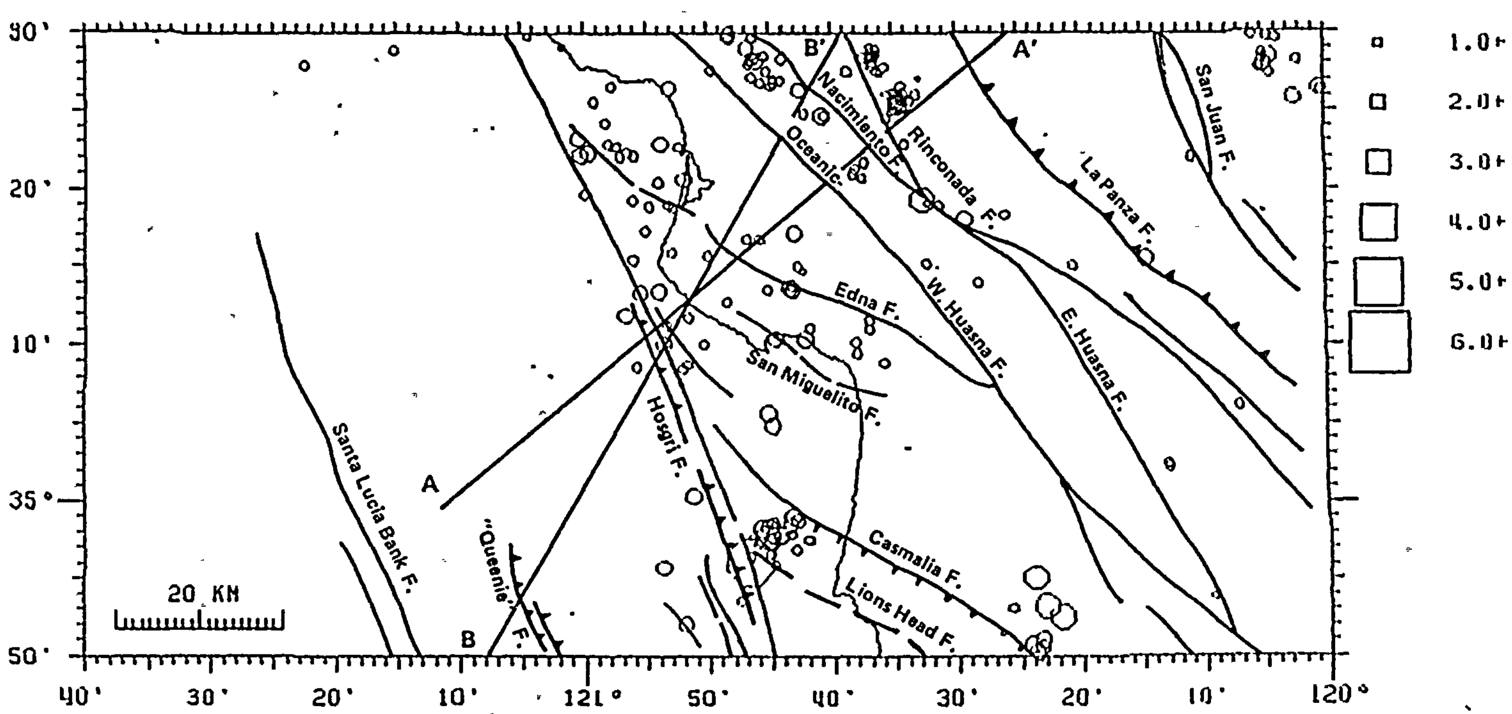
Status of Investigation

- Field mapping initiated
  - Five marine terraces identified. Detailed field mapping in progress.
  - Reconnaissance mapping of bedrock distribution in progress.
- Age dating initiated
  - six fossil localities identified and sampled
  - four additional fossil localities identified
- Property access for seismic, drilling, trenching studies initiated
- Wilmar Avenue beach exposure evaluated and logged
  - fault attitude N65° to 70°W, 50° to 60° NE
  - slickensides indicate vertical displacement
  - 21-foot vertical separation of W.C.P. suggests reverse displacement
  - juxtaposition of Rincon and Squire suggests continuing Quaternary displacement along pre-existing structure

P-8

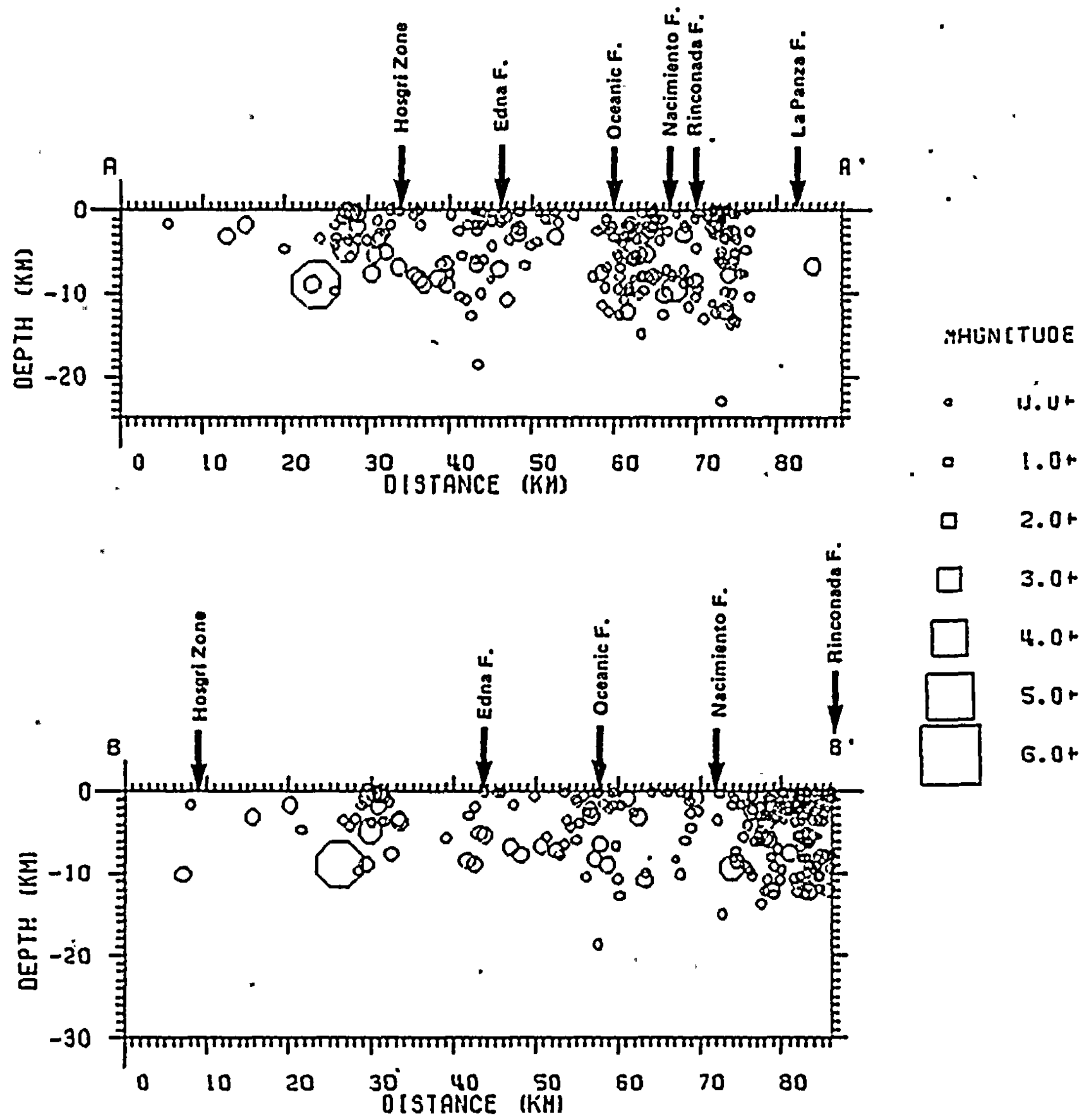
SAN LUIS/PISMO REGION

1980-JULY, 1986 CALNET EQS; ERH<20, ERZ≤5



SAN LUIS/PISMO REGION

1980-JULY, 1986 CALNET EQS; ERH<20, ERZ<5



Enclosure 5b

PACIFIC GAS AND ELECTRIC COMPANY

PG&E 77 BEALE STREET, RM. #2661A • SAN FRANCISCO, CALIFORNIA 94106 • (415) 972-2791 • TWX 910-372-6587

LLOYD S. CLUFF
MANAGER
GEOSCIENCES

October 14, 1986

Dear Workshop Participant:

Diablo Canyon Long Term Seismic Program
NRC/PGandE Ground Motions Workshop
October 23 and 24, 1986
Conference Rooms 1753 and 1752
77 Beale Street Building
San Francisco

As requested by Hans Schierling (NRC), we are sending the enclosed information in advance of the subject workshop so that everyone will be informed of the subject matter to be presented and discussed.

We look forward to a productive two-day workshop.

Sincerely,

Lloyd S Cluff

LSC:rle

Enclosures

DIABLO CANYON LONG TERM SEISMIC PROGRAM (LTSP)
GROUND MOTIONS
NRC/PGandE WORKSHOP
17TH FLOOR CONFERENCE ROOMS
77 BEALE STREET BUILDING
SAN FRANCISCO

AGENDA (TENTATIVE)

GROUND MOTIONS

THURSDAY, OCTOBER 23, 1986 (ROOM 1753)

8:00 a.m. - 8:30 a.m.	Introduction • NRC • PGandE
8:30 a.m. - 12:30 p.m.	Ground-Motions Input to Phase IIIA Studies • Time Histories for Fragility Evaluation • Input to Soil/Structure Interaction (SSI) • Input to Seismic Hazard Analysis • Discussion
12:30 p.m. - 1:30 p.m.	Lunch
1:30 p.m. - 5:00 p.m.	Ground-Motions Input to Phase IIIB Studies - Work in Progress • Empirical • Numerical • Discussion

FRIDAY, OCTOBER 24, 1986 (ROOM 1752)

8:00 a.m. - 9:00 a.m.	Additional Topics • USGS - K. Campbell • Discussion
9:00 a.m. - 10:00 a.m.	Instrumentation • Additional Ground-Motions Instruments at Site • Discussion

SOIL/STRUCTURE INTERACTION

10:00 a.m. - 10:30 a.m.	Introduction
10:30 a.m. - 12:30 p.m.	• Incorporation of Ground Motion Characteristics in SSI Studies • Discussion
12:30 p.m. - 1:30 p.m.	Lunch
1:30 p.m. - 3:30 p.m.	NRC Caucus and Discussion

LSC/YBS/FWB:rle
10/15/86

DIABLO CANYON LONG TERM SEISMIC PROGRAM (LTSP)
GROUND MOTIONS
NRC/PGandE WORKSHOP
OCTOBER 23-24, 1986

In accordance with the scope of work outlined for Phase III, the LTSP ground motions tasks have been structured with the objective of producing specific products needed during the conduct of fragility, SSI, and seismic hazard analysis. These products include 3-component acceleration time histories, attenuation relationships for horizontal and vertical peak ground accelerations, velocities and response spectra, as well as information on incidence angle and spatial coherence of seismic waves. Topics to be presented and discussed during this workshop include progress to date on the development of ground motions input to:

- Phase IIIA Fragility Analysis
- Soil/Structure Interaction Analysis
- Seismic Hazard Analysis

We will also discuss our progress to date and continuing work plans for development of ground motions input to Phase IIIB:

- Soil/Structure Interaction Analysis
- Seismic Hazards Analysis

The methods of analysis have employed both empirical approaches and numerical modeling methods.

A summary of the viewgraphs for presentation on ground motions work follows.

[illegible]

SUMMARY OF VIEWGRAPHS FOR PRESENTATION ON GROUND MOTIONS WORK

Viewgraphs	Topic Area
I-1 to I-3	Introduction to Ground Motions Input to Phase IIIA Studies
II-1 to II-47	Development of 3-component acceleration time histories for Phase IIIA fragility analysis by spectral modification of actual strong motion records
III-1 to III-16	Selection of 3-component acceleration time histories for Phase IIIA soil/structure interaction (SSI) analysis by empirical approach
IV-1 to IV-35	Development of 3-component acceleration time histories and preliminary analysis of wave characteristics by numerical modeling for Phase IIIA fragility and SSI analyses
V-1 to V-37	Development of ground motions input to Phase IIIA seismic hazard analysis by empirical approach
VI-1	Introduction of work in progress on ground motions input to Phase IIIB SSI and seismic hazard analyses
VII-1 to VII-24	Examination of apparent incidence angle of SV waves from strong motion records
VIII-1 to VIII-3	Work in progress on development of attenuation relationships for horizontal and vertical PGA, PGV and SA from available strong motion recordings
IX-1 to IX-63	Work in progress on development of ground motions input to Phase IIIB SSI and seismic hazard analyses by numerical modeling
X-1	Status on processing of additional ground motion records and installation of additonal ground motion instruments at the site
XI-1 to XI-6	Incorporation of ground motion results for SSI analyses

I-1

GROUND-MOTIONS INPUT TO PHASE IIIA STUDIES

SCHEDULE REQUIREMENTS AND APPROACHES

DATE	APPLICATION	GROUND-MOTIONS PRODUCTS	APPROACHES
JUNE 1986	FRAGILITY ANALYSIS	SUITE OF REALISTIC TIME HISTORIES	EMPIRICAL & NUMERICAL
SEPTEMBER 1986	SSI ANALYSIS	PRELIMINARY TIME HISTORIES	EMPIRICAL
		PRELIMINARY WAVE CHARACTERISTICS	EMPIRICAL & NUMERICAL
NOVEMBER 1986	SEISMIC HAZARD ANALYSIS	PRELIMINARY RESPONSE SPECTRA	EMPIRICAL

YBT:hw
10/13/86

PRELIMINARY
OCT 23 1986

GROUND-MOTIONS INPUT FOR PHASE IIIA FRAGILITY ANALYSIS

13 3-COMPONENT ACCELERATION TIME HISTORIES ARE PROVIDED:

- 3 ACTUAL RECORDS WITHOUT MODIFICATION
- 4 ACTUAL RECORDS MODIFIED FOR DISTANCE
- 2 ACTUAL RECORDS MODIFIED FOR SITE CONDITION
- 1 ACTUAL RECORD MODIFIED FOR MAGNITUDE
- 1 ACTUAL RECORD MODIFIED FOR MAGNITUDE AND DISTANCE
- 2 SYNTHETIC RECORDS BY EMPIRICAL GREEN'S FUNCTION SUMMATION METHOD

YBT:hw
10/13/86

PRELIMINARY
OCT 23 1986

GROUND-MOTIONS INPUT FOR PHASE IIIA SSI ANALYSIS

- THREE SETS OF REPRESENTATIVE 3-COMPONENT ACCELERATION TIME HISTORIES ARE SELECTED
- PRELIMINARY ESTIMATES OF INCIDENCE ANGLES OF P AND S WAVES ARE MADE

GROUND-MOTIONS INPUT FOR PHASE IIIA SEISMIC HAZARD ANALYSIS

- ATTENUATION RELATIONSHIPS FOR HORIZONTAL PGA AND 5% DAMPED SA
- RELATIONSHIPS BETWEEN SA AT OTHER DAMPINGS AND 5% DAMPED SA
- RELATIONSHIPS BETWEEN VERTICAL AND HORIZONTAL PGA AND SA

YBT:hw
10/13/86

PRELIMINARY
OCT 23 1986

I-3

PG&E Diablo Canyon Power Plant
Long Term Seismic Program (LTSP)

Empirical Ground Motion Study

Input to Phase IIIA Studies

TIME HISTORIES FOR FRAGILITY EVALUATION

PRELIMINARY
OCT 23 1986

II-1

OVERVIEW

A SUITE OF ACCELERATION TIME HISTORIES HAS BEEN DEVELOPED FOR USE IN THE FRAGILITY EVALUATIONS OF THE LONG-TERM SEISMIC PROGRAM (LTSP) FOR THE PG&E DIABLO CANYON POWER PLANT.

THESE TIME HISTORIES HAVE BEEN DEVELOPED FROM THE EXISTING AVAILABLE STRONG MOTION RECORDINGS DATA BASE.

THE OBJECTIVE OF THIS STUDY WAS TO DEVELOP A SUITE OF TIME HISTORIES THAT ARE REALISTIC AND APPROPRIATE TO THE DOMINANT EARTHQUAKE CHARACTERISTICS IDENTIFIED BY AN EXPLORATORY PROBABILISTIC SEISMIC HAZARD ASSESSMENT FOR THE PLANT SITE.

PRELIMINARY
OCT 23 1986

JAE: 10/23/86

TARGET CRITERIA

TARGET CRITERIA FOR SELECTION AND DEVELOPMENT OF THE SUITE OF TIME HISTORIES FOR THE FRAGILITY EVALUATIONS WERE A PRODUCT OF A NUMBER OF CONSIDERATIONS.

CHARACTERISTICS OF EARTHQUAKES PROVIDING DOMINANT CONTRIBUTIONS TO THE SEISMIC HAZARD FOR THE PLANT SITE FROM THE EXPLORATORY PROBABILISTIC HAZARD ASSESSMENT:

* EARTHQUAKES OF MAGNITUDE 6.5 OR GREATER
* RUPTURE TO SITE DISTANCES OF 10 KM OR LESS
* SHALLOW CRUSTAL EARTHQUAKES
* VARIETY OF RUPTURE (FOCAL) MECHANISMS

LOCAL SITE CONDITIONS:

* ROCK AND/OR ROCKLIKE SUBSURFACE MATERIALS

FRAGILITY EVALUATION INDEX:

* A NORMALIZATION INDEX WAS SPECIFIED BY THE FRAGILITY EVALUATION TEAM; THAT INDEX BEING AN AVERAGE RESPONSE SPECTRAL ACCELERATION (SA) OF 2.25G FOR THE HORIZONTAL COMPONENTS OF EACH RECORDING WITHIN THE FREQUENCY RANGE OF 3 TO 8.5 HZ. SELECTED/DEVELOPED RECORDINGS WITH SA CHARACTERISTICS AS NEAR TO THAT INDEX WERE PREFERABLE.

GENERAL APPROACH

THE GENERAL APPROACH TO SELECTION/DEVELOPMENT OF THE SUITE OF TIME HISTORIES FOR THE FRAGILITY EVALUATIONS WAS EMPIRICAL IN NATURE:

* NATURAL EARTHQUAKE GROUND MOTION RECORDINGS WERE UTILIZED
* INTENT WAS TO SATISFY THE TARGET CRITERIA
* PREFERENCE WAS GIVEN TO CANDIDATE RECORDINGS THAT REQUIRED MINIMAL MODIFICATION ADJUSTMENTS
* MODIFICATIONS TO THE TIME HISTORIES WERE MADE IN ACCORDANCE WITH: SCALING RELATIONSHIPS BASED UPON OBSERVATIONAL STRONG MOTION DATA

PRELIMINARY
OCT 23 1986

CANDIDATE STRONG MOTION RECORDINGS

THE DATA BANK OF AVAILABLE WORLDWIDE STRONG MOTION RECORDINGS AND RECORDING STATION INFORMATION WAS SCREENED TO IDENTIFY POTENTIAL CANDIDATES FOR THE SUITE OF TIME HISTORIES TO BE USED FOR THE FRAGILITY EVALUATIONS.

IDENTIFICATION CRITERIA:

* EARTHQUAKES OF MAGNITUDE GREATER THAN 5.

* SHALLOW FOCAL-DEPTH CRUSTAL EARTHQUAKES

* RUPTURE-TO-STATION DISTANCES OF UP TO 25 KM

* LOCAL SUBSURFACE STATION CONDITIONS OF ROCK OR ROCKLIKE (INCLUDING VERY STIFF SOIL) MATERIALS; SIGNIFICANT RECORDINGS WITH OTHER SITE CONDITIONS THAT OTHERWISE VERY CLOSELY SATISFIED THE TARGET CRITERIA WERE ALSO INCLUDED AS POTENTIAL CANDIDATES

A SET OF APPROXIMATELY SIXTY POTENTIAL CANDIDATE RECORDINGS WAS IDENTIFIED.

PRELIMINARY
OCT 23 1986

JAE: 10/23/86

CANDIDATE GROUND MOTION RECORDINGS FOR EMPIRICAL APPROACH

EARTHQUAKE	M	STATION	DIST. (km)	SITE CLASS.	a_{max} (g)	Selection Criteria M	Dist	Site
31 Oct 1935 Helena, Montana	5.6	Federal Building	8	Rock	0.156		●	●
22 Mar 1957 San Francisco	5.3	Golden Gate Park	9	Rock	0.127		●	●
10 Dec 1965 Koyna, India	6.0	Koyna Dam	10	Rock-Gallery	0.631	0	●	0
27 Jun 1966 Parkfield	6.4	Cholame-Shandon #5	5	Stiff Alluv.	0.467	◒	●	◒
		Cholame-Shandon #8	9	Stiff Alluv.	0.279	◒	●	◒
		Temblor	10	Rock	0.411	◒	●	●
12 Sep 1970 Lytle Creek	5.4	Wrightwood	15	Stiff Alluv.	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	1.170	●	●	●
		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	Stiff Alluv.	0.335	●		◒
23 Dec 1972 Managua	6.2	Esso Refinery	7	Stiff Alluv.	0.390	0	●	◒
01 Aug 1975 Oroville	5.6	Oroville Dam	10	Rock	0.108		●	●
17 May 1976 Gazli, USSR	7.0	Karakyr Point	4	Rock/Stiff Alluv.	0.70	●	●	●
13 Aug 1978 Santa Barbara	5.6	SCE Goleta	9	Stiff Alluv.	0.285		●	◒
16 Sep 1978 Tabas, Iran	7.5	Tabas	3	Stiff Alluv./Rock	0.81	●	●	●
		Dayhook	17	Rock (?)	0.39	●	0	●
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		●	●

PRELIMINARY
OCT 23 1986

(Continued)

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
15 Oct 1979 Imperial Valley	6.9	El Centro #8	4	Deep Alluv.	0.619	●	●	
		El Centro #4	4	Deep Alluv.	0.489	●	●	
		Differential Array	5	Deep Alluv.	0.487	●	●	
		Holtville P.O.	8	Deep Alluv.	0.259	●	●	
		Imperial F.F.	8	Deep Alluv.	0.237	●	●	
		El Centro #10	9	Deep Alluv.	0.231	●	●	
		Brawley Airport	9	Deep Alluv.	0.222	●	●	
		Superstition Mtn.	25	Rock	0.202	●		●
26 Jan 1980 Livermore	5.0	Contra Loma Park	4	Stiff Alluv.	0.254		●	0
		Morgan Territory	8	Rock	0.272		●	●
25 May 1980 Mammoth Lakes	6.1	Convict Creek	9	Stiff Alluv.	0.451	0	●	◐
		Long Valley Dam	16	Rock-Abut.	0.427	0		●
		Long Valley Dam	16	Rock-Dnstm	0.109	0		●
25 May 1980 Mammoth Lakes	6.1	Convict Creek	17	Stiff Alluv.	0.235	0		◐
		Long Valley Dam	20	Rock-Abut.	0.508	0		●
		Long Valley Dam	20	Rock-Dnstm	0.112	0		●
25 May 1980 Mammoth Lakes	5.7	Convict Creek	10	Stiff Alluv.	0.485		●	◐
		Long Valley Dam	20	Rock-Abut.	0.292			●
		Long Valley Dam	20	Rock-Dnstm	0.083			●
27 May 1980 Mammoth Lakes	6.2	Convict Creek	15	Stiff Alluv.	0.324	0		◐
		Long Valley Dam	16	Rock-Abut.	1.024	0		●
		Long Valley Dam	16	Rock-Dnstm	0.219	0		●
		Paradise Lodge	22	Rock	0.119	0		●
02 May 1983 Coalinga	6.5	Pleasant Valley Pump Station	10	Stiff Alluv./ Rock	0.610	●	◐	●
08 May 1983 Coalinga Aft.	5.3	Anticline Ridge	13	Rock	0.290			●
		Skumk Hollow	13	Rock	0.353			●
21 Jul 1983 Coalinga Aft.	6.0	Anticline Ridge	13	Rock	1.153	0		●
		Sulphur Baths	13	Rock	0.136	0		●
25 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	0	◐	●
		Coyote Lake Dam	6	Rock	1.304	0	●	●
		Gilroy #6	18	Rock	0.293	0		●
		Gilroy #1	20	Rock	0.100	0		●
23 Nov 1984 Bishop	5.9	Paradise Lodge	10	Rock	0.240		●	●
Dec 1985 Canadian	7		10			●	●	

PRELIMINARY
OCT 23 1986

SELECTION/DEVELOPMENT OF TIME HISTORIES SUITE

POTENTIAL CANDIDATE RECORDINGS WERE EXAMINED AND SCREENED WITH RESPECT TO THE FRAGILITY EVALUATION TARGET CRITERIA.

TARGET CRITERIA:

* EARTHQUAKES OF MAGNITUDE 6.5 OR GREATER

* RUPTURE-TO-SITE DISTANCES OF 10 KM OR LESS

* SHALLOW FOCAL-DEPTH CRUSTAL EARTHQUAKES

* VARIETY OF RUPTURE (FOCAL) MECHANISMS

* LOCAL SITE SUBSURFACE CONDITIONS OF ROCK AND/OR ROCKLIKE MATERIALS

* FRAGILITY EVALUATION INDEX: AN AVERAGE RESPONSE SPECTRAL ACCELERATION (SA) OF 2.25G FOR THE HORIZONTAL COMPONENTS OF EACH RECORDING WITHIN THE FREQUENCY RANGE OF 3 TO 8.5 HZ. RECORDINGS WITH SA CHARACTERISTICS AS NEAR TO THAT INDEX WERE PREFERABLE.

PRELIMINARY
OCT 23 1986

JAL : 10/23/86

CHARACTERISTICS OF SELECTED STRONG MOTION RECORDS

EARTHQUAKE DATE	MAGNITUDE	RUPTURE MECHANISM	RECORDING STATION SITE CONDITIONS DISTANCE	COMP	Original Record Peak Accel. (g)	Peak Veloc. (cm/sec)	V/a cm/sec g
Gazli, U.S.S.R. 17 May 1976	Ms = 7.0 ML = 6.4	Thrust	Karakyr Point Rock/Stiff Alluv. ~4 km	EAST	0.70	47.2	68
				NORT	0.66	44.4	68
				VERT	1.41	53.5	38
Tabas, Iran 16 Sep 1978	Ms = 7.5 ML = 6.6	Thrust	Tabas Stiff Alluv./Rock 3 km	TRAN	0.70	105	150
				LONG	0.81	91.5	113
				VERT(1)	0.74	41.5	56
			Dayhook Rock (?) 17 km	N10E(1)	0.39	27.5	70
				N80W(1)	0.38	36.7	97
				VERT(1)	0.18	12.2	66
San Fernando, CA 09 Feb 1971	Ms = 6.6 ML = 6.4	Thrust	Pacoima Dam Rock 3 km	S14W	1.17	114	97
				N76W	1.08	58.3	54
				DOWN	0.71	57.8	81
			Lake Hughes #12 Rock 20 km	N21E	0.37	14.7	40
				N69W	0.29	12.8	44
				DOWN	0.16	4.1	25
			Castaic Stiff Alluvium 25 km	N21E	0.33	16.5	50
				N69W	0.29	27.8	96
				DOWN	0.18	6.4	36
Imperial Valley, CA 15 Oct 1979	Ms = 6.9 ML = 6.6	Strike-Slip	Superstition Mtn. Rock 25 km	S45E	0.20	9.02	45
				N45E	0.12	4.86	42
				UP	0.08	2.10	26
			Differential Array Deep Alluvium 5 km	N00E	0.49	42.5	87
				N90W	0.35	67.8	192
				UP	0.75	20.0	27
			El Centro # 4 Deep Alluvium 4 km	S50W	0.37	77.6	210
				S40E	0.49	37.1	76
				UP	0.25	14.4	58
Parkfield, CA 27 Jun 1966	Ms = 6.4 ML = 5.6	Strike-Slip	Temblor Rock 10 km	N65W	0.28	14.5	51
				S25W	0.41	22.5	55
				VERT	0.17	4.4	27
Morgan Hill, CA 24 Apr 1984	Ms = 6.1 ML = 6.2	Strike-Slip	Coyote Lake Dam Rock 6 km	N75W	1.30	79.7	61
				S15W	0.71	51.9	73
				UP	0.40	15.4	38
Coalinga, CA 02 May 1983	Ms = 6.7 ML = 6.5	Thrust	Pleasant Valley Pump Station (Switchyard) Stiff Alluv./Rock 10 km	N45E	0.61	73.9	121
				S45E	0.53	39.5	75
				UP	0.38	16.1	43
Coalinga, CA Aftershock 21 Jul 1983	Ms = 5.7 ML = 6.0	Reverse	Sulphur Baths Rock 13 km	N90E	0.12	5.63	49
				N00E	0.14	5.57	41
				UP	0.09	4.28	50

Notes: (1) Data from Niazi (1985).
(2) Data from B. Tsai of PG&E.

PRELIMINARY
OCT 23 1986

SELECTION/DEVELOPMENT OF TIME HISTORIES SUITE (CONTINUED)

A SUITE OF THIRTEEN RECORDINGS WAS SELECTED WITH THE FOLLOWING AS-RECORDED CHARACTERISTICS:

* EIGHT EARTHQUAKES OF MAGNITUDE 6 TO 7.5 (NINE GREATER THAN 6.5) PRODUCED THE RECORDINGS

* DISTANCES RANGED BETWEEN 3 AND 25 KM (EIGHT AT 10 KM OR LESS)

* ELEVEN ROCK OR VERY STIFF SOIL AND TWO DEEP ALLUVIUM SITES

* THREE FOCAL MECHANISMS - THRUST (SEVEN), STRIKE-SLIP (FIVE) AND REVERSE (ONE)

* VARIETY OF GEOMETRIES OF STATION LOCATION RELATIVE TO RUPTURE SURFACE AND PROPAGATION DIRECTION

PRELIMINARY
OCT 23 1986

JAE:10/23/86

MODIFICATION APPROACH

THREE CATEGORIES:

* NO MODIFICATION/SCALING (SATISFIES TARGET CRITERIA)
    - KARAKYR POINT, GAZLI
    - TABAS, TABAS
    - PACOIMA DAM, SAN FERNANDO

* CONSTANT (RIGID BODY) SCALING MODIFICATION (DISTANCE)
    - DAYHOOK, TABAS
    - LAKE HUGHES #12, SAN FERNANDO
    - CASTAIC, SAN FERNANDO
    - SUPERSTITION MOUNTAIN, IMPERIAL VALLEY
    - TEMBLOR, PARKFIELD
    - PLEASANT VALLEY PUMP STATION, COALINGA
    - SULPHUR BATHS, COALINGA AFTERSHOCK

* FREQUENCY DEPENDENT SCALING MODIFICATION (MAGNITUDE OR SITE SUBSURFACE CONDITIONS)
    - TEMBLOR, PARKFIELD (MAGNITUDE)
    - COYOTE LAKE DAM, MORGAN HILL (MAGNITUDE)
    - SULPHUR BATHS, COALINGA AFTERSHOCK (MAGNITUDE)
    - EL CENTRO DIFFERENTIAL ARRAY, IMPERIAL VALLEY (SITE)
    - EL CENTRO ARRAY # 4, IMPERIAL VALLEY (SITE)

PRELIMINARY
OCT 23 1986

DATE: 10/23/86

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

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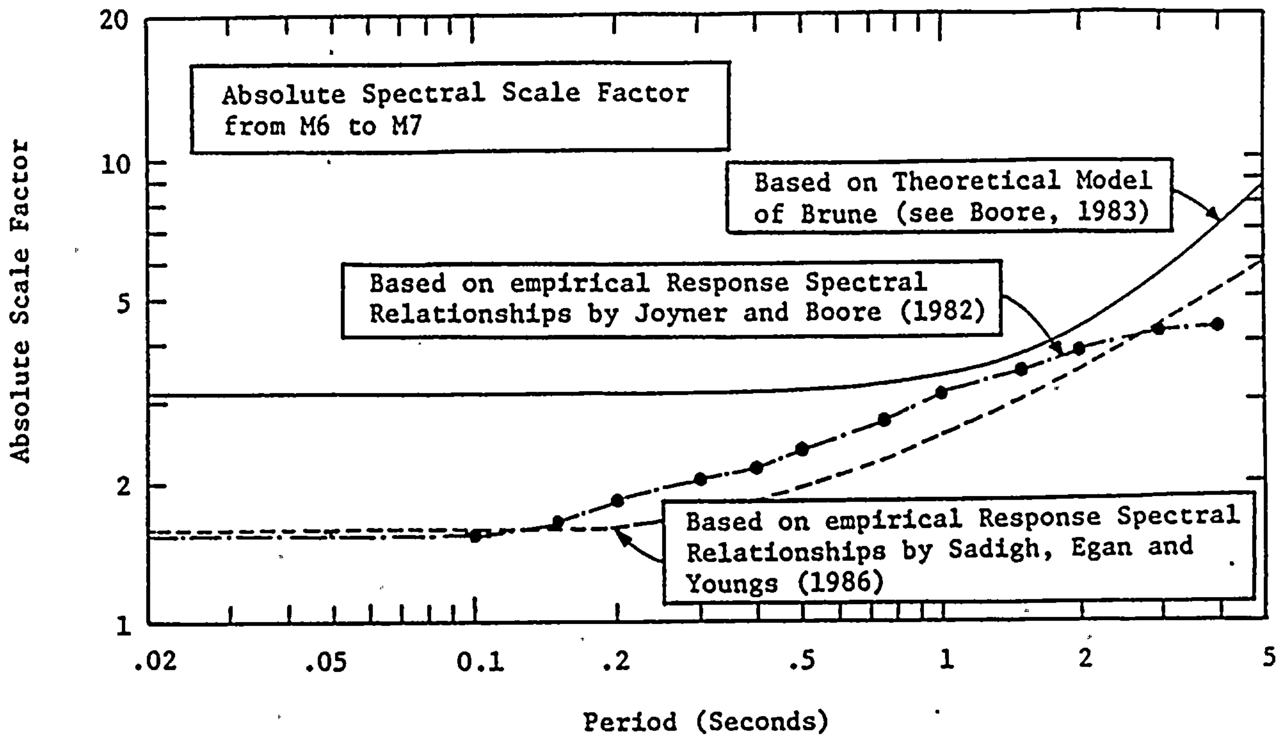
OCT 23 1986



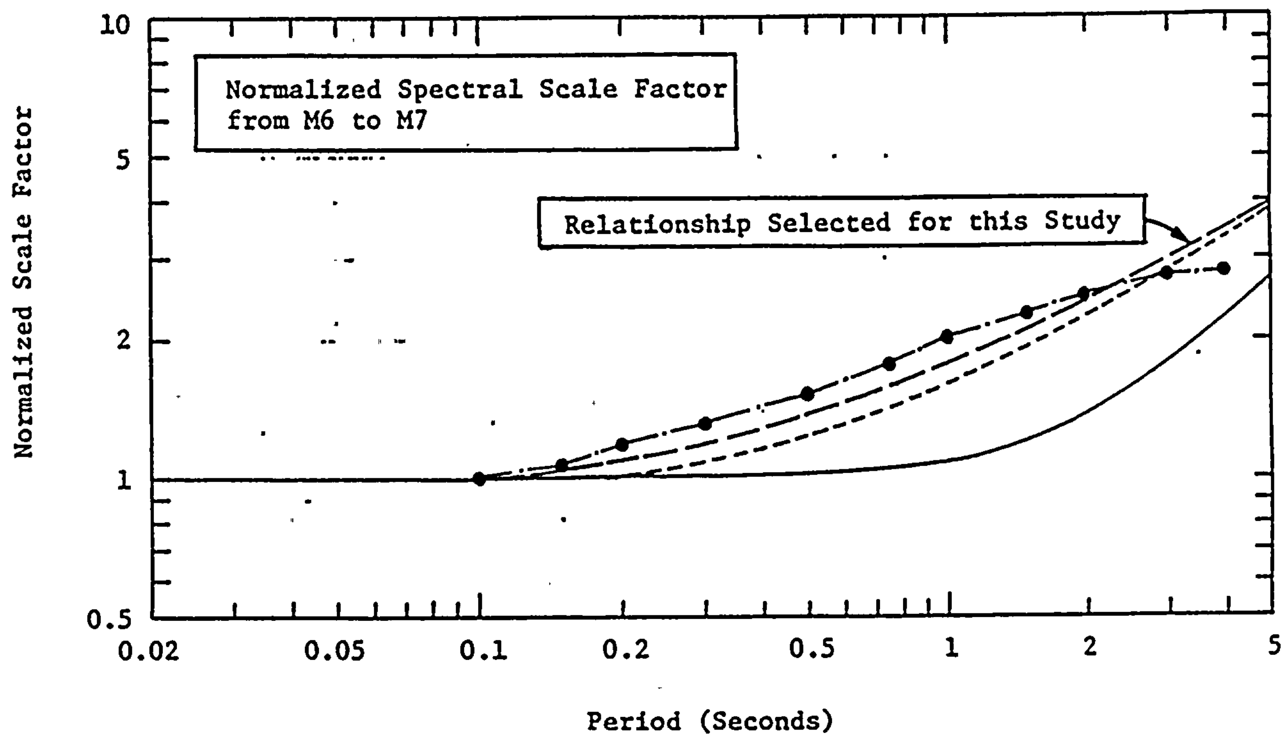


Illustration of Theoretical and Empirical
Magnitude Scaling Relationships

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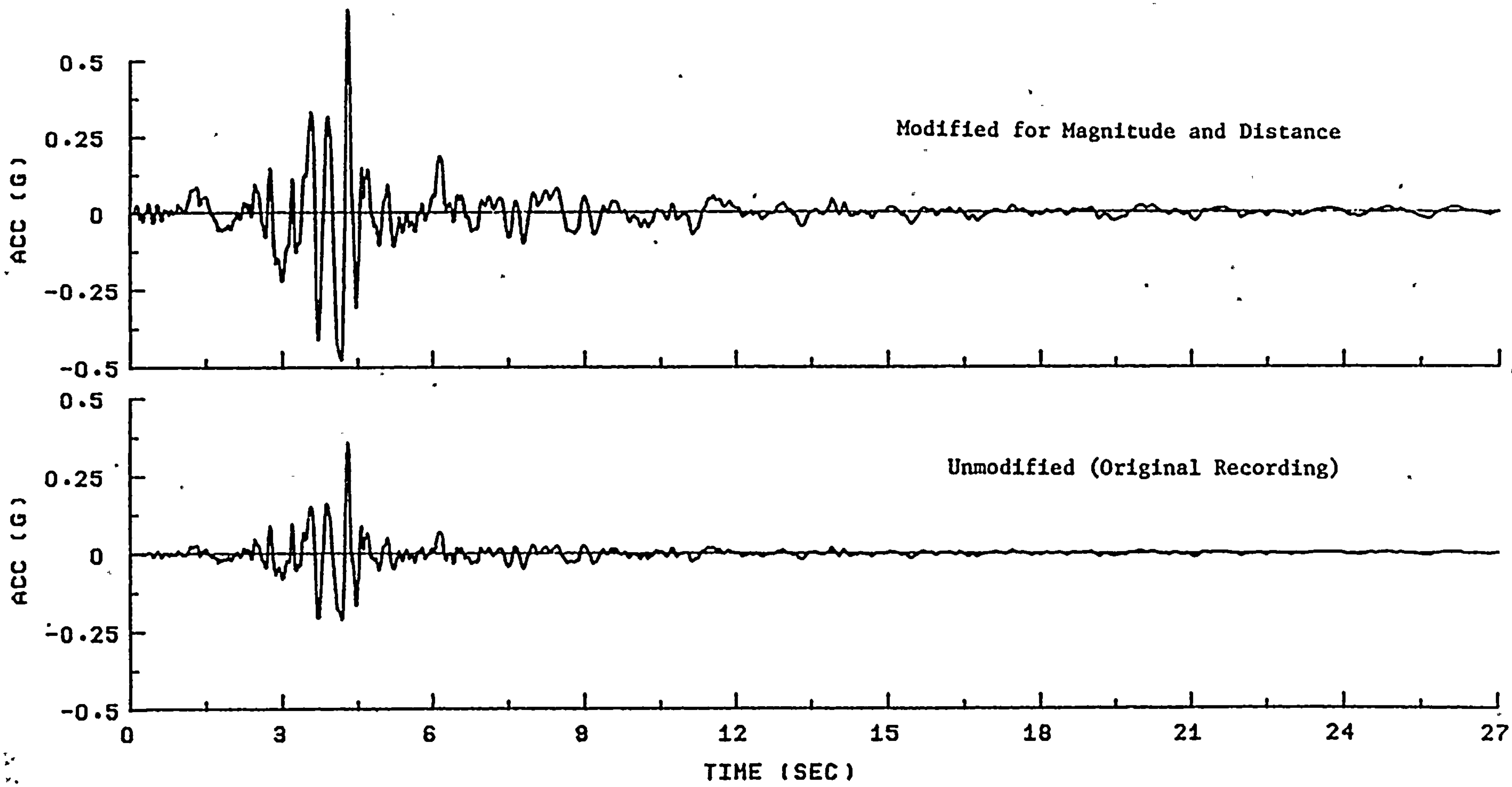
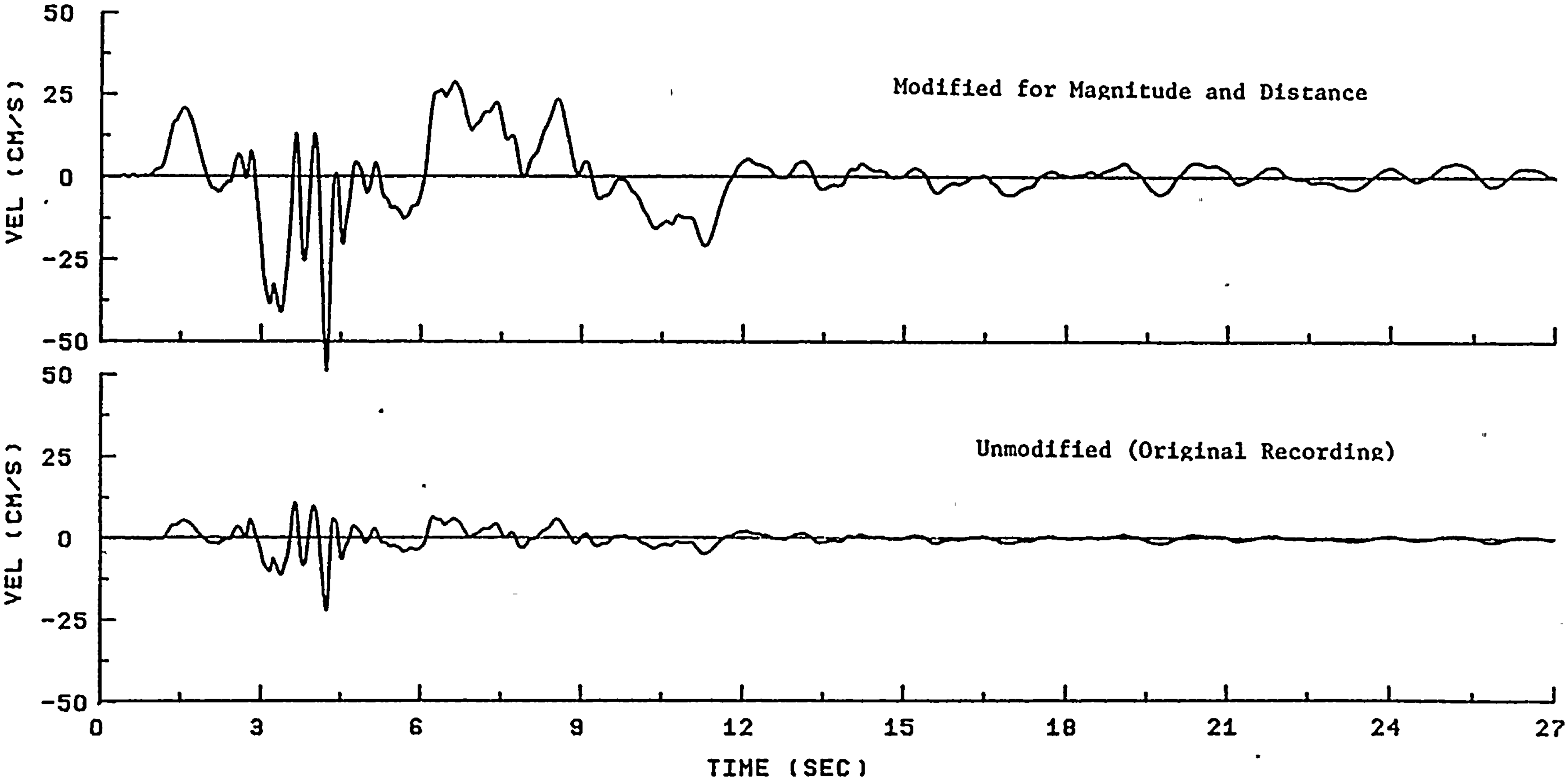


Comparison of the Modified and Unmodified Acceleration Time Histories
from the Temblor Recording (Component S25W) of the Parkfield Earthquake.

PRELIMINARY
OCT 23 1986

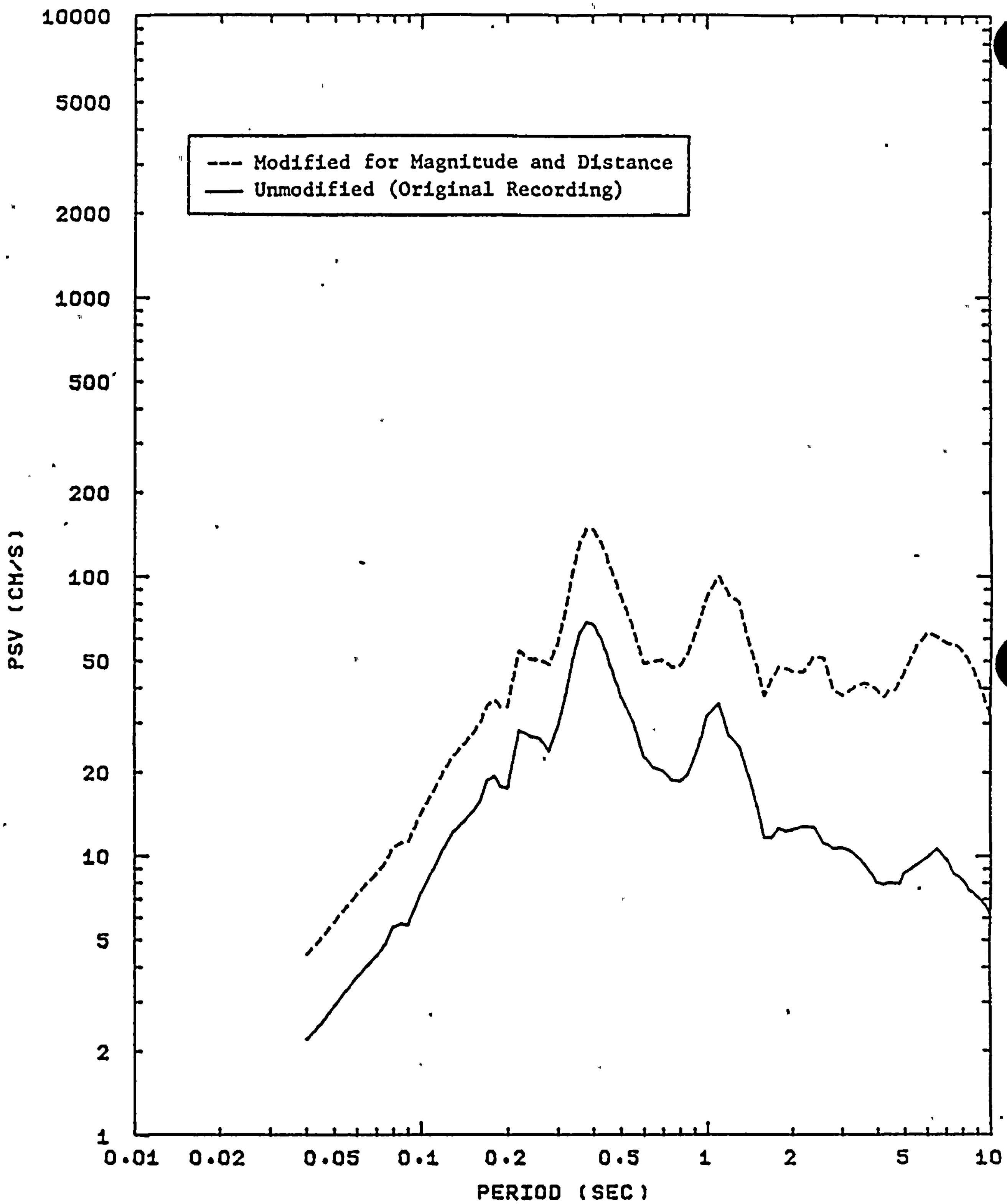
II-114



Comparison of the Modified and Unmodified Velocity Time Histories
from the Temblor Recording (Component S25W) of the Parkfield Earthquake.

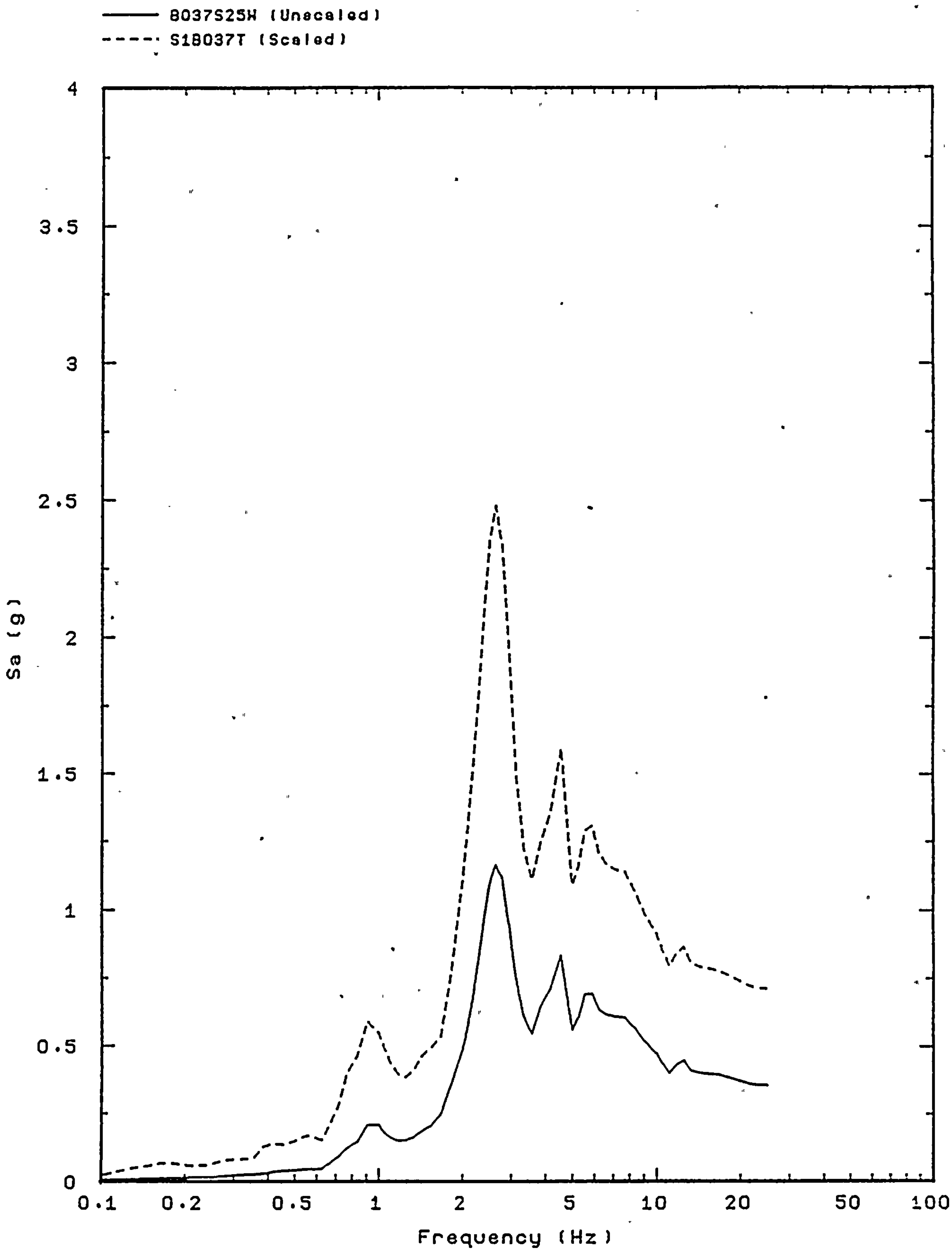
PRELIMINARY
OCT 23 1986

II-15

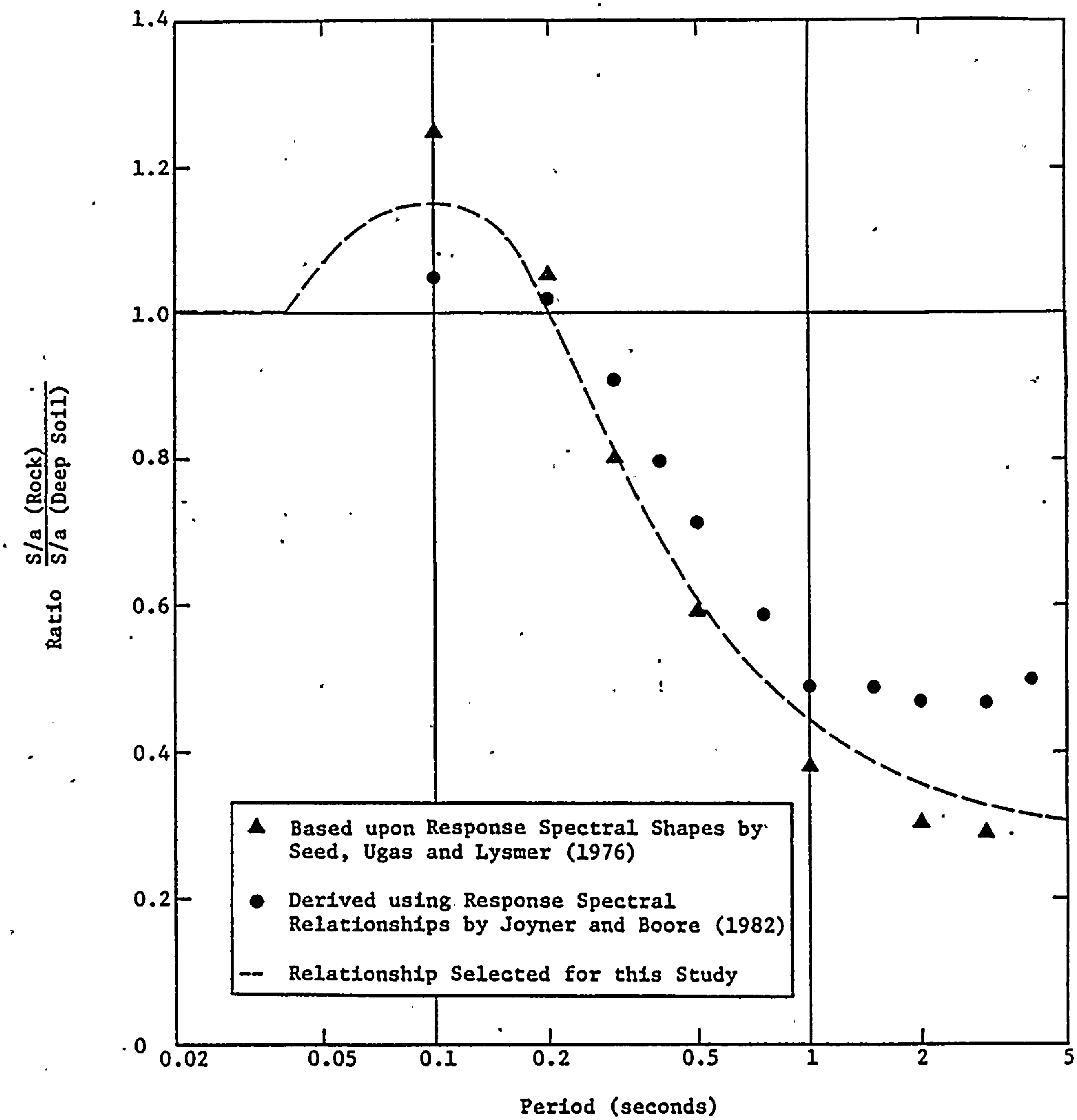


Comparison of the Modified and Unmodified Acceleration Response Spectra (5% damping) from the Temblor Recording (Component S25W) of the Parkfield Earthquake.

PRELIMINARY
OCT 23 1986

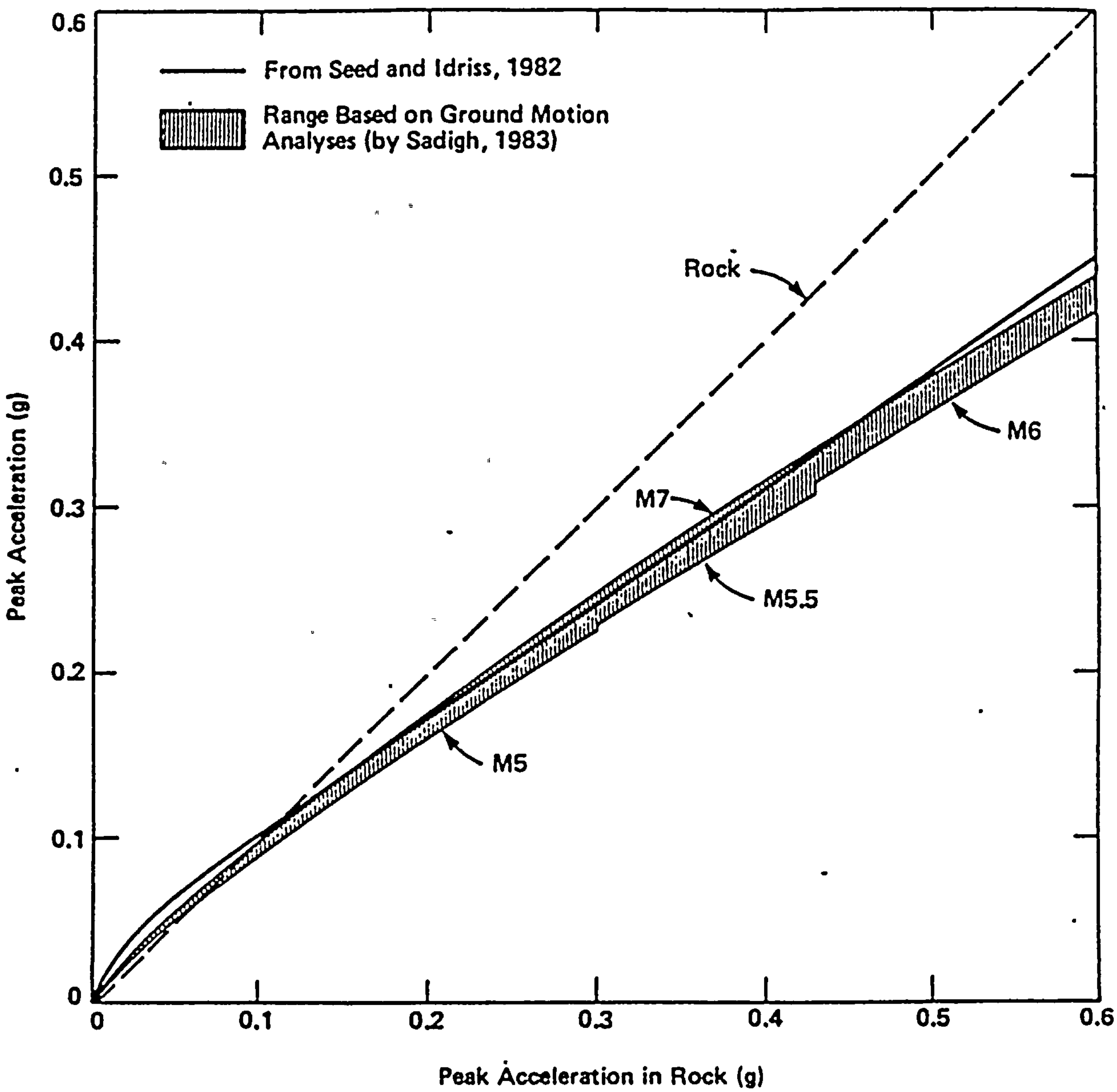


PRELIMINARY
OCT 23 1986



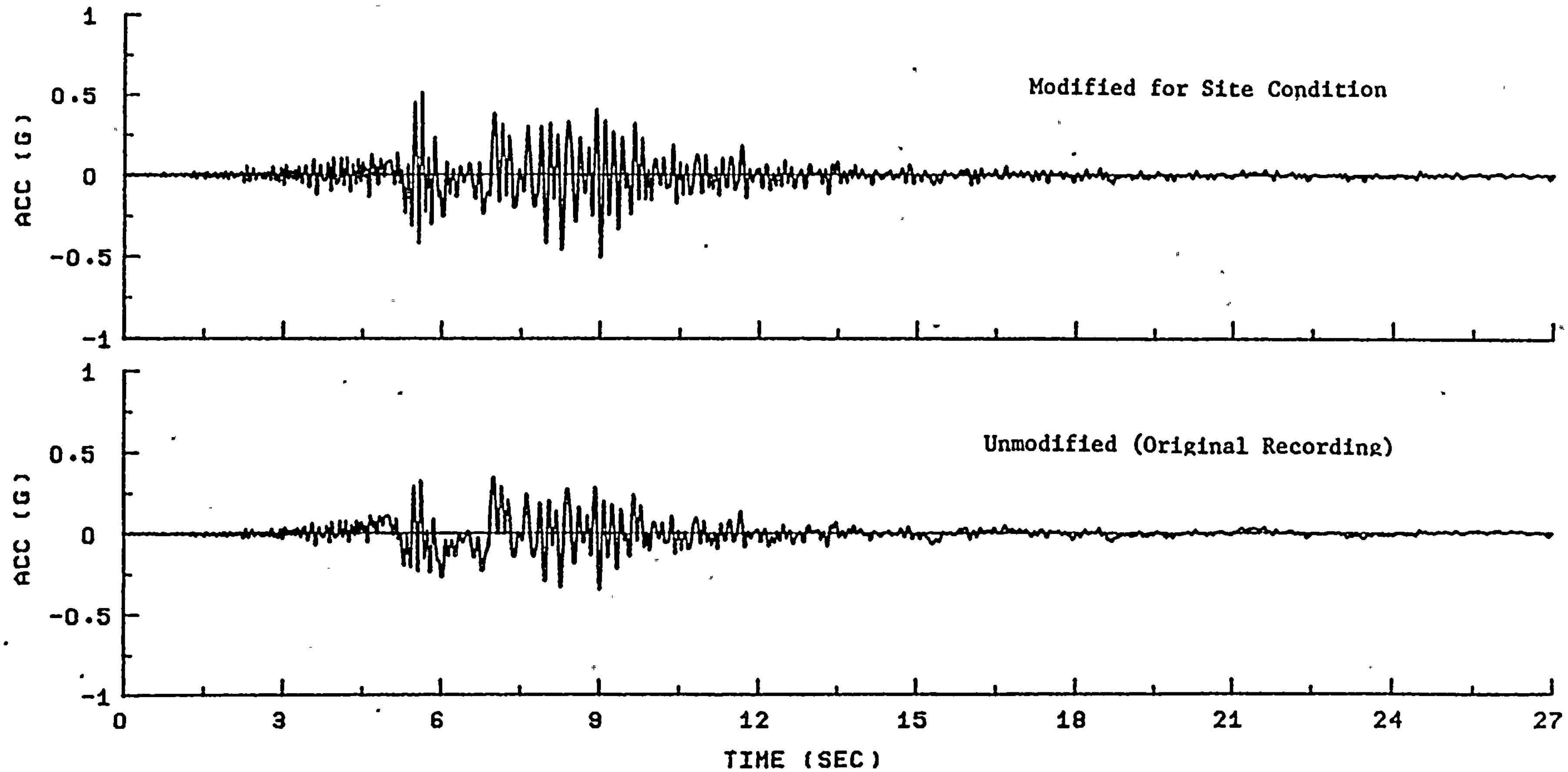
Relationships between Normalized Response Spectra for Rock and Deep Soil Site Conditions

PRELIMINARY
OCT 23 1986



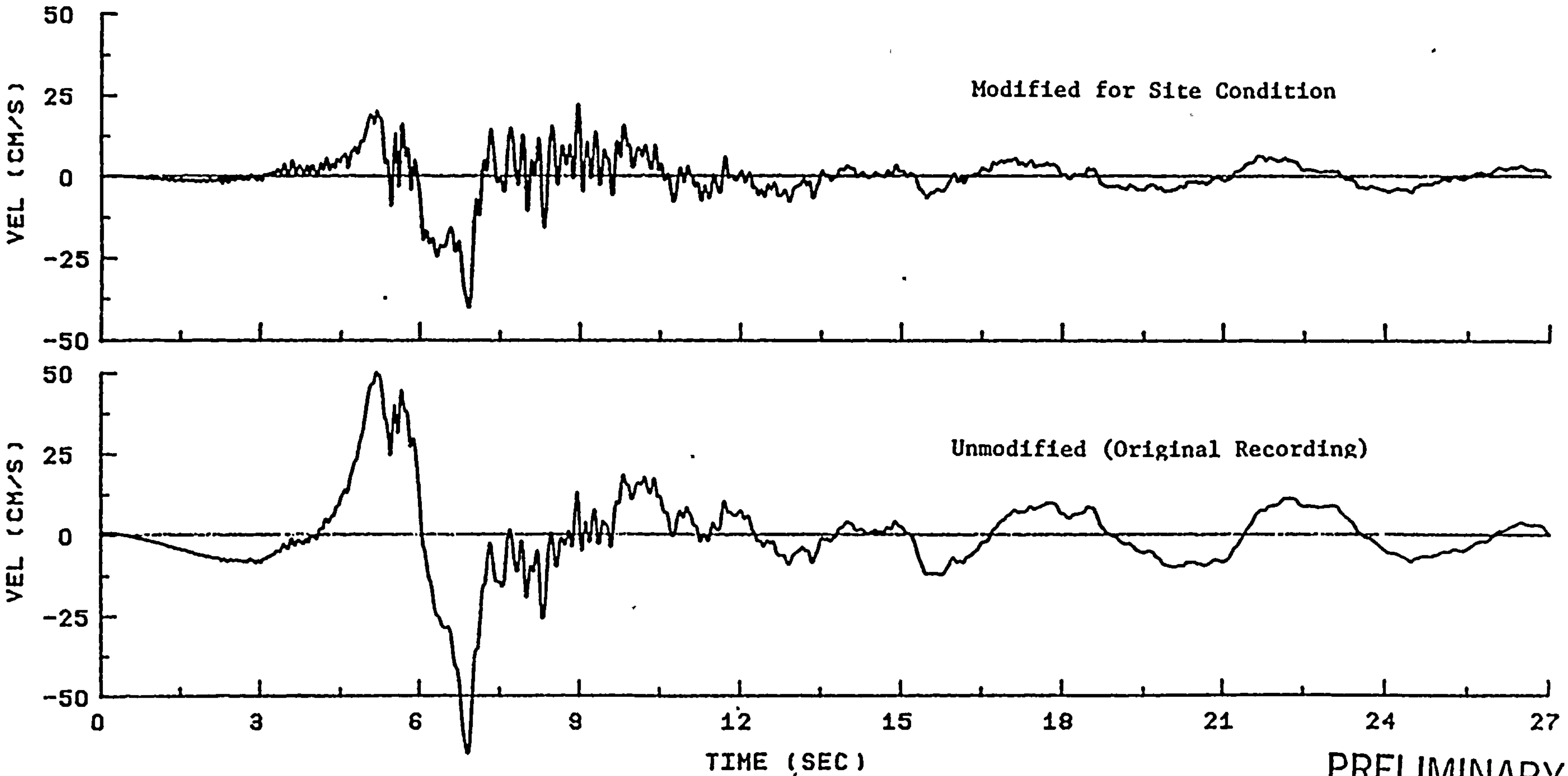
Relationships Between Peak Acceleration on Rock and Deep Soil

PRELIMINARY
OCT 23 1986



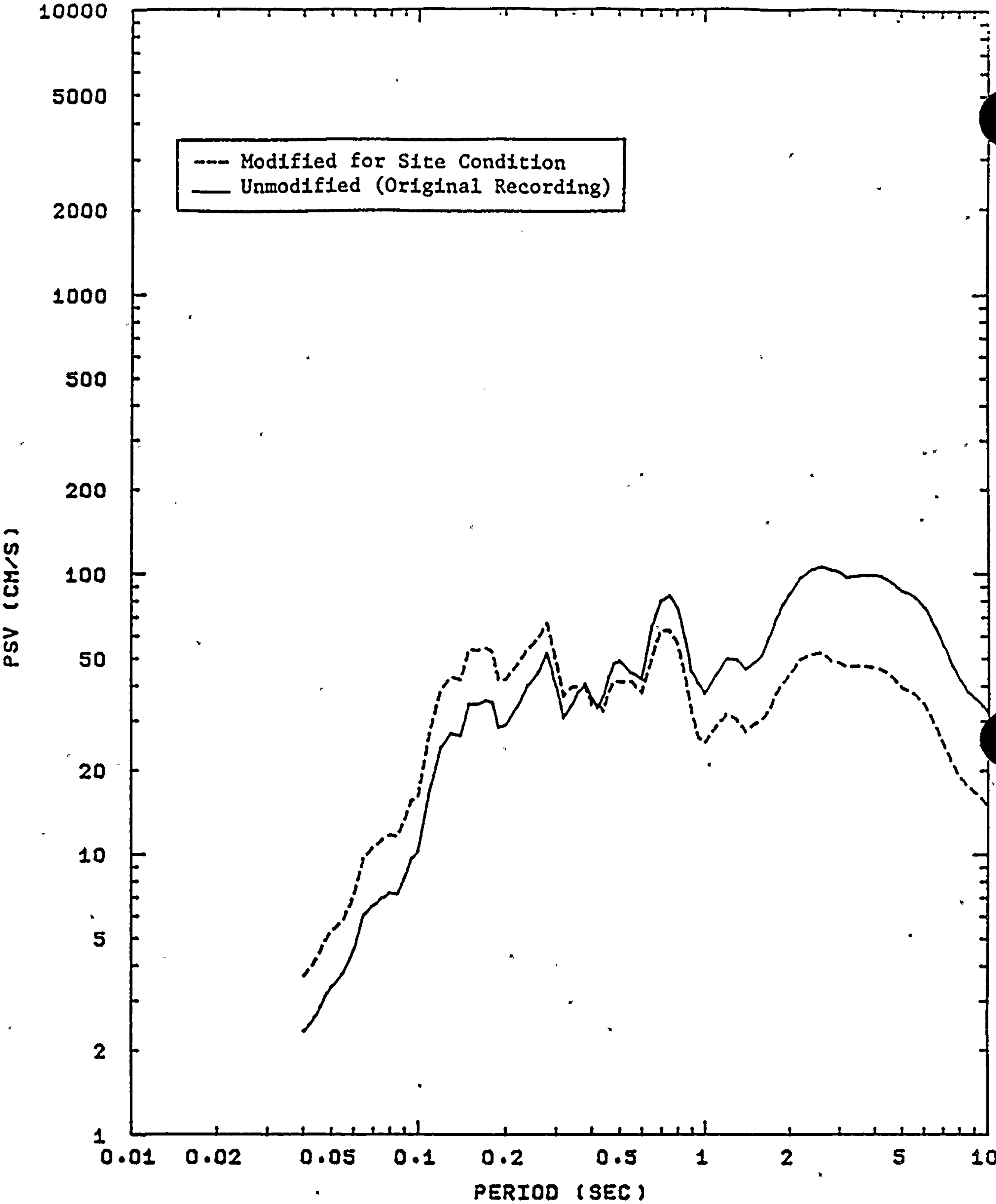
Comparison of the Modified and Unmodified Acceleration Time Histories from the El Centro Differential Array (Component 270) of the 1979 Imperial Valley Earthquake.

PRELIMINARY
OCT 23 19



PRELIMINARY
OCT 23 1986

Comparison of the Modified and Unmodified Velocity Time Histories from the El Centro Differential Array (Component 270) of the 1979 Imperial Valley Earthquake.



Comparison of the Modified and Unmodified Response Spectra (5% damping) from the El Centro Differential Array (Component 270) of the 1979 Imperial Valley Earthquake.

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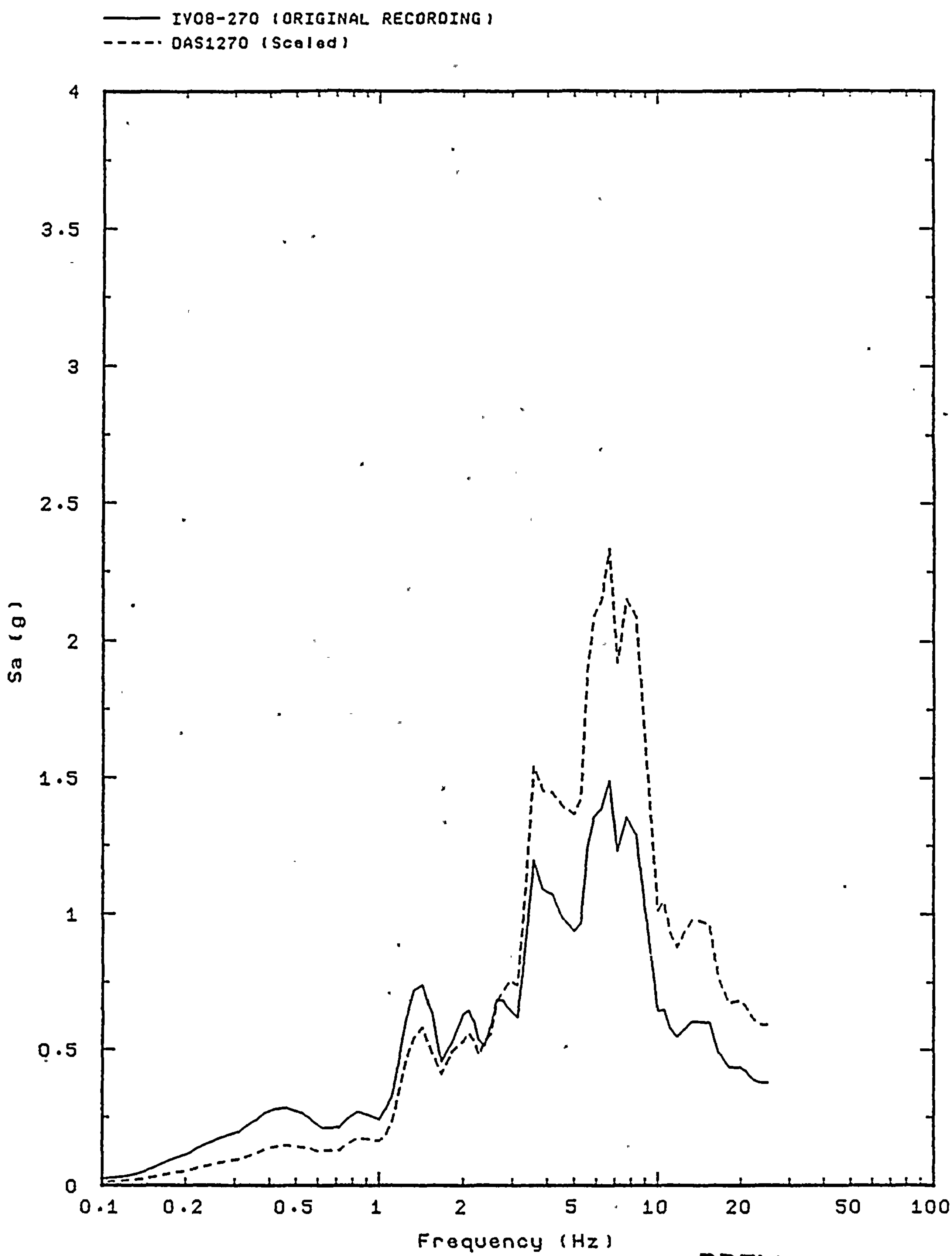
OCT 23 1986



PRELIMINARY
OCT 23 1986

CHARACTERISTICS OF SELECTED STRONG MOTION RECORDS

EARTHQUAKE DATE	MAGNITUDE	RUPTURE MECHANISM	RECORDING STATION SITE CONDITIONS DISTANCE	COMP	Original Record Peak Accel. (g)	Original Record Peak Veloc. (cm/sec)	Original Record V/a cm/sec g	Modified Record Peak Accel. (g)	Modified Record Peak Veloc. (cm/sec)	Modified Record V/a cm/sec g	$S_a\|_{3Hz}^{8.5}$ (g)
Gazli, U.S.S.R.	Ms = 7.0	Thrust	Karakyr Point	EAST	0.70	47.2	68	0.70	47.2	68	1.33
17 May 1976	ML = 6.4		Rock/Stiff Alluv.	NORT	0.66	44.4	68	0.66	44.4	68	
			~4 km	VERT	1.41	53.5	38	1.41	53.5	38	
Tabas, Iran	Ms = 7.5	Thrust	Tabas	TRAN	0.70	105	150	0.70	105	150	2.33
16 Sep 1978	ML = 6.6		Stiff Alluv./Rock	LONG	0.81	91.5	113	0.81	91.5	113	
			3 km	VERT(1)	0.74	41.5	56	0.74	41.5	56	
			Dayhook	N10E(1)	0.39	27.5	70	0.66	46.8	70	1.39(2)
			Rock (?)	N80W(1)	0.38	36.7	97	0.64	62.4	97	
			17 km	VERT(1)	0.18	12.2	66	0.31	20.7	66	
San Fernando, CA	Ms = 6.6	Thrust	Pacoima Dam	S14W	1.17	114	97	1.17	114	97	1.90
09 Feb 1971	ML = 6.4		Rock	N76W	1.08	58.3	54	1.08	58.3	54	
			3 km	DOWN	0.71	57.8	81	0.71	57.8	81	
			Lake Hughes #12	N21E	0.37	14.7	40	0.94	36.8	40	2.23
			Rock	N69W	0.29	12.8	44	0.72	32.0	44	
			20 km	DOWN	0.16	4.1	25	0.41	10.3	25	
			Castaic	N21E	0.33	16.5	50	1.07	52.8	50	1.90
			Stiff Alluvium	N69W	0.29	27.8	96	0.92	89.0	96	
			25 km	DOWN	0.18	6.4	36	0.58	20.5	36	
Imperial Valley, CA	Ms = 6.9	Strike-Slip	Superstition Mtn.	S45E	0.20	9.02	45	0.59	27.0	45	1.10
15 Oct 1979	ML = 6.6		Rock	N45E	0.12	4.86	42	0.35	14.7	42	
			25 km	UP	0.08	2.10	26	0.24	6.2	26	
			Differential Array	N00E	0.49	42.5	87	0.57	31.7	56	1.45
			Deep Alluvium	N90W	0.35	67.8	192	0.51	40.2	78	
			5 km	UP	0.75	20.0	27	1.15	15.1	13	
			El Centro # 4	S50W	0.37	77.6	210	0.48	45.2	94	1.20
			Deep Alluvium	S40E	0.49	37.1	76	0.68	40.3	58	
			4 km	UP	0.25	14.4	58	0.45	14.2	32	
Parkfield, CA	Ms = 6.4	Strike-Slip	Temblor	N65W	0.28	14.5	51	0.55	47.9	87	1.23
27 Jun 1966	ML = 5.6		Rock	S25W	0.41	22.5	55	0.70	58.7	83	
			10 km	VERT	0.17	4.4	27	0.23	13.9	62	
Morgan Hill, CA	Ms = 6.1	Strike-Slip	Coyote Lake Dam	N75W	1.30	79.7	61	1.66	124	74	1.99
24 Apr 1984	ML = 6.2		Rock	S15W	0.71	51.9	73	0.89	85.7	97	
			6 km	UP	0.40	15.4	38	0.44	24.7	56	
Coalinga, CA	Ms = 6.7	Thrust	Pleasant Valley Pump	N45E	0.61	73.9	121	0.85	103	121	1.90
02 May 1983	ML = 6.5		Station (Switchyard)	S45E	0.53	39.5	75	0.74	55.3	75	
			Stiff Alluv./Rock	UP	0.38	16.1	43	0.53	22.6	43	
			10 km								
Coalinga, CA	Ms = 5.7	Reverse	Sulphur Baths	N90E	0.12	5.63	49	0.34	20.6	62	0.84
Aftershock	ML = 6.0		Rock	N00E	0.14	5.57	41	0.37	23.4	64	
21 Jul 1983			13 km	UP	0.09	4.28	50	0.23	15.9	68	

Notes: (1) Data from Niazi (1985).
(2) Data from B. Tsai of PG&E.

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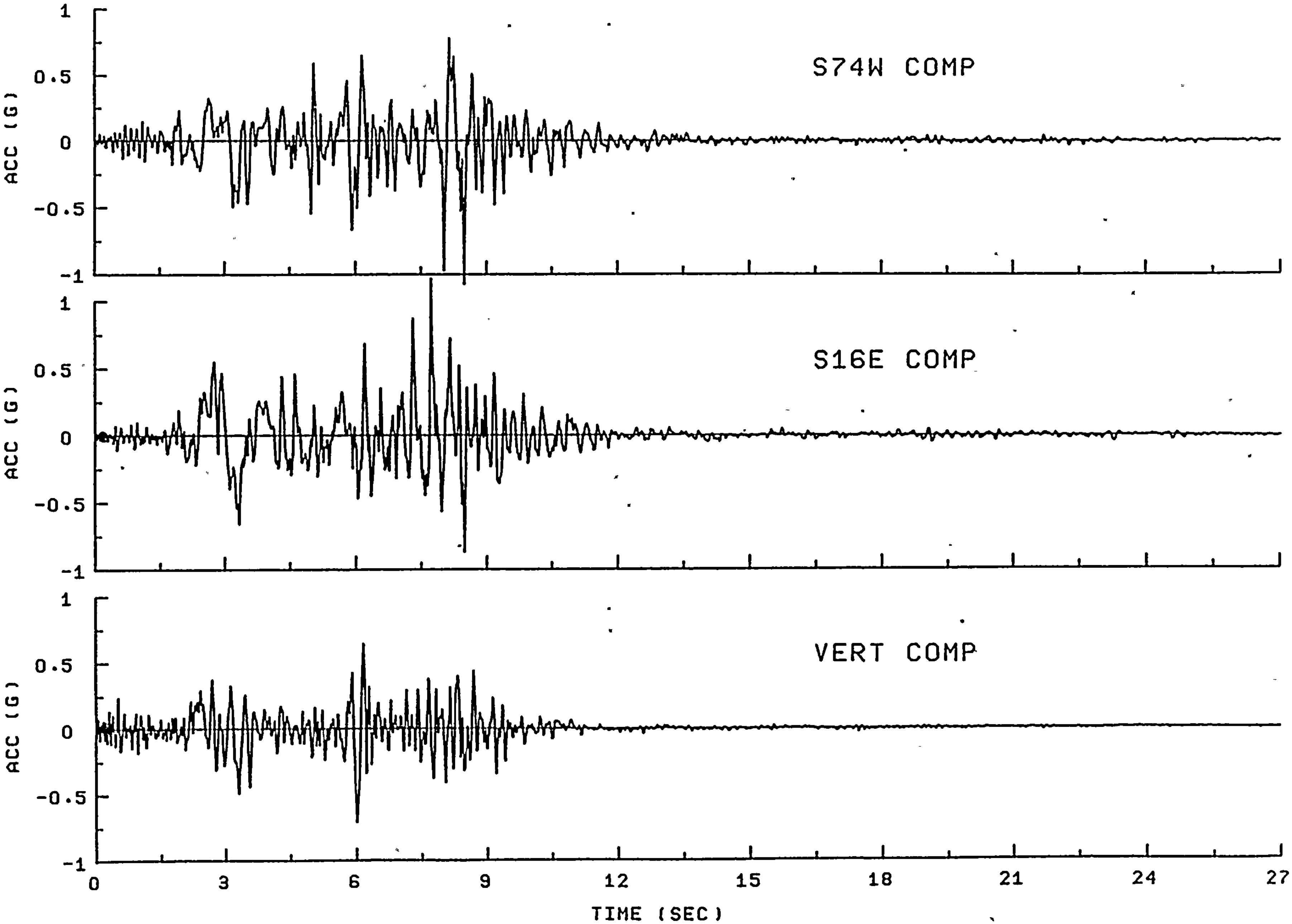
OCT 23 1986



Acceleration Time Histories from the Pacoima Dam Recording of the San Fernando Earthquake (unmodified).

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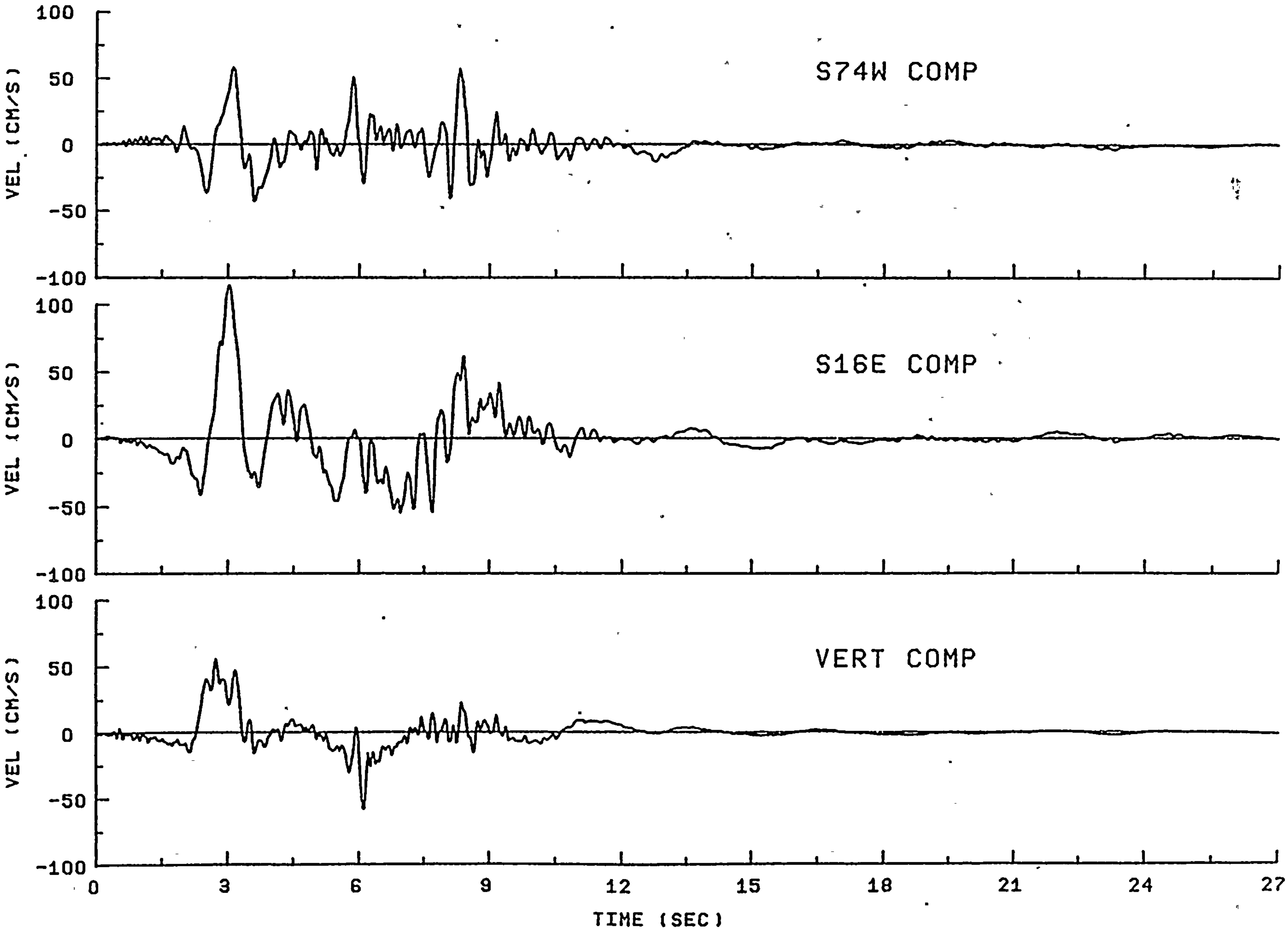
OCT 23 1986



Velocity Time Histor[illegible] from the Pacoima Dam Recording of the San Fernando Earthqua[illegible] (unmodified).

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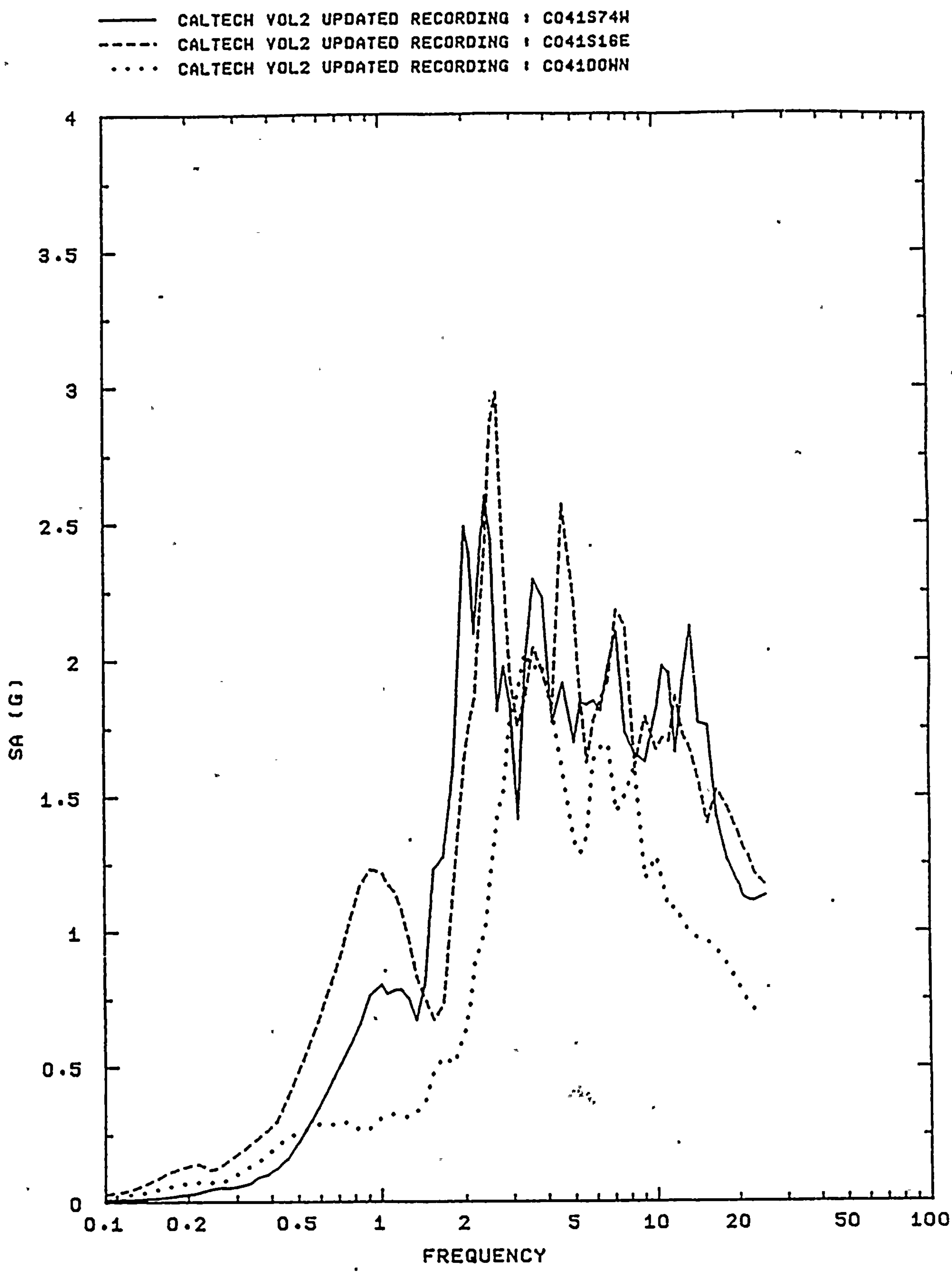

Response Spectral Acceleration (5% Damping) from the Pacoima Dam Recording of the San Fernando Earthquake (unmodified).

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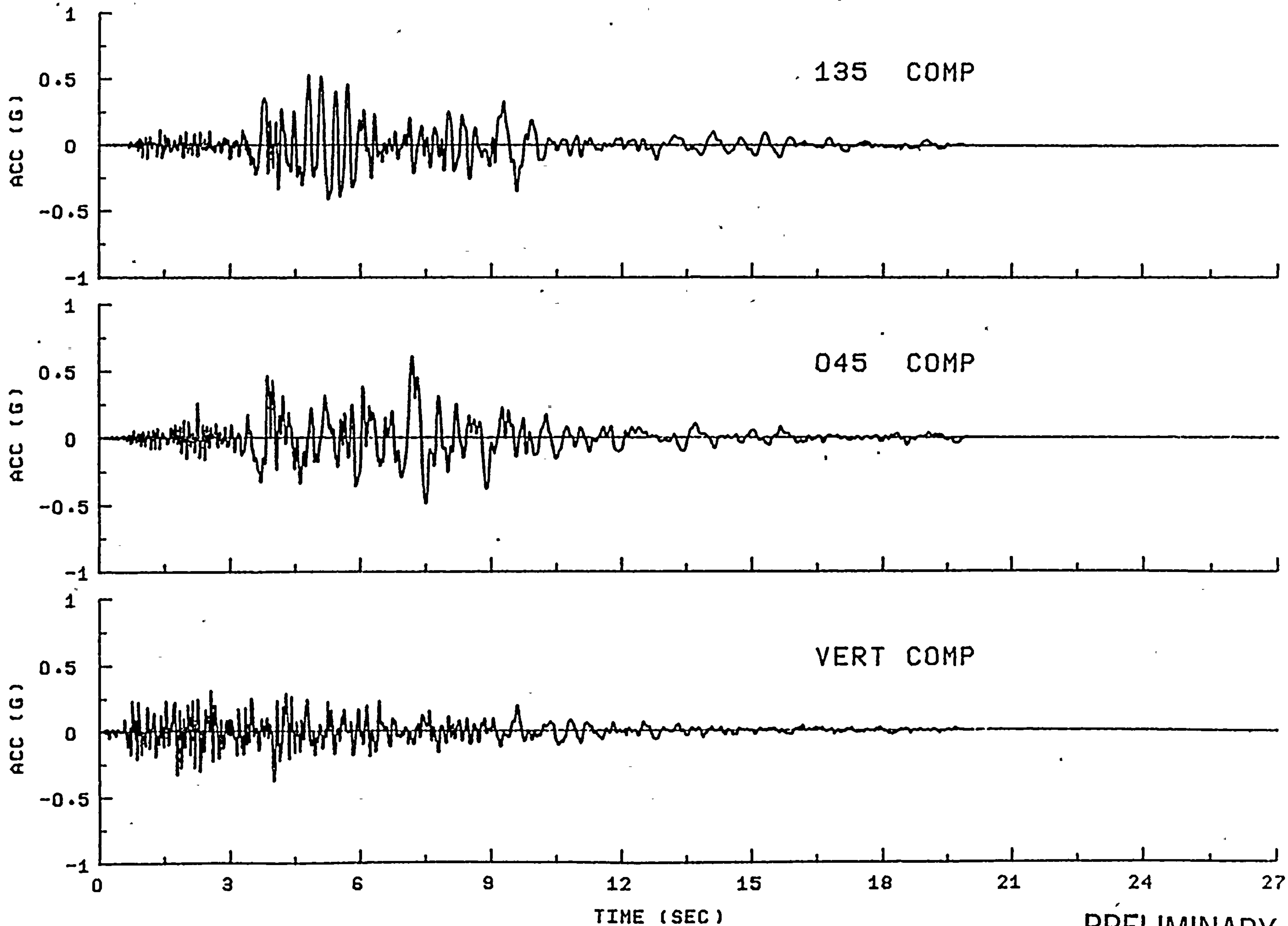
OCT 23 1986

82-II



Acceleration Time Histories from the Pleasant Valley
Pump Station ording of the Coalinga Earthquake

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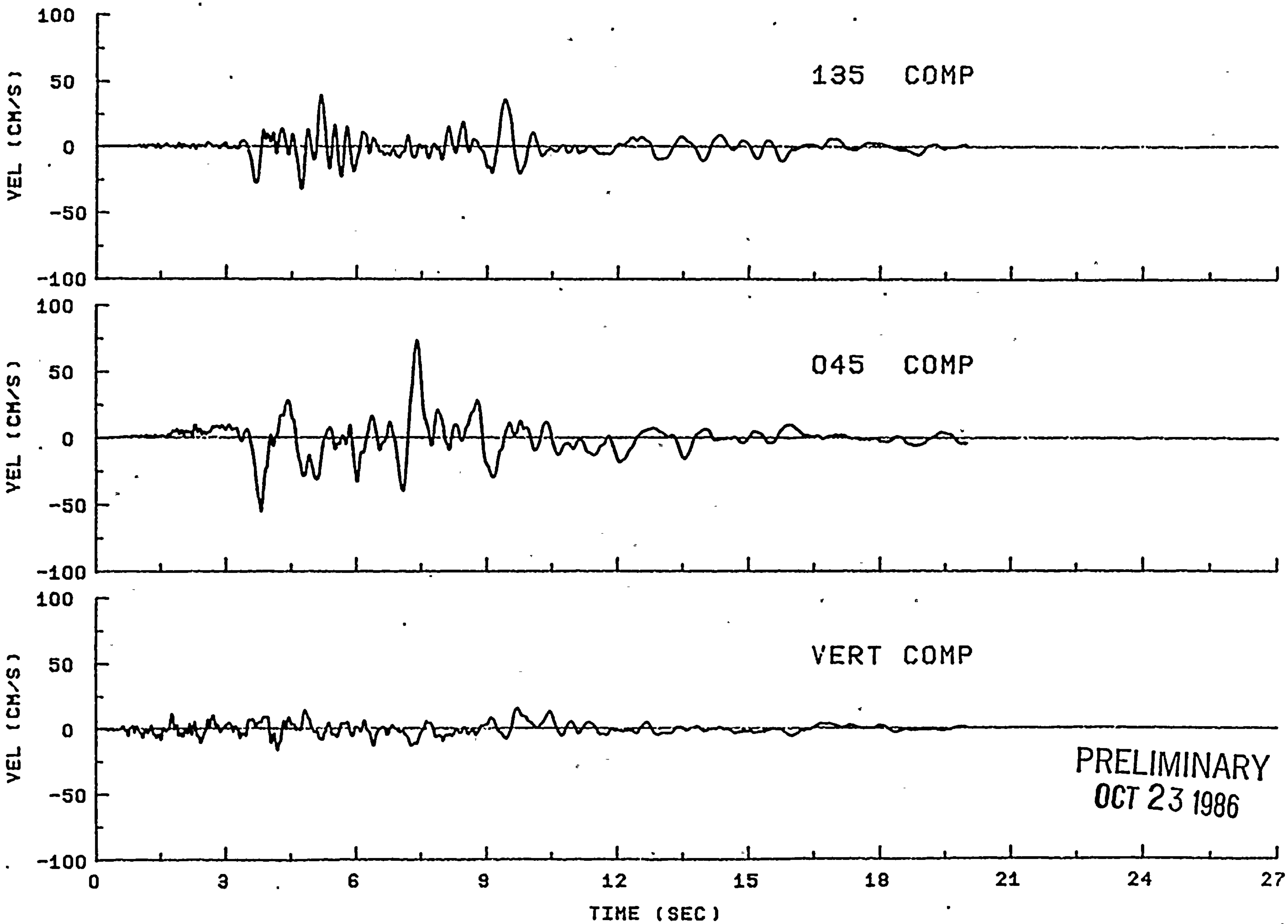
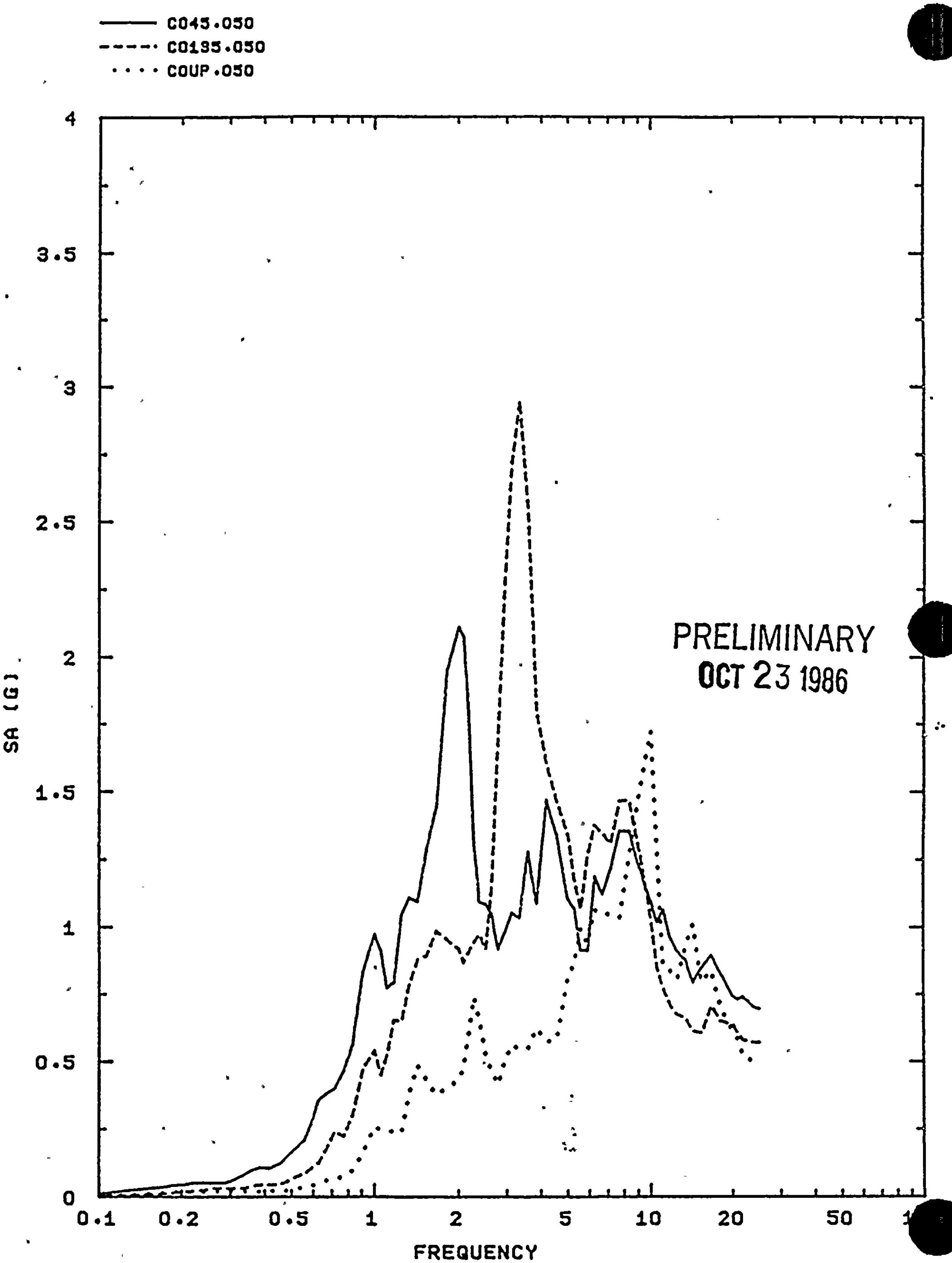
OCT 23 1986

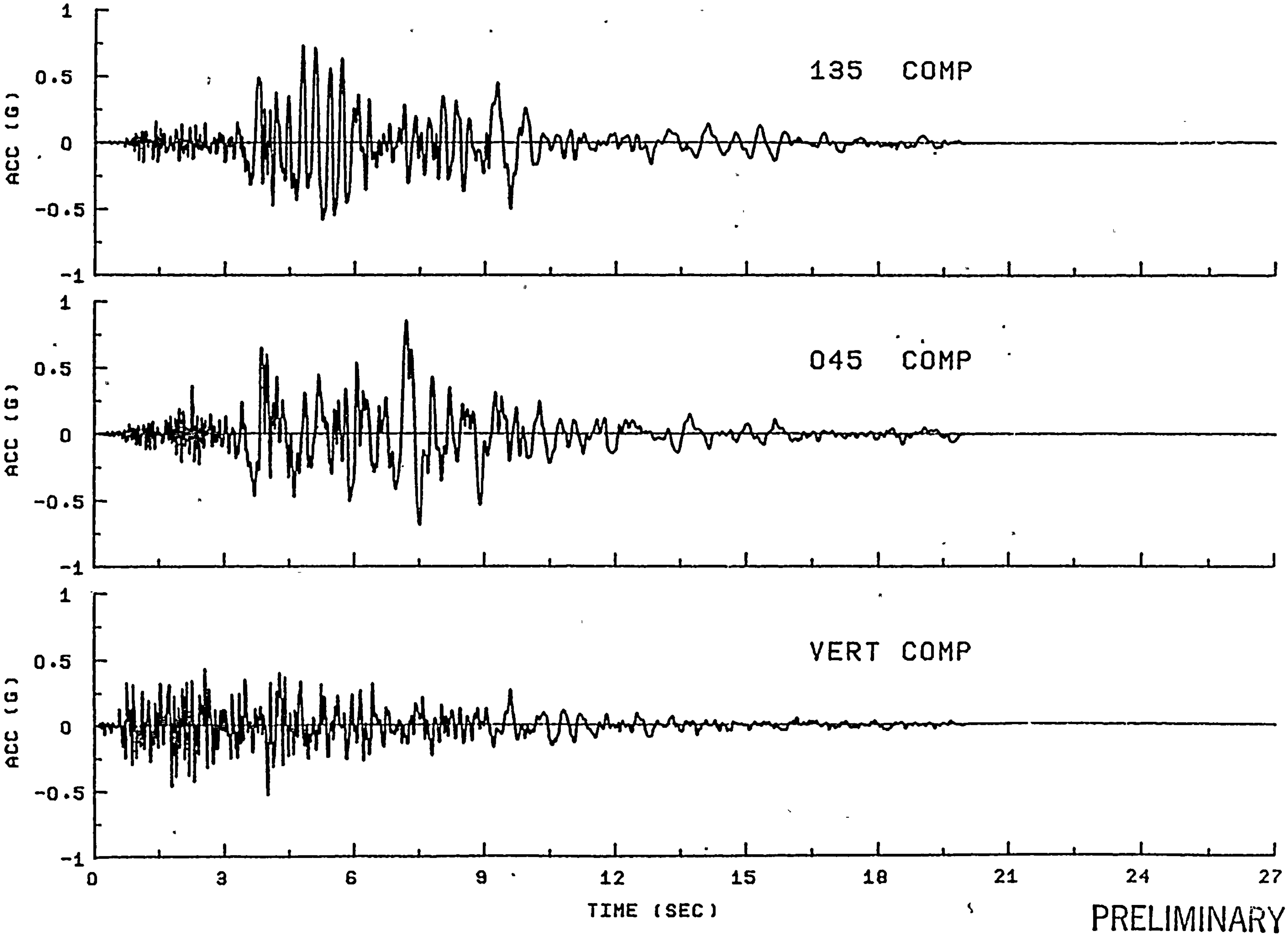
62-II



Velocity Time Histories form the Pleasant Valley Pump Station Recording of the Coalinga Earthquake



Response Spectral Acceleration (5% Damping) from the Pleasant Valley Pump Station Recording of the Coalinga Earthquake



Acceleration Time Histories from the Pleasant Valley Pump Station Recording of the Coalinga Earthquake

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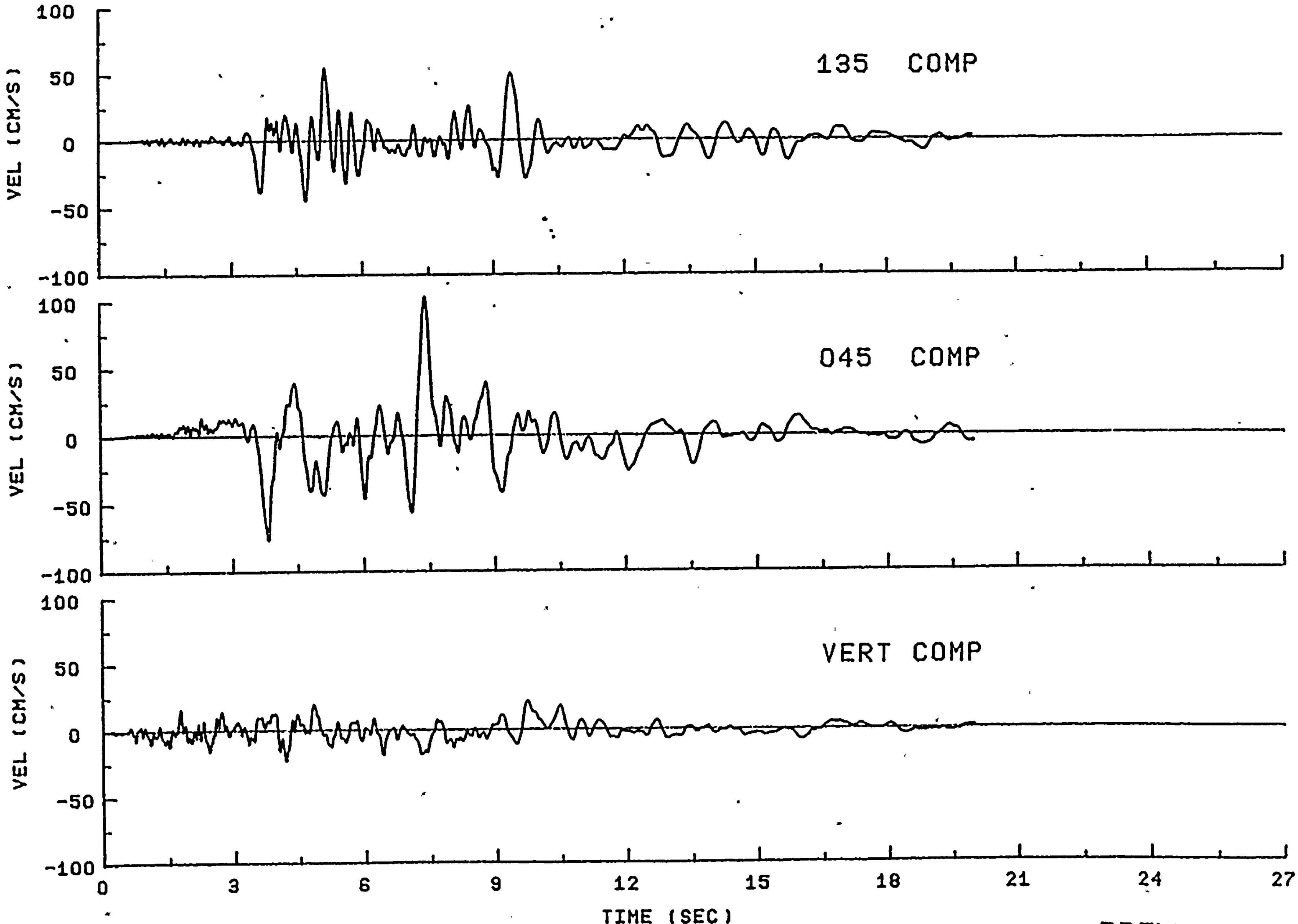
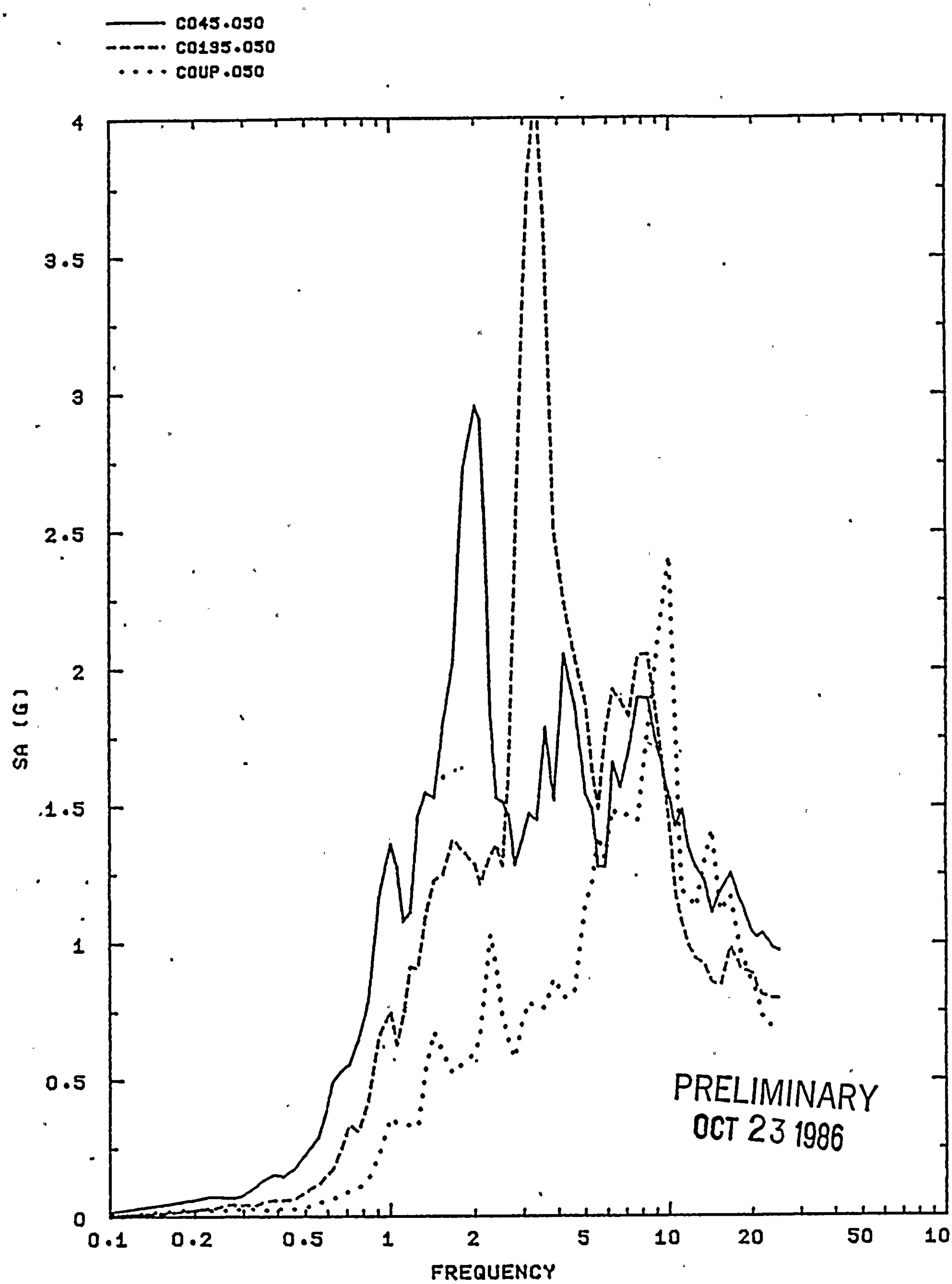
OCT 23 1986

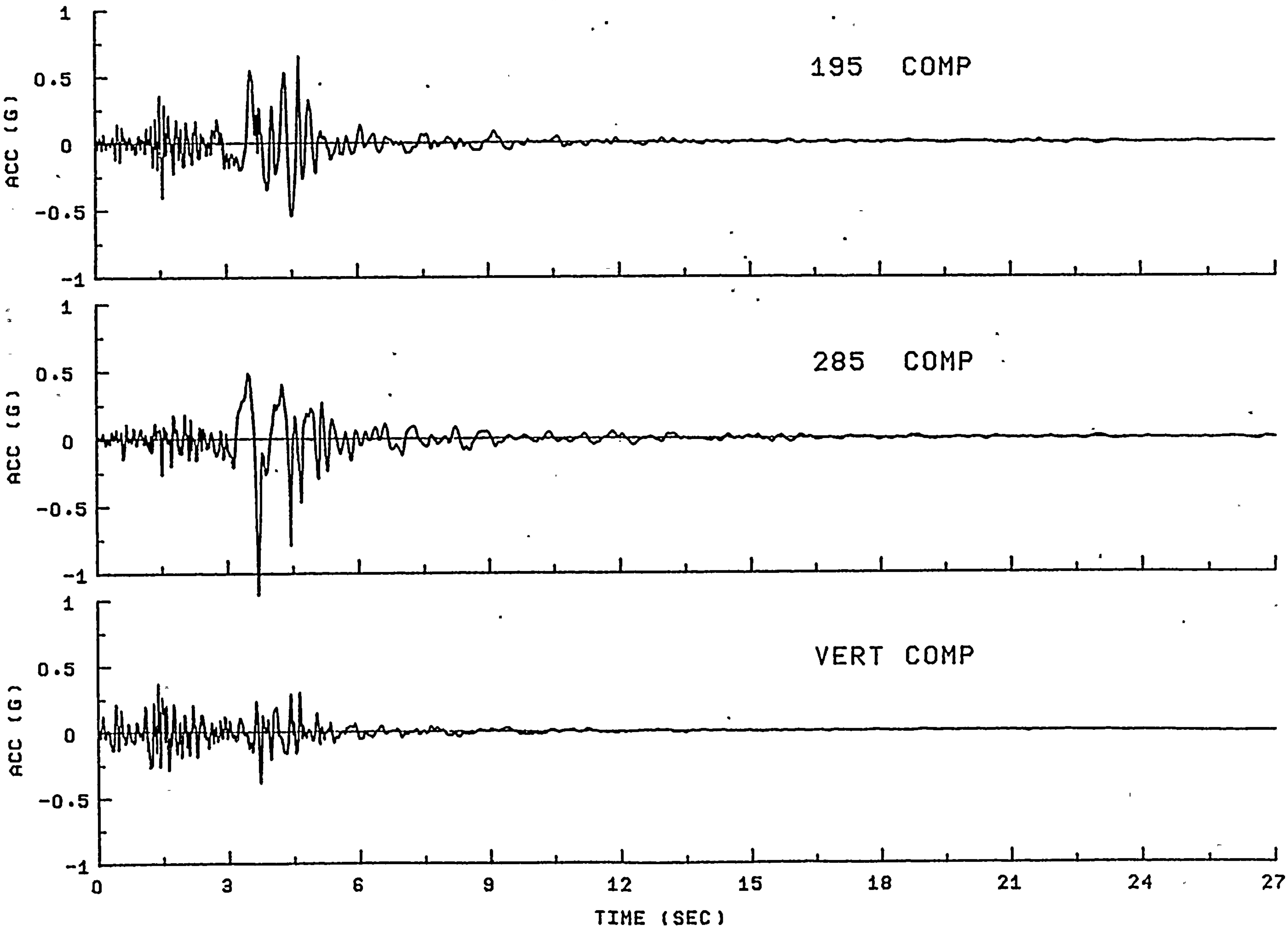


Velocity Time Histori from the Pleasant Valley Pump Station
Recording of the Coa Earthquake

PRELIMINARY
OCT 23



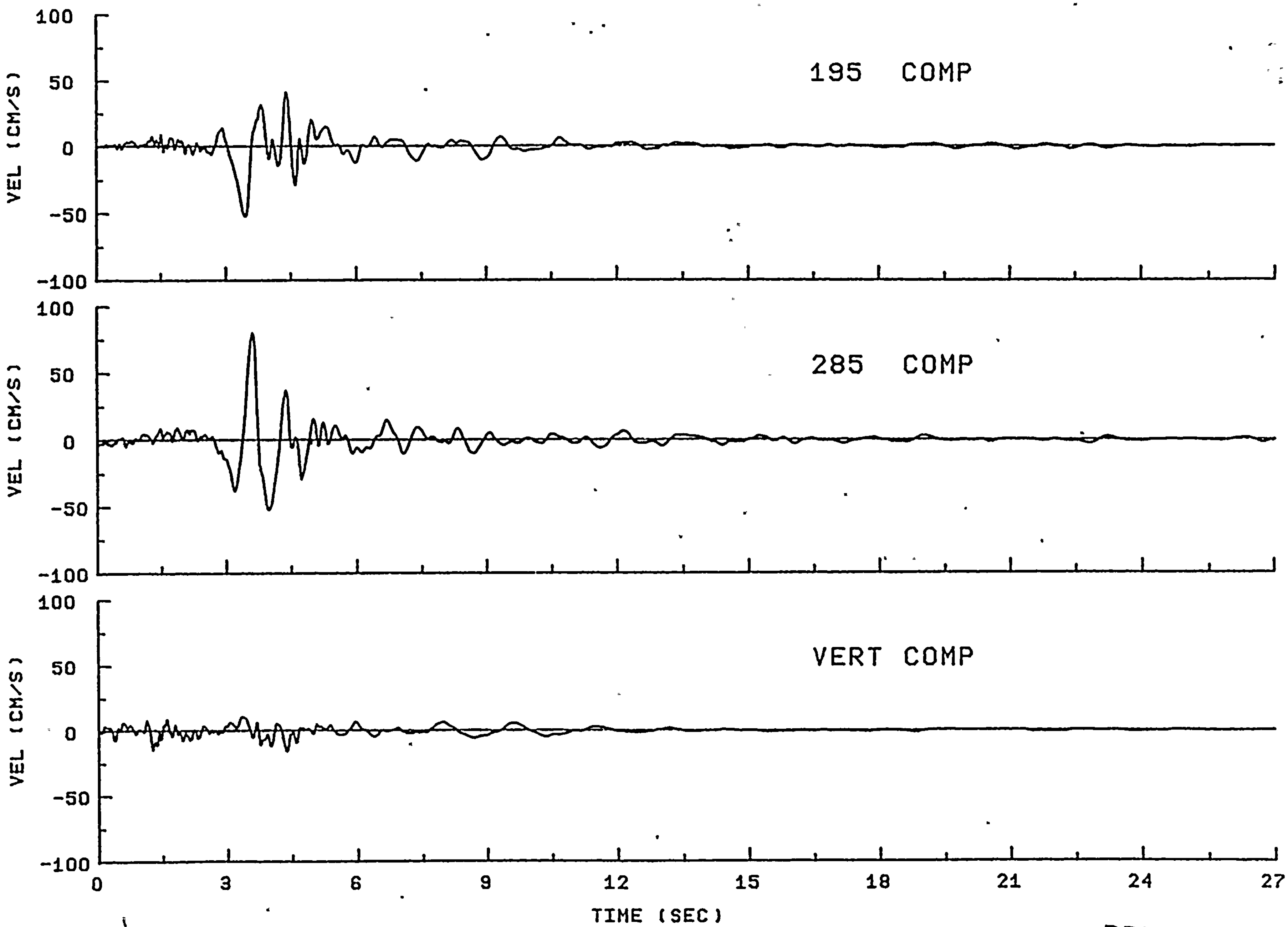
Response Spectral Acceleration (5% Damping) from the
Pleasant Valley Pump Station Recording of the Coalinga Earthquake



Acceleration Time Histories from the Coyote Lake Dam Recording of the Morgan Hill Earthquake.

PRELIMINARY
OCT 23

SC-3-II



Velocity Time Histories from the Coyote Lake Dam Recording of the Morgan Hill Earthquake.

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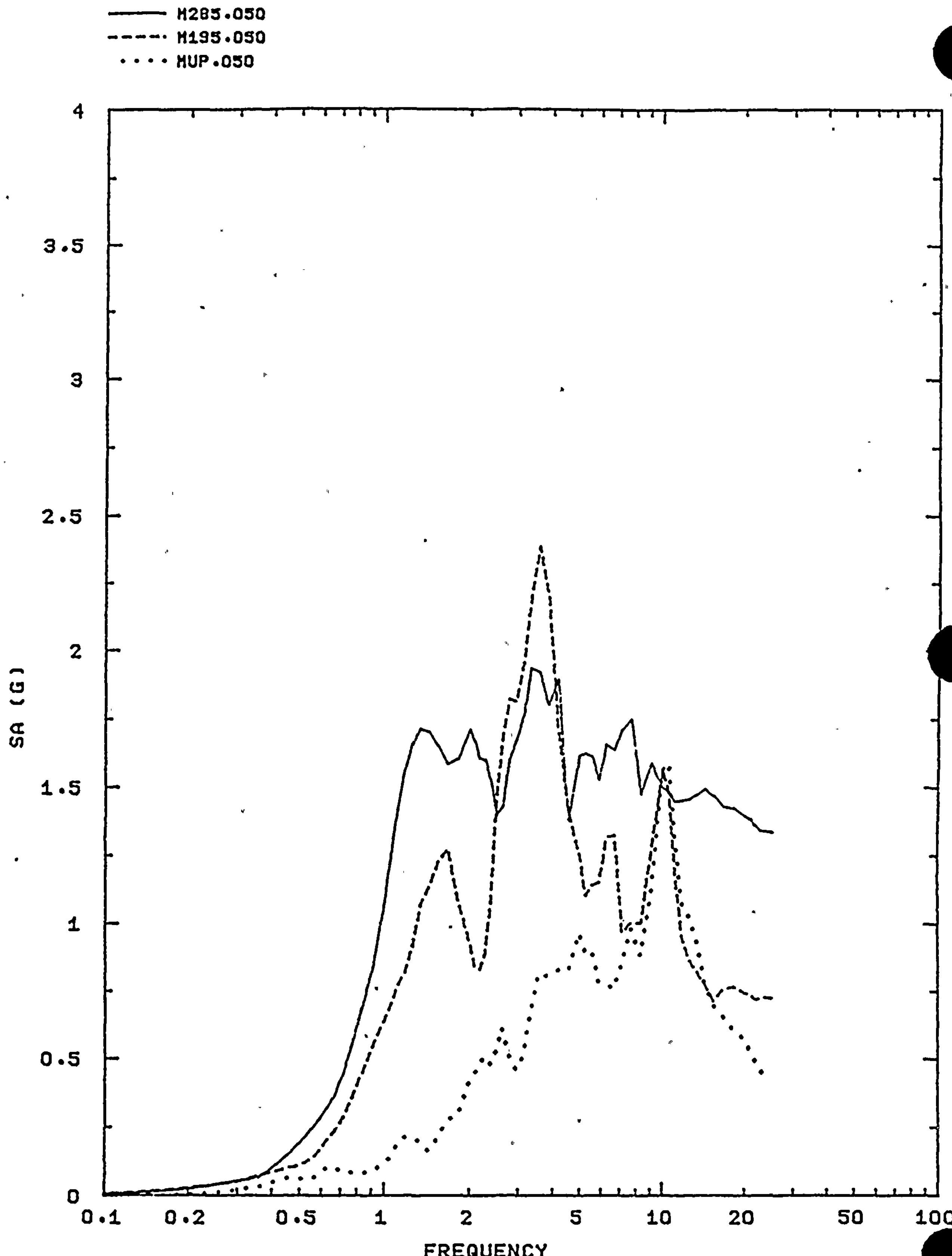
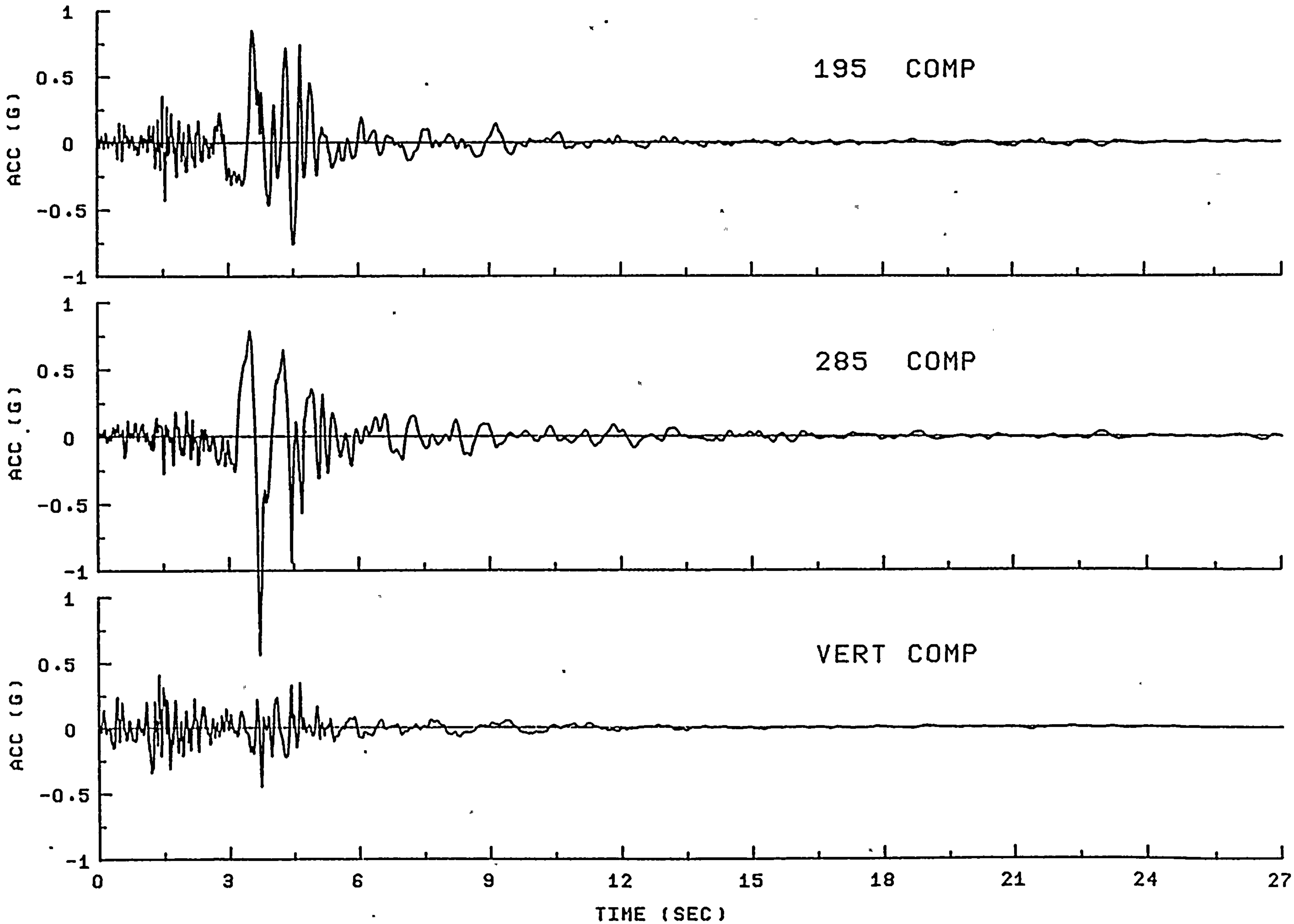


Response Spectral Acceleration (5% Damping) from the Coyote Lake Dam Recording of the Morgan Hill Earthquake.

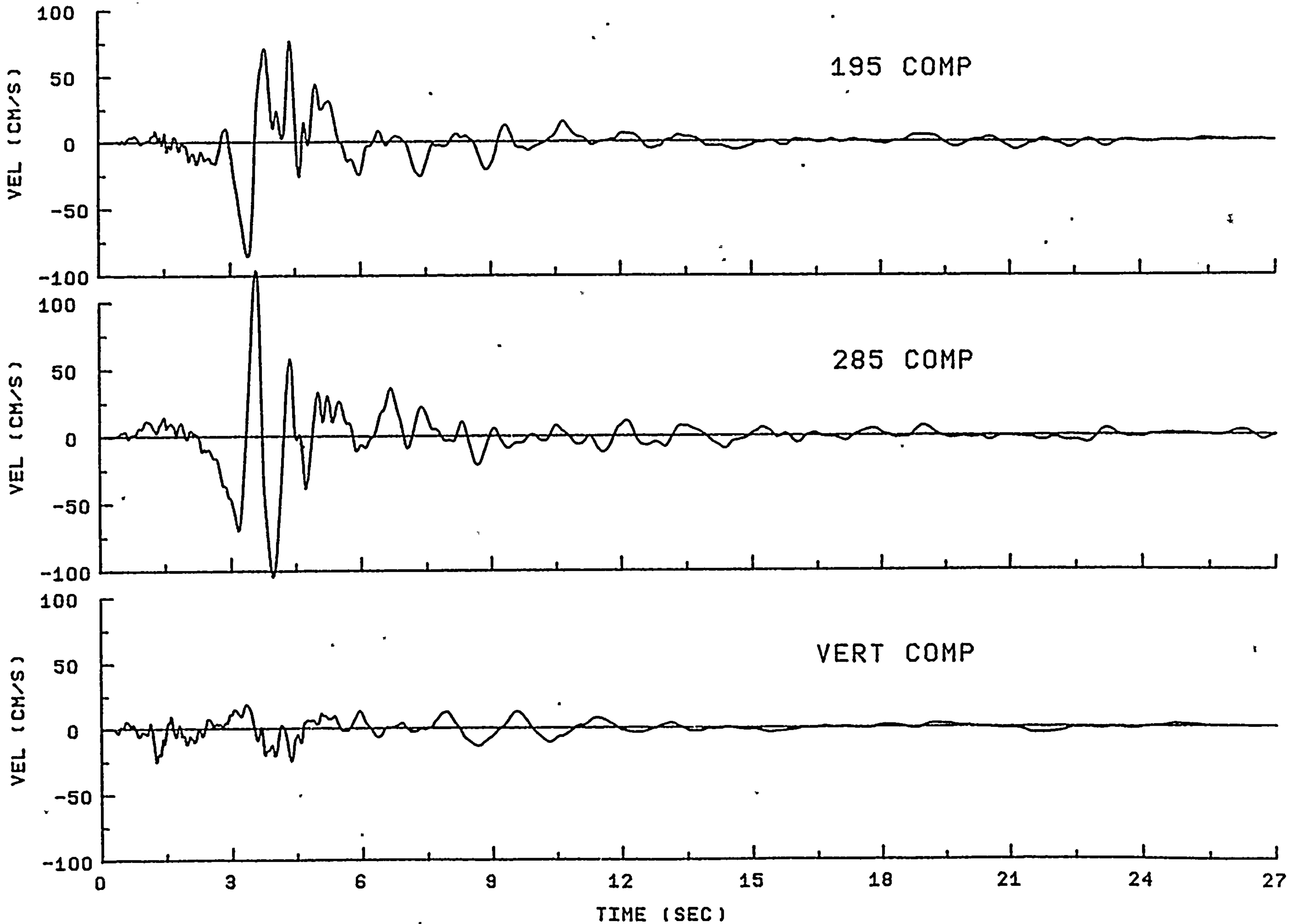
PRELIMINARY
OCT 23 1986

II-36



Acceleration Time Histories from the Coyote Lake Dam Recording of the Morgan Hill Earthquake (modified for magnitude).

PRELIMINARY
OCT 23 1986

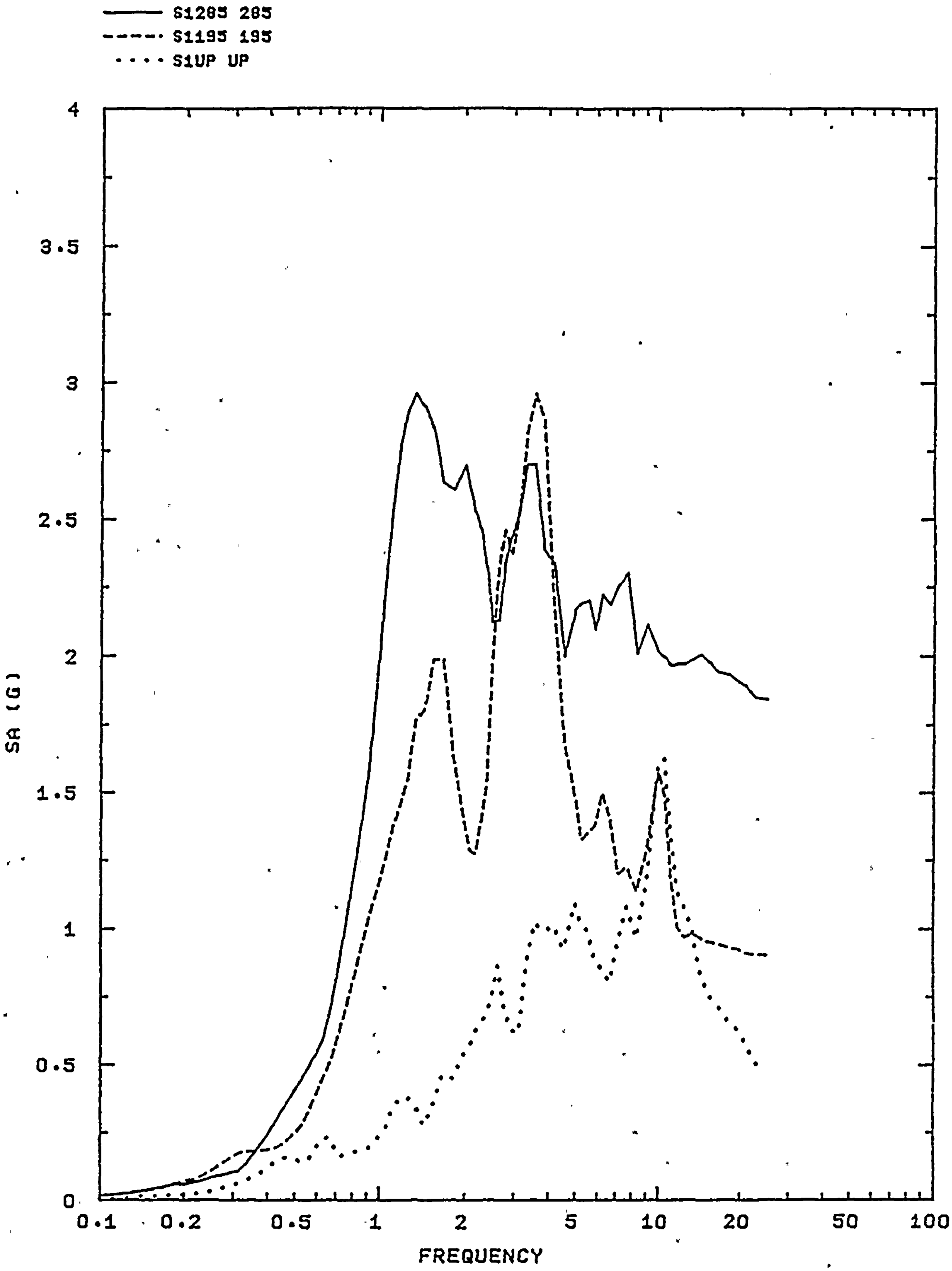


Velocity Time Histories from the Coyote Lake Dam Recording of the Morgan Hill Earthquake (modified for magnitude).

PRELIMINARY

OCT 2 86

85-II



Response Spectral Acceleration (5% Damping) from the Coyote Lake Dam Recording of the Morgan Hill Earthquake (modified for magnitude).

PRELIMINARY
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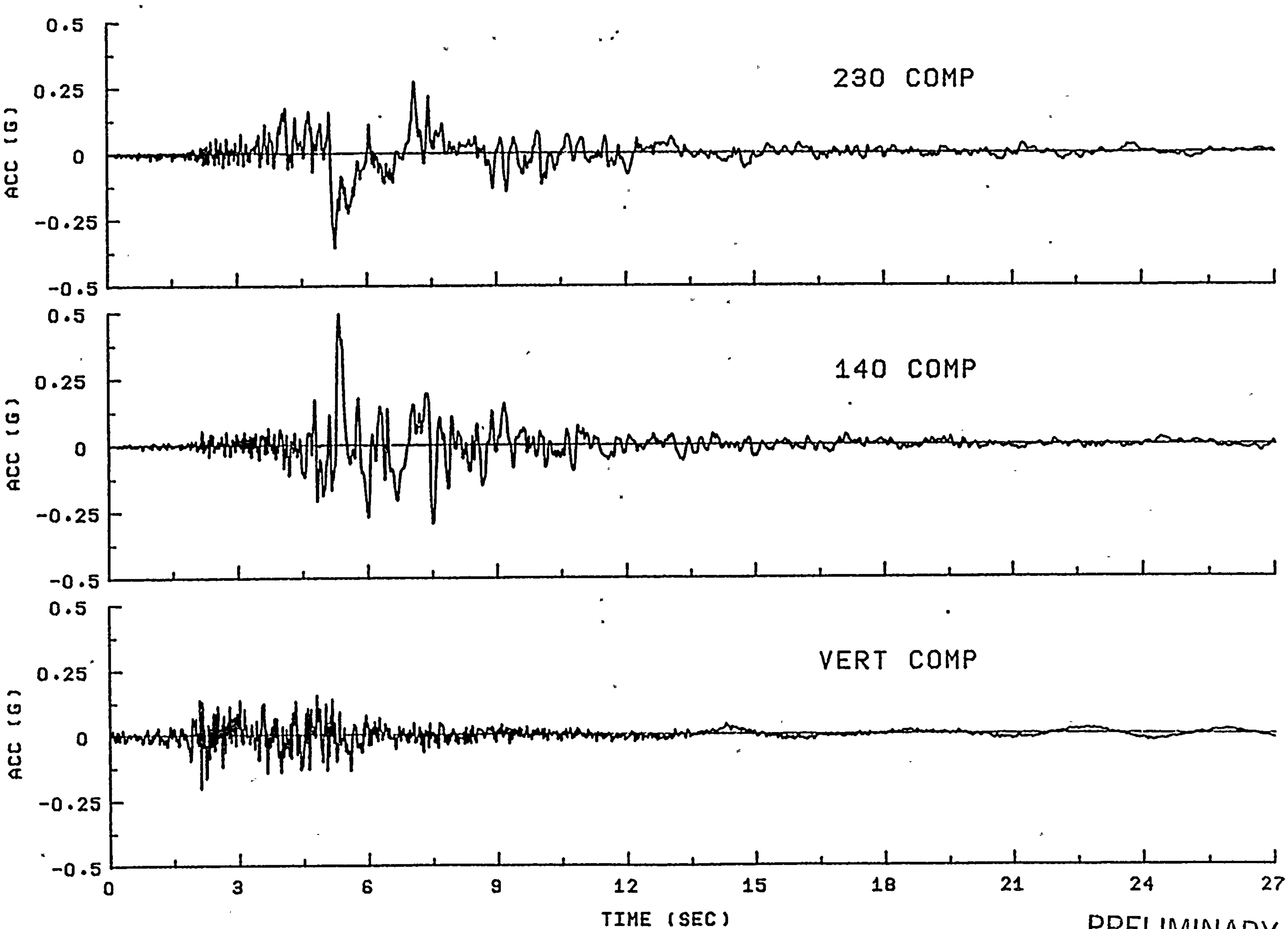
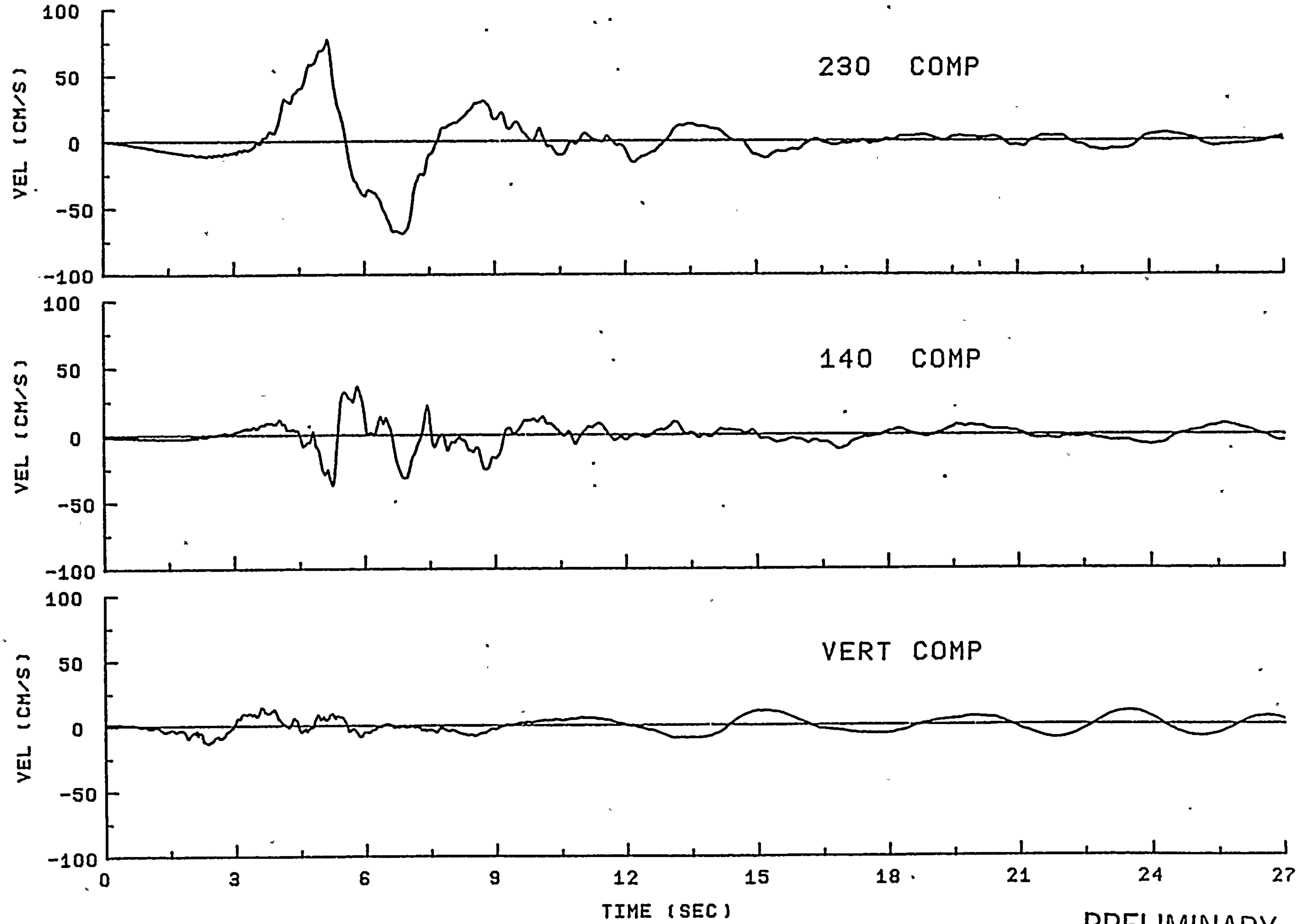


Acceleration Time Histories from the El Centro No. 4 Recording of the Imperial Valle rthquake.

PRELIMINARY
OCT 23 1986



Velocity Time Histories from the El Centro No. 4 Recording of the Imperial Valley Earthquake.

PRELIMINARY
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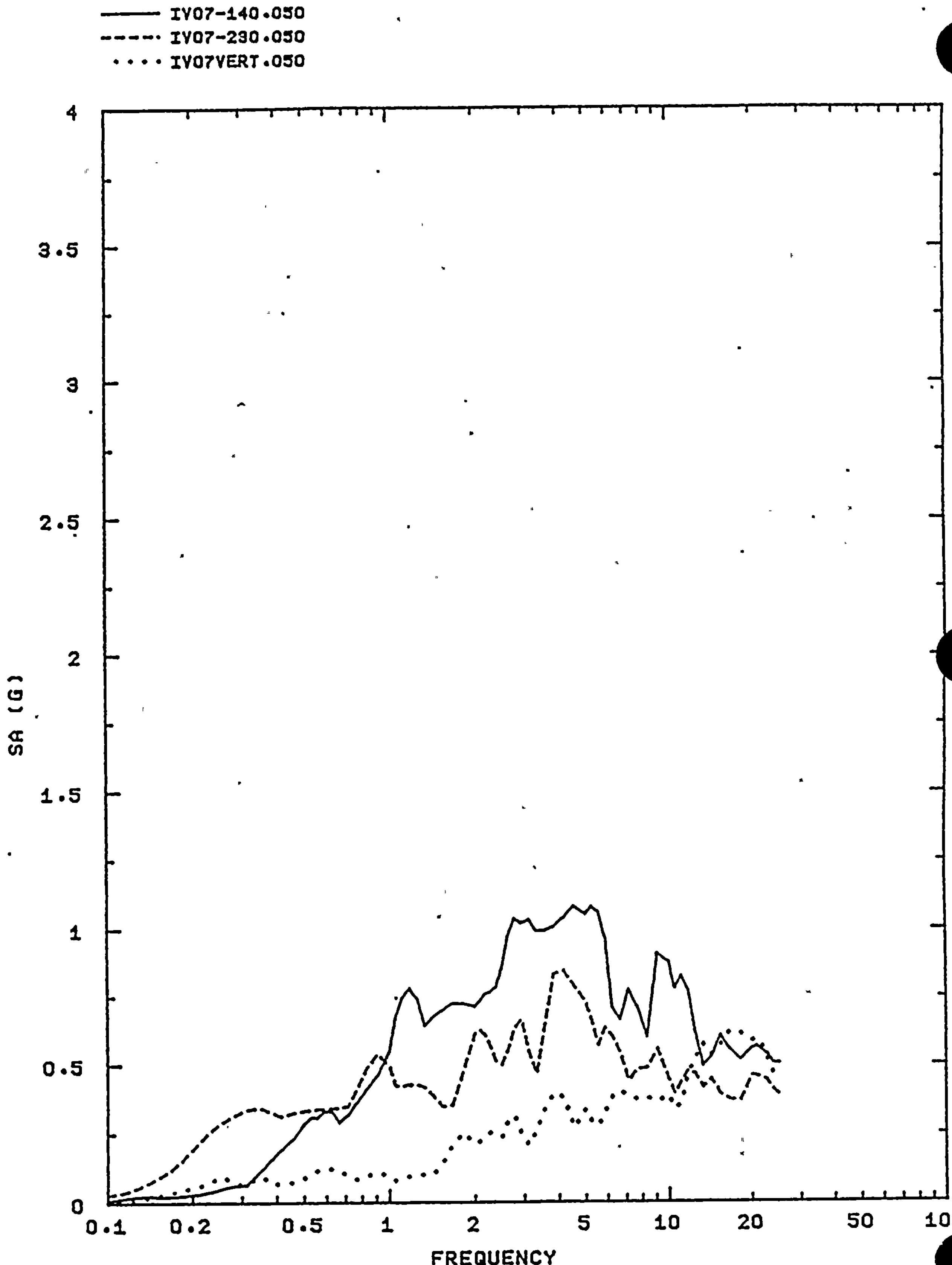

Response Spectral Acceleration (5% Damping) from the El Centro No. 4 Recording of the Imperial Valley Earthquake.

PRELIMINARY
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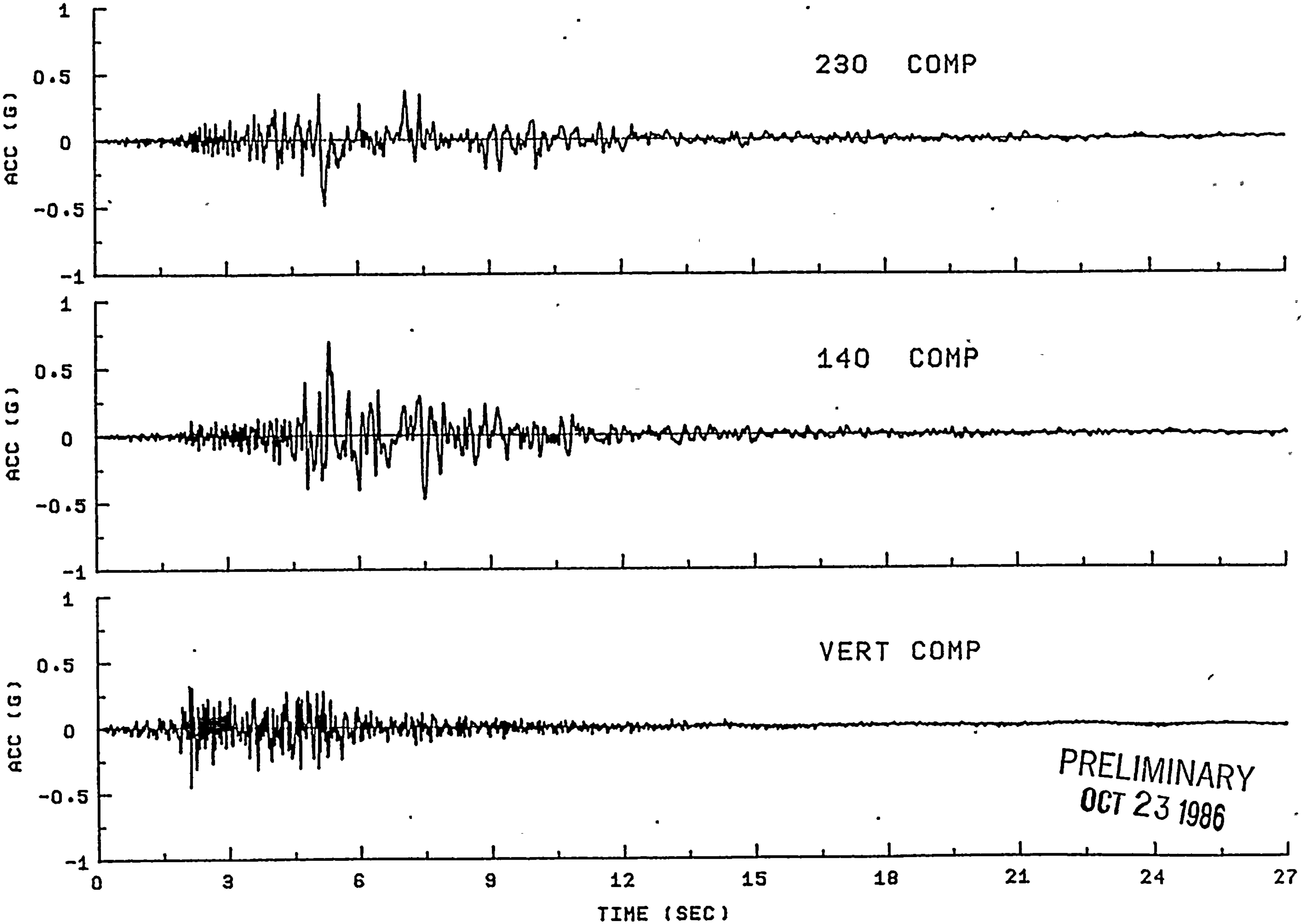
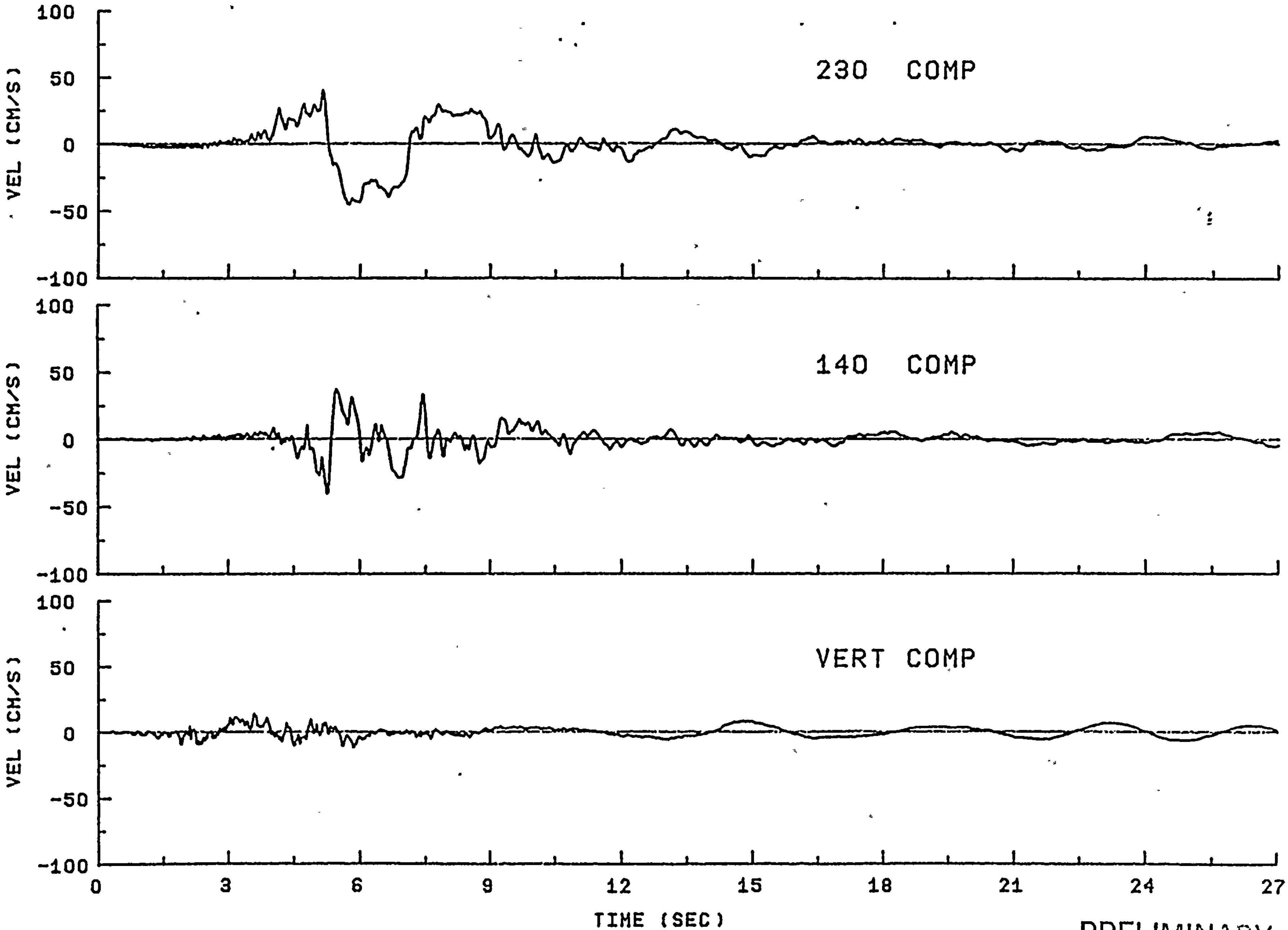


Acceleration Time Histories from the El Centro No. 4 Recording of the Imperial Valley Earthquake (modified for site condition).



Velocity Time Histories from the El Centro No. 4 Recording of the Imperial Valley Earthquake (modified for site condition).

PRELIMINARY
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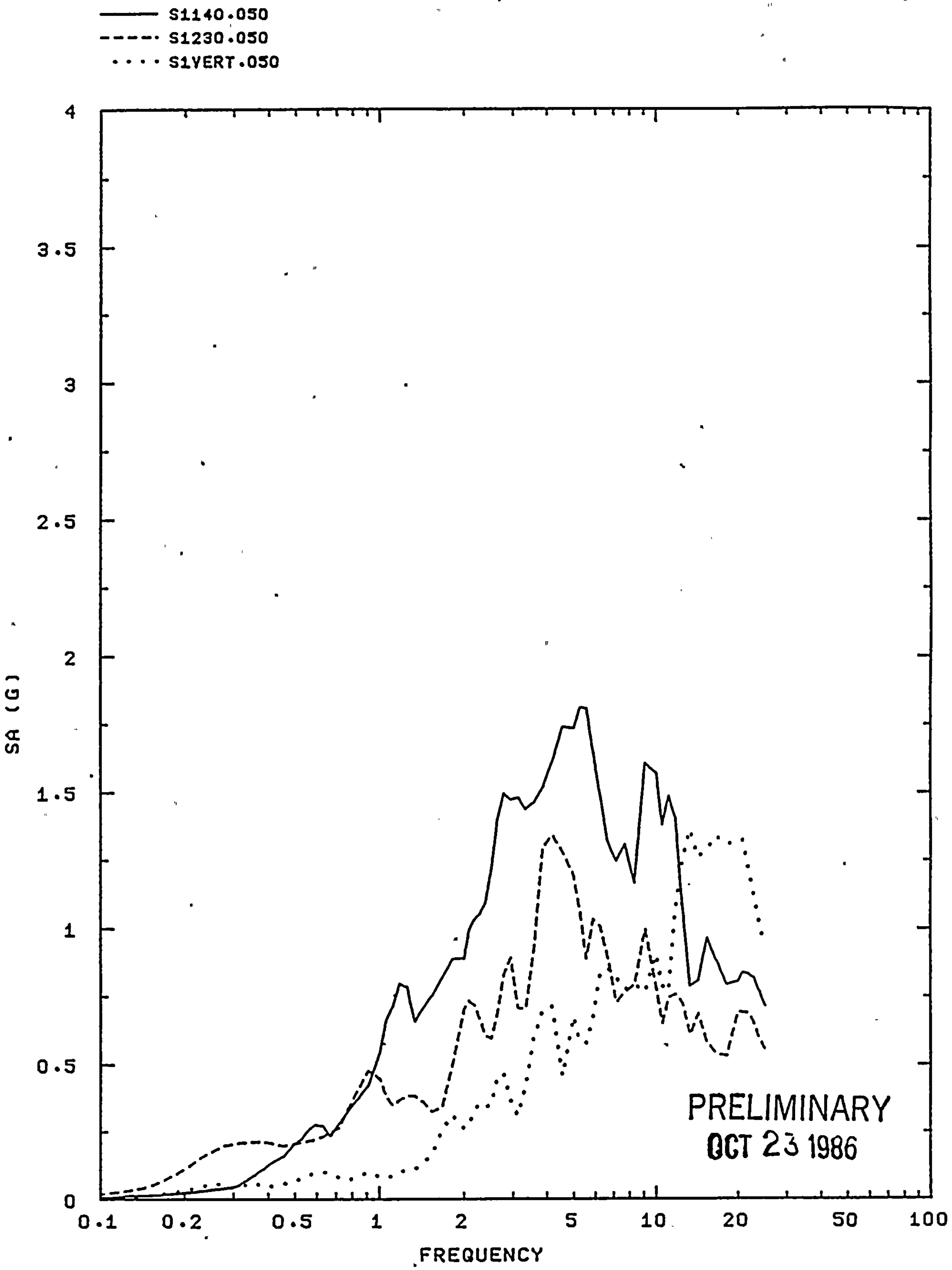
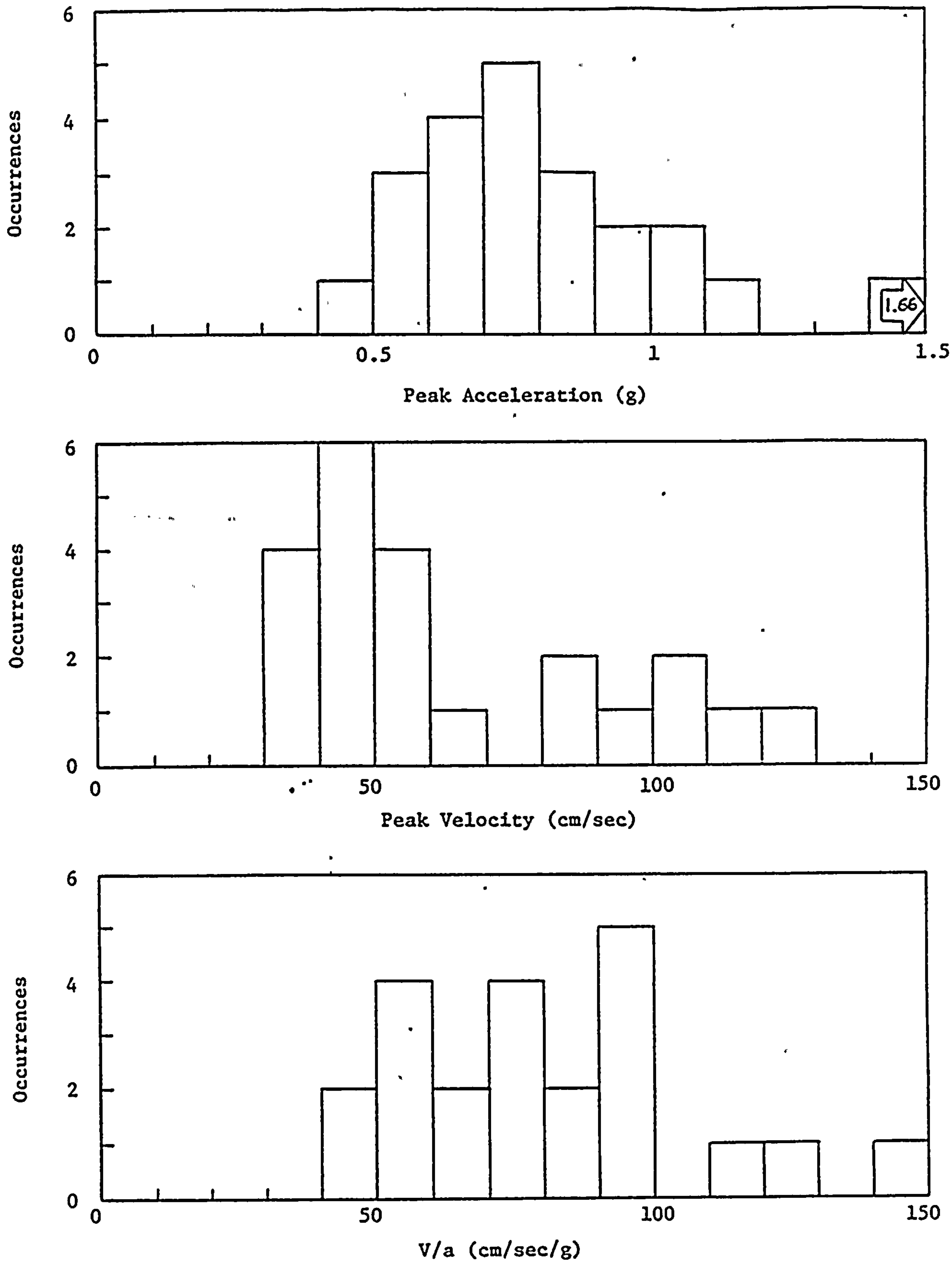


Response Spectral Acceleration (5% Damping) from the El Centro No. 4 Recording of the Imperial Valley Earthquake (modified for site condition).



Histograms of Horizontal Ground Motion Characteristics for the Modified Records

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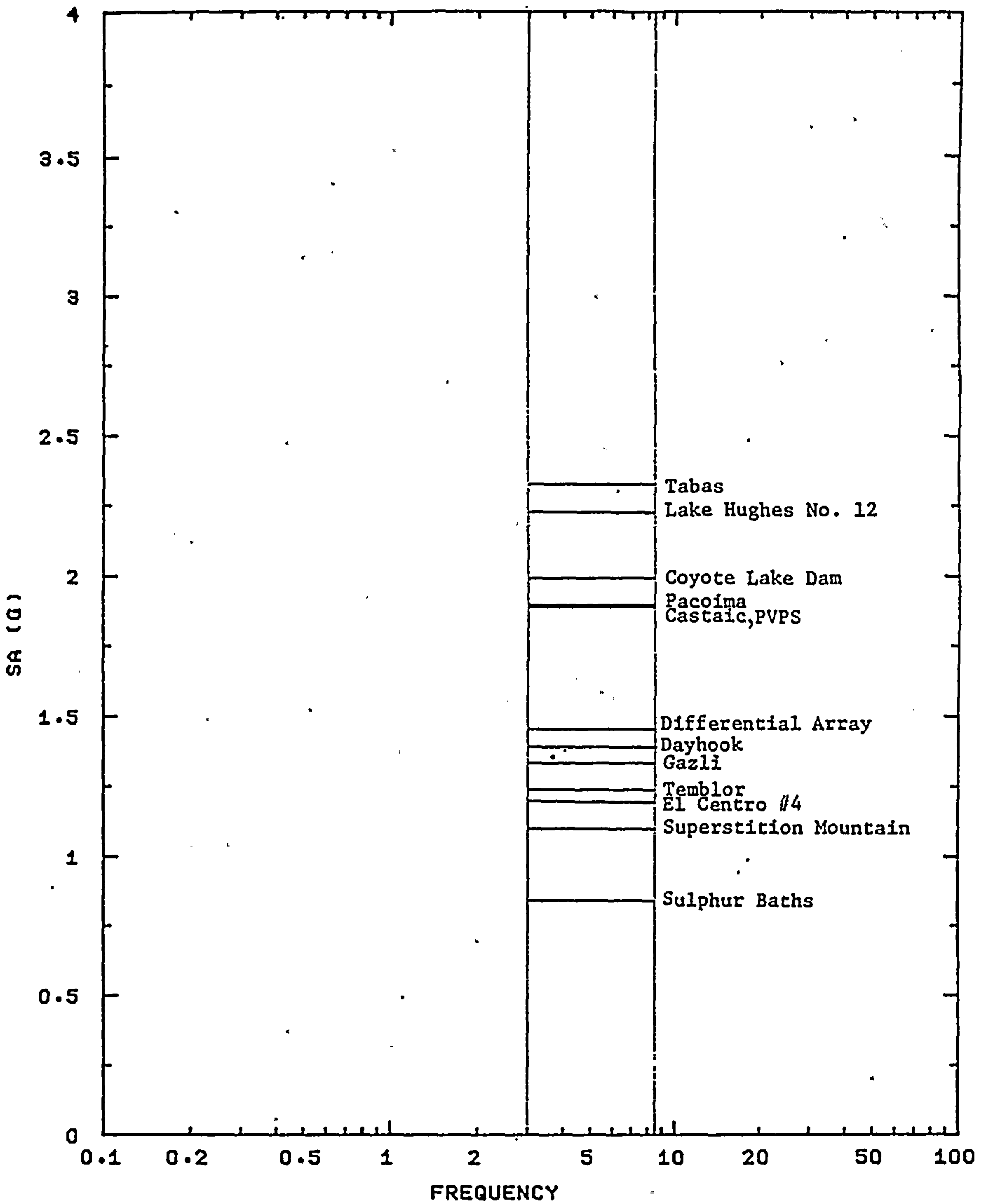

Summary of S_a Values for Modified Records Averaged Over Frequency Range 3 to 8.5 Hz.

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PG&E Diablo Canyon Power Plant
Long Term Seismic Program (LTSP)

Empirical Ground Motion Study

Input to Phase IIIA Studies

TIME HISTORIES FOR SOIL/STRUCTURE INTERACTION ANALYSES

PRELIMINARY
OCT 23 1986

III-1

EMPIRICAL GROUND MOTION STUDY

INPUT FOR PHASE III-A

SOIL-STRUCTURE INTERACTION ANALYSES

- Select eight records from those identified as Category (A) for fragility studies

- Establish the median response spectrum of eight records selected

- Identify the record (or records) which best match the median horizontal spectrum of the eight records

  - compare absolute value of horizontal spectrum

  - compare shape of horizontal spectrum

  - compare vertical/horizontal relation of record. spectrum, and its vertical with respect to median vertical spectrum

PRELIMINARY
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TABLE A-1 - CHARACTERISTICS OF SELECTED STRONG MOTION RECORDS FOR FRAGILITY STUDIES FOR PG&E DIABLO CANYON POWER PLANT

EARTHQUAKE DATE	MAGNITUDE	RUPTURE MECHANISM	RECORDING STATION SITE CONDITIONS DISTANCE	COMP	Original Record: Peak Accel. (g)	Original Record: Peak Veloc. (cm/sec)	Original Record: V/a cm/sec g	Modified Record: Peak Accel. (g)	Modified Record: Peak Veloc. (cm/sec)	Modified Record: V/a cm/sec g	Modified Record: $S_a\|_{3Hz}^{8.5}$ (g)	Rating
Gazli, U.S.S.R.	Ms = 7.0	Thrust	Karakyr Point	EAST	0.70	47.2	68	0.70	47.2	68	1.33	(A)
17 May 1976	ML = 6.4		Rock/Stiff Alluv.	NORT	0.66	44.4	68	0.66	44.4	68		
			~4 km	VERT	1.41	53.5	38	1.41	53.5	38		
Tabas, Iran	Ms = 7.5	Thrust	Tabas	TRAN	0.70	105	150	0.70	105	150	2.33	(A)
16 Sep 1978	ML = 6.6		Stiff Alluv./Rock	LONG	0.81	91.5	113	0.81	91.5	113		
			3 km	VERT(1)	0.74	41.5	56	0.74	41.5	56		
			Dayhook	N10E(1)	0.39	27.5	70	0.66	46.8	70	1.39(2)	(A)
			Rock (?)	N80W(1)	0.38	36.7	97	0.64	62.4	97		
			17 km	VERT(1)	0.18	12.2	66	0.31	20.7	66		
San Fernando, CA	Ms = 6.6	Thrust	Pacoima Dam	S14W	1.17	114	97	1.17	114	97	1.90	(A)
09 Feb 1971	ML = 6.4		Rock	N76W	1.08	58.3	54	1.08	58.3	54		
			3 km	DOWN	0.71	57.8	81	0.71	57.8	81		
			Lake Hughes #12	N21E	0.37	14.7	40	0.94	36.8	40	2.23	(B)
			Rock	N69W	0.29	12.8	44	0.72	32.0	44		
			20 km	DOWN	0.16	4.1	25	0.41	10.3	25		
			Castaic	N21E	0.33	16.5	50	1.07	52.8	50	1.90	(A)
			Stiff Alluvium	N69W	0.29	27.8	96	0.92	89.0	96		
			25 km	DOWN	0.18	6.4	36	0.58	20.5	36		
Imperial Valley, CA	Ms = 6.9	Strike-Slip	Superstition Mtn.	S45E	0.20	9.02	45	0.59	27.0	45	1.10	(C)
15 Oct 1979	ML = 6.6		Rock	N45E	0.12	4.86	42	0.35	14.7	42		
			25 km	UP	0.08	2.10	26	0.24	6.2	26		
			Differential Array	N00E	0.49	42.5	87	0.57	31.7	56	1.45	(A)
			Deep Alluvium	N90W	0.35	67.8	192	0.51	40.2	78		
			5 km	UP	0.75	20.0	27	1.15	15.1	13		
			El Centro # 4	S50W	0.37	77.6	210	0.48	45.2	94	1.20	(A)
			Deep Alluvium	S40E	0.49	37.1	76	0.68	40.3	58		
			4 km	UP	0.25	14.4	58	0.45	14.2	32		
Parkfield, CA	Ms = 6.4	Strike-Slip	Temblor	N65W	0.28	14.5	51	0.55	47.9	87	1.23	(B)
27 Jun 1966	ML = 5.6		Rock	S25W	0.41	22.5	55	0.70	58.7	83		
			10 km	VERT	0.17	4.4	27	0.23	13.9	62		
Morgan Hill, CA	Ms = 6.1	Strike-Slip	Coyote Lake Dam	N75W	1.30	79.7	61	1.66	124	74	1.99	(A)
24 Apr 1984	ML = 6.2		Rock	S15W	0.71	51.9	73	0.89	85.7	97		
			6 km	UP	0.40	15.4	38	0.44	24.7	56		
Coalinga, CA	Ms = 6.7	Thrust	Pleasant Valley Pump	N45E	0.61	73.9	121	0.85	103	121	1.90	(A)
02 May 1983	ML = 6.5		Station (Switchyard)	S45E	0.53	39.5	75	0.74	55.3	75		
			Stiff Alluv./Rock	UP	0.38	16.1	43	0.53	22.6	43		
			10 km									
Coalinga, CA Aftershock	Ms = 5.7	Reverse	Sulphur Baths	N90E	0.12	5.63	49	0.34	20.6	62	0.84	(D)
21 Jul 1983	ML = 6.0		Rock	N00E	0.14	5.57	41	0.37	23.4	64		
			13 km	UP	0.09	4.28	50	0.23	15.9	68		

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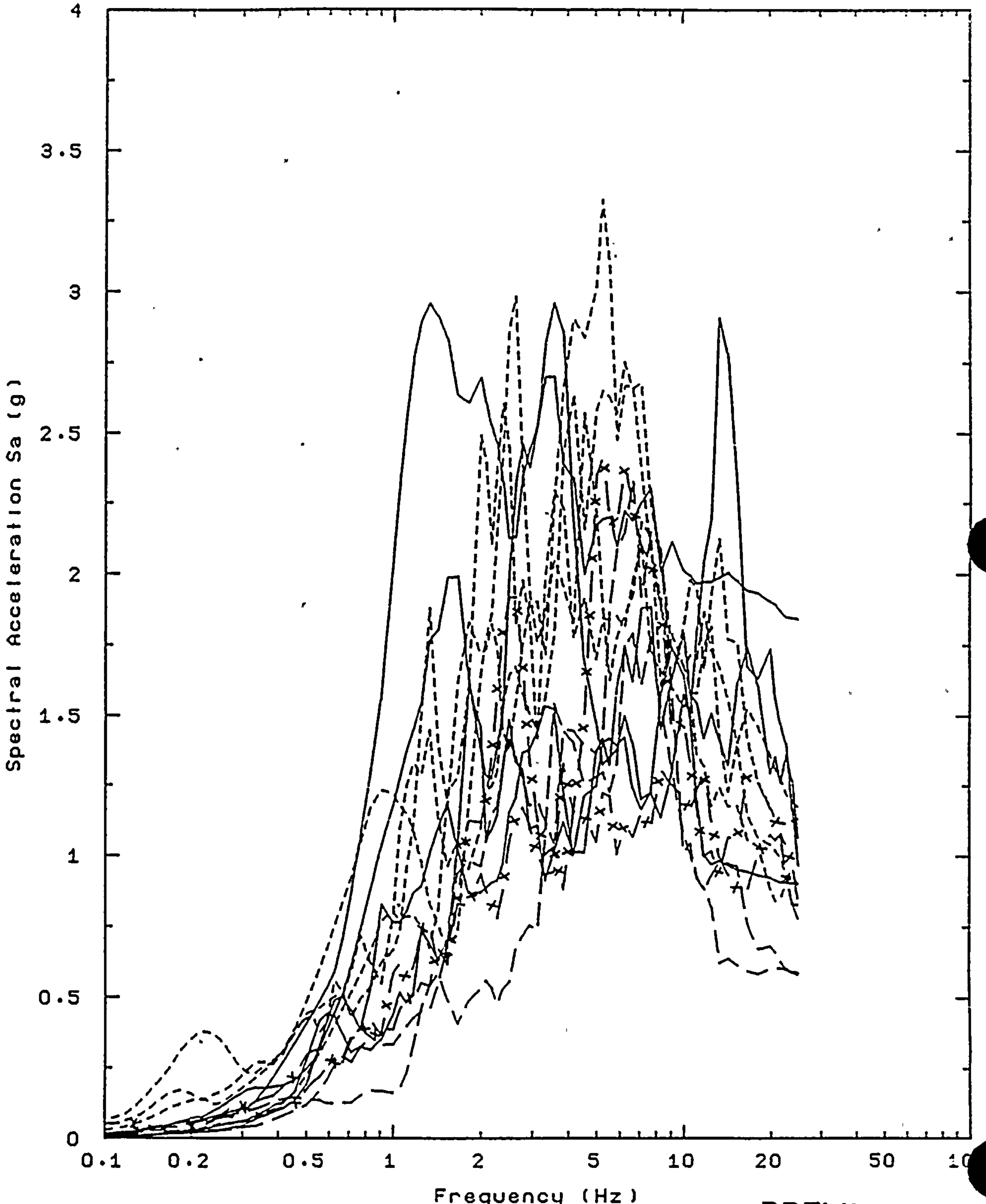

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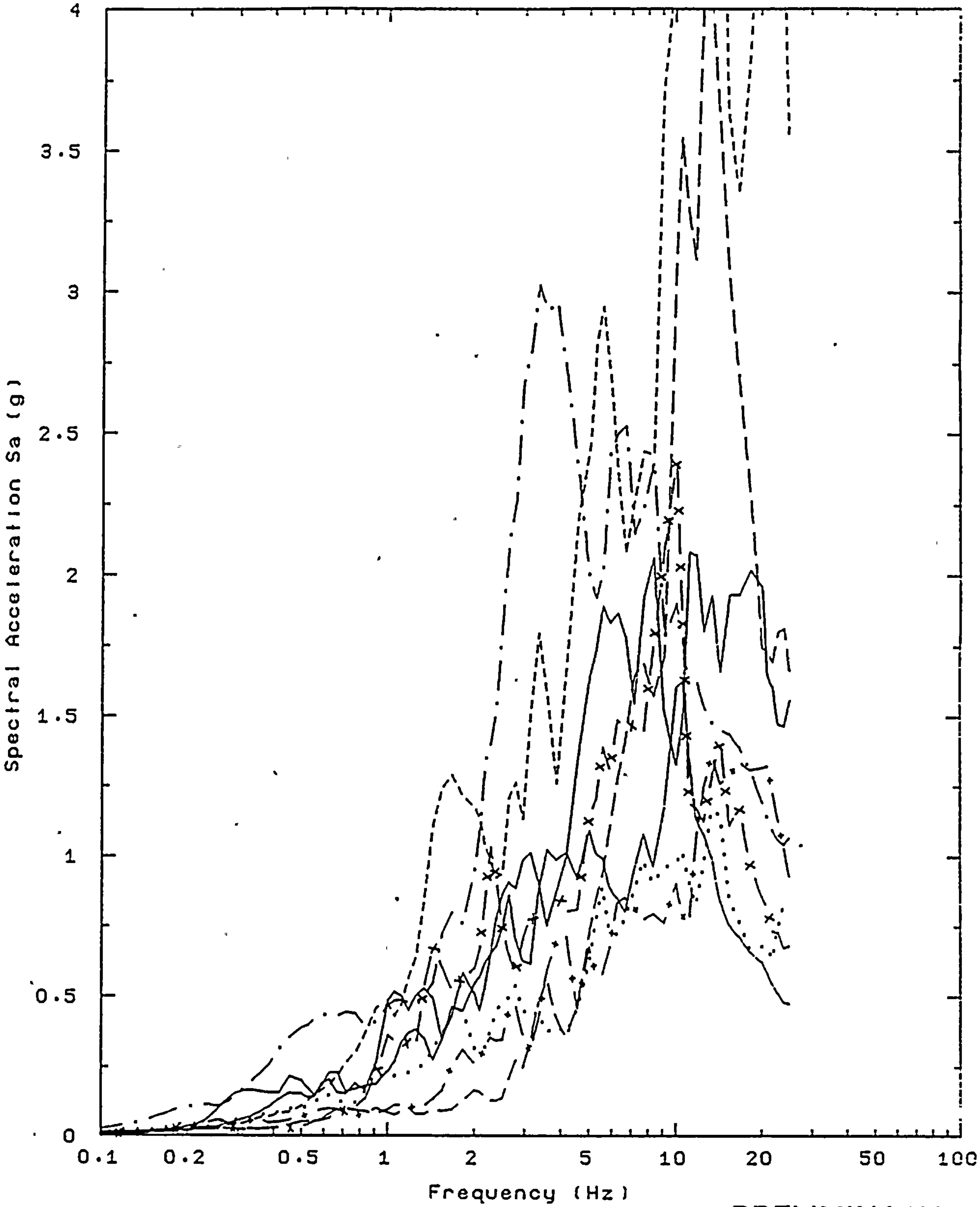
CURVES OF 16 SETS OF HORIZ RECORDS

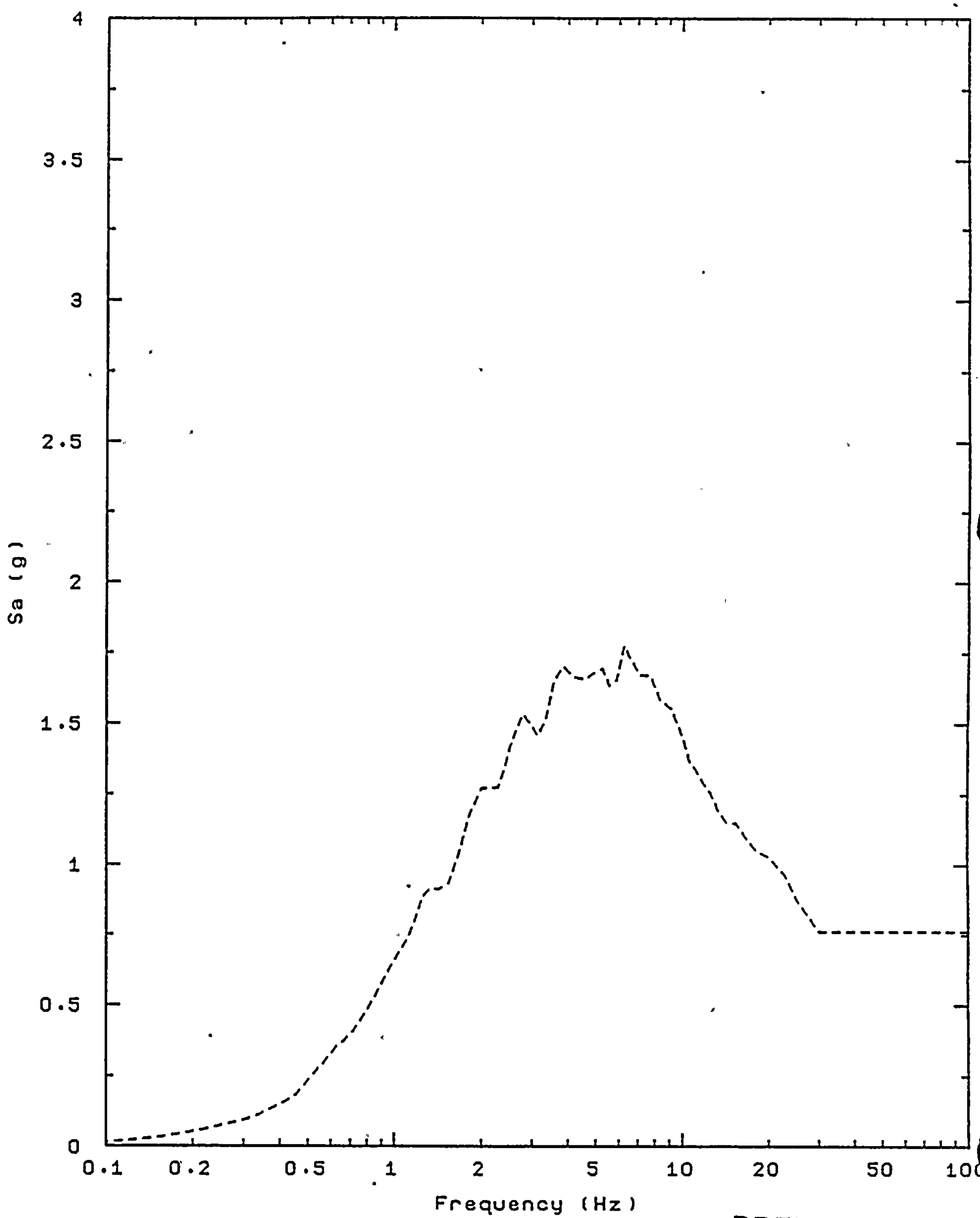
III-4



SPECTRAL ACCELERATIONS (VERTICAL)

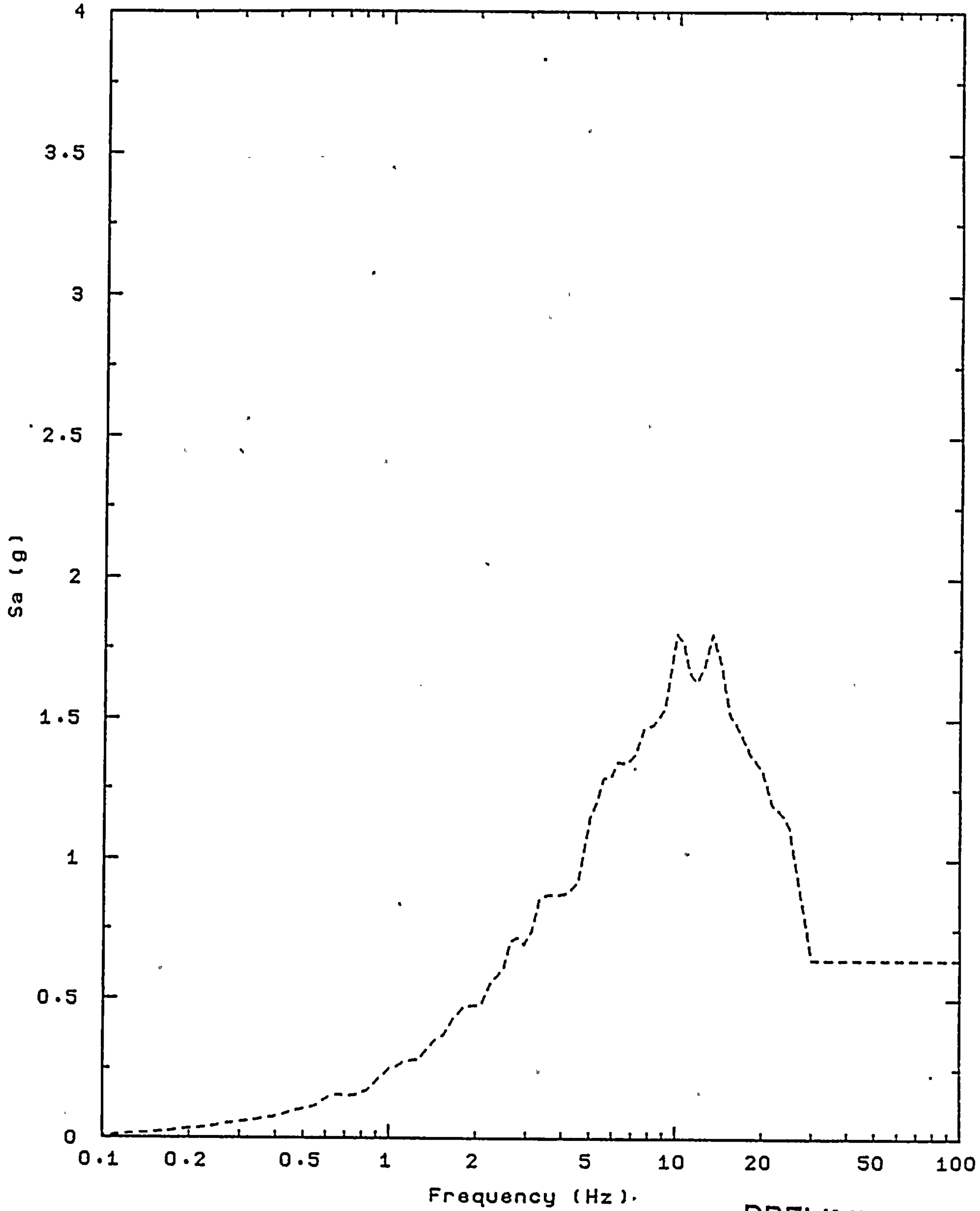
PRELIMINARY
OCT 23 1986

III-5



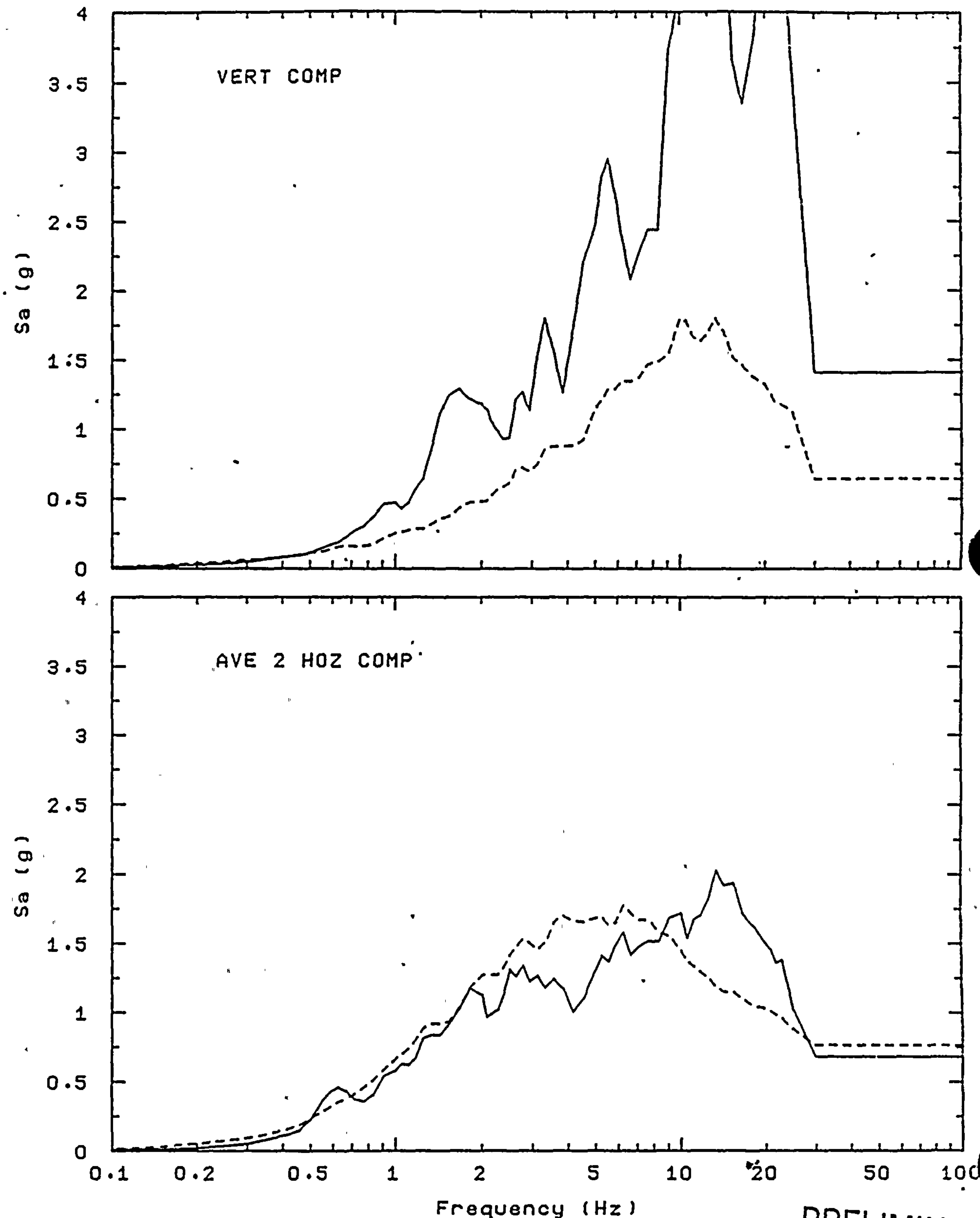
MEDIAN OF 8 SETS OF HORIZ RECORDS

PRELIMINARY
OCT 23 1986



MEDIAN OF 8 SETS OF RECORDS (VERTICAL)

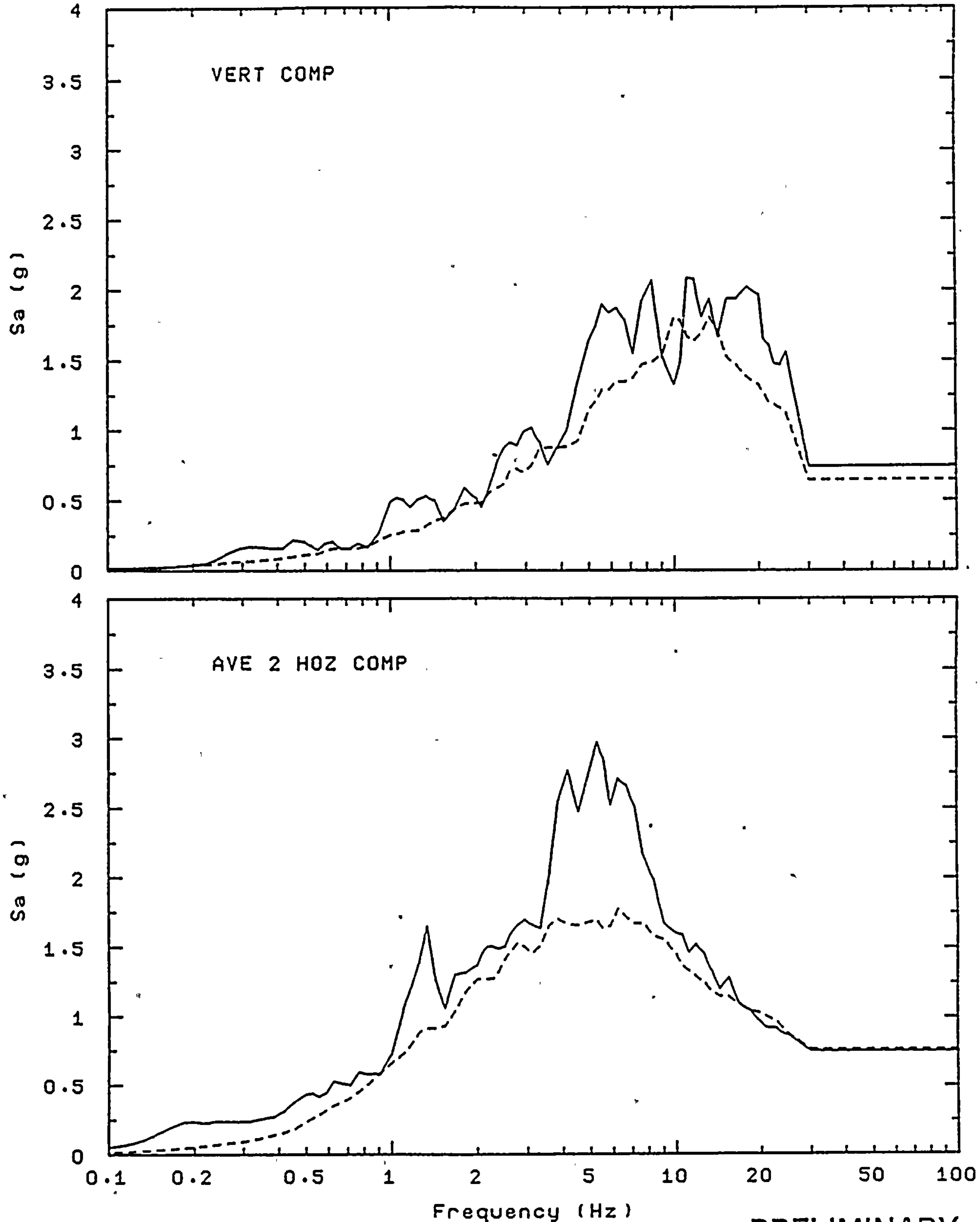
PRELIMINARY
OCT 23 1986



GAZLI SPECT ACC

III-8

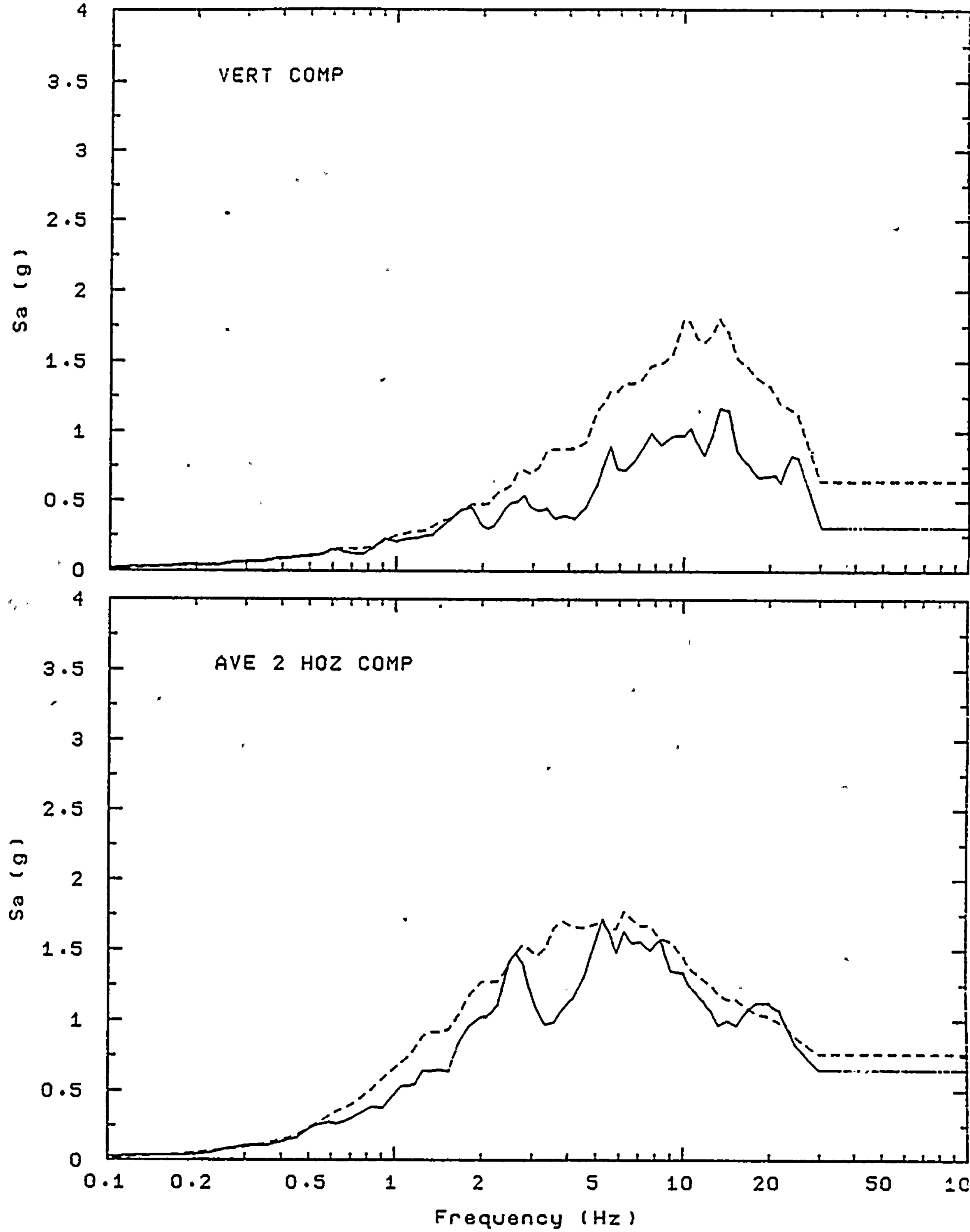
PRELIMINARY
OCT 23 1980



TABAS SPECT ACC

III-9

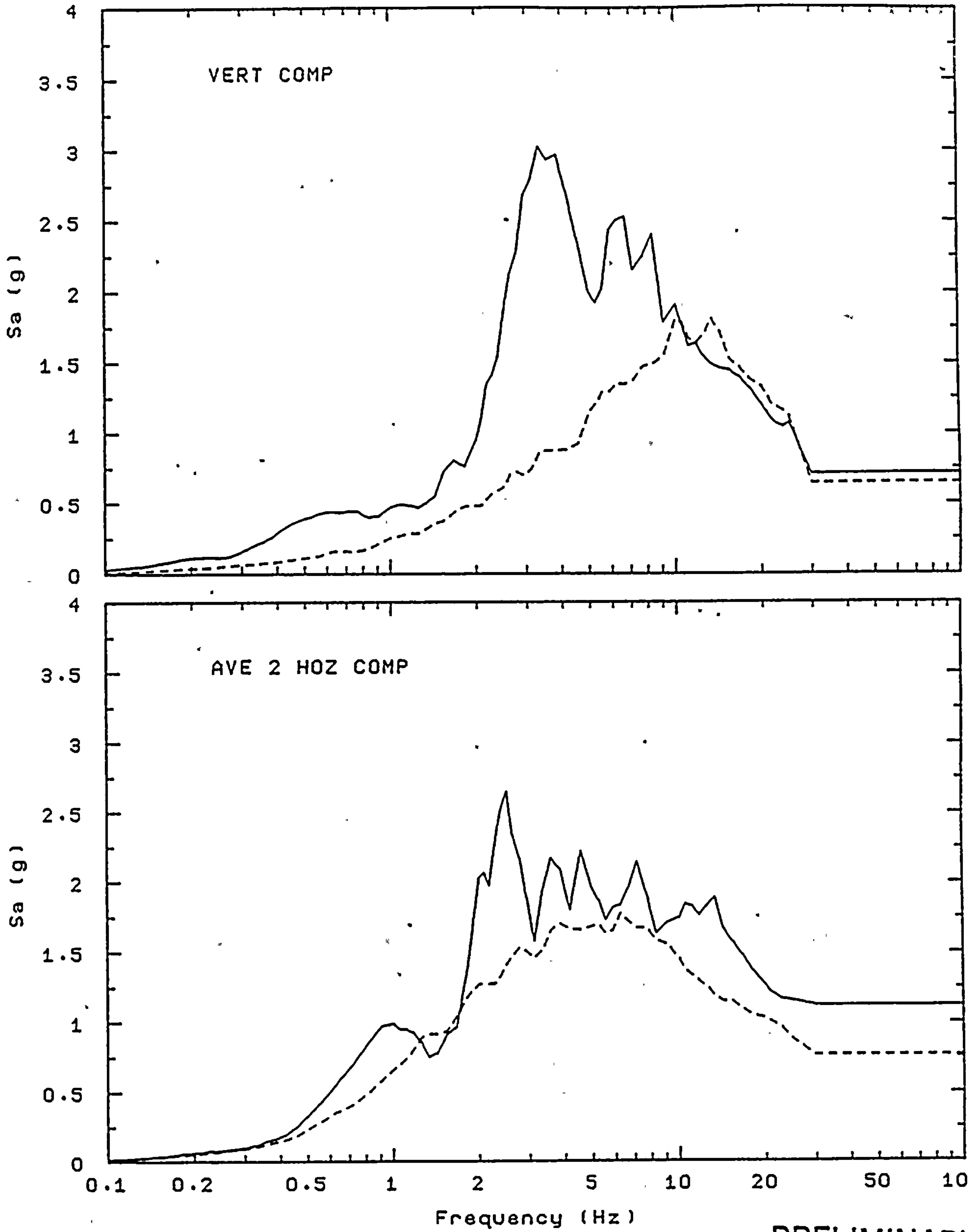
PRELIMINARY
OCT 23 1986



DAYHOOK SPCET ACC

III-10

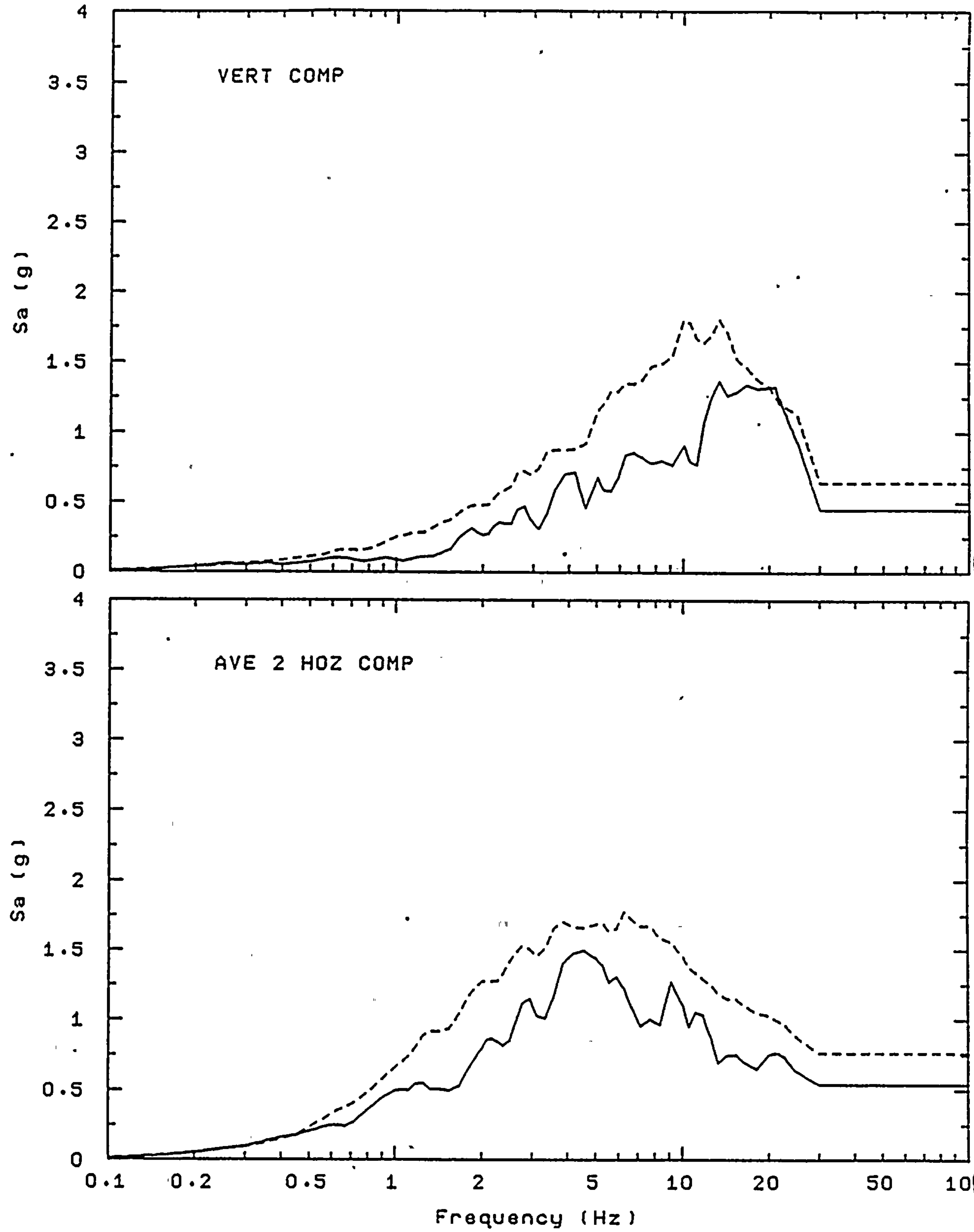
PRELIMINARY
OCT 23 1986



PRELIMINARY
OCT 23 1989

PACOIMA SPCET ACC

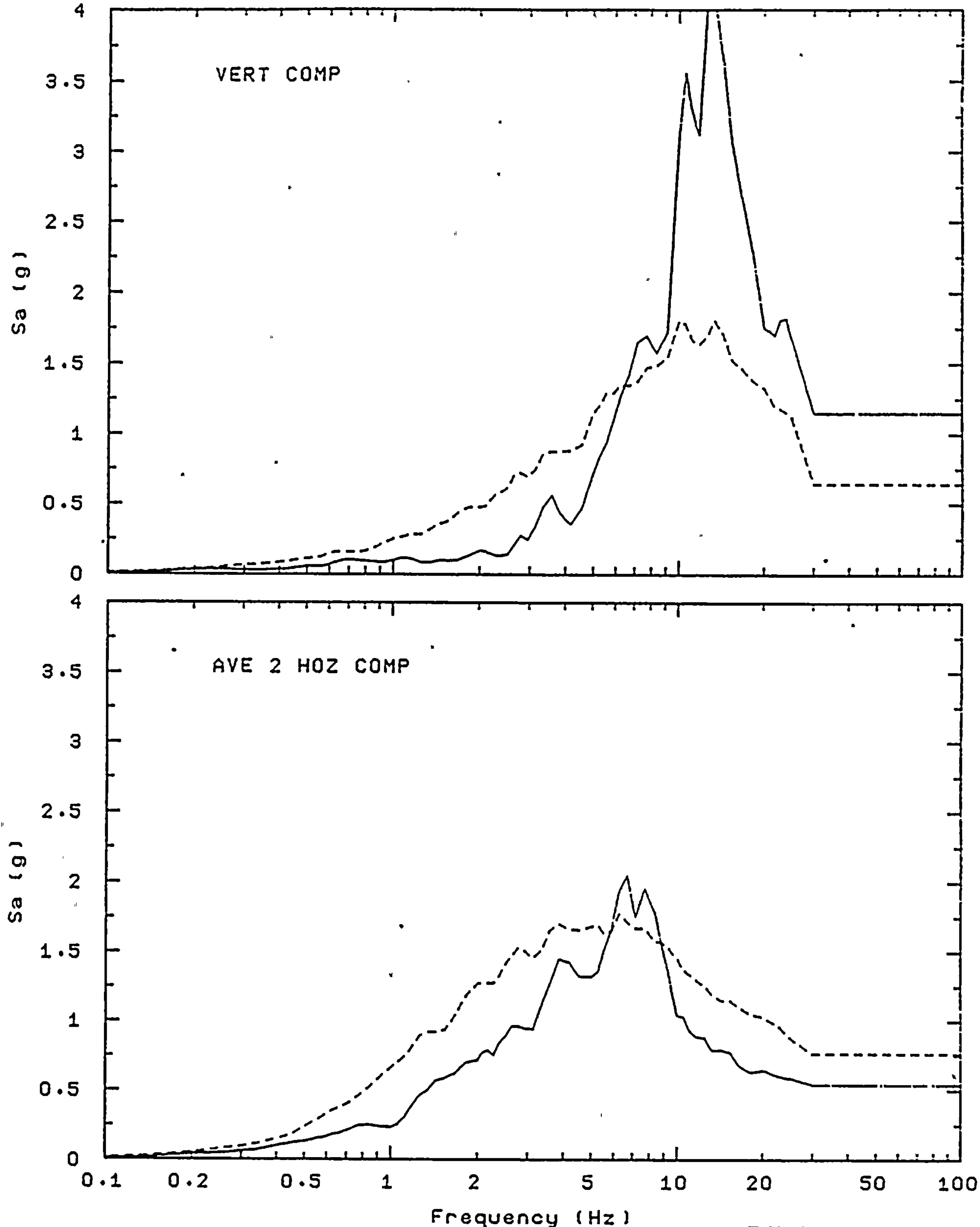
III-11



EL CENTRO NO 4 SPCET ACC

III-12

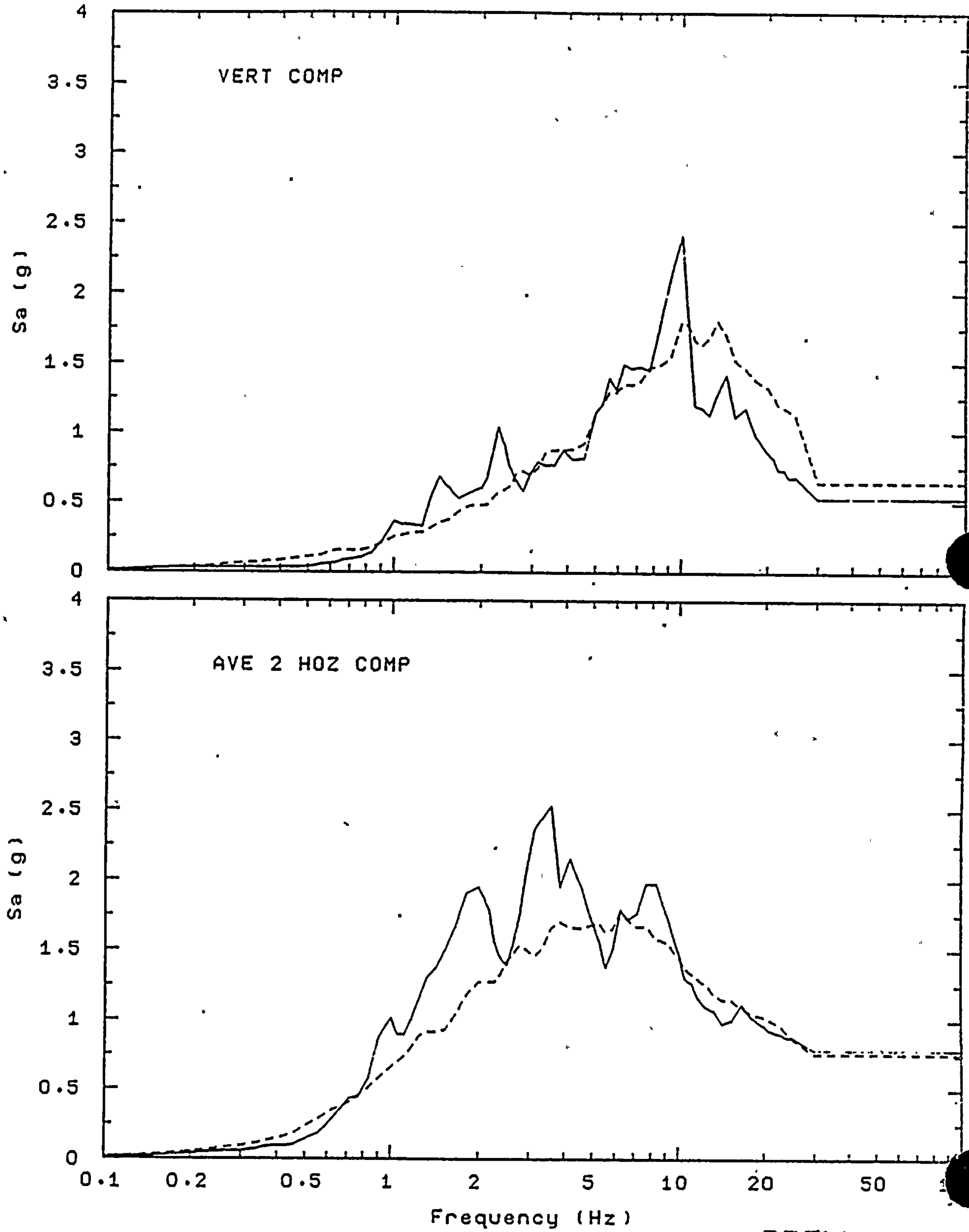
PRELIMINARY
OCT 23 1986



PRELIMINARY
OCT 23 1986

DIFF ARRAY SPECT ACC

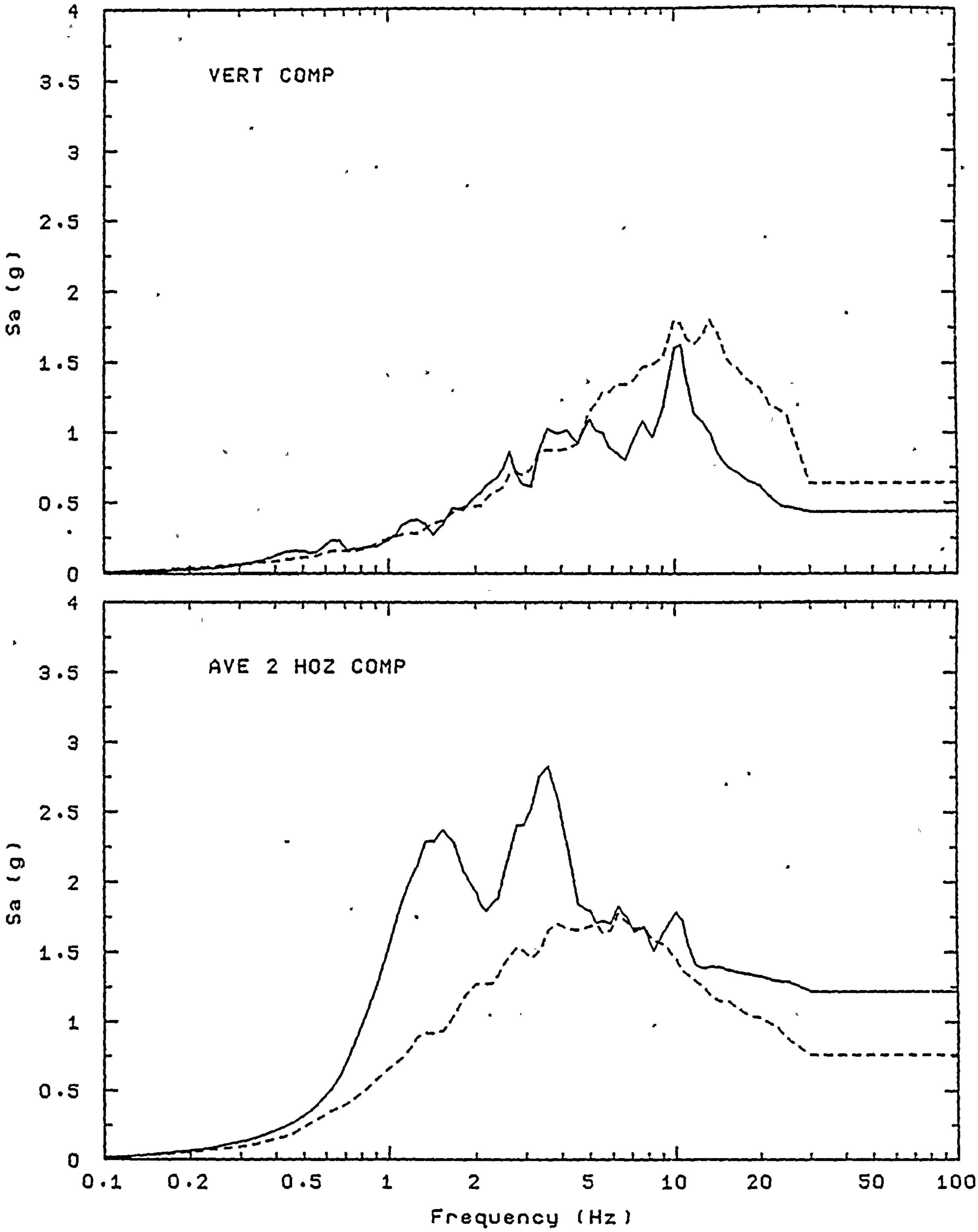
III-13



PL VALLEY PUMP STN SPECT-ACC

III-14

PRELIMINARY
OCT 23 1986



COYOTE LAKE DAM SPECT ACC

III-16 III-15

PRELIMINARY
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TABLE 1: Ranking of Records for Use in SSI Analysis for PGandE Diablo Canyon Power Plant

	Weighting Factor=1			Weighting Factor=3		Weighting Factor = 1	Ranking		
RECORD NAME	MAG	DIST	SITE COND	ABS HOR SPEC	HOR SPEC SHAPE	VERT/HORIZ RELATION & VERT-MEDIAN RELATN	ABS SPECT ORDINATES	SPECT SHAPE	
GAZLI	1	1	1	2	2	3	1.63	1.63	(E)
TABAS	1	1	1	1	1.5	1	1.0	1.19	(A)
DAYHOOK	1	2	1	2	1	2	1.63	1.25	(D)
PACOIMA	1	1	1	1	1	2	1.43	1.13	(B)
EL CENTRO NO. 4	1	1	2	2	1	1	1.5	1.13	(C)
DIFF ARRAY	1	1	2	3	3	3	2.13	2.13	(G)
PT. VALLEY PUMP STN	1	2	1	3	3	2	2.0	2.0	(F)

1 = Best fit
2 = medium
3 = least

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NUMERICAL MODELING - PHASE IIIA

OBJECTIVE: PROVIDE INPUTS INTO FRAGILITY AND SSI ANALYSES

INPUTS: 3 - COMPONENT ACCELEROGRAMS

PRELIMINARY CHARACTERIZATION OF WAVE FIELD

PRELIMINARY
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ASPECTS OF SIMULATION APPROACH

- EMPIRICAL GREEN'S FUNCTION SUMMATION
  (HADLEY AND HELMBERGER, 1980)
- FAULT SEGMENTS ASSIGNED EQUAL SOURCE STRENGTH
- "ASPERITIES" INTRODUCED VIA STOCHASTIC COMPONENTS
  OF RUPTURE VELOCITY AND SLIP FUNCTION
- SITE - TRANSFERRED ACCELEROGRAMS OF THE 1979 IMPERIAL
  VALLEY EARTHQUAKE USED AS EMPIRICAL GREEN'S FUNCTIONS

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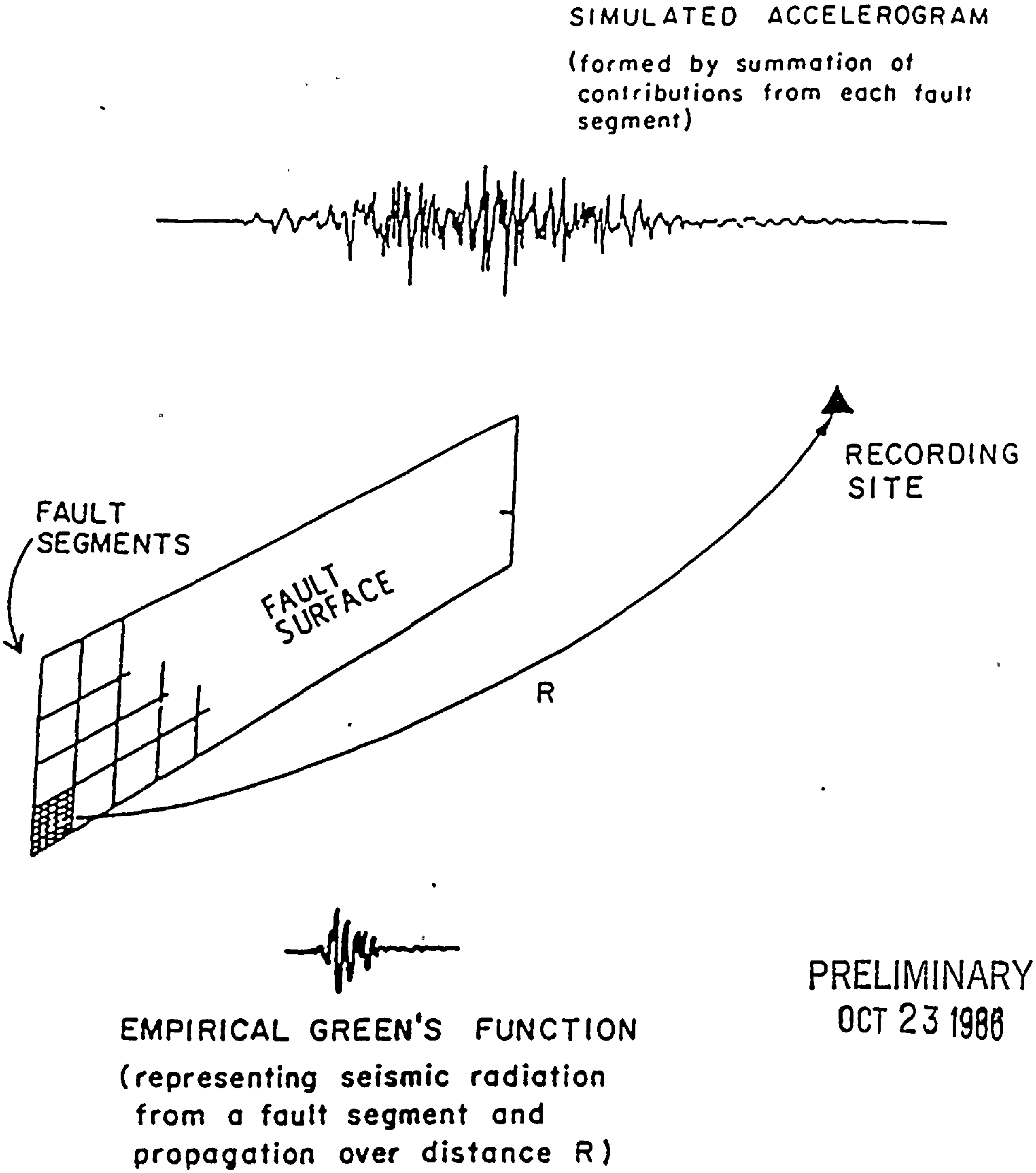
EMPIRICAL GREEN'S FUNCTION APPROACH

(HADLEY AND HELMBERGER, 1980)



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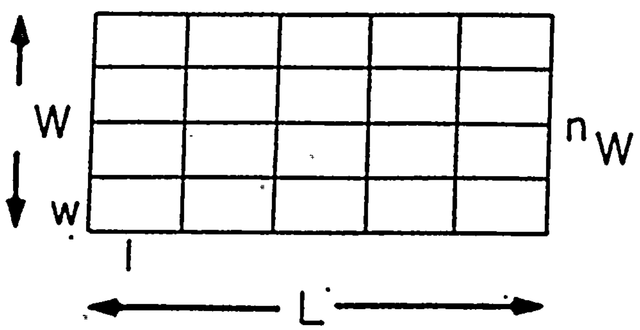
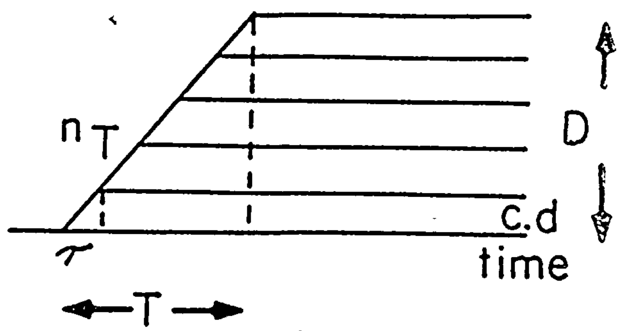
SCALING PROCEDURE

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

$n_L = L/l$

$n_W = W/w$

$n_T = T/\tau = LW/lw$ dynamic similarity condition

$T = \sqrt{LW} / 2.4\beta$ (Geller), β = shear velocity

c = constant required to preserve moment ratio

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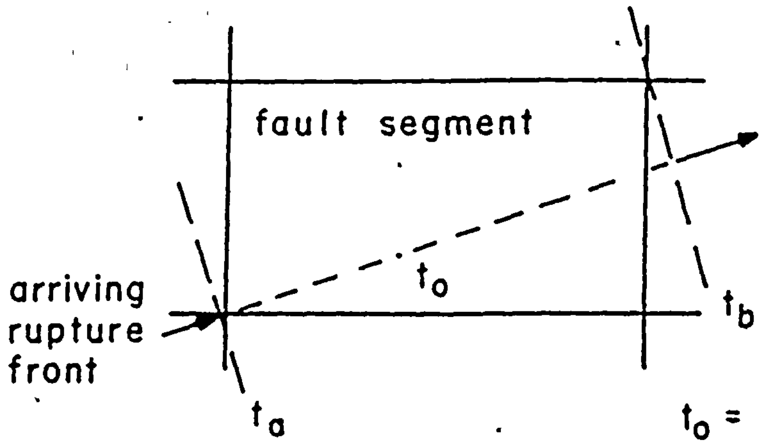
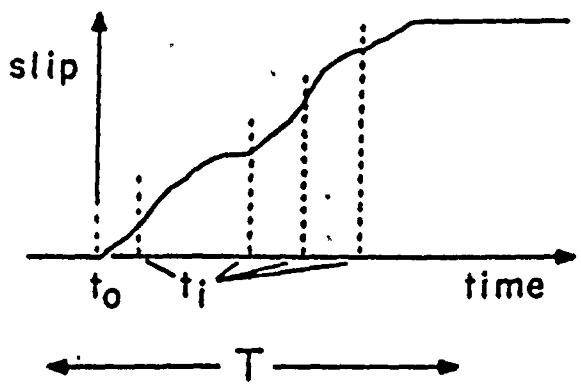
Randomization Of Rupture Velocity



$t_o = R(t_a, t_b)$

Randomization Of Slip Time Function



$t_i = R(t_o, t_o + T)$

$(i = 1, n_T)$

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

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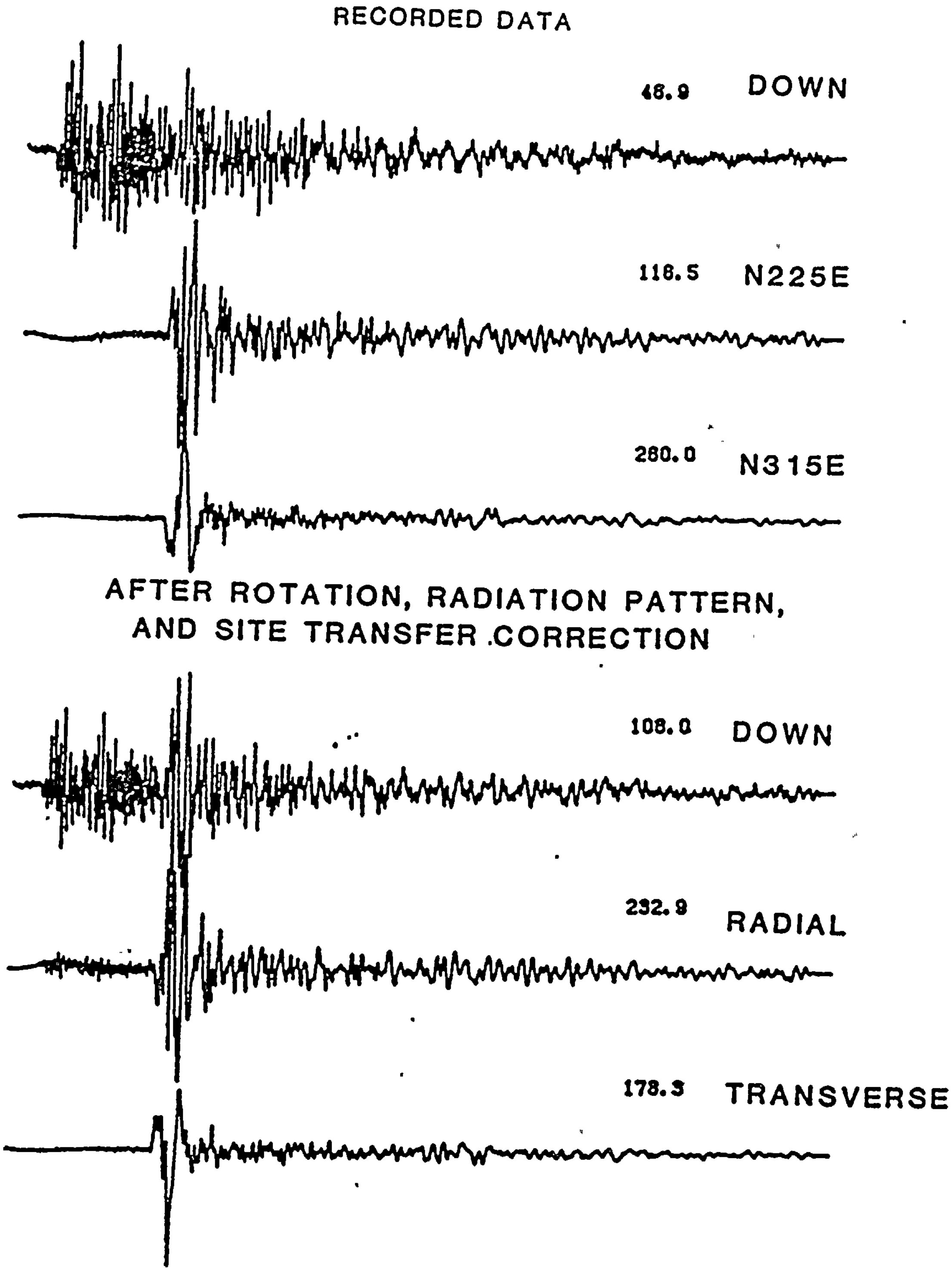
ACCELEROGRAM OF IMPERIAL VALLEY AFTERSHOCK RECORDED AT HOLTVILLE



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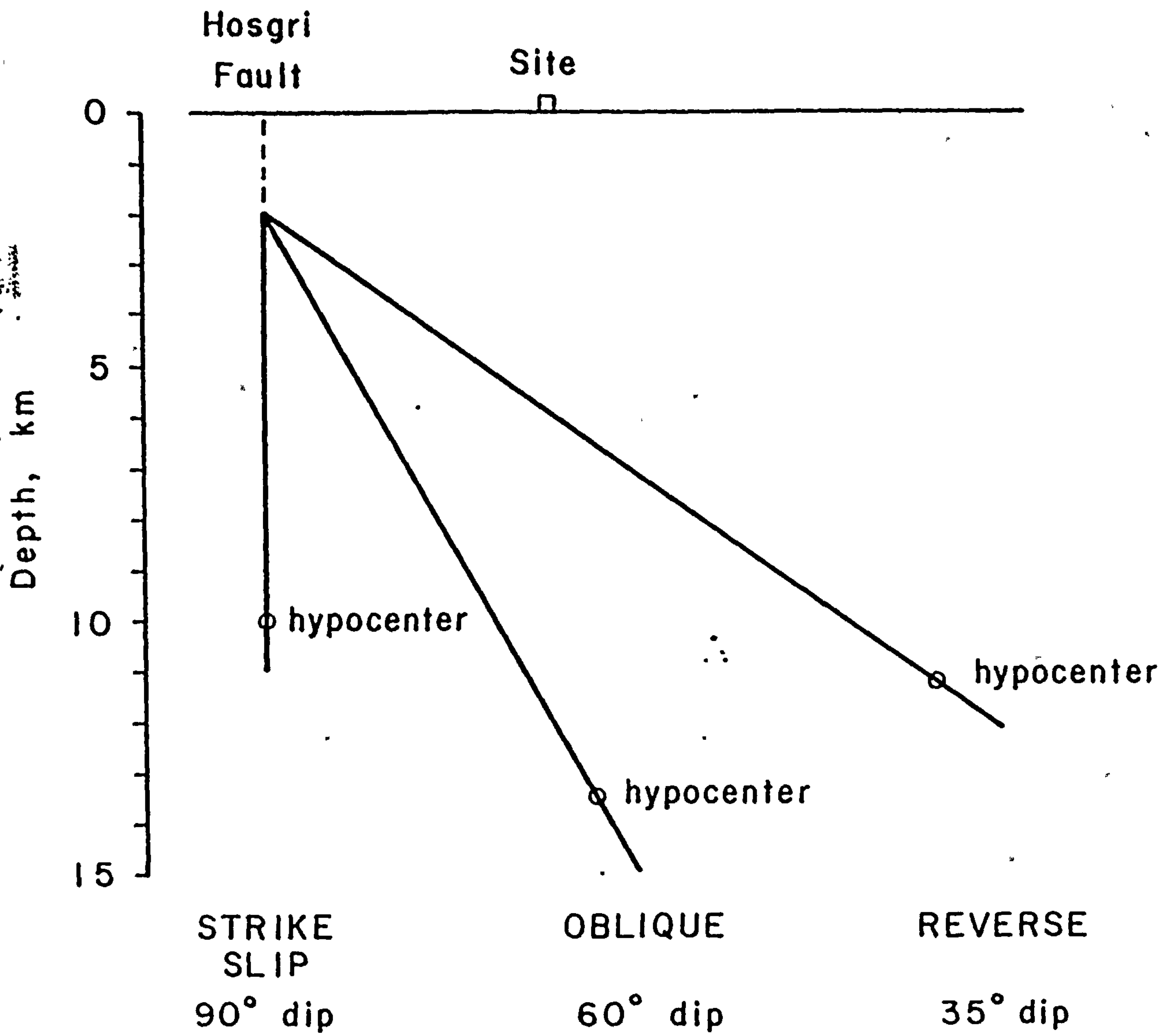
L-III

M = 7 Fault Models - Vertical Cross Section



PRELIMINARY
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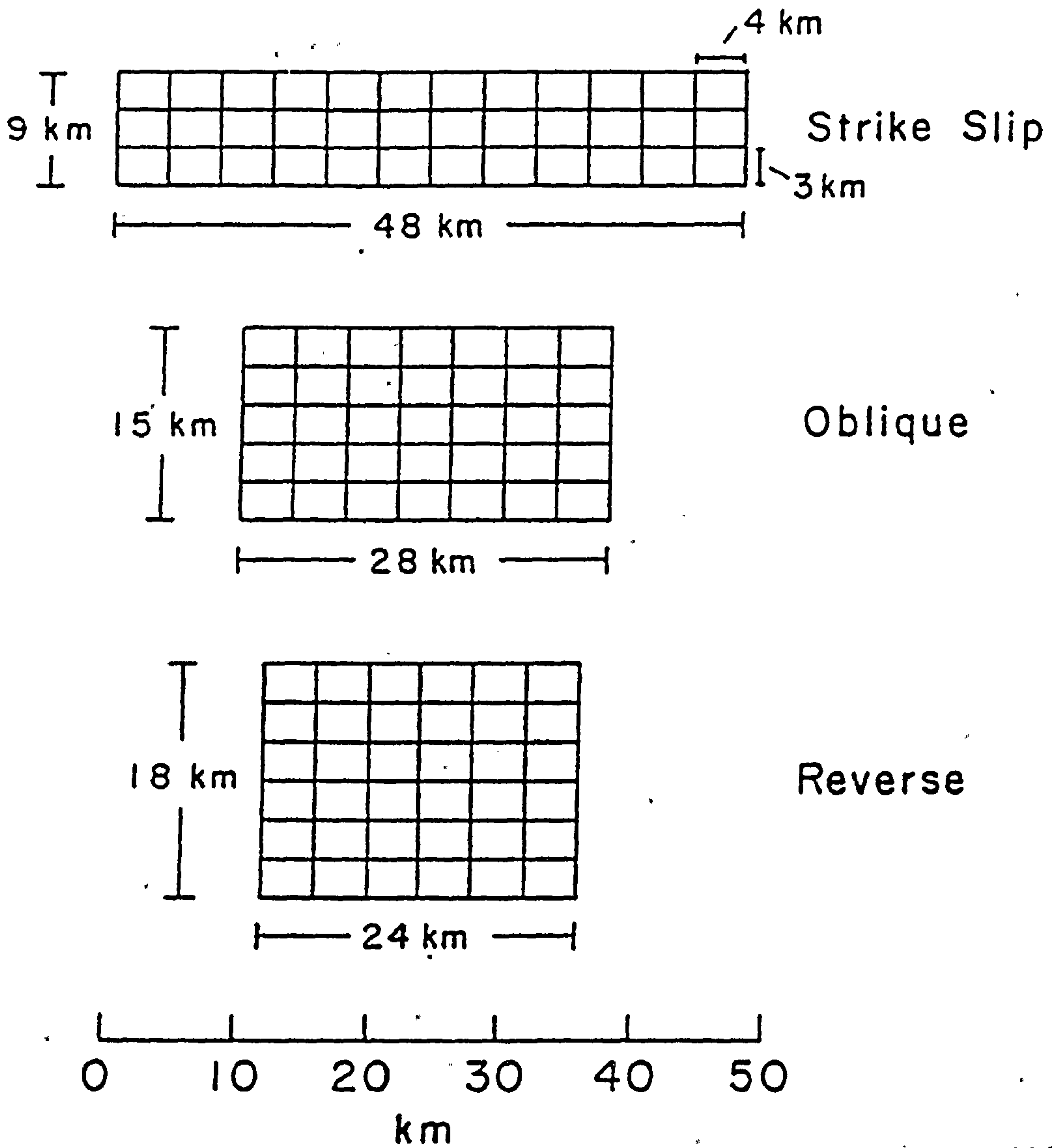
M = 7 Fault Models Showing Segmentation



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SIMULATED TIME HISTORIES

MAGNITUDES: MOMENT MAGNITUDE 7

FAULTING MECHANISMS: VERTICAL STRIKE-SLIP

STEEPLY DIPPING OBLIQUE

SHALLOW DIPPING REVERSE

RUPTURE MODES: BILATERAL - HYPOCENTER OPPOSITE SITE

UNILATERAL - HYPOCENTER SOUTH OF SITE

PRELIMINARY
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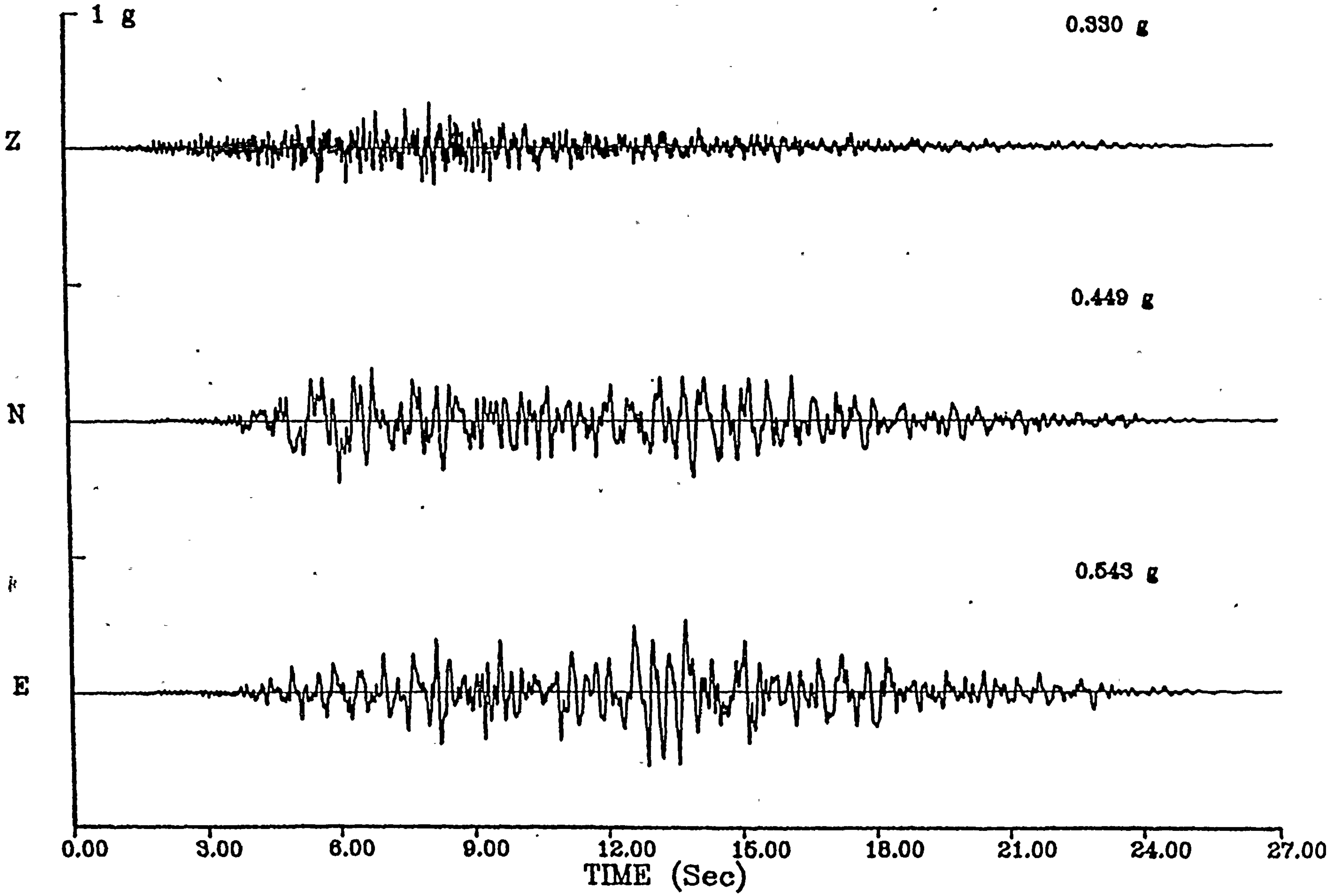
M=7.0 STRIKE SLIP BILATERAL



PRELIMINARY
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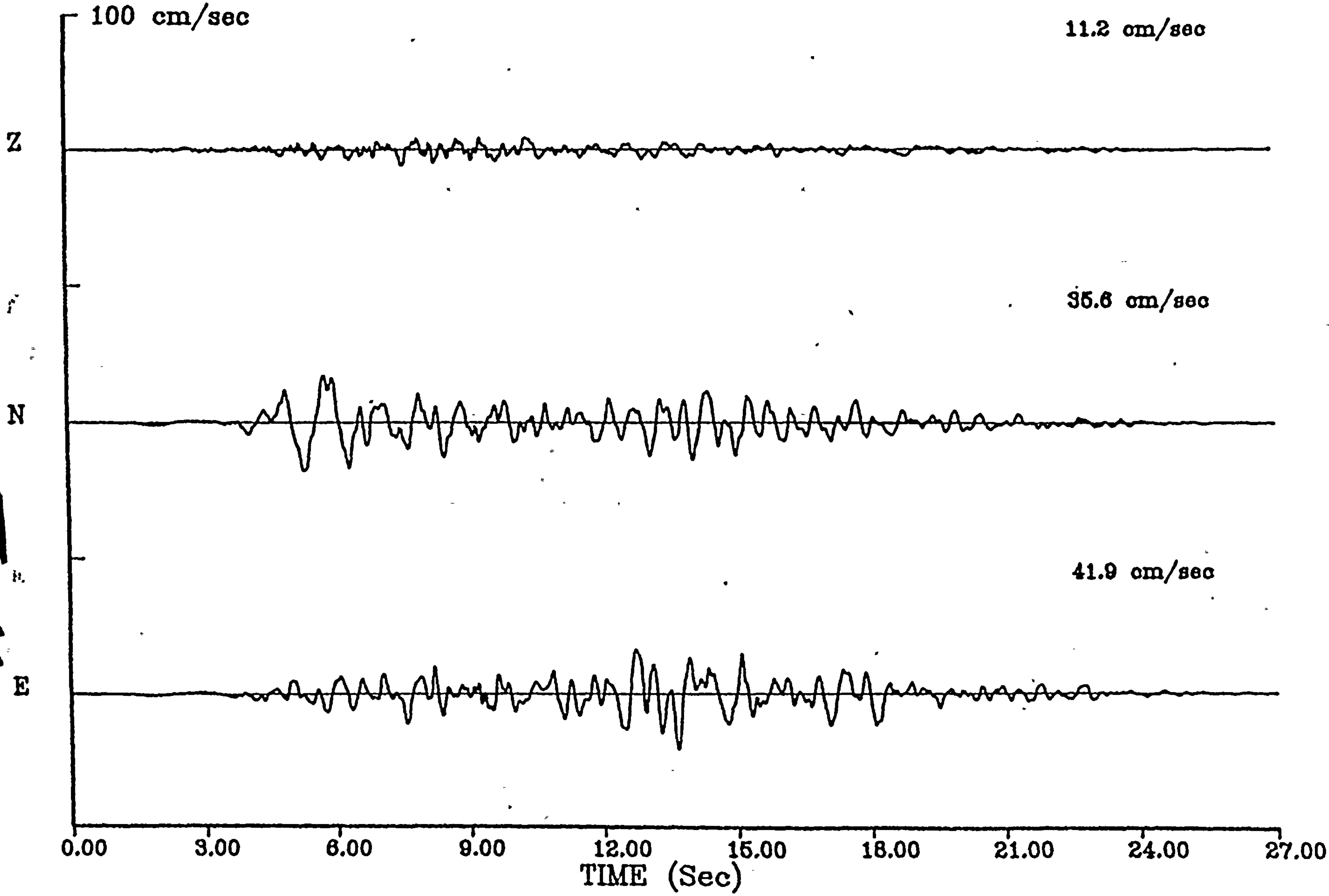
M=7.0 STRIKE SLIP BILATERAL



11-XII

PRELIMINARY
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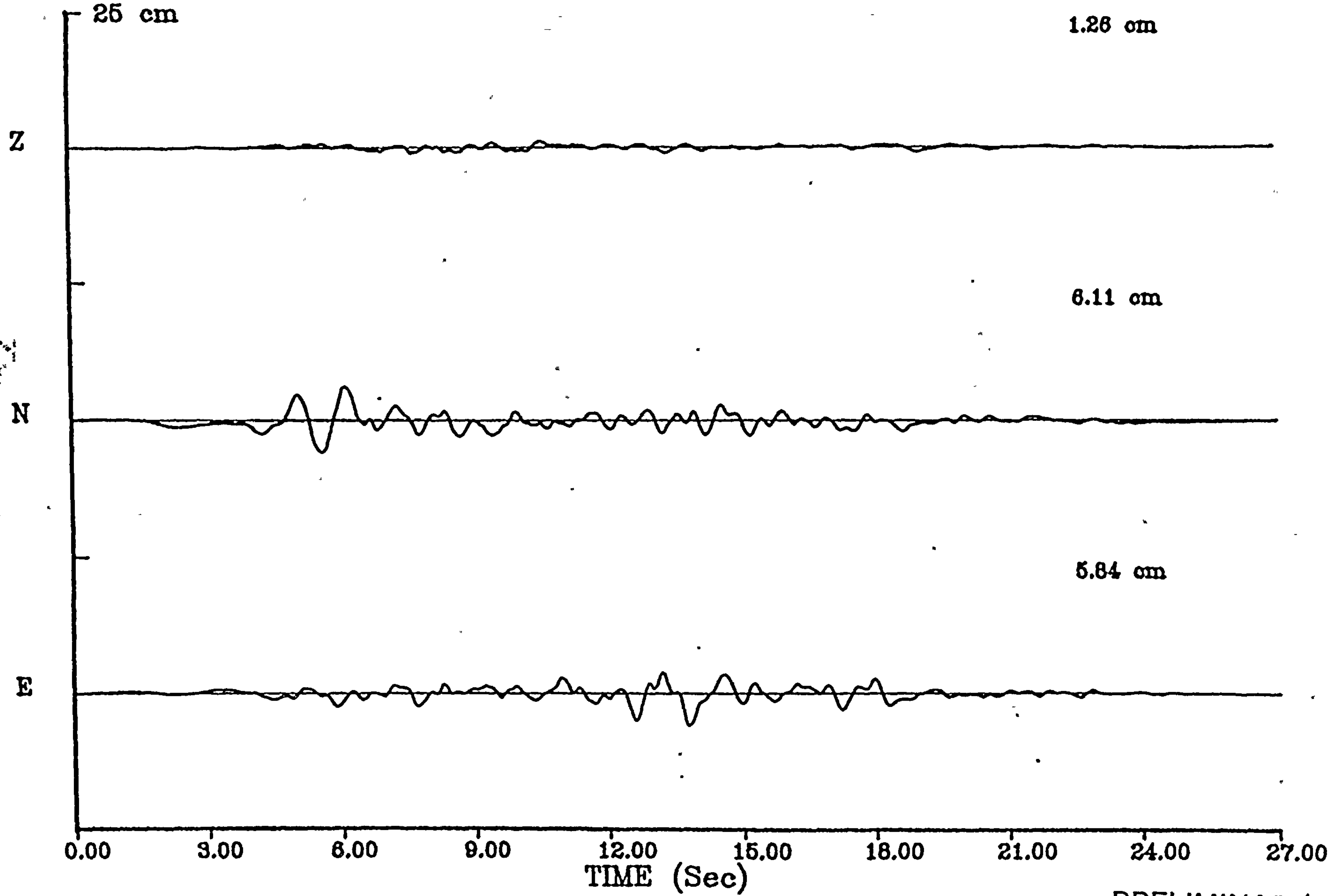
M=7.0 STRIKE SLIP BILATERAL



21-III-12

PRELIMINARY
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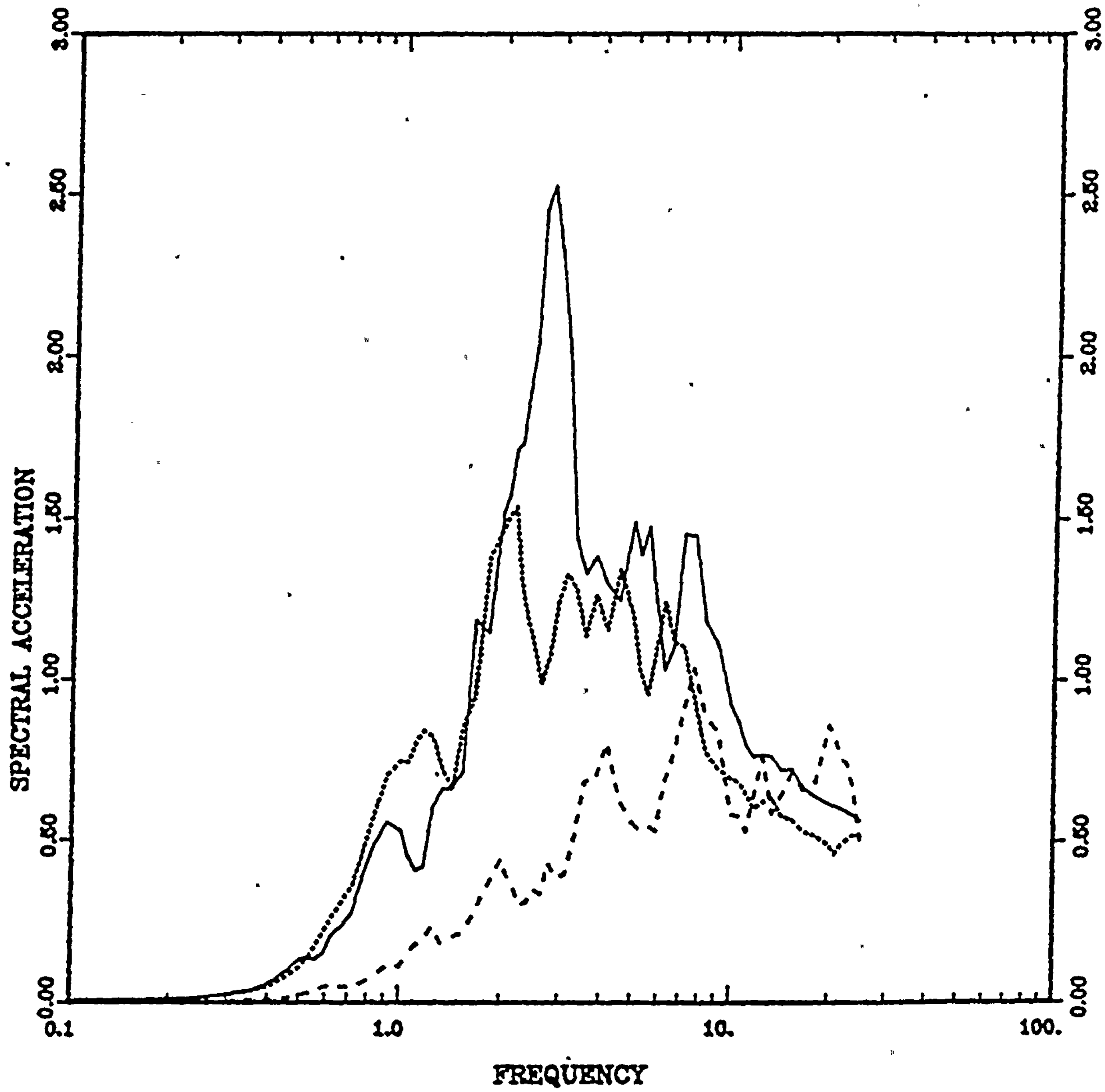
M=7.0 STRIKE SLIP BILATERAL

Damping: 0.05

Component: Z -------

N ————

E ————



PRELIMINARY
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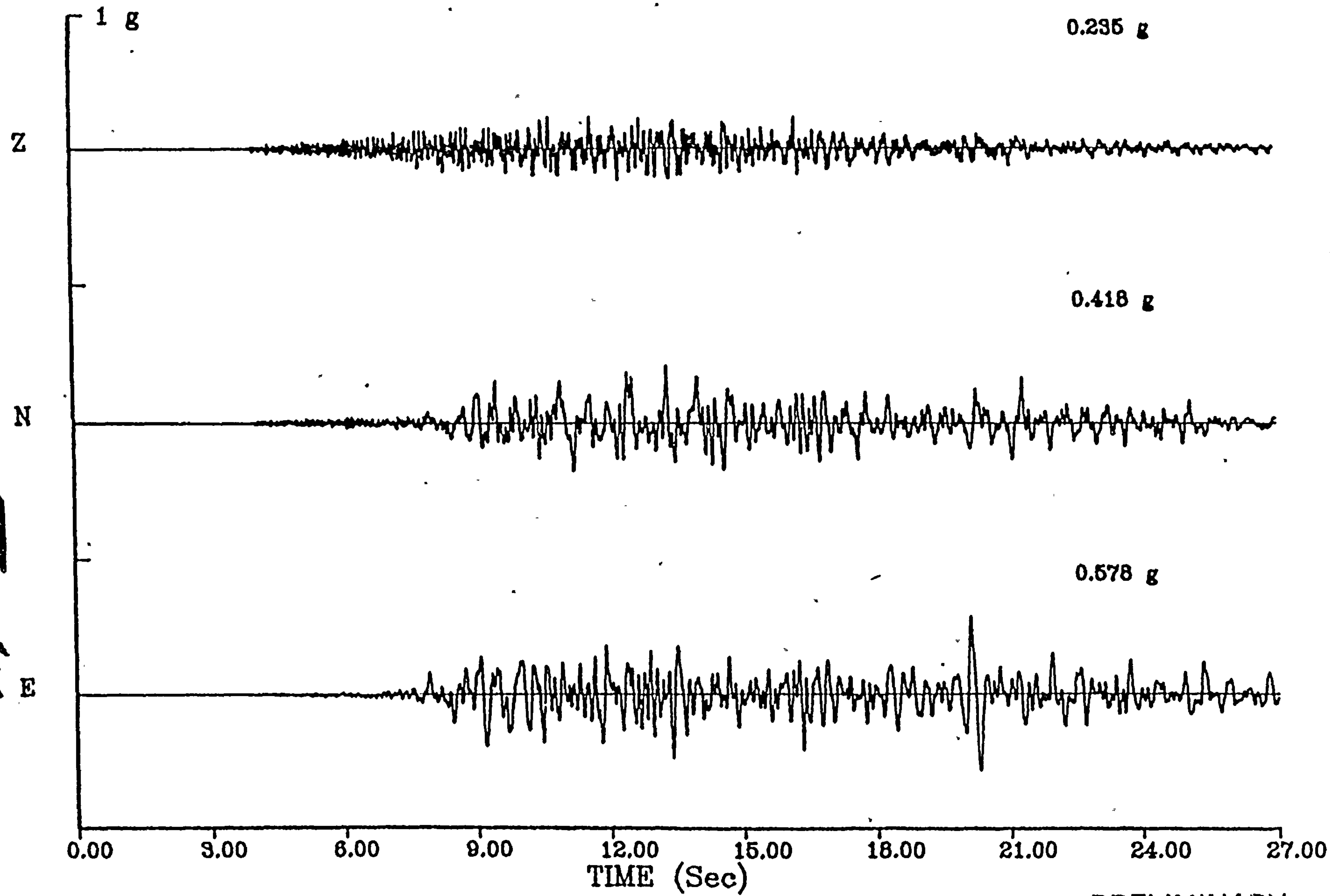
M=7.0 STRIKE SLIP UNILATERAL



4/1-XI

PRELIMINARY
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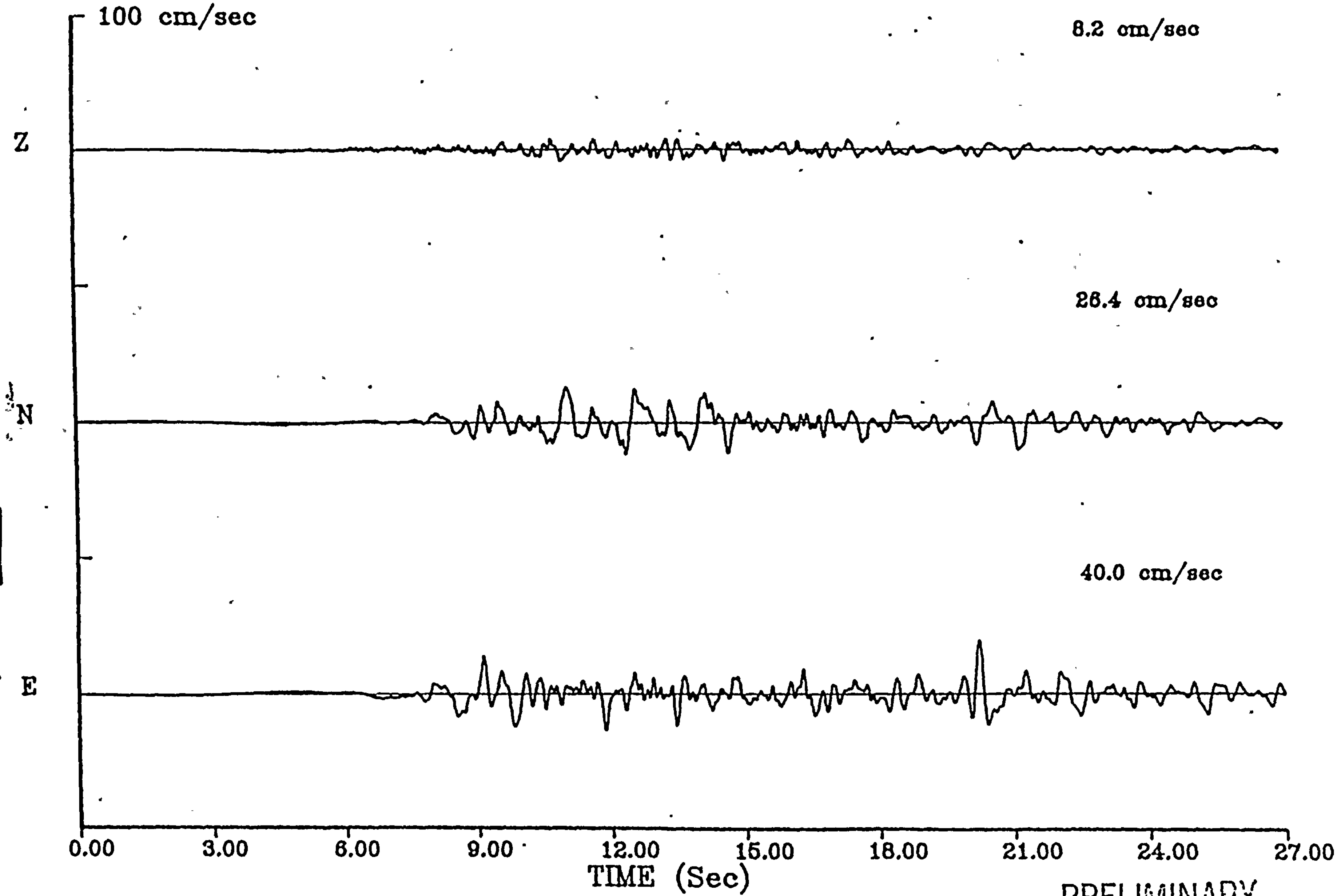
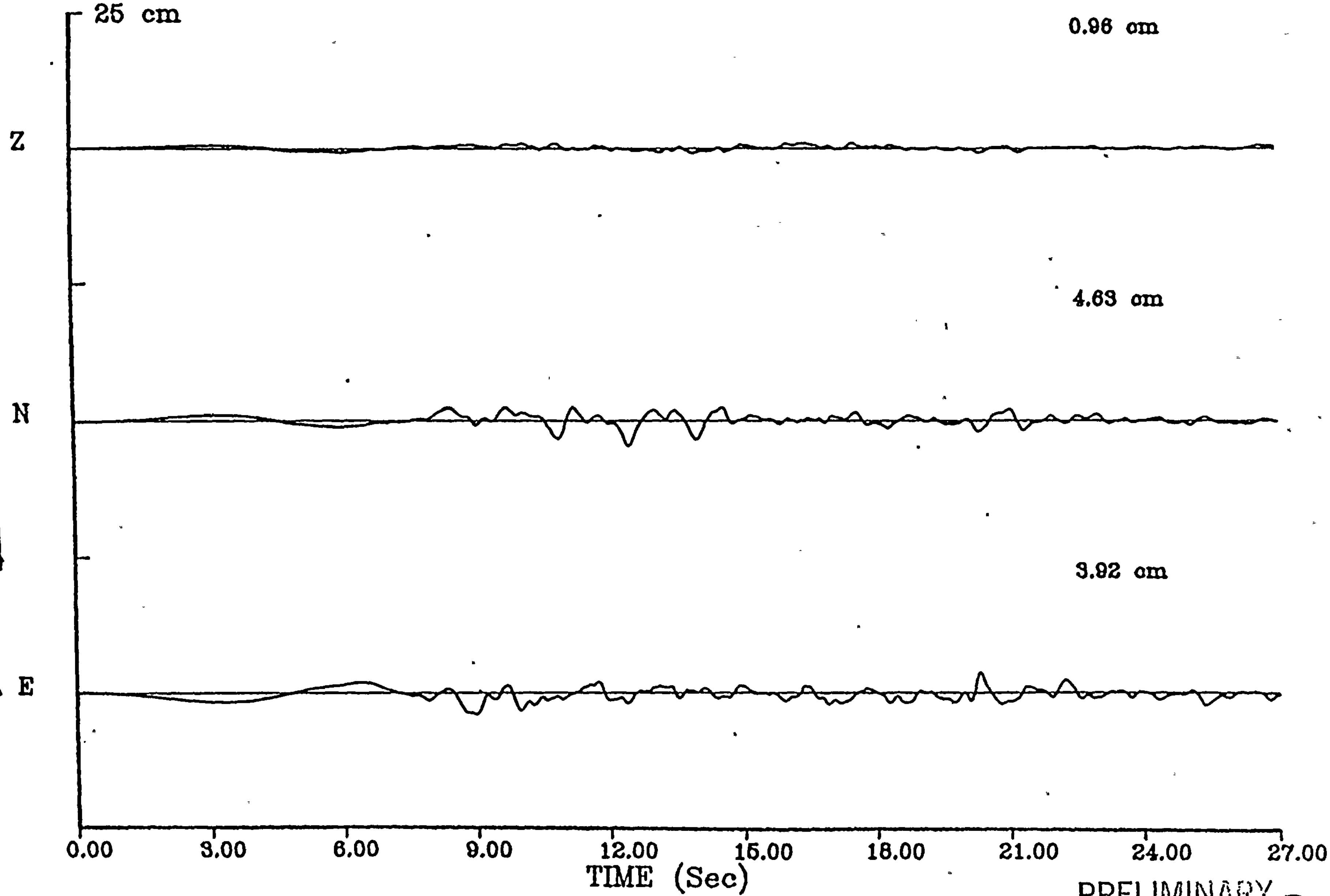
M=7.0 STRIKE SLIP UNILATERAL



PRELIMINARY
OCT 23 1986

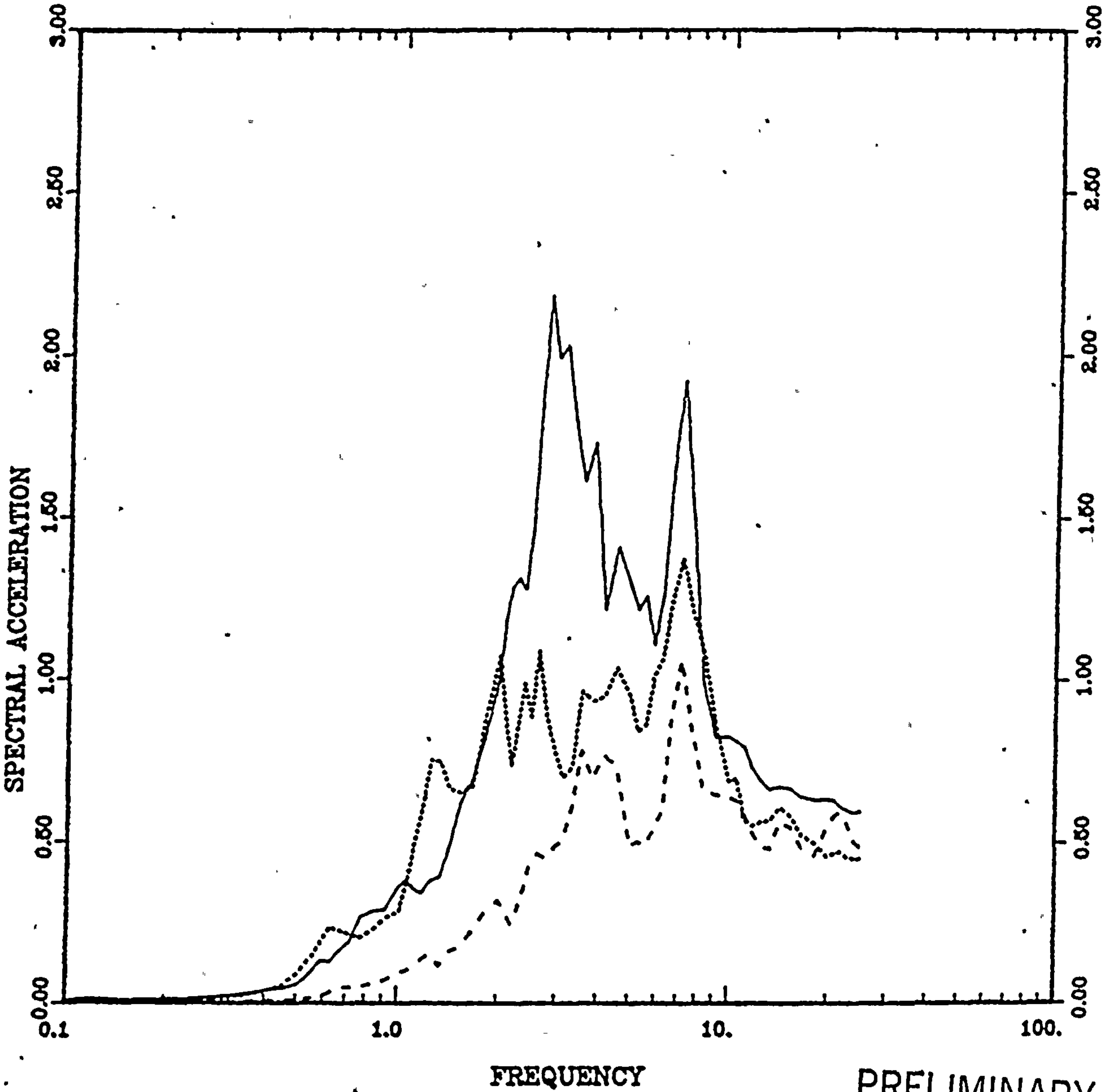
M=7.0 STRIKE SLIP UNILATERAL



PRELIMINARY
OCT 23 1986

M=7.0 STRIKE SLIP UNILATERAL

Damping: 0.05
Component: Z - - - - - - -
N ————
E ——·——



PRELIMINARY
OCT 23 1986

ANALYSIS OF WAVE COMPOSITION

FAULTING MECHANISMS:

STRIKE - SLIP
OBLIQUE SLIP
REVERSE SLIP

RUPTURE MODES:

BILATERAL
UNILATERAL

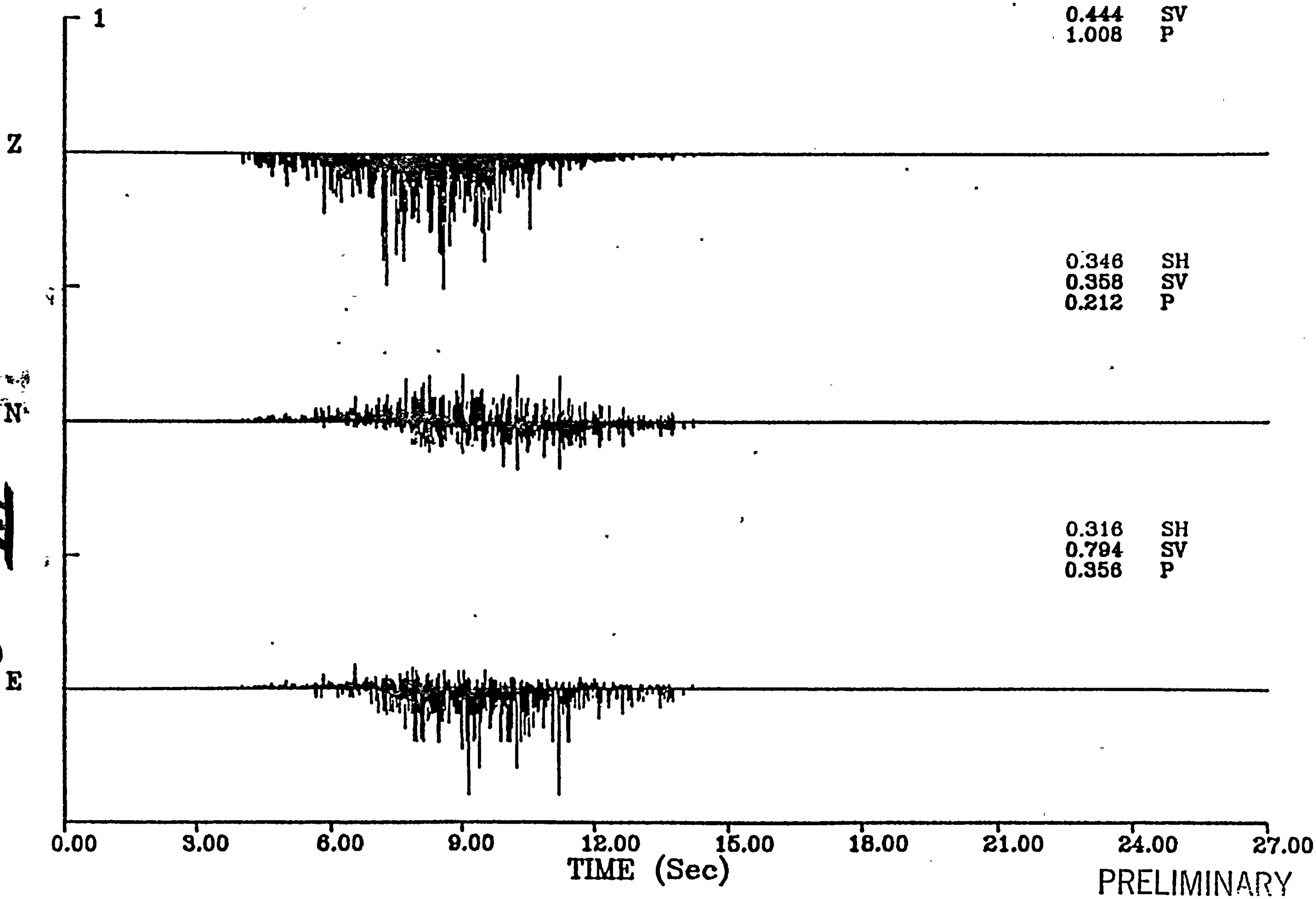
NOTES:

THE ORIGINAL FIGURES ARE IN COLOR, WITH P, SV AND SH CONTRIBUTIONS SHOWN IN DIFFERENT COLORS

CONTRIBUTIONS FROM INDIVIDUAL FAULT SEGMENTS ARE SHOWN AS SPIKES ON A RELATIVE AMPLITUDE SCALE

PRELIMINARY
OCT 23 1986

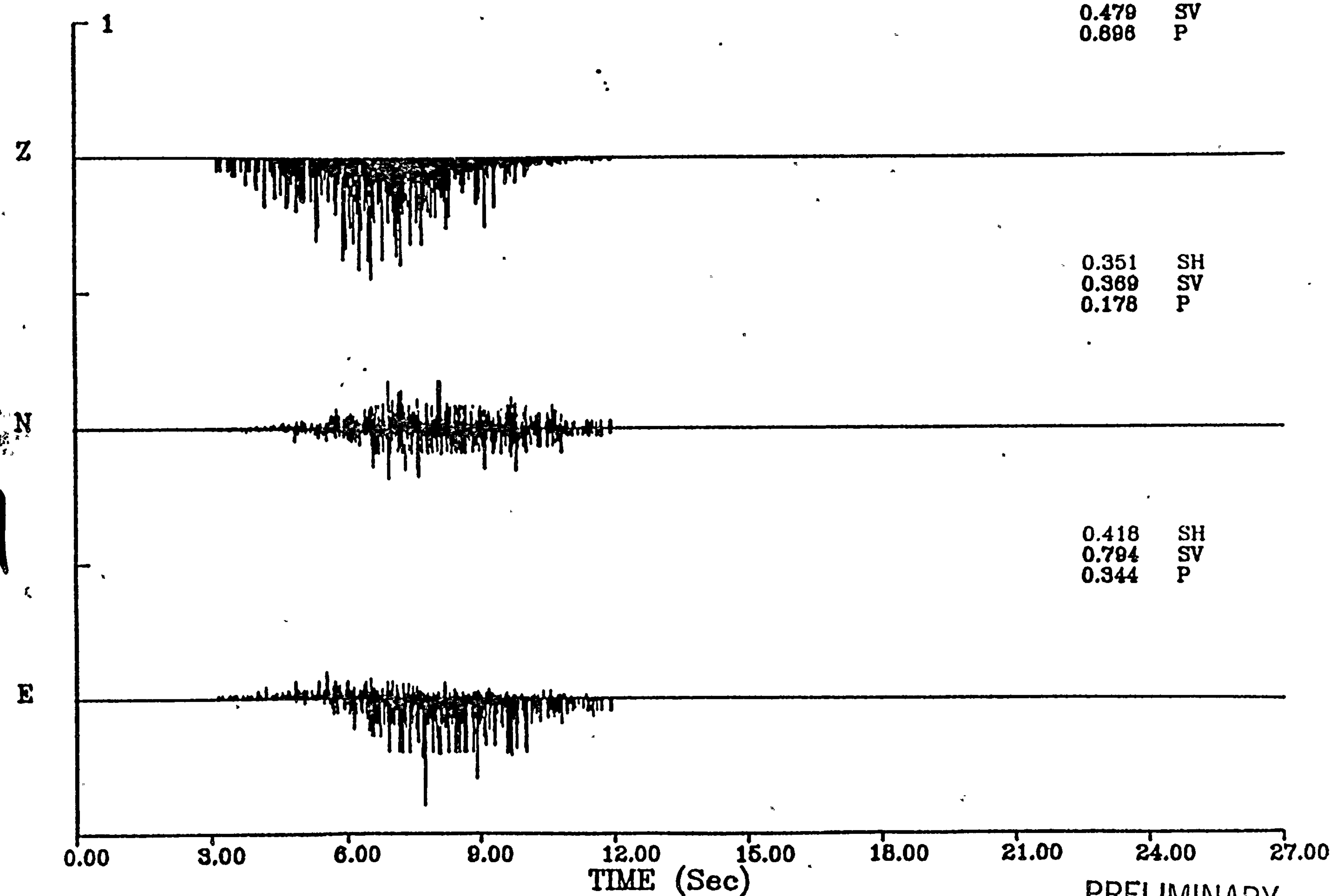
WAVE COMPOSITION M=7 REVERSE UNILATERAL



PRELIMINARY

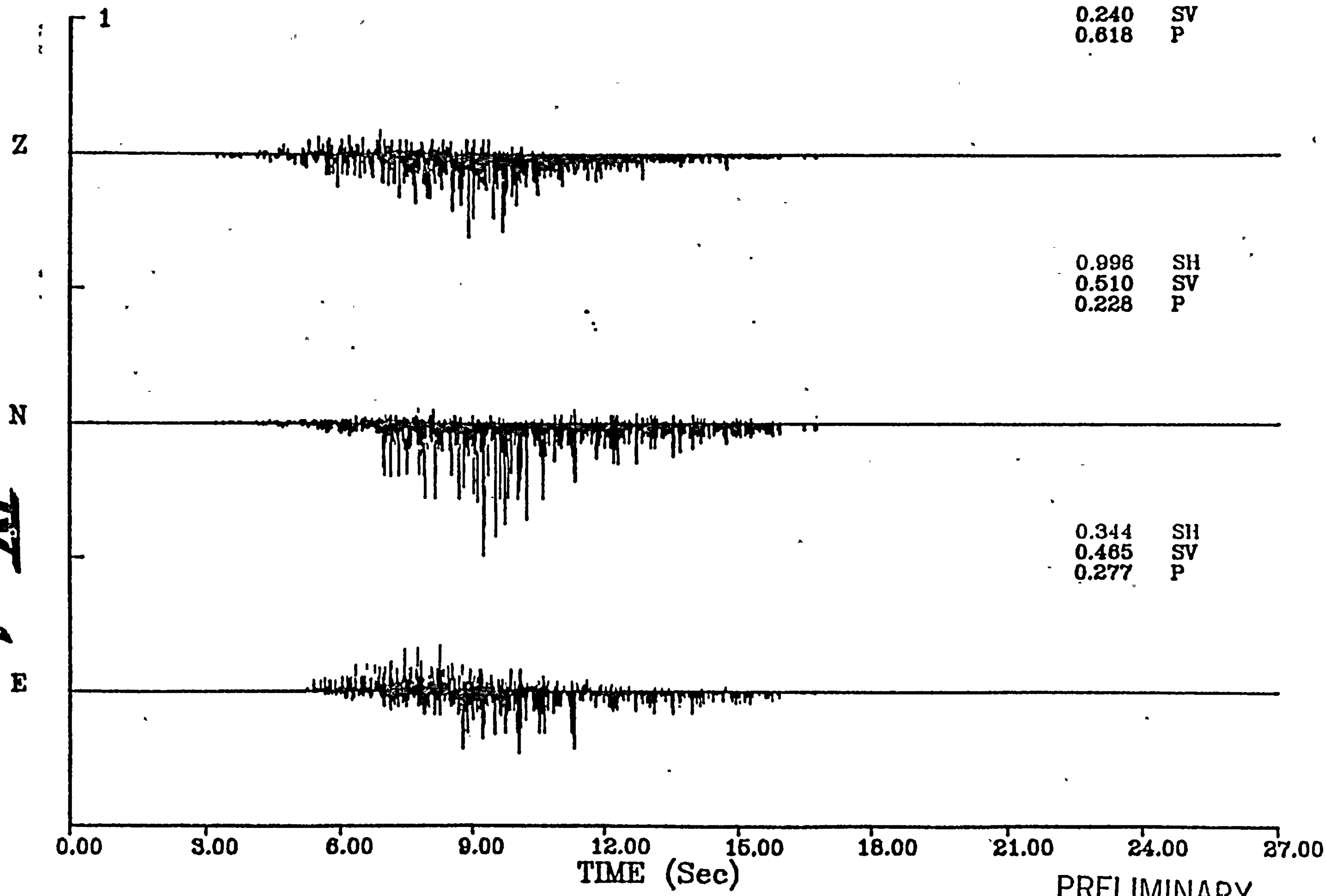
OCT 23 1986

WAVE COMPOSITION M=7 REVERSE BILATERAL



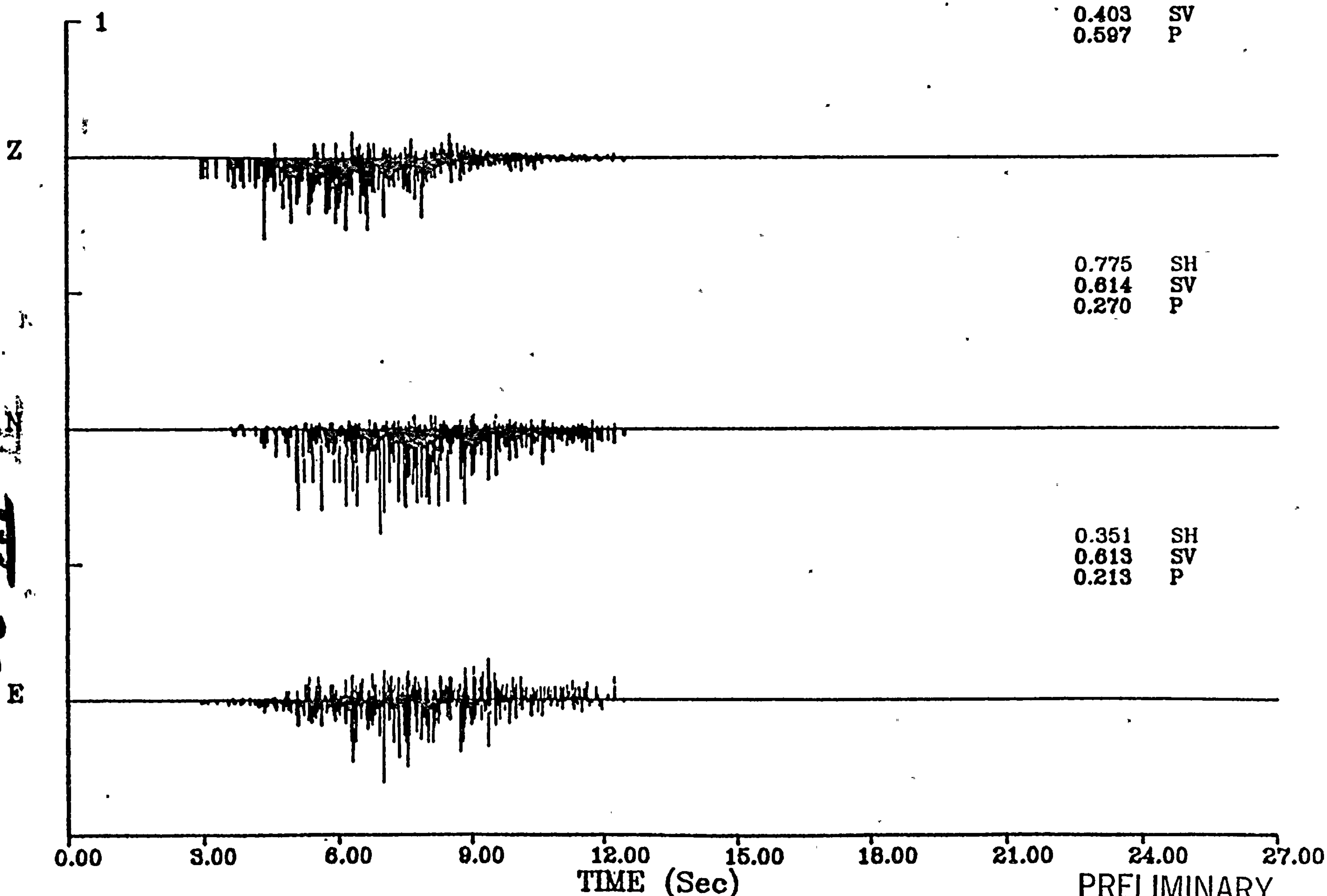
PRELIMINARY
OCT 23 1986

WAVE COMPOSITION M=7 OBLIQUE UNILATERAL



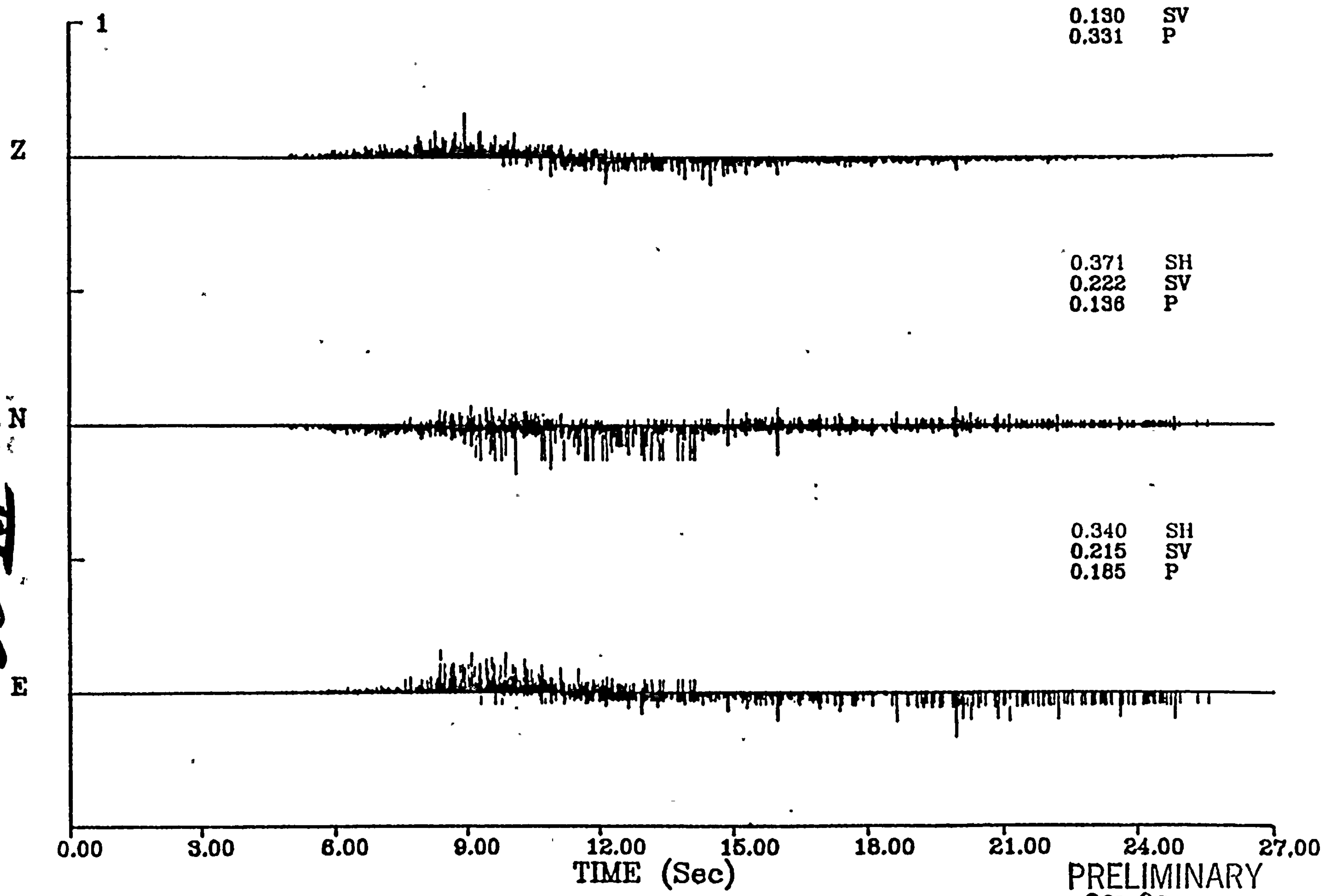
PRELIMINARY
OCT 23 1986

WAVE COMPOSITION M=7 OBLIQUE BILATERAL



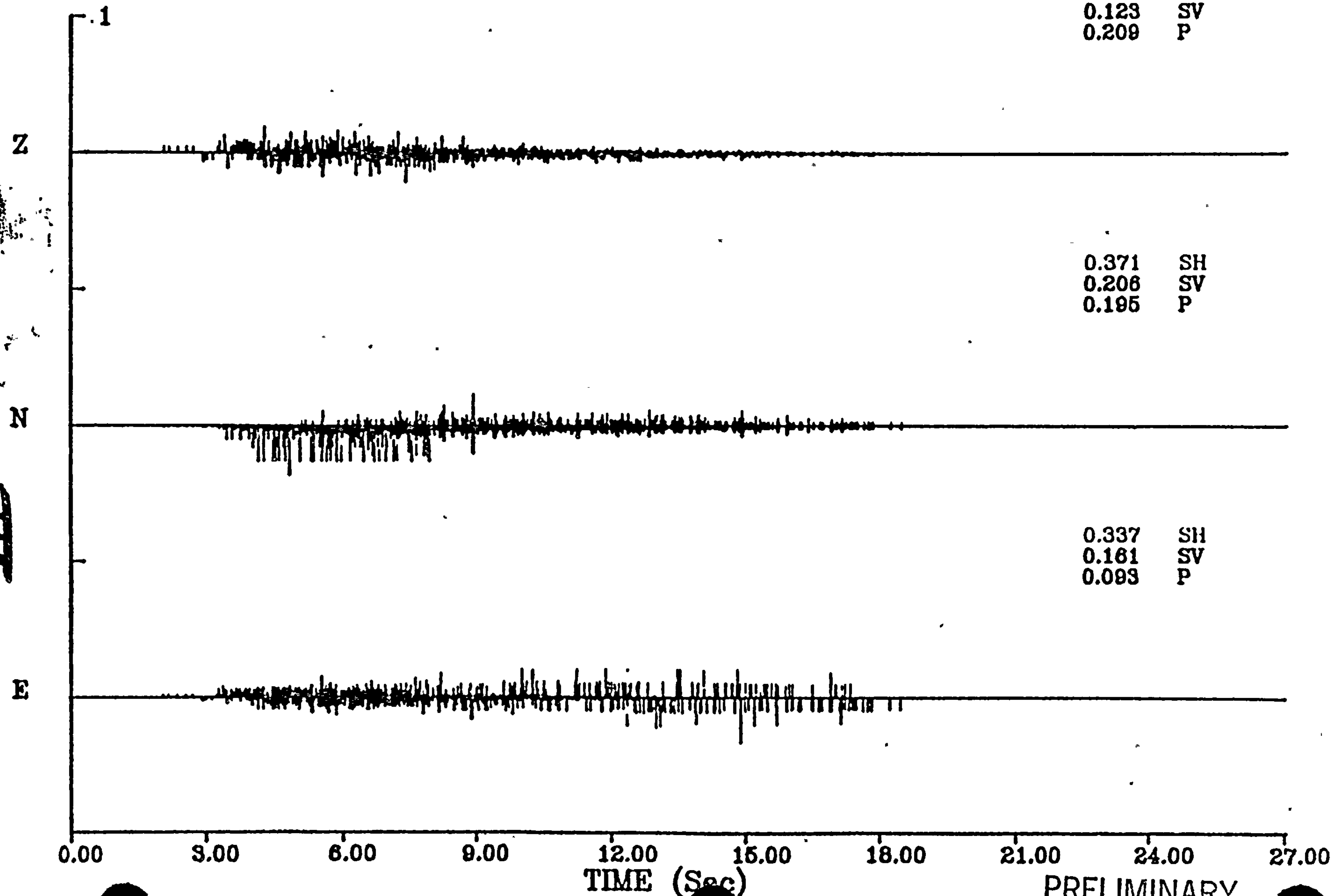
PRELIMINARY
OCT 23 1986

WAVE COMPOSITION M=7 STRIKE SLIP UNILATERAL

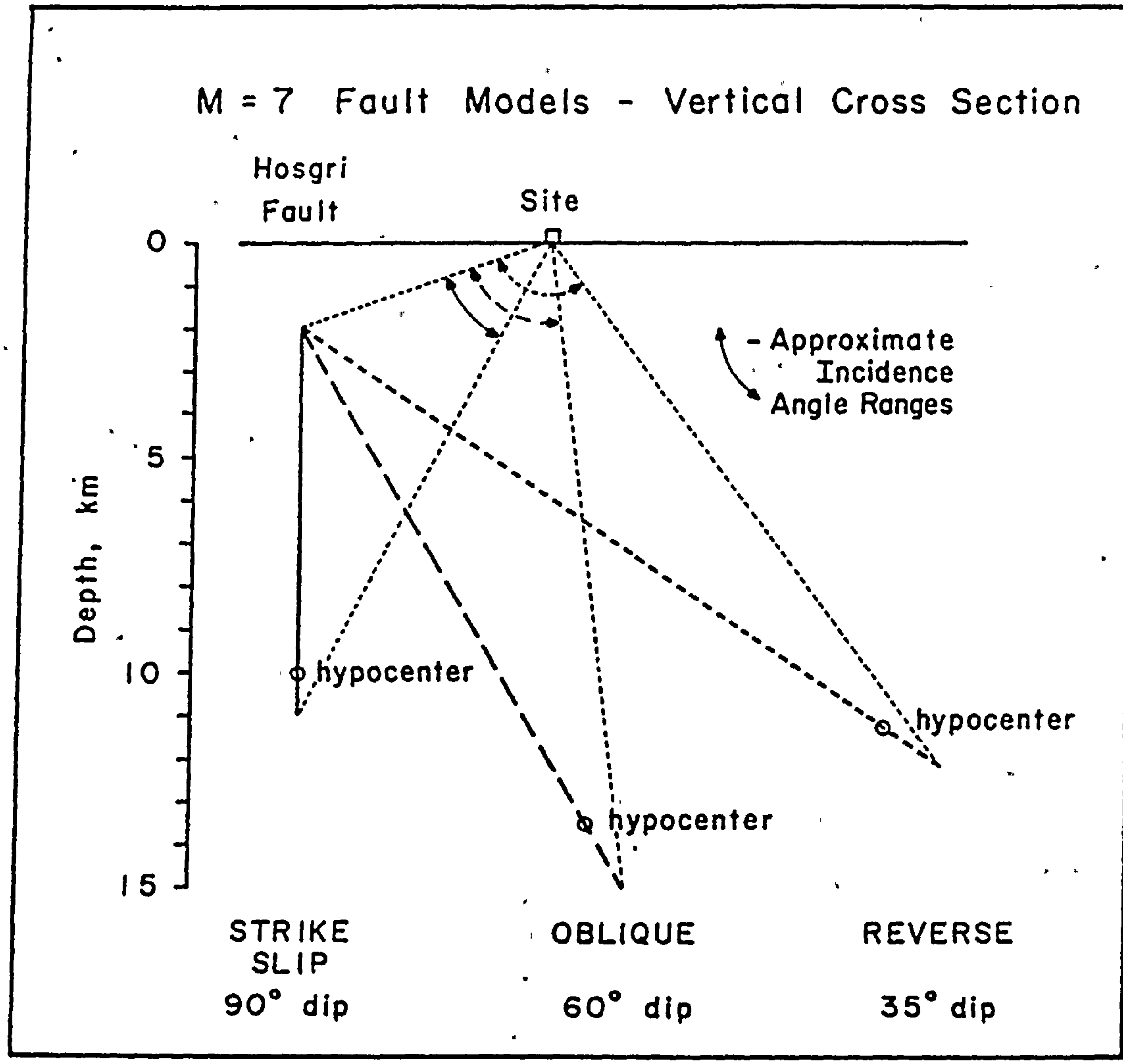


PRELIMINARY
OCT 23 1986

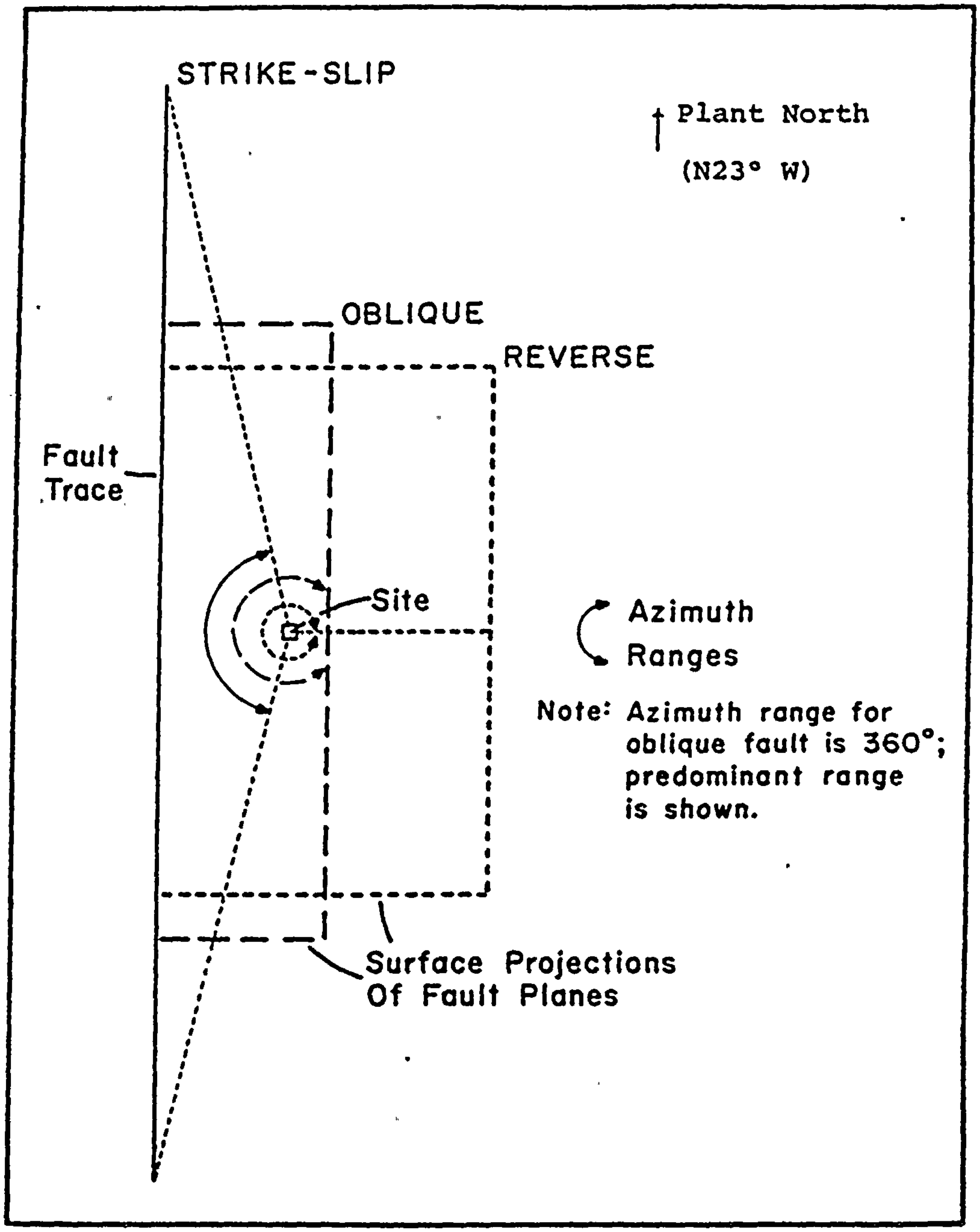
WAVE COMPOSITION M=7 STRIKE SLIP BILATERAL



PRELIMINARY
OCT 23 1986



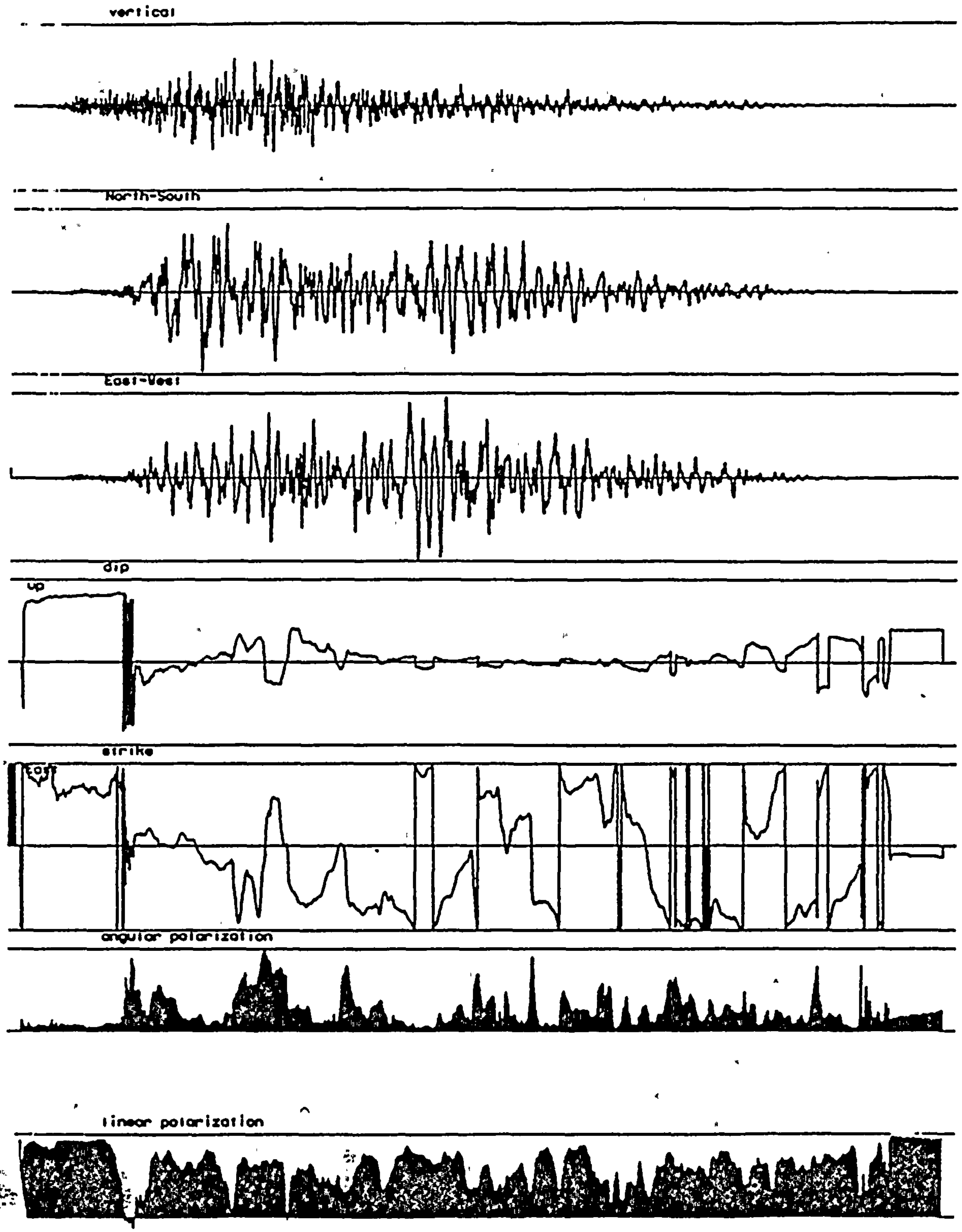
PRELIMINARY
OCT 23 1986



PRELIMINARY
OCT 23 1986

Complex polarization output: M=7.0 strike-slip bilateral

start= 0 length = 6000 window= 81
upflip= 0 rflip = 0 tflip= 0

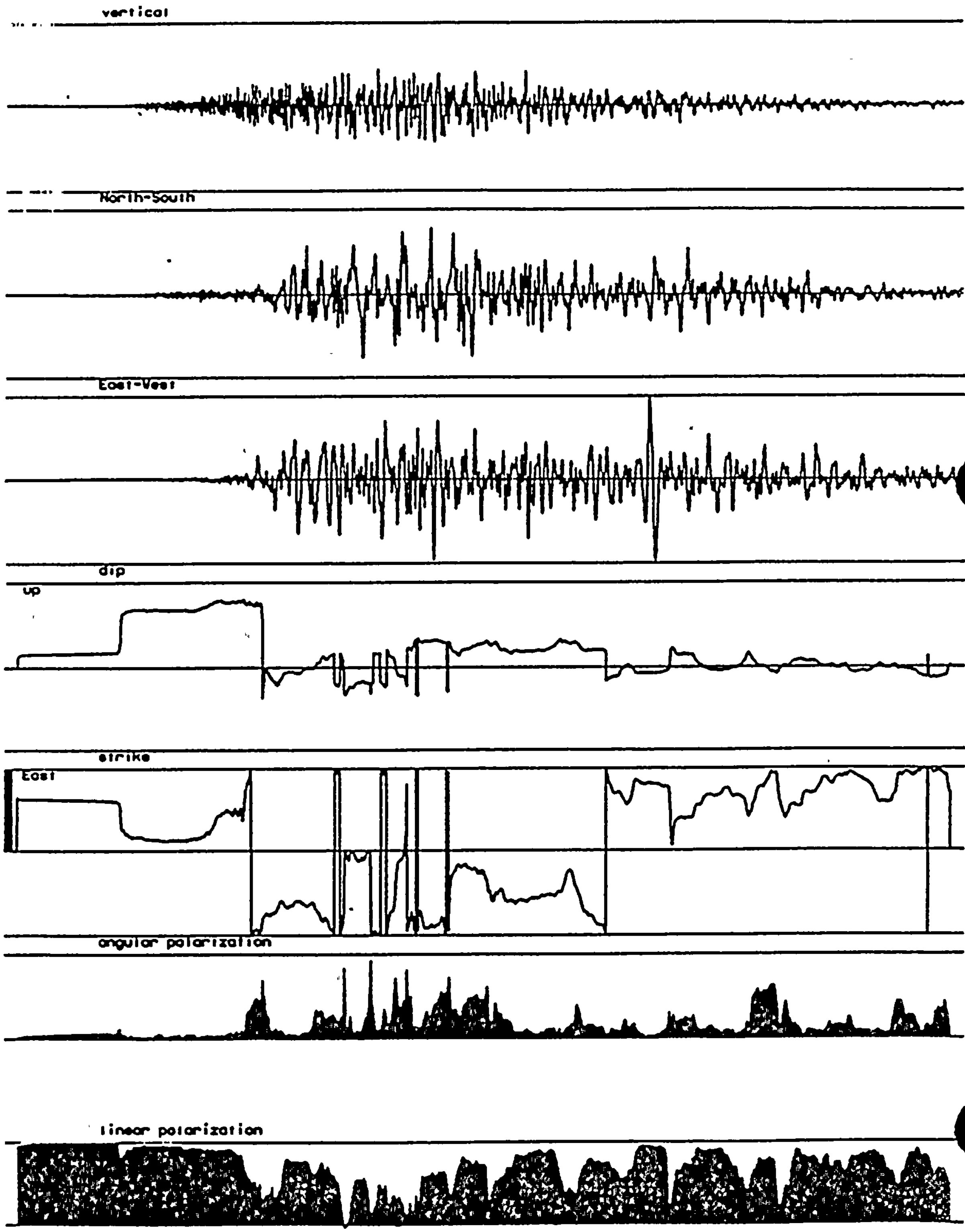


IV-27

PRELIMINARY
OCT 23 1986

Complex polarization output: M=7.0 strike-slip unilateral

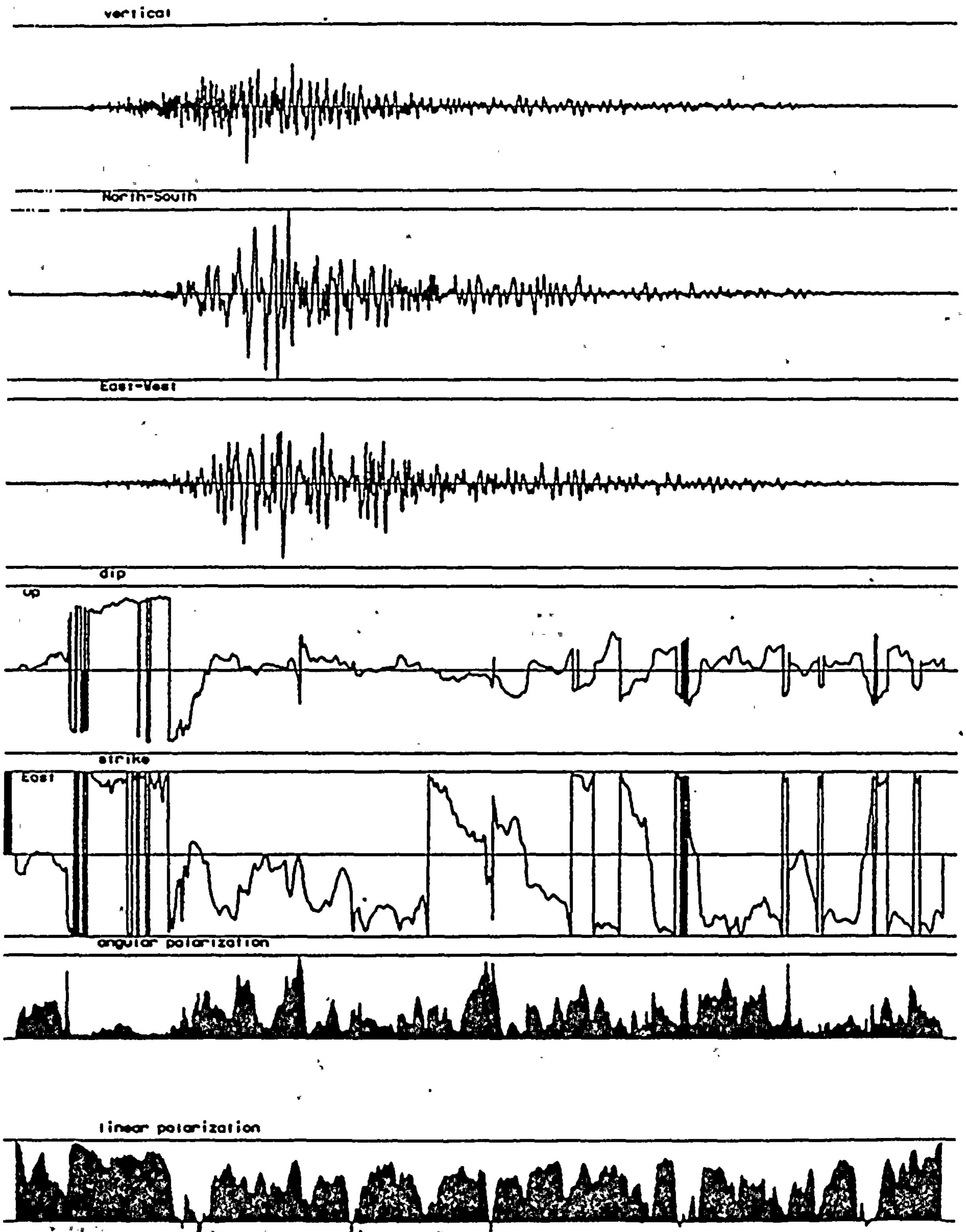
start= 0 length = 6000 window= 81
upflip= 0 rflip = 0 tflip= 0



PRELIMINARY
OCT 23 1986

Complex polarization output: M=7.0 oblique bilateral

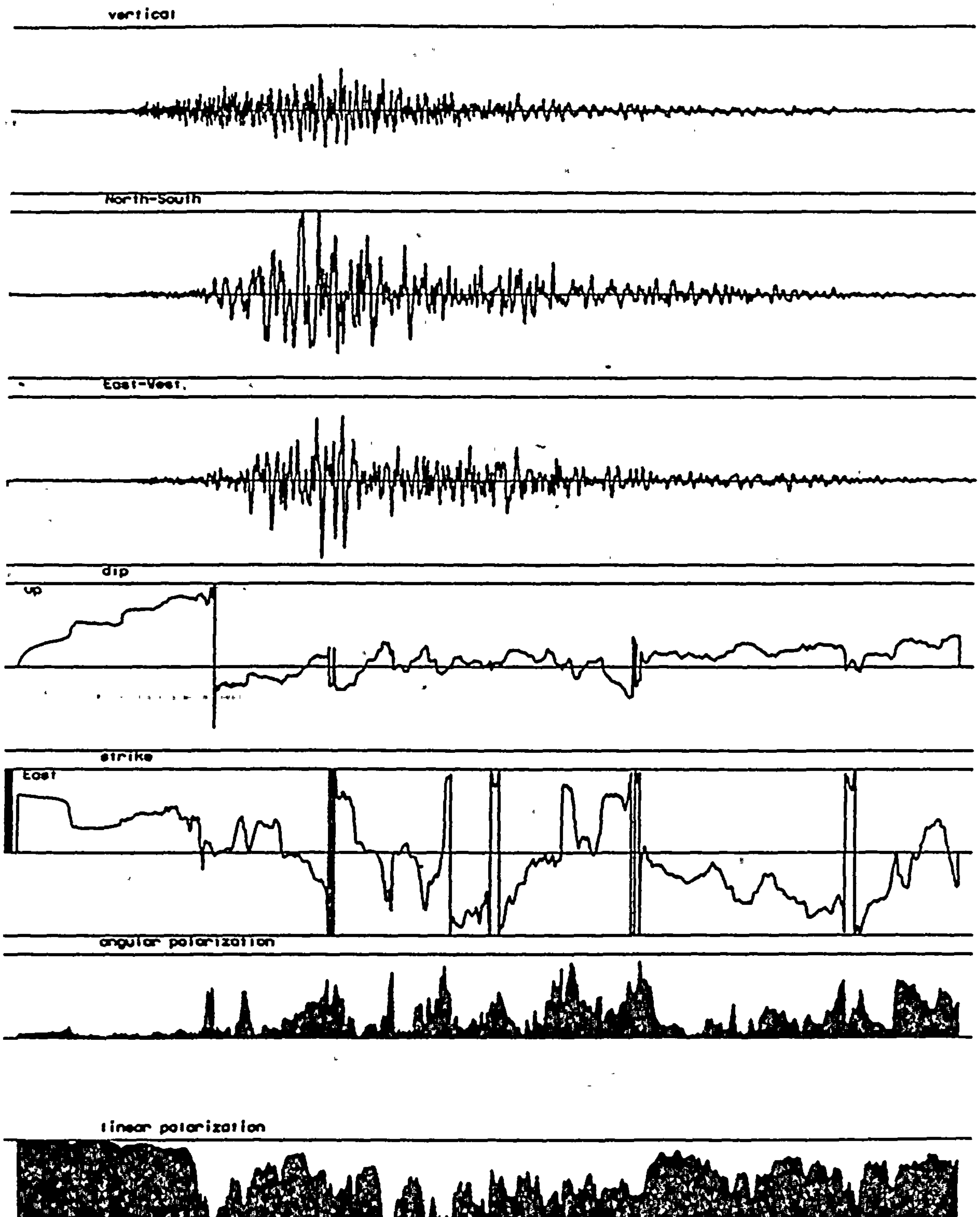
start= 0 length = 6000 window= 81
upflip= 0 rflip = 0 tflip= 0



PRELIMINARY
OCT 23 1986

Complex polarization output: M=7.0 oblique unilateral

start= 0 length = 6000 window= 81
upflip= 0 rflip = 0 tflip= 0



PRELIMINARY
OCT 23 1986

Complex polarization output: M=7.0 reverse bilateral

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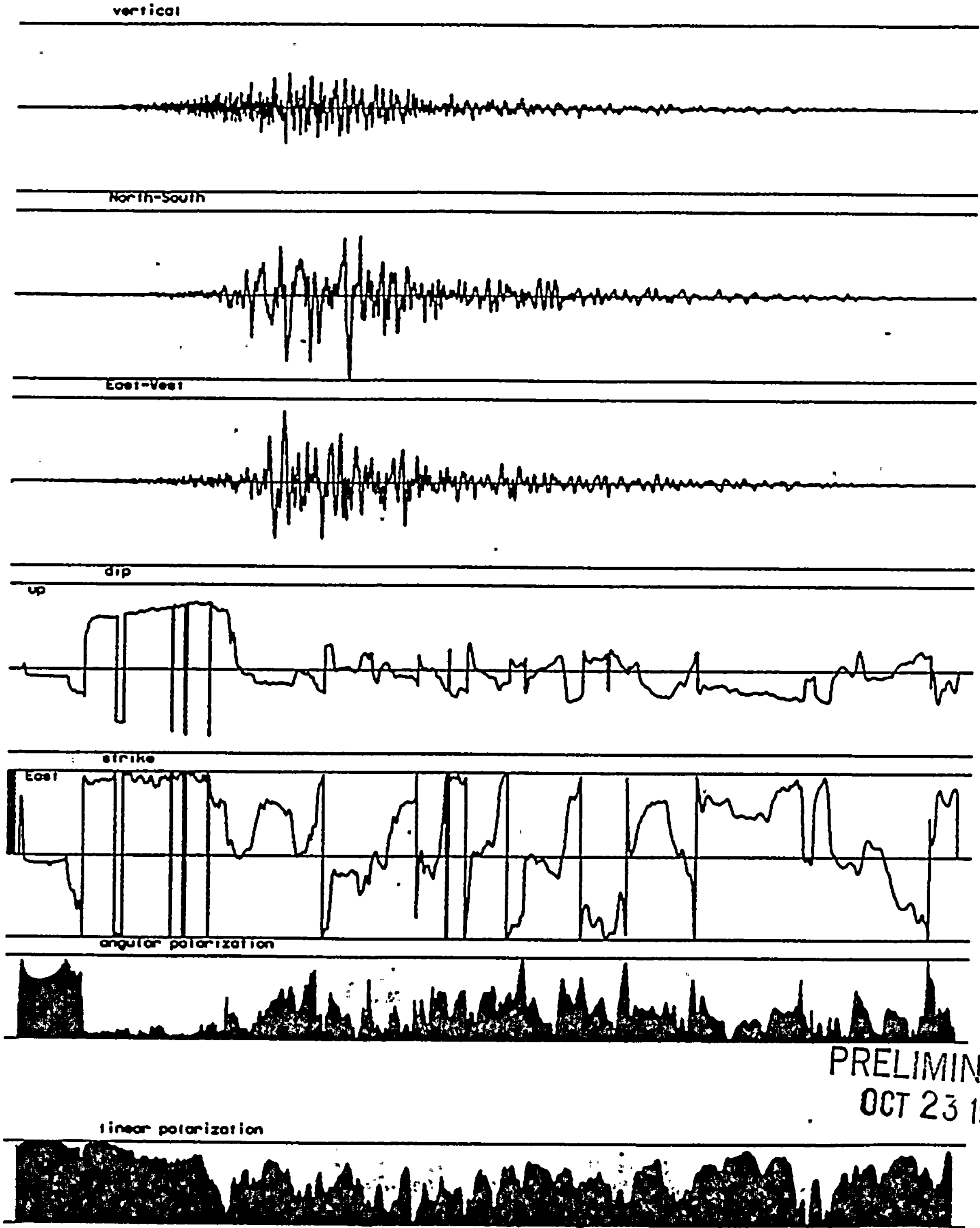
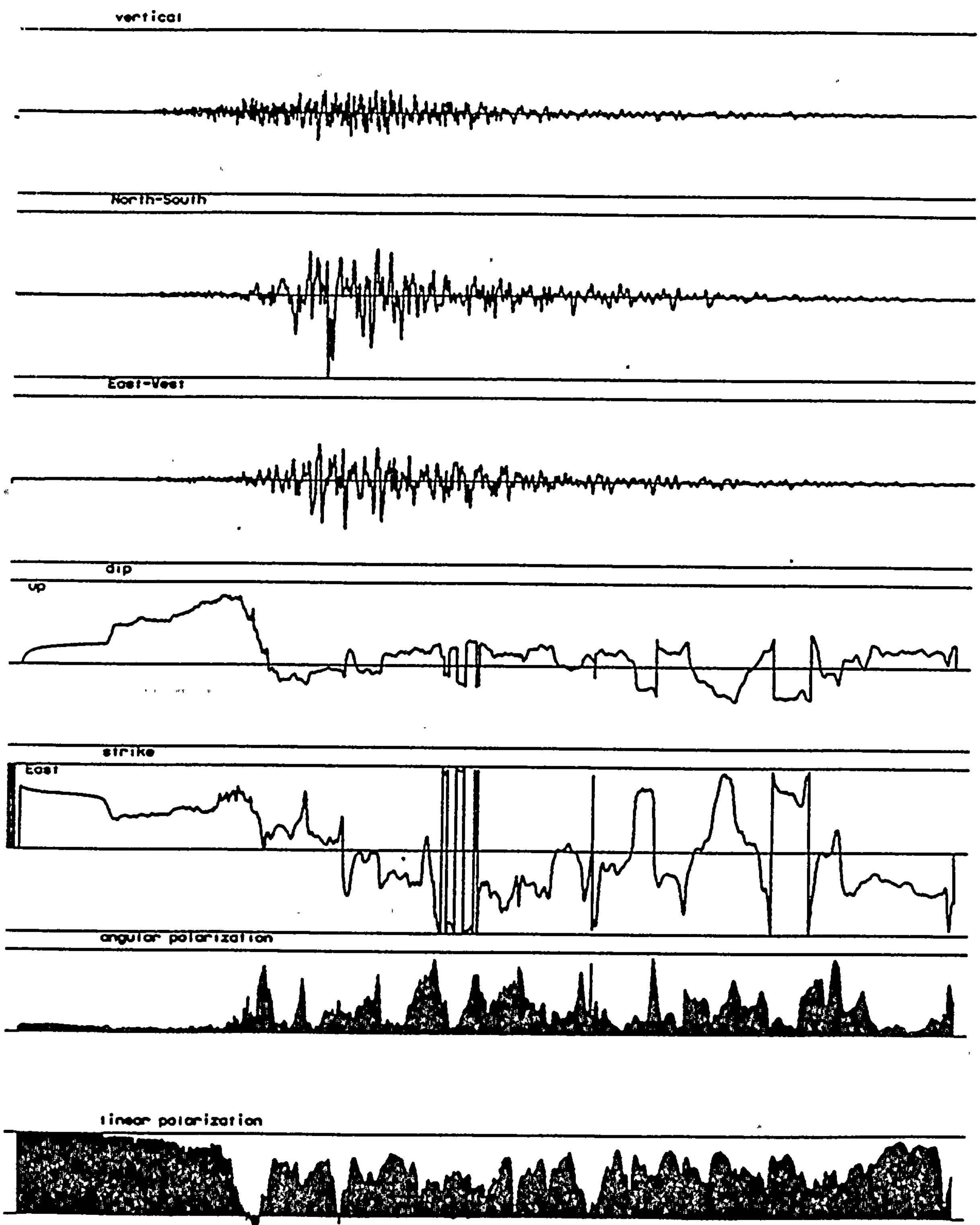


PRELIMINARY
OCT 23 1986

Complex polarization output: M=7.0 reverse unilateral

start= 0 length = 6000 window= 81
upflip= 0 rflip = 0 tflip= 0



IV-32

PRELIMINARY
OCT 23 1986

CONCLUSIONS FROM ANALYSIS OF WAVE COMPOSITION

- STRIKE-SLIP SIMULATIONS ARE DOMINATED BY SH MOTION
- OBLIQUE FAULT SIMULATIONS CONTAIN SIGNIFICANT P, SV AND SH MOTIONS
- REVERSE FAULT SIMULATIONS ARE DOMINATED BY P AND SV MOTIONS
- ARRIVING WAVES HAVE WIDE RANGES IN AZIMUTH
- ARRIVING WAVES HAVE WIDE RANGES IN ANGLE OF INCIDENCE

PRELIMINARY
OCT 23 1986

EVALUATION OF SIMULATED TIME HISTORIES

STRIKE-SLIP RESULTS ARE MORE REALISTIC THAN DIP-SLIP RESULTS

- LIMITATION IN DISTANCE RANGE OF I.V. GREEN'S FUNCTIONS (7.5 KM) HAS LESS EFFECT
- LIMITATION IN RADIATION PATTERN CORRECTIONS HAS LESS EFFECT
- I.V. GREEN'S FUNCTIONS ARE FROM A STRIKE-SLIP SOURCE

HORIZONTAL COMPONENTS ARE MORE REALISTIC THAN VERTICAL COMPONENTS

- ONSET OF P WAVES TRUNCATED AT SOME STATIONS
- P TIMING DISCREPANCIES REMAIN AFTER DISTANCE CORRECTIONS WHILE S WAVES ARE CORRECTLY TIMED
- P RADIATION PATTERN CORRECTION APPLIED TO VERTICAL SV

PRELIMINARY
OCT 23 1986

SELECTION OF TIME HISTORIES FOR INPUT INTO FRAGILITY AND SSI ANALYSES

THE TWO STRIKE-SLIP TIME HISTORY SIMULATIONS WERE SELECTED FOR USE IN THE FRAGILITY AND SSI ANALYSES.

REALISTIC ASPECTS OF THE TIME HISTORIES AS INPUTS INTO THE FRAGILITY AND SSI ANALYSES

- WAVE COMPOSITION AND PHASING OF THE THREE COMPONENTS
- OVERALL DURATION OF STRONG MOTION
- SPECTRAL SHAPE
- PEAK GROUND MOTION VALUES

PRELIMINARY
OCT 23 1986

PG&E Diablo Canyon Power Plant
Long Term Seismic Program (LTSP)

Empirical Ground Motion Study

Input to Phase IIIA Studies

INPUT TO SEISMIC HAZARD ANALYSIS

PRELIMINARY
OCT 23 1986

V-1

CHARACTERIZATION OF EARTHQUAKE GROUND MOTIONS

FOR USE IN PHASE IIIA SEISMIC HAZARDS ANALYSIS

Characterization of earthquake ground motions for use in Phase IIIA seismic hazards analysis consists of the following components.

1) Attenuation relationships for horizontal peak ground acceleration and 5-percent damped spectral acceleration for periods of vibration up to 2 seconds. The relationships provide estimates of the median ground motion levels as a function of earthquake magnitude and source-to-site distance as well as the dispersion about the median values.

2) Relationships characterizing the effect of damping (relative to 5-percent damping level) on the response of spectral ordinates at different periods in the period range of interest.

3) Relationships between vertical and horizontal peak ground acceleration and spectral acceleration as a function of earthquake magnitude and source-to-site distance.

The attenuation relationships described in item (1) above are required as input to probabilistic seismic hazard analysis to construct equal-hazard 5-percent damped horizontal response spectra. Using the relationships described in items (2) and (3) above, these 5-percent damped horizontal response spectra can be generalized to other damping levels (2 to 10 percent) and to vertical motions.

PRELIMINARY
OCT 23 1986

Attenuation Relationships for Horizontal Response Spectral Acceleration

- Joyner and Fumal (1985)

Attenuation relationships provided for PGA and Spectral Velocity for 12 periods in the range 0.1 to 4 seconds. The relationships are those developed by Joyner and Boore (1981), 1982a, 1982b). Attenuation relationships are provided for both "soil" and "rock".

Note: Following plots are those for "rock" relationships and for randomly oriented horizontal component.

- Sadigh et al (1986)

Attenuation relationships provided for PGA and Spectral Velocity in the period range 0.04 to 10 seconds. Separate relationships were derived for "deep soil" and "rock" site conditions. Sadigh et al (1986) updated the original relationships presented in Sadigh (1983, 1984) and extending them to periods up to 10 seconds.

Note: Following plots are those for "rock relationships.

- Campbell (1983)

Attenuation relationships provided for PGA and Spectral Velocity for periods 0.10, 0.12, 0.15 and 0.20 seconds. Relationships provided for different fault types.

Note: Following plots are those for basic case designated herein as Campbell (1983) applicable to normal, normal-oblique, and strike-slip faults and those for reverse and reverse-oblique faults designated herein as Campbell (R).

- Seed et al (1980)

Attenuation relationships will be developed by combining "rock" attenuation relationships by Seed and Schnabel (modified form of Schnabel and Seed, 1973; presented in Seed and Idriss, 1982) with the "rock" spectral shape of Seed, Ugas, Lysmer (1976). Adjustments for magnitude effect on spectral shape will also be required.

- Idriss (1985)

Attenuation relationship will be developed by combining attenuation relationships by Idriss (1985) recommended for use for stiff to rock site conditions with "rock" spectral shape for "rock proposed by Idriss (1985) and considered appropriate for M 6.5 to 7. Adjustment for magnitude effect will also be required.

PRELIMINARY
OCT 23 1986

References

Campbell, K., 1983, The effects of site characteristics on near-source recordings of strong-ground motion: Proceedings of Conference XXII; site-specific effects of soil and rock on ground motion and implications for earthquake resistant design, USGS Open File Report 83-845.

Joyner, W.B. and D.M. Boore, 1981, Peak horizontal acceleration and velocity from strong-motion records including records from the 1979 Imperial Valley, California Earthquake: Bulletin of the Seismological Society of America, vol. 71, no. 6, pp. 2011-2038.

Joyner, W.B. and D. M. Boore, 1982a. Estimation of response spectral values as functions of magnitude, distance, and site conditions: U.S. Geological Survey Open-File Report No. 82-881, 14 p.

Joyner, W.B. and D.M. Boore, 1982b, Prediction of earthquake response spectra, U.S. Geological Survey Open-File Report 82-977.

Joyner, W.B. and T.E. Fumal, 1985, Predictive mapping of ground motion, in evaluating earthquake hazards in the Los Angeles Region: U.S. Geological Survey Professional Paper 1360.

Sadigh, K., 1980. A comparative study of the response spectra for the three components of strong motion records: Interpretation of Strong-Motion Earthquake Records Obtained in and/or near Buildings, UCLA Report No. 8015, Proceedings of a Workshop Sponsored by the National Science Foundation.

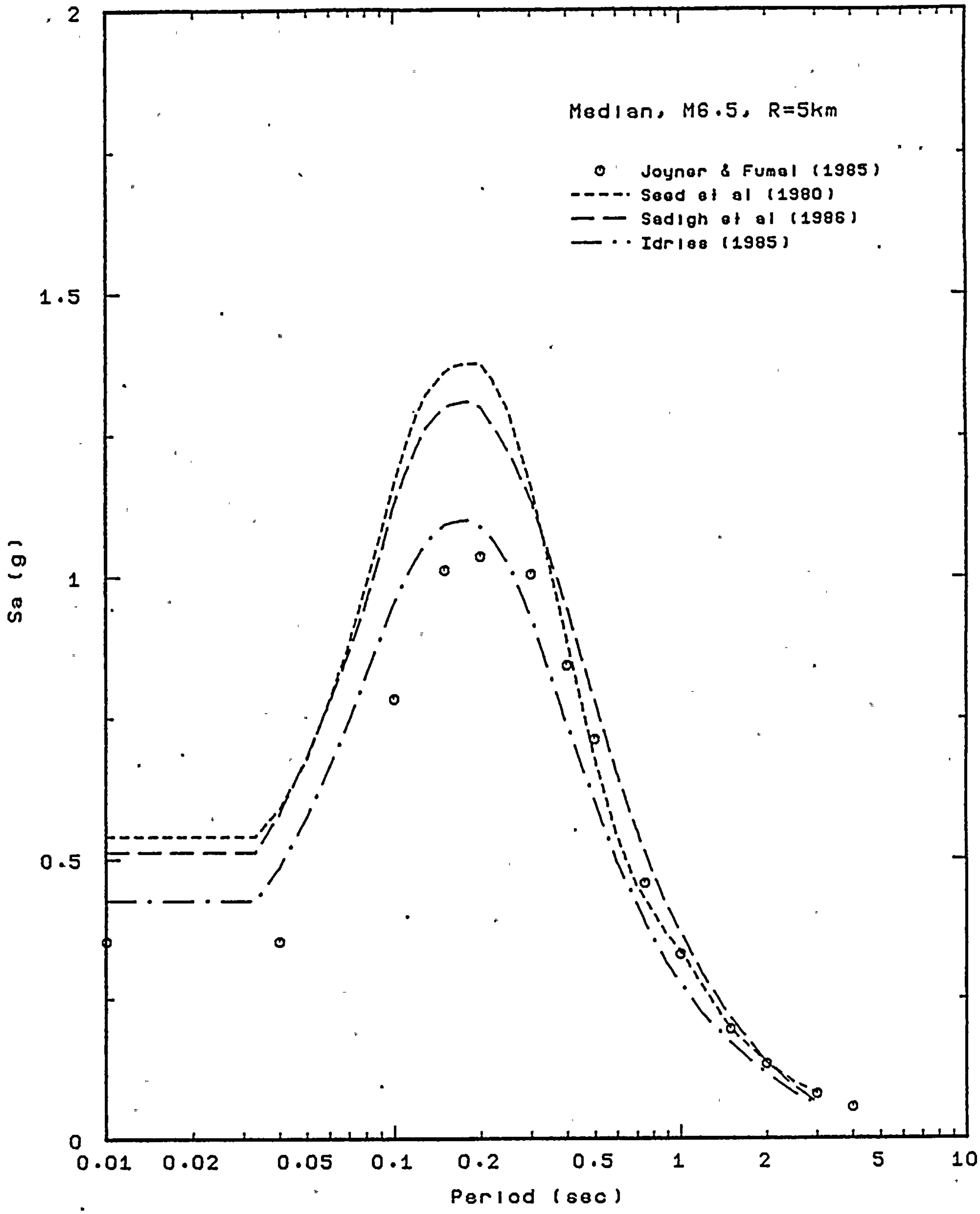
Sadigh, K., 1983, Considerations in the development of site-specific spectra: Proceeding of conference XXII; site-specific effects of soil and rock on ground motion and the implications for earthquake resistant design, U.S. Geological Survey Open File Report 83-845.

Sadigh, K., 1984, Characteristics of strong motion records and their implications for earthquake-resistant design: EERI Seminar No. 12, Stanford, California, July 19, 1984, EERI Publication No. 84-06.

Sadigh, K., J.A. Egan, and R.R. Youngs, 1986, Specification of ground motion for seismic design of long period structures (abs.): Earthquake Notes, v. 57, no. 1.

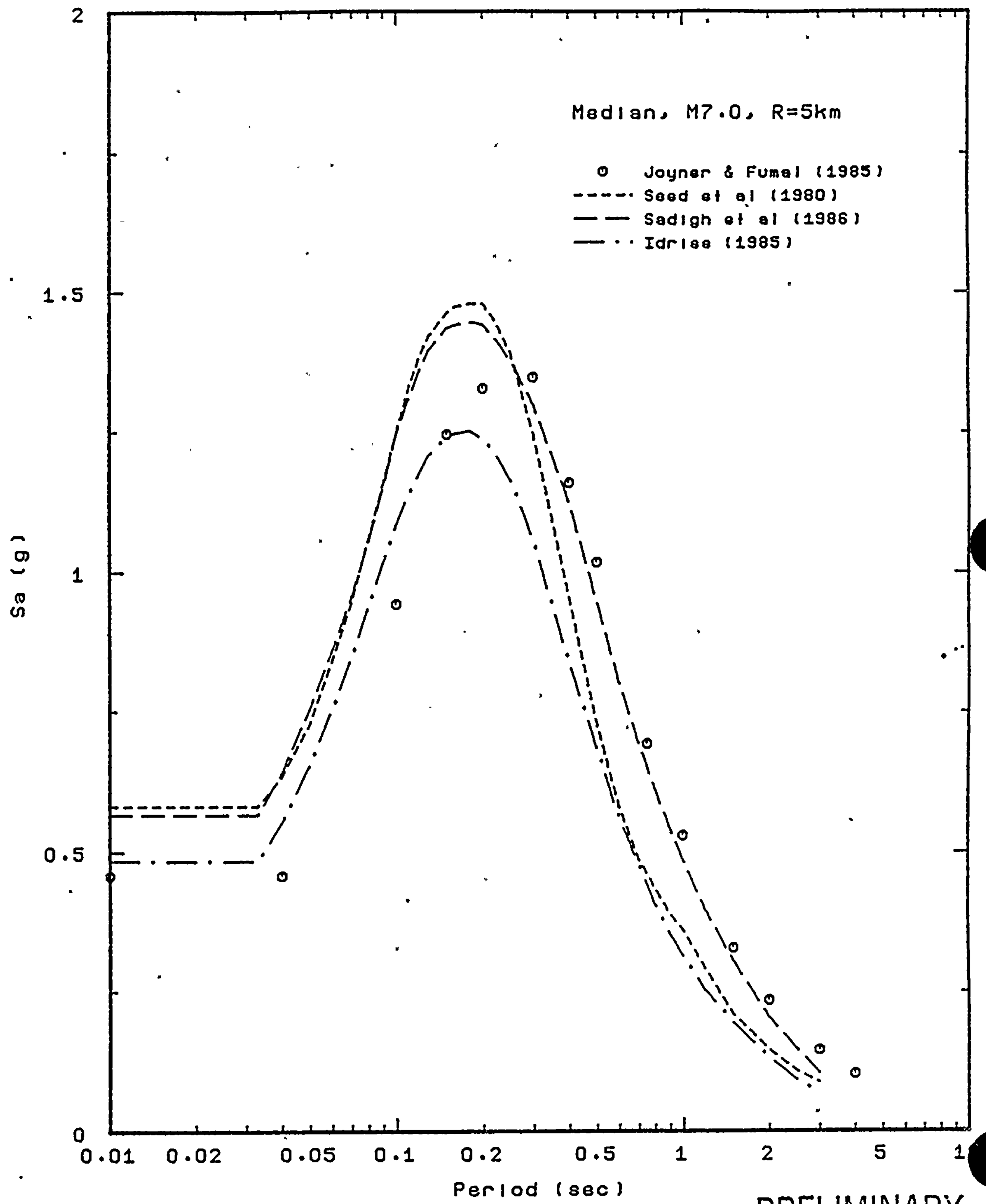
Seed, H.B., Ugas, C., and Lysmer, J., 1976. Site-dependent spectra for earthquake-resistant design: Bulletin of the Seismological Society of America, v. 66, no. 1, pp. 221-243.

Seed, H.B. and Idriss, I.M., 1982. Ground motion and soil liquefaction during earthquakes: Earthquake Engineering Research Institute, Berkeley, California, v. 5 of a series titled: Engineering Monographs on Earthquake Criteria, Structural Design, and Strong Motion Records



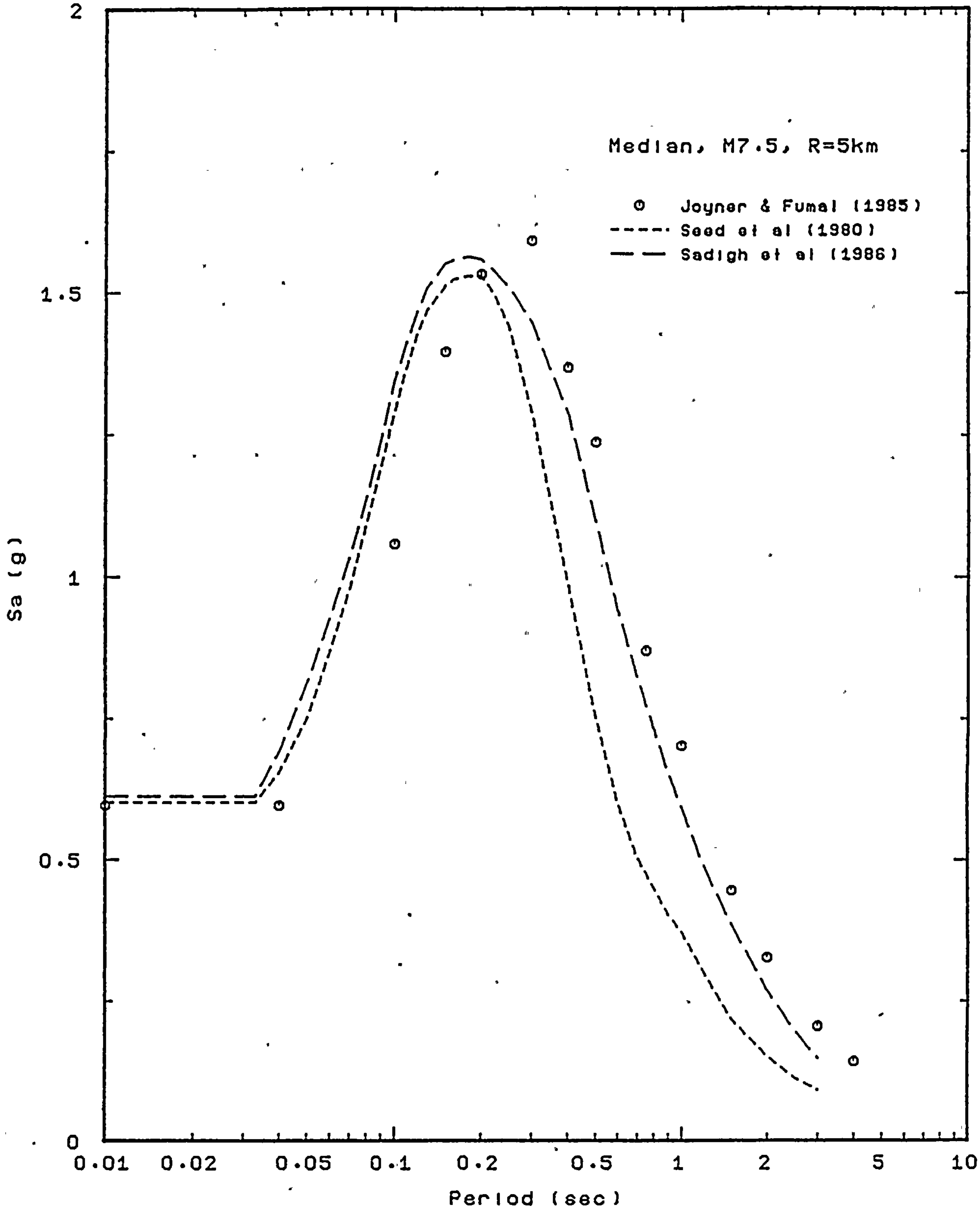
V-5

PRELIMINARY
OCT 23 1986



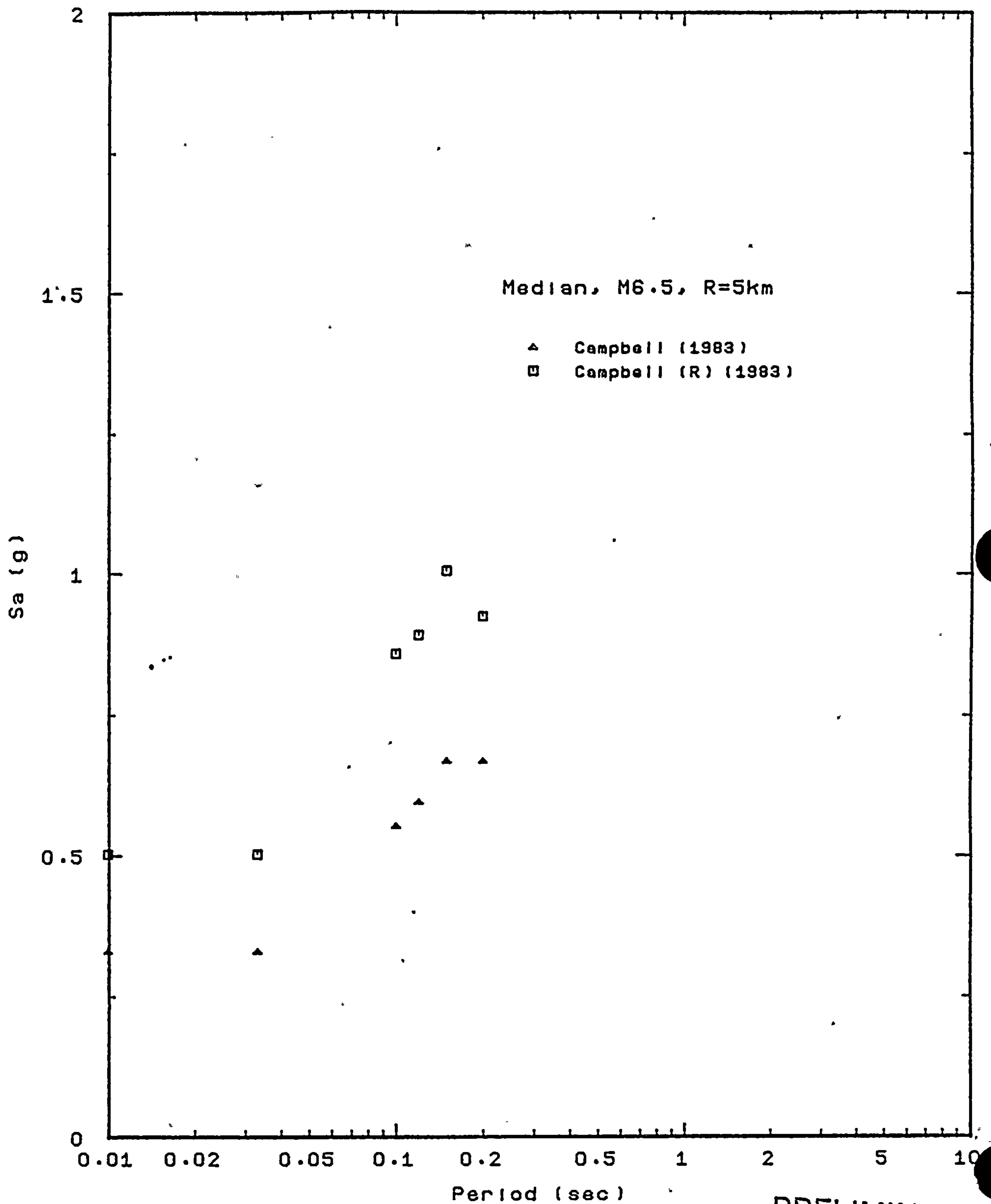
V-6

PRELIMINARY
OCT 23 1986

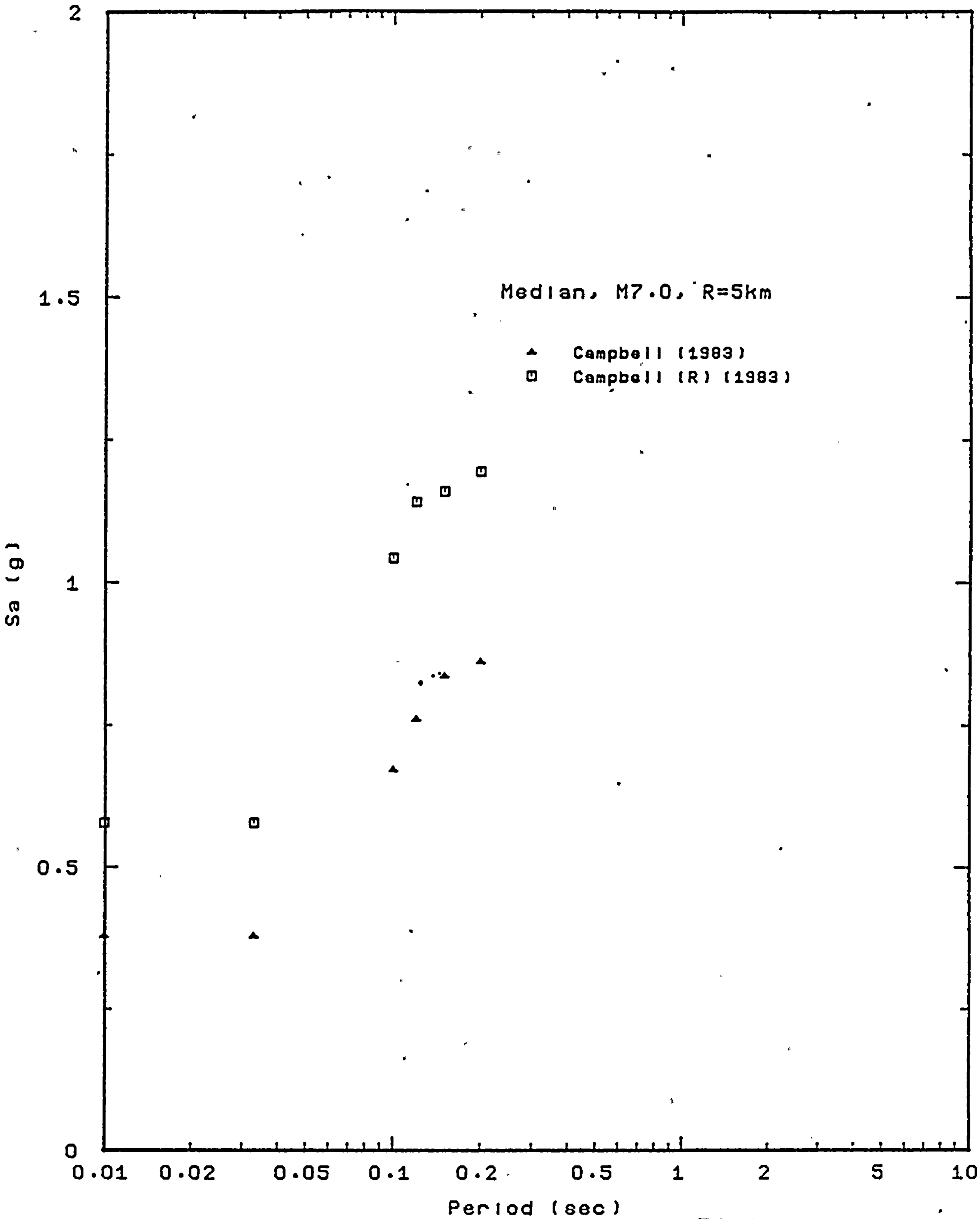


PRELIMINARY
OCT 23 1986

V-7

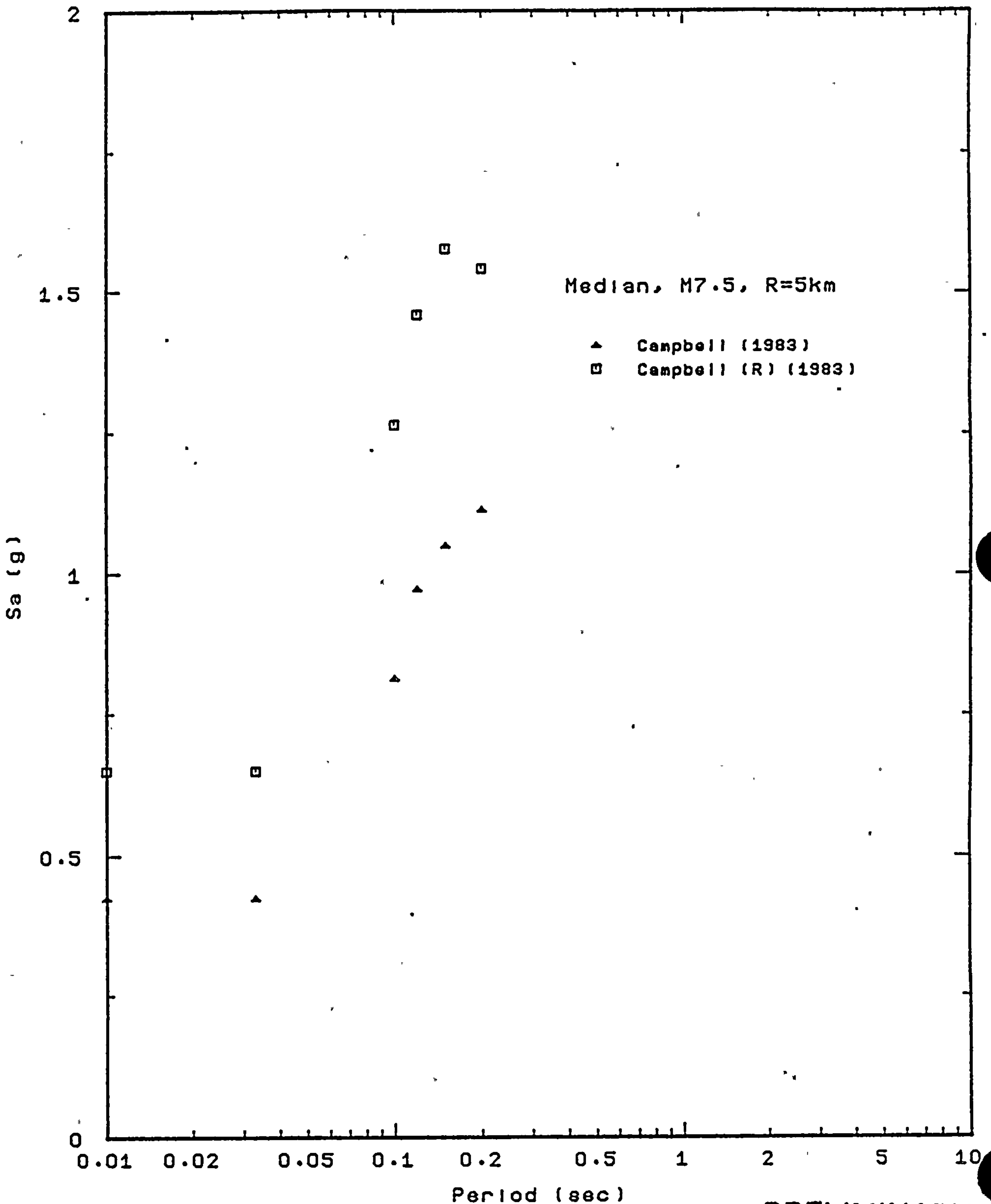

Median, M6.5, R=5km
Campbell (1983)
Campbell (R) (1983)
Sa (g)
Period (sec)
0
0.5
1
1.5
2
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10

V-8



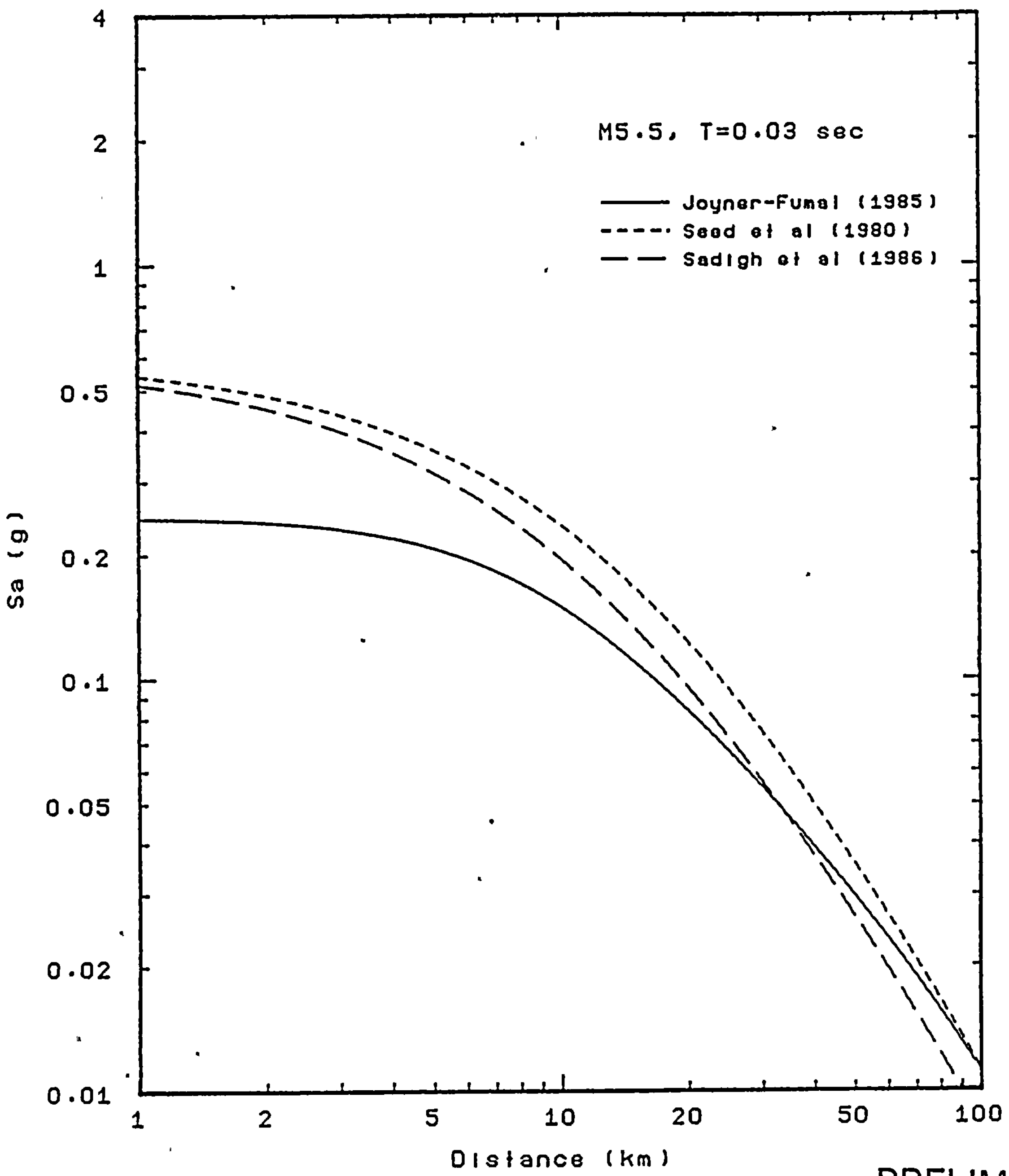
PRELIMINARY
OCT 23 1986

V-9



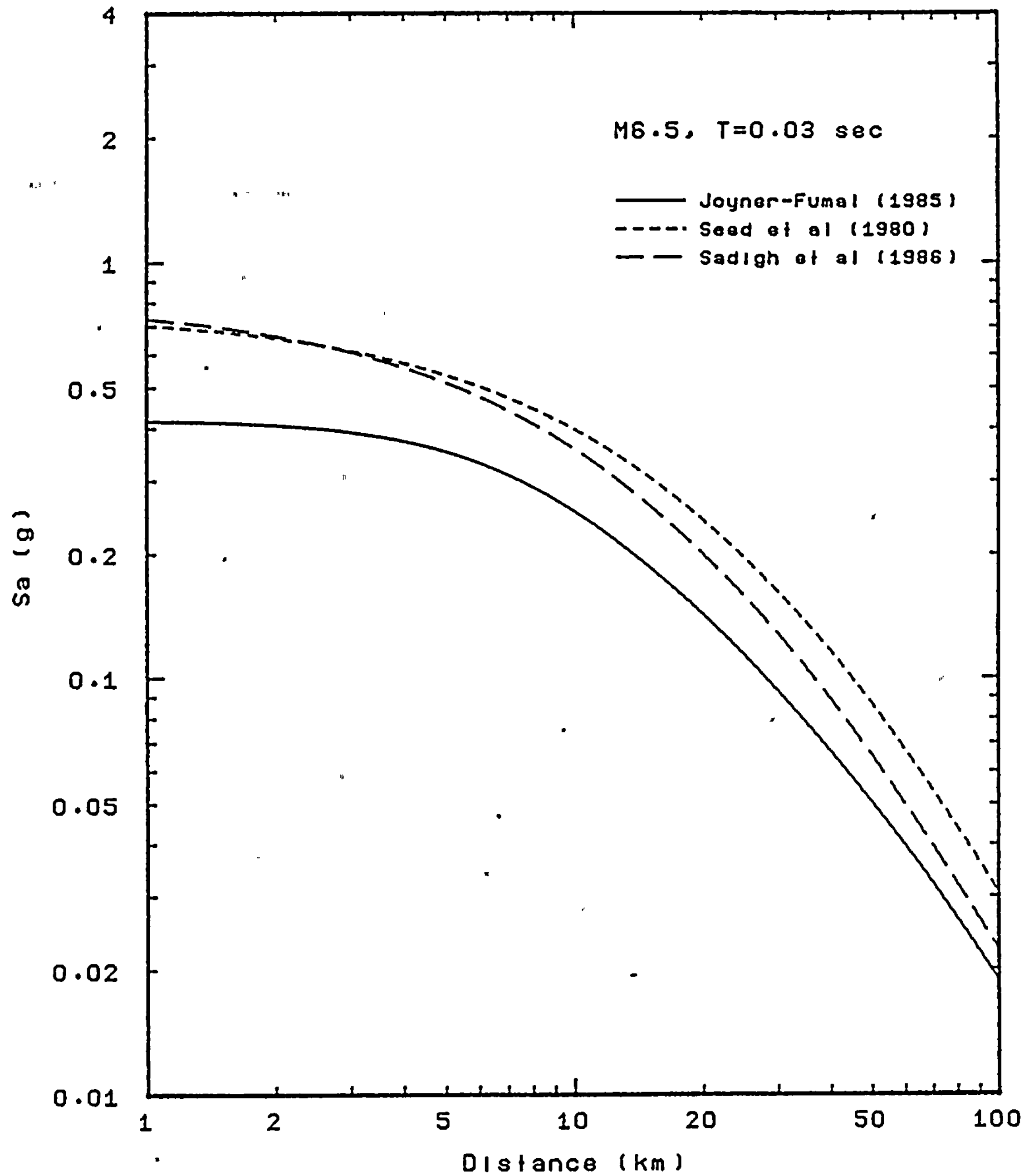
PRELIMINARY
OCT 23 1986

V-10



PRELIMINARY
OCT 23 1986

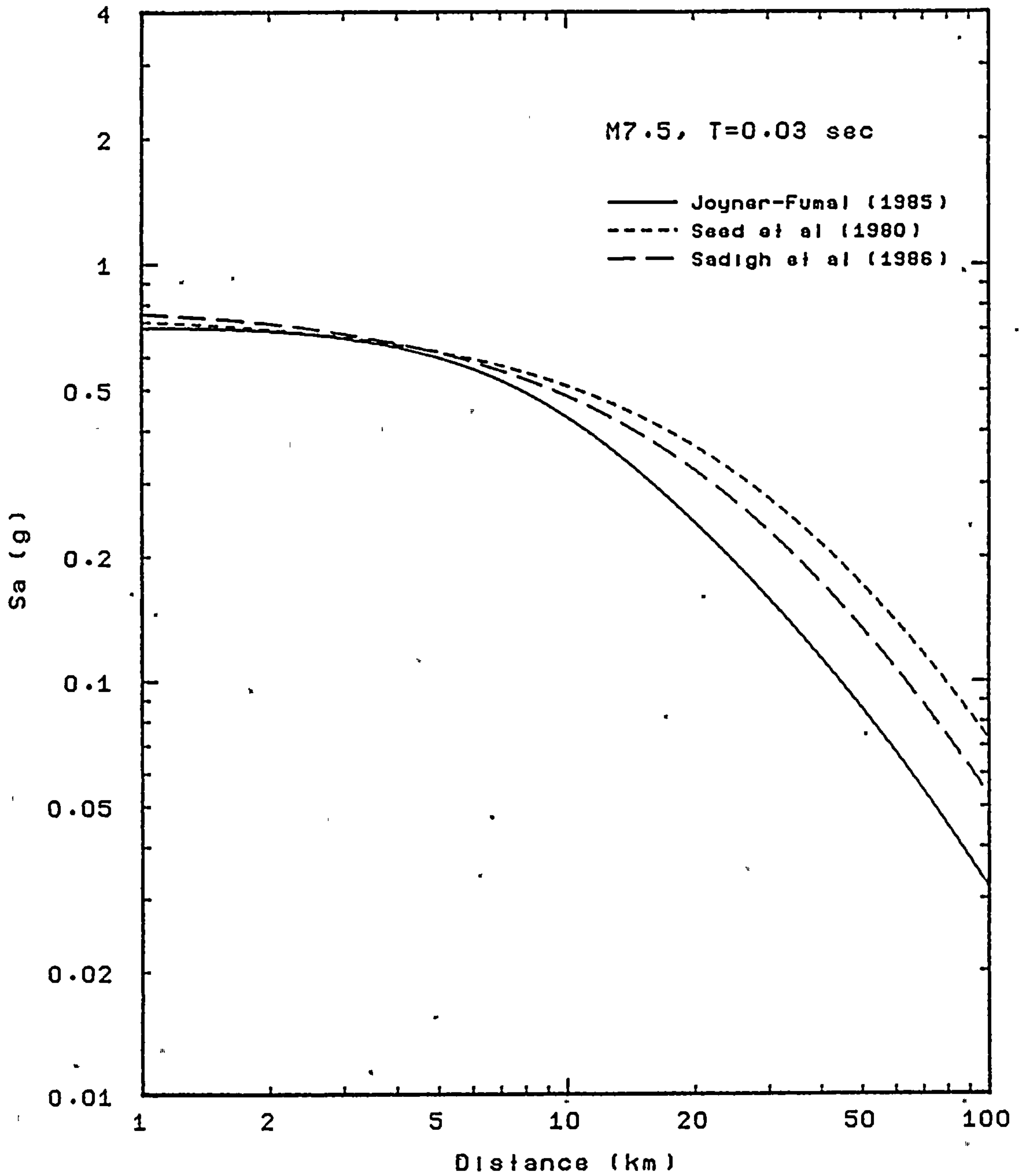
Attenuation Relationship Comparison



Attenuation Relationship Comparison

PRELIMINARY
OCT 23 1986

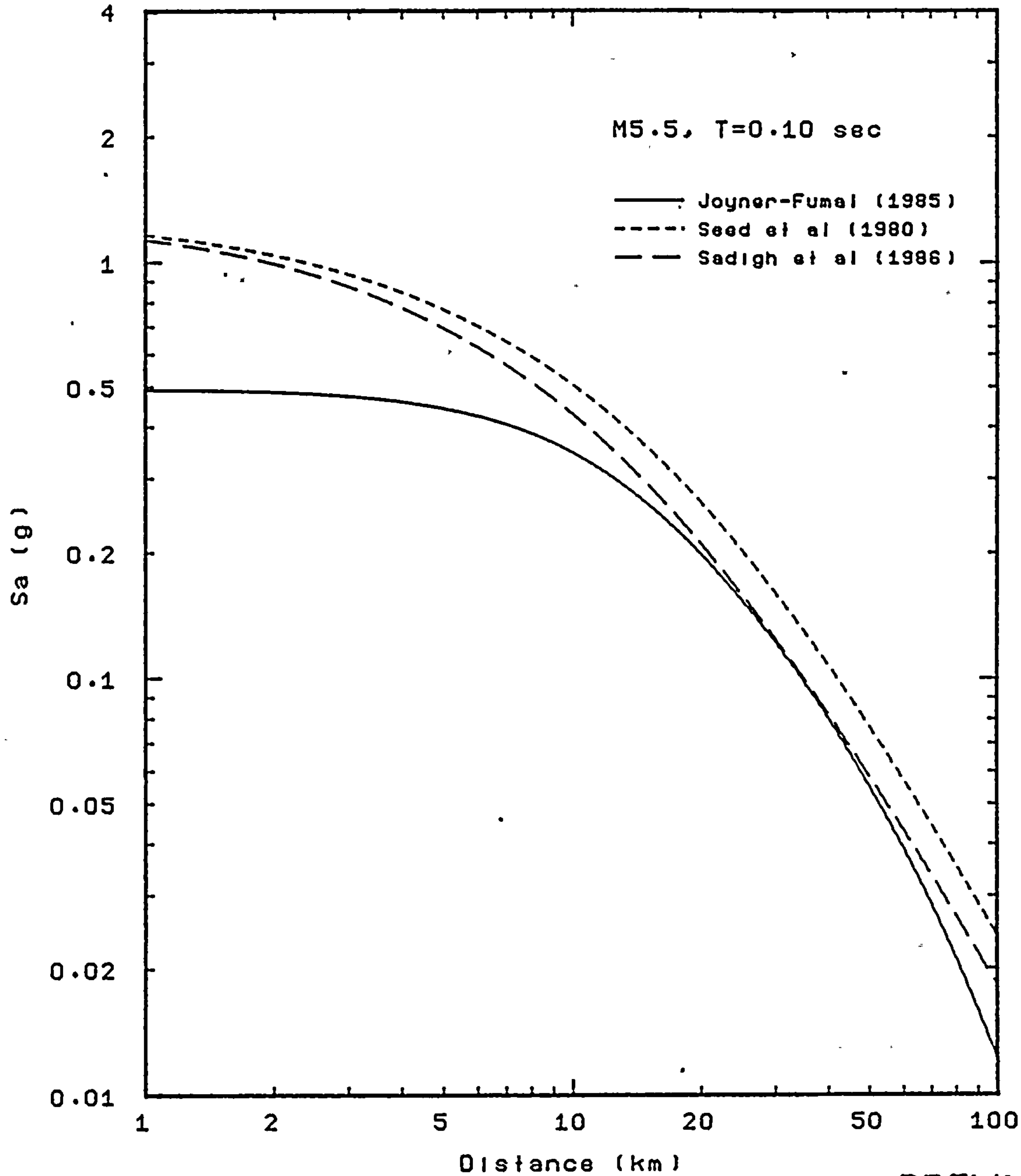
T-V-12



Attenuation Relationship Comparison

PRELIMINARY
OCT 23 1986

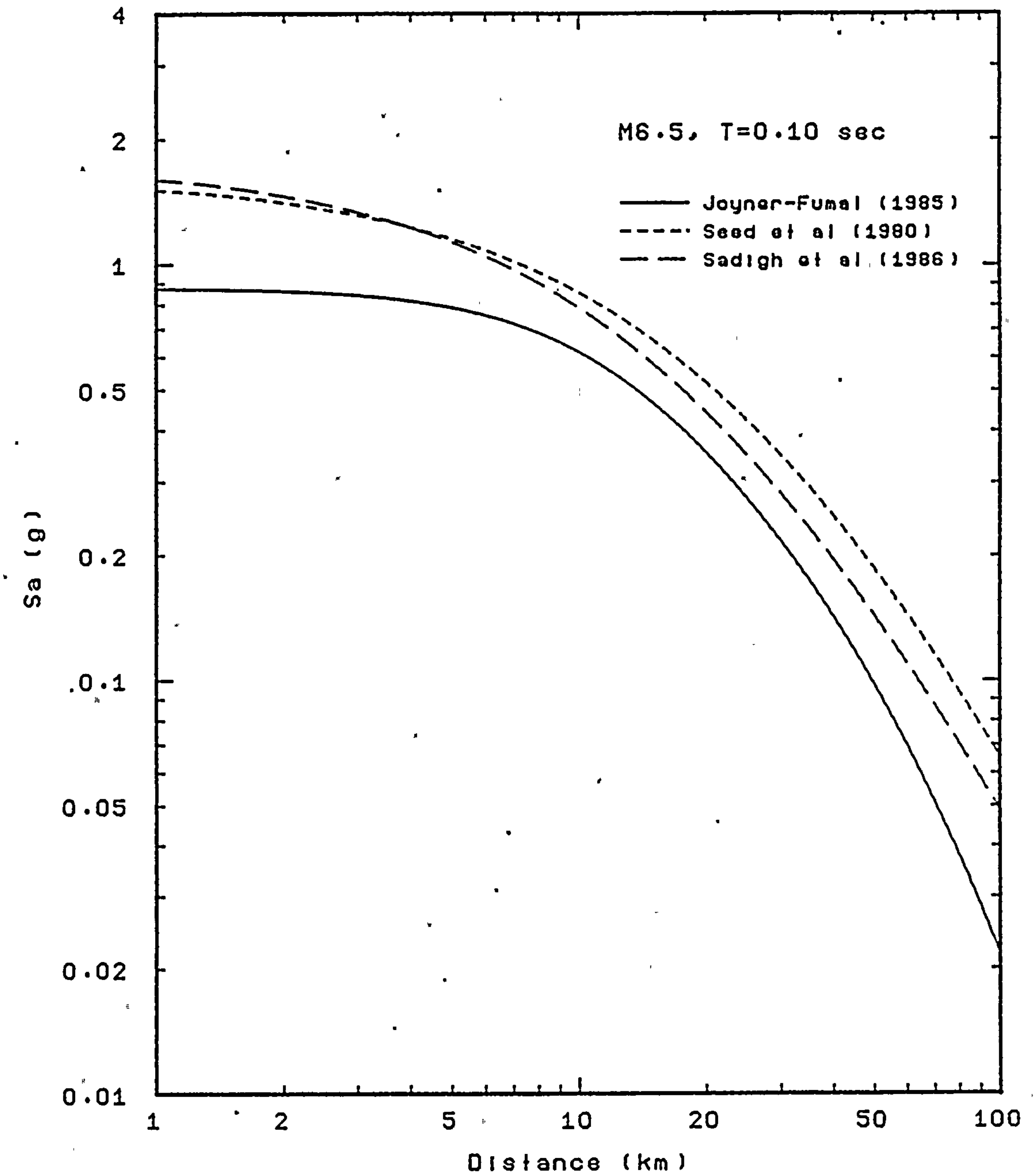
V-13



Attenuation Relationship Comparison

PRELIMINARY
OCT 23 1986

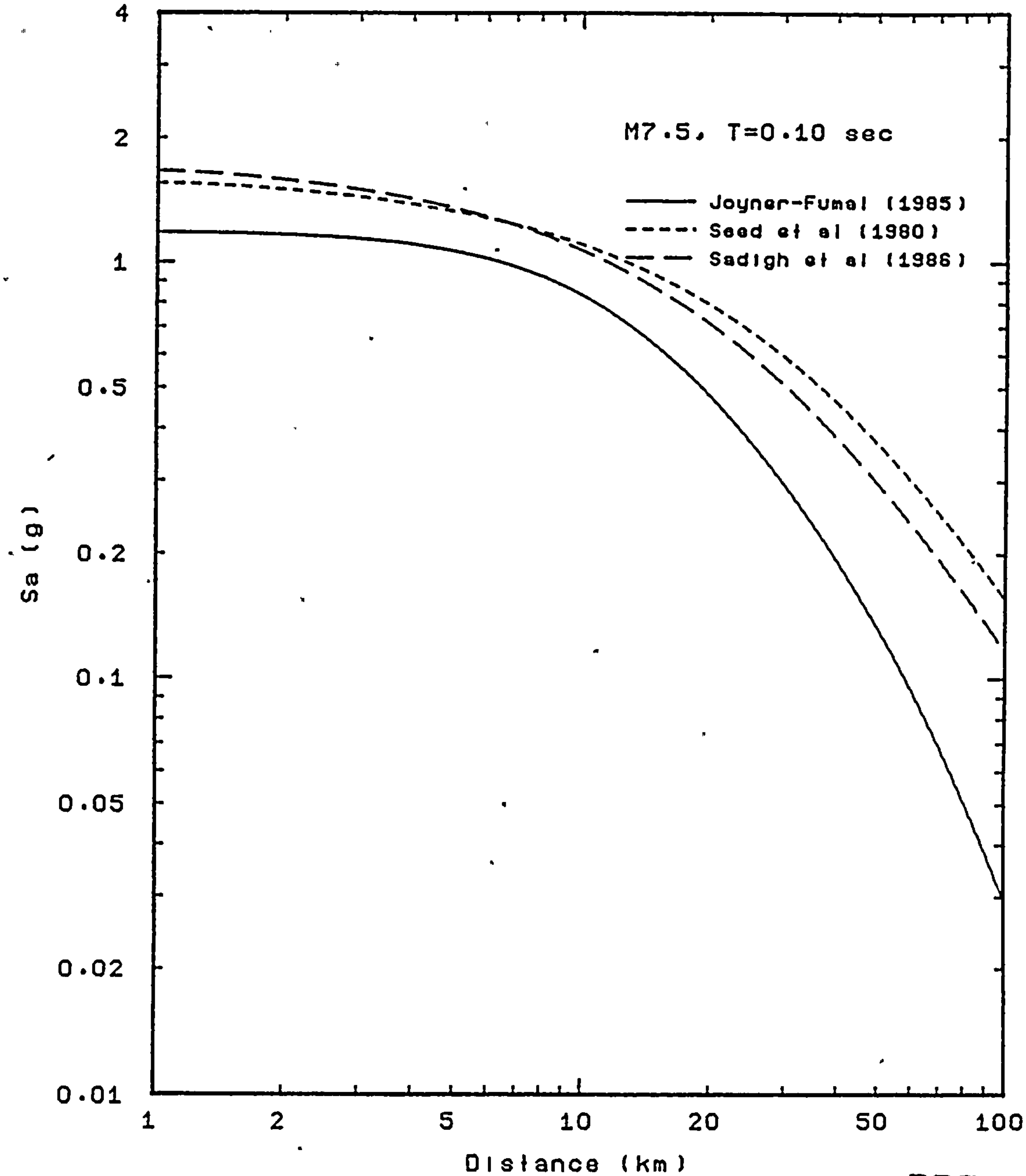
V-14



Attenuation Relationship Comparison

PRELIMINARY
OCT 23 1986

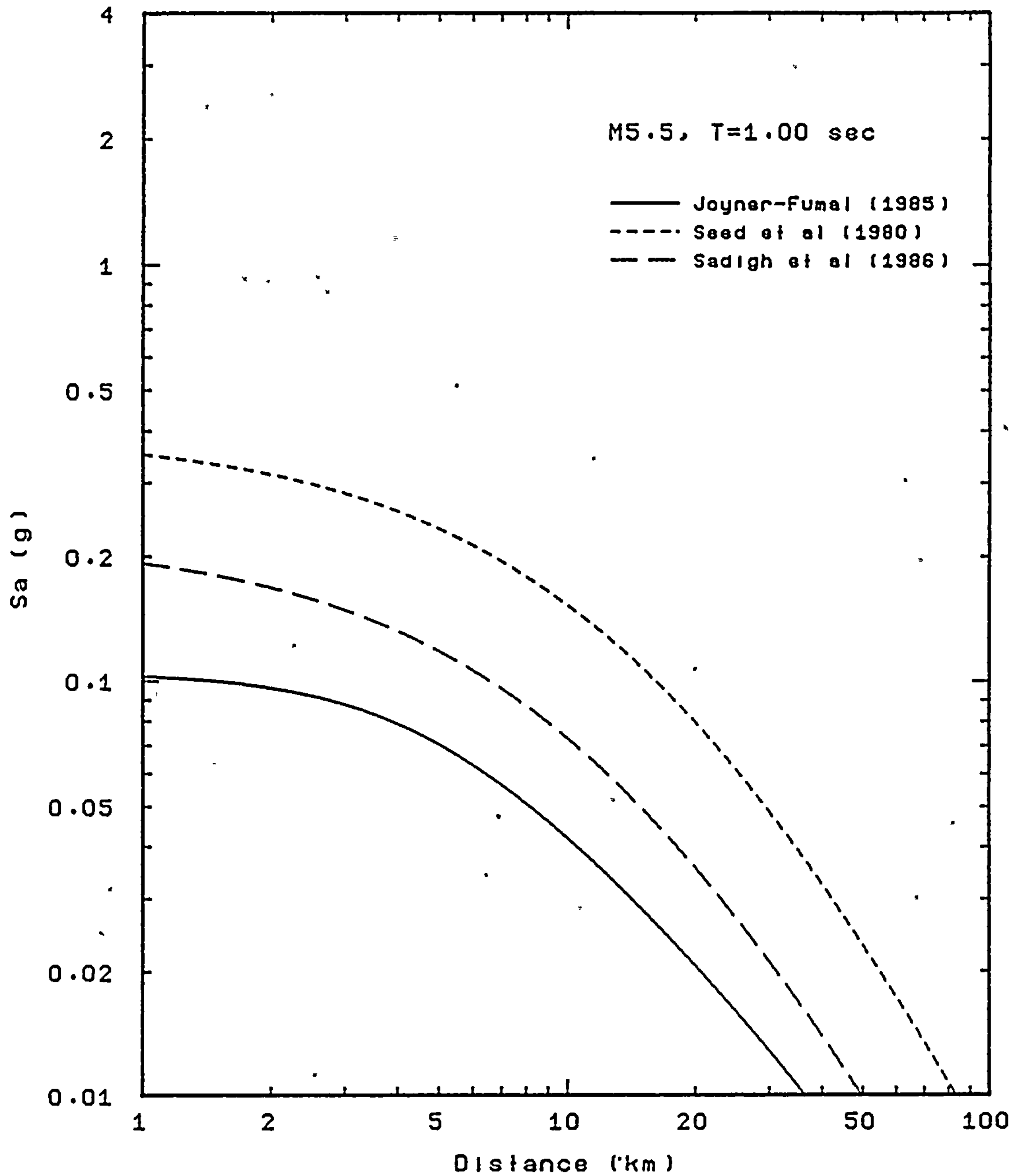
V-15



Attenuation Relationship Comparison

PRELIMINARY
OCT 23 1986

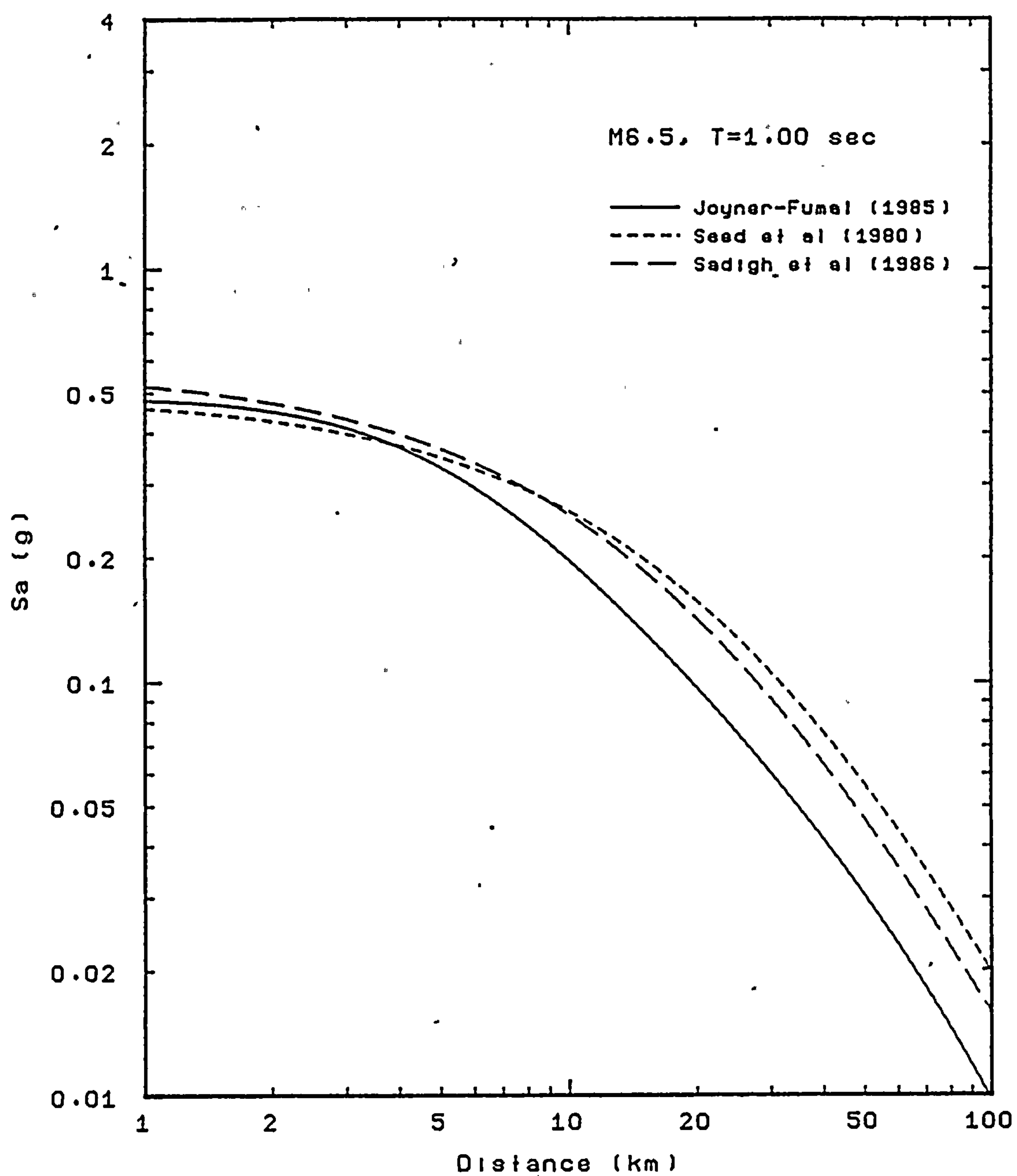
V-16



Attenuation Relationship Comparison

V-17

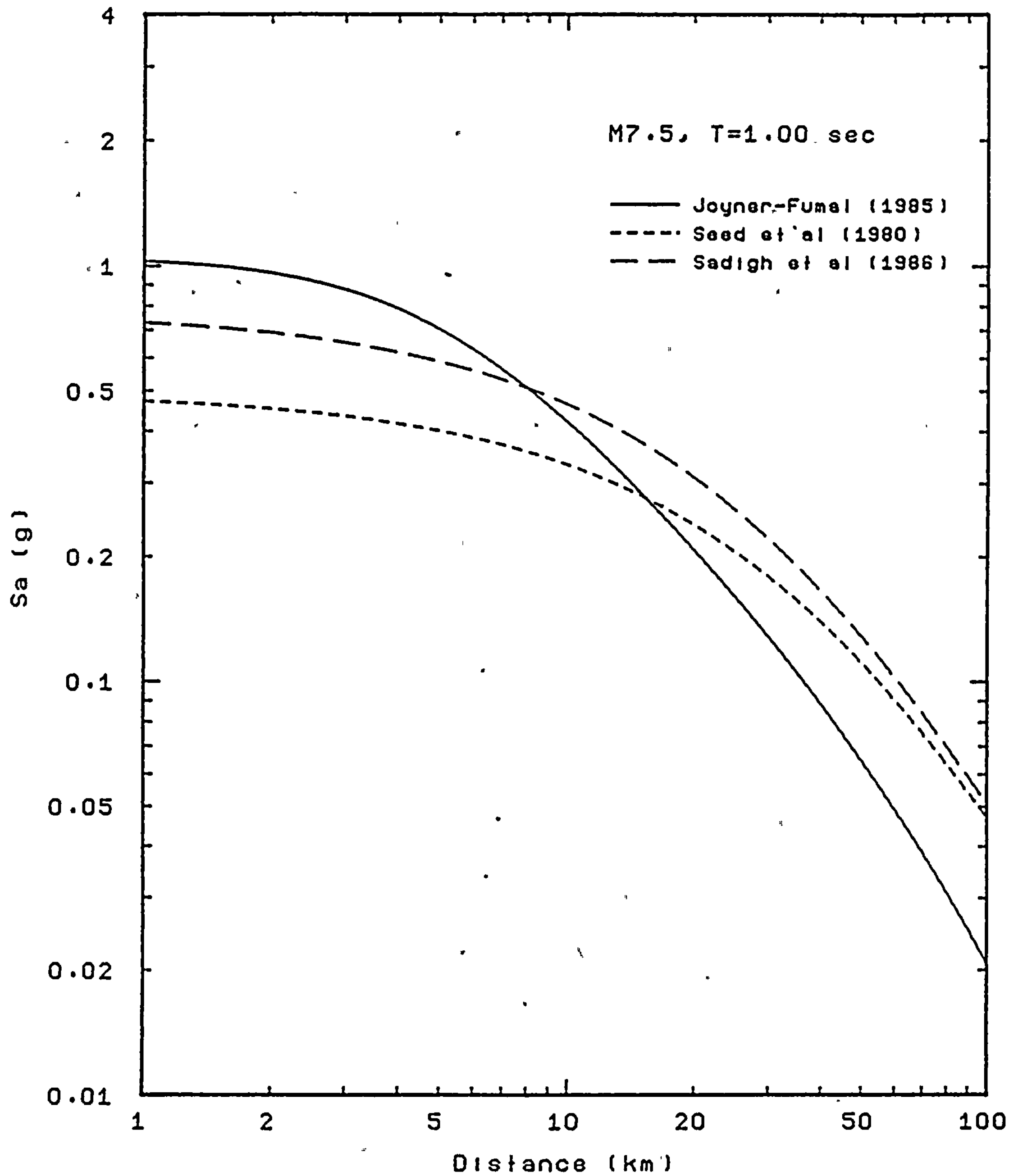
PRELIMINARY
OCT 23 1986



Attenuation Relationship Comparison

PRELIMINARY
OCT 23 1986

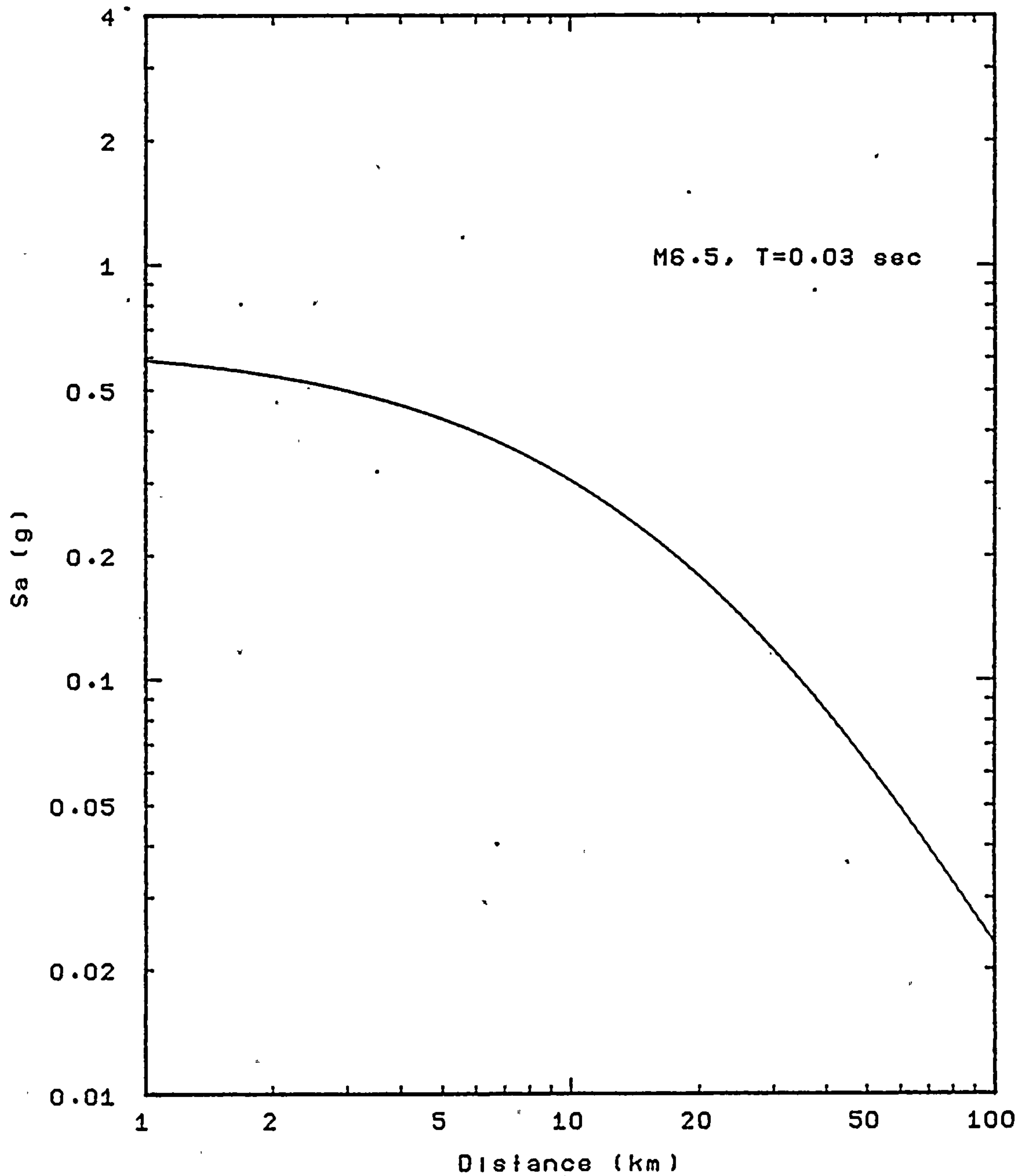
V-18



Attenuation Relationship Comparison

V-19

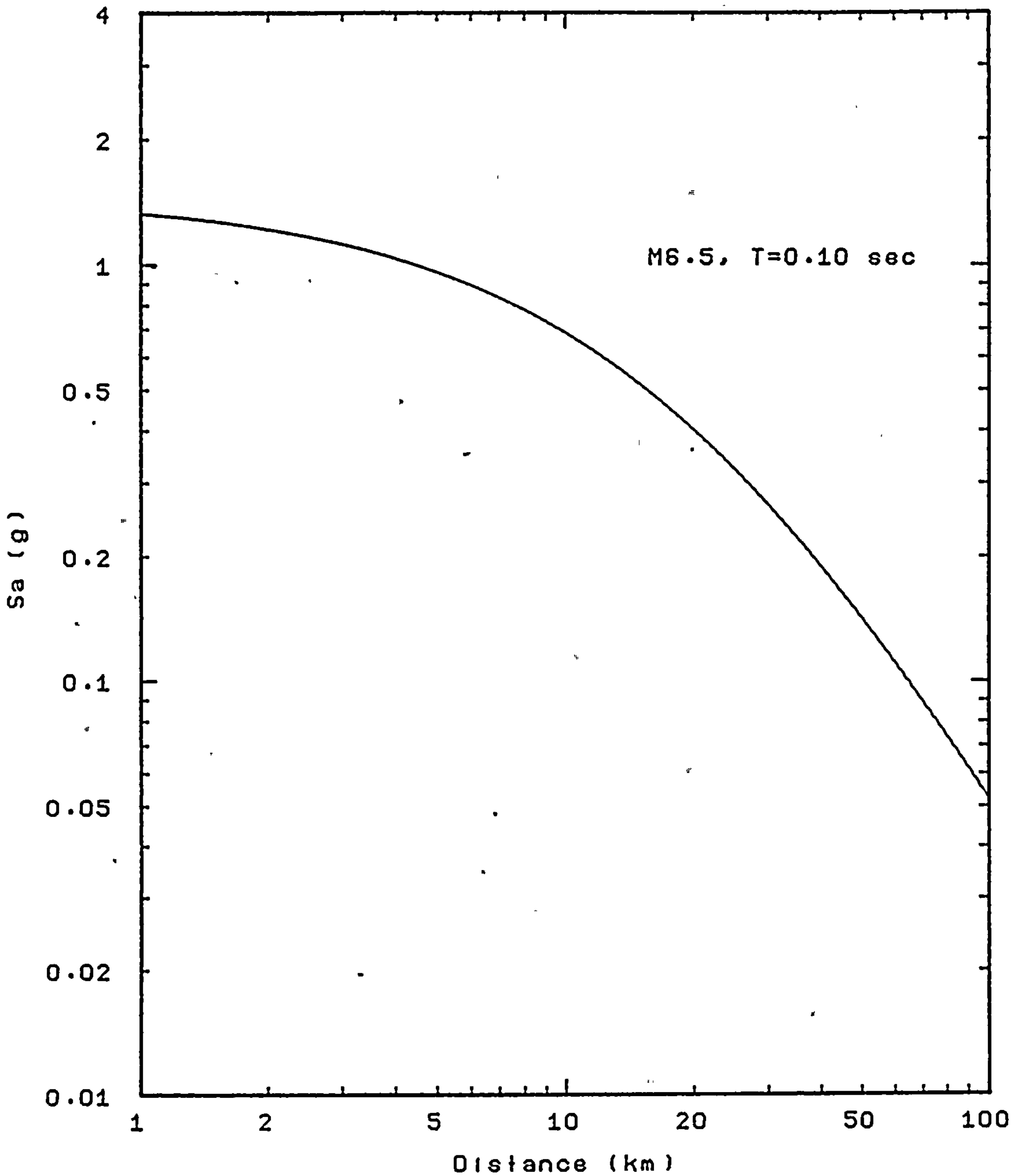
PRELIMINARY
OCT 23 1986



Idriss (1985)

PRELIMINARY
OCT 23 1986

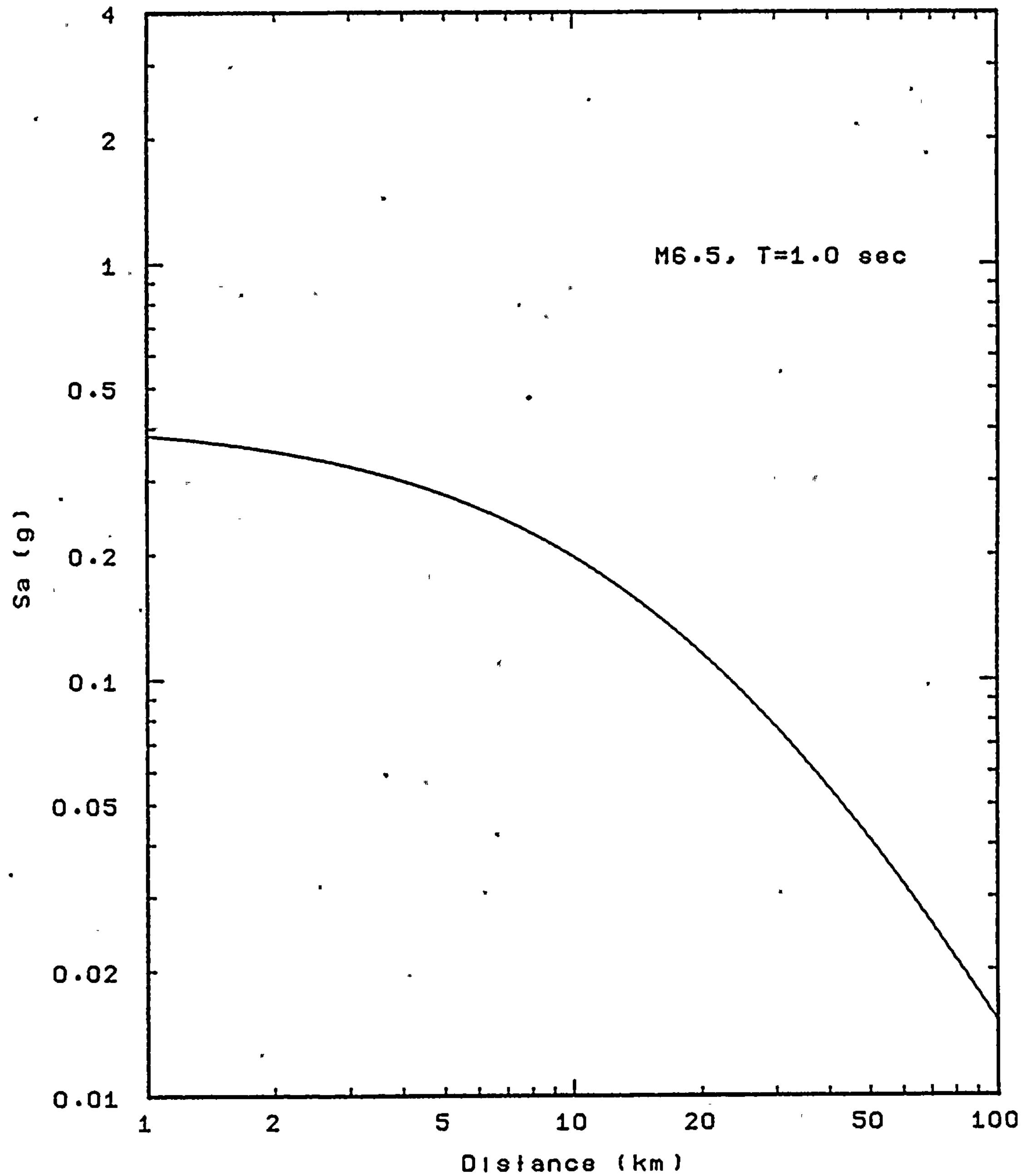
V-20



Idriss (1985)

PRELIMINARY
OCT 23 1986

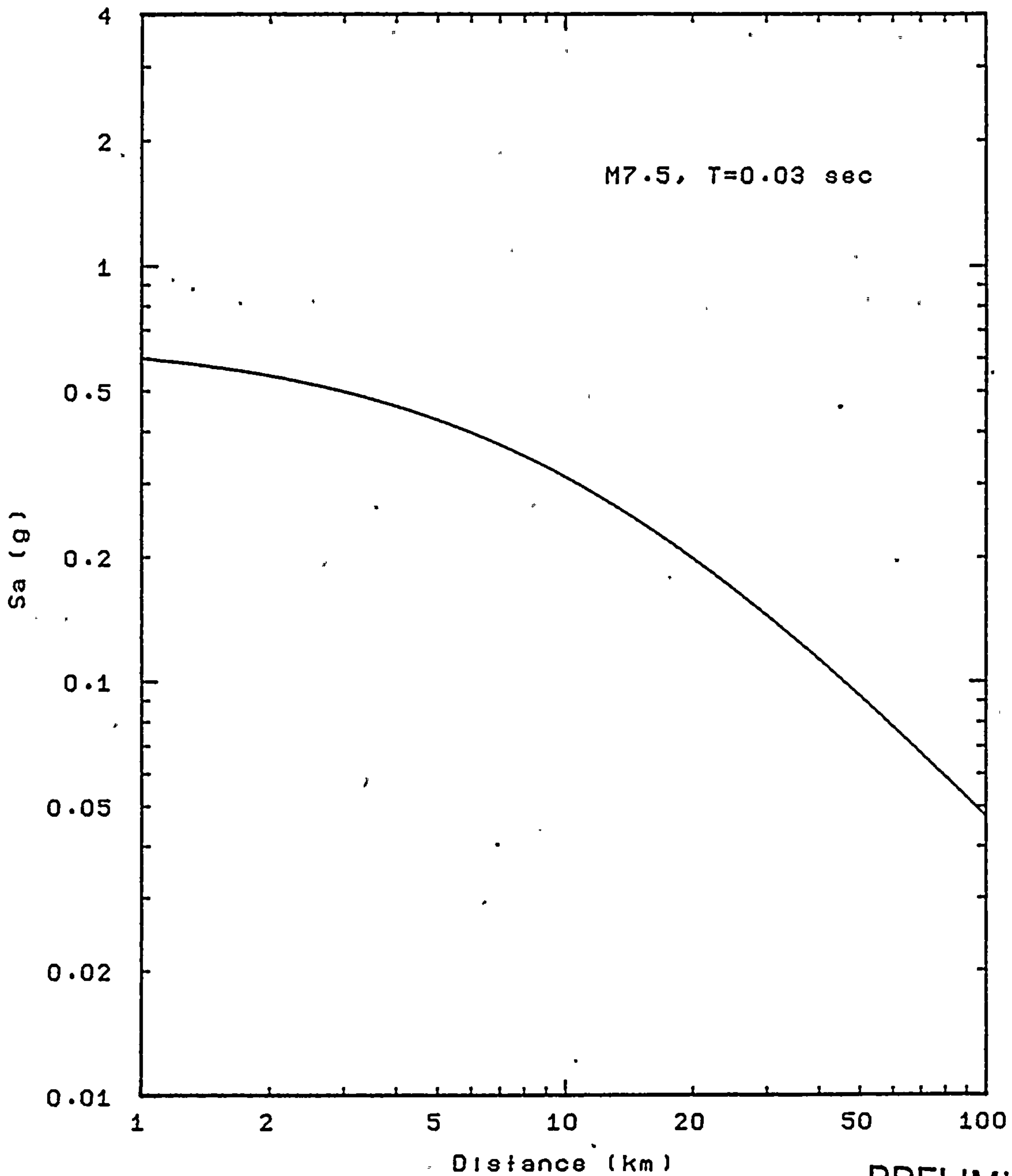
V-21



Idriss (1985)

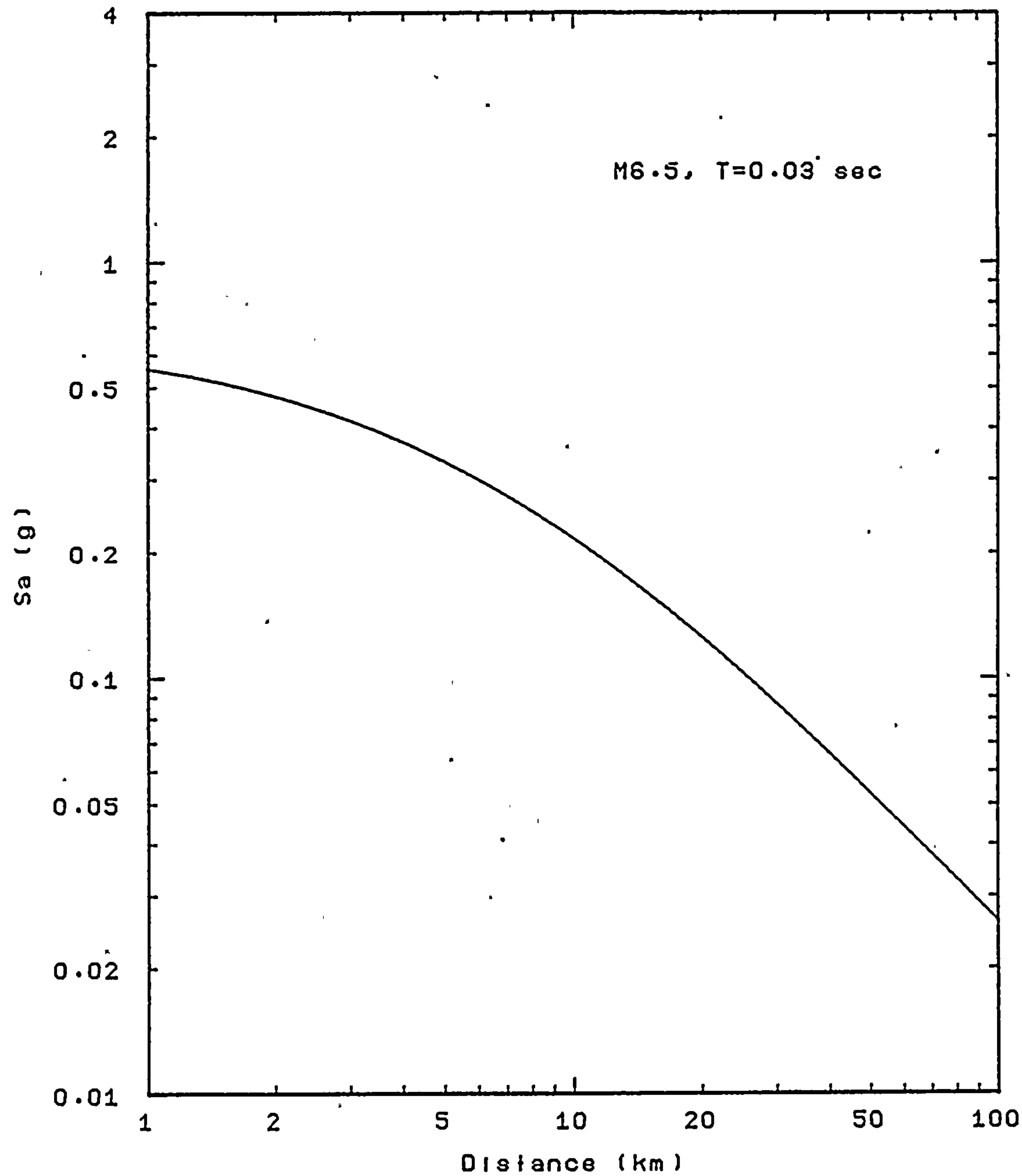
V-22

PRELIMINARY
OCT 23 1986



Campbell (1983)

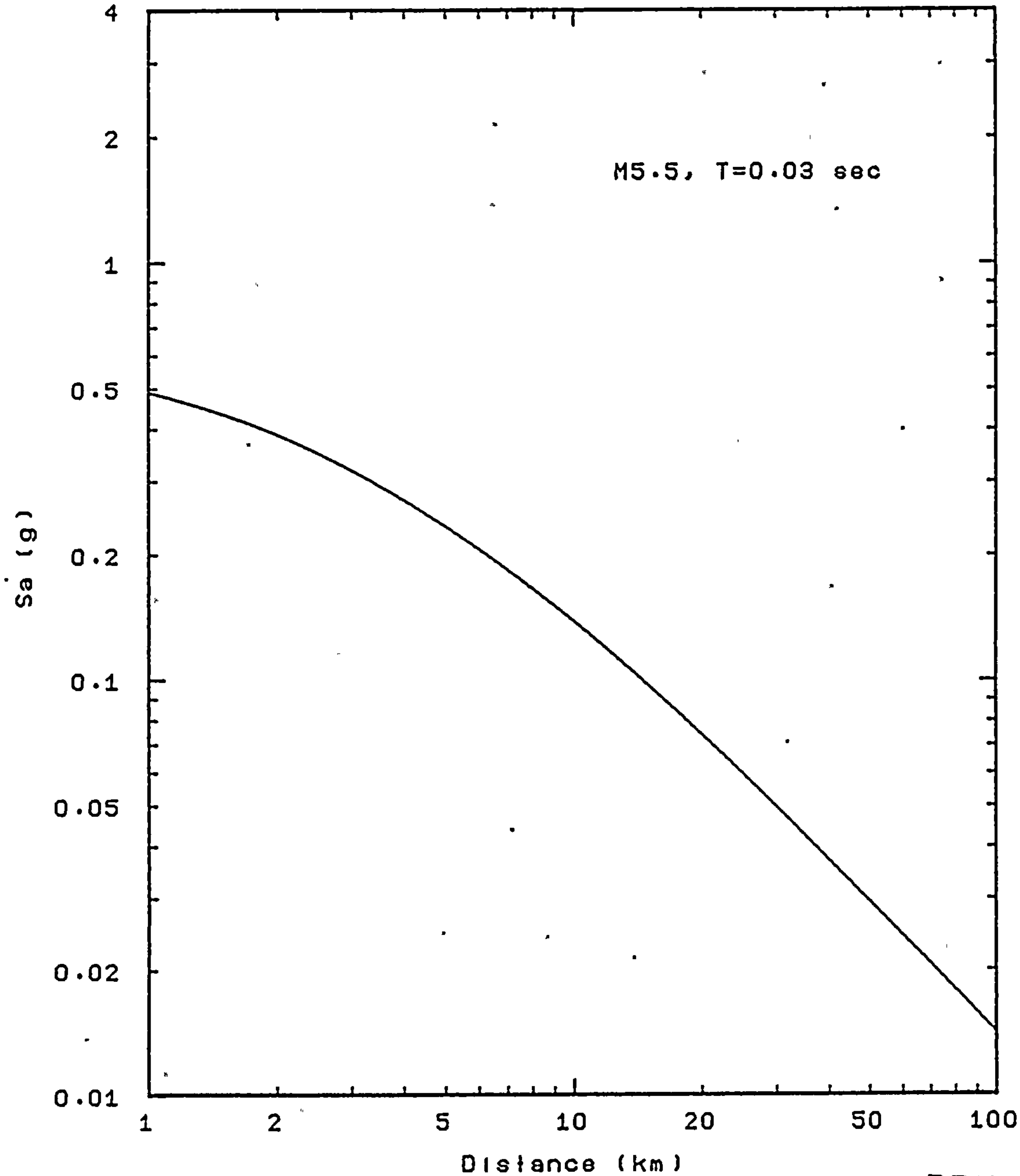
V-23



Campbell (1983)

V-24

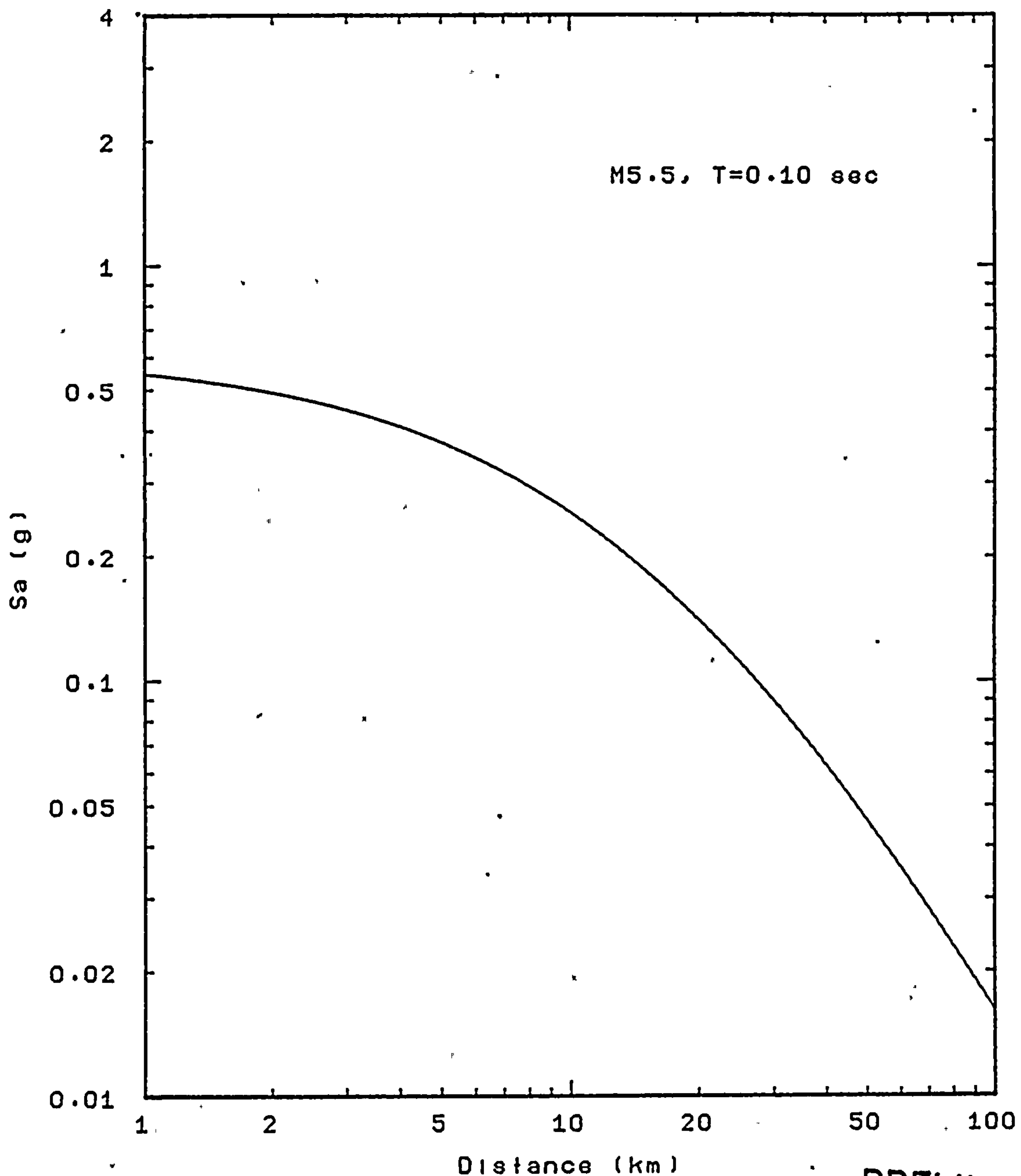
PRELIMINARY
OCT 23 1986



Campbell (1983)

IV-25

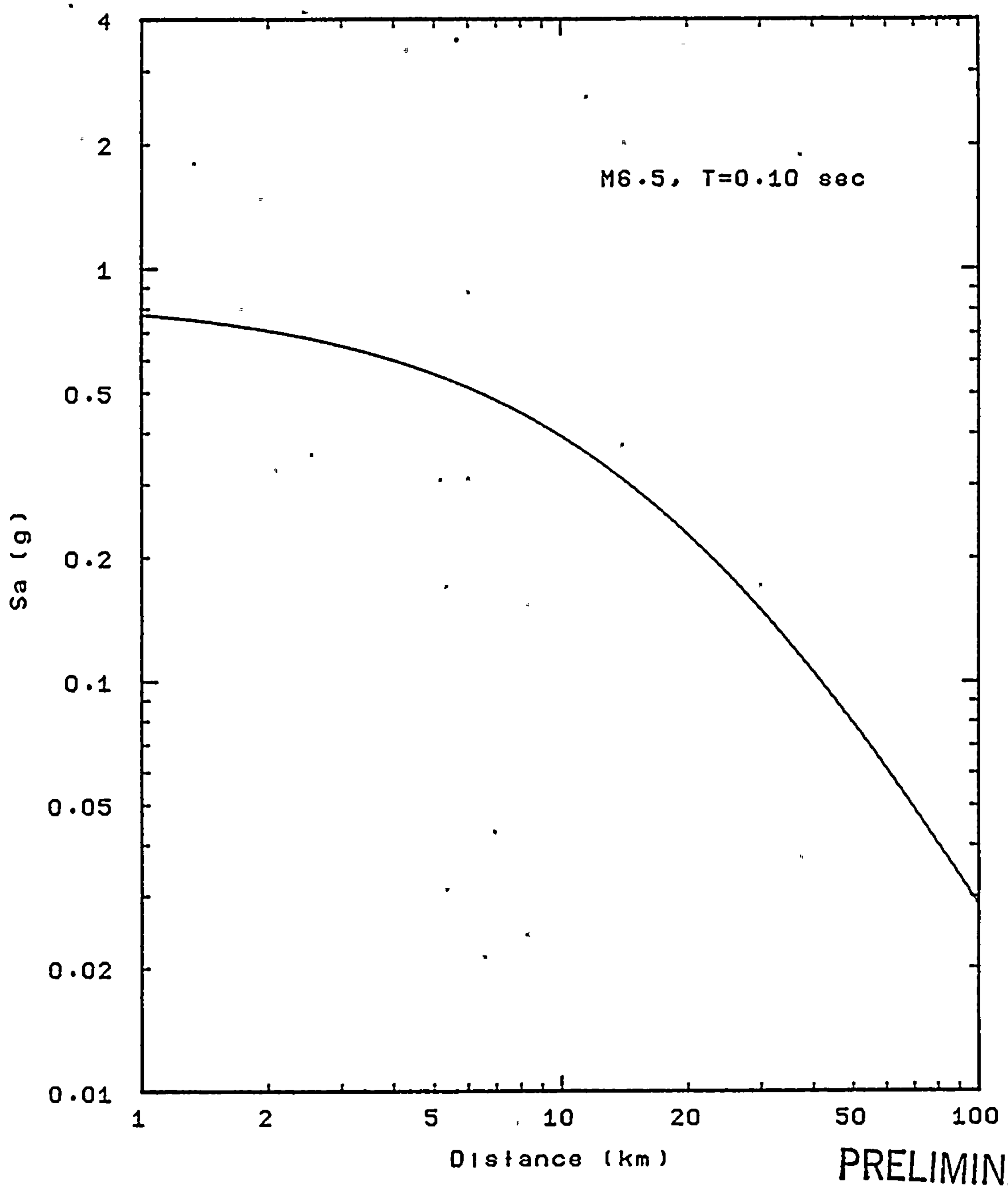
PRELIMINARY
OCT 23 1986



Campbell (1983)

V-26

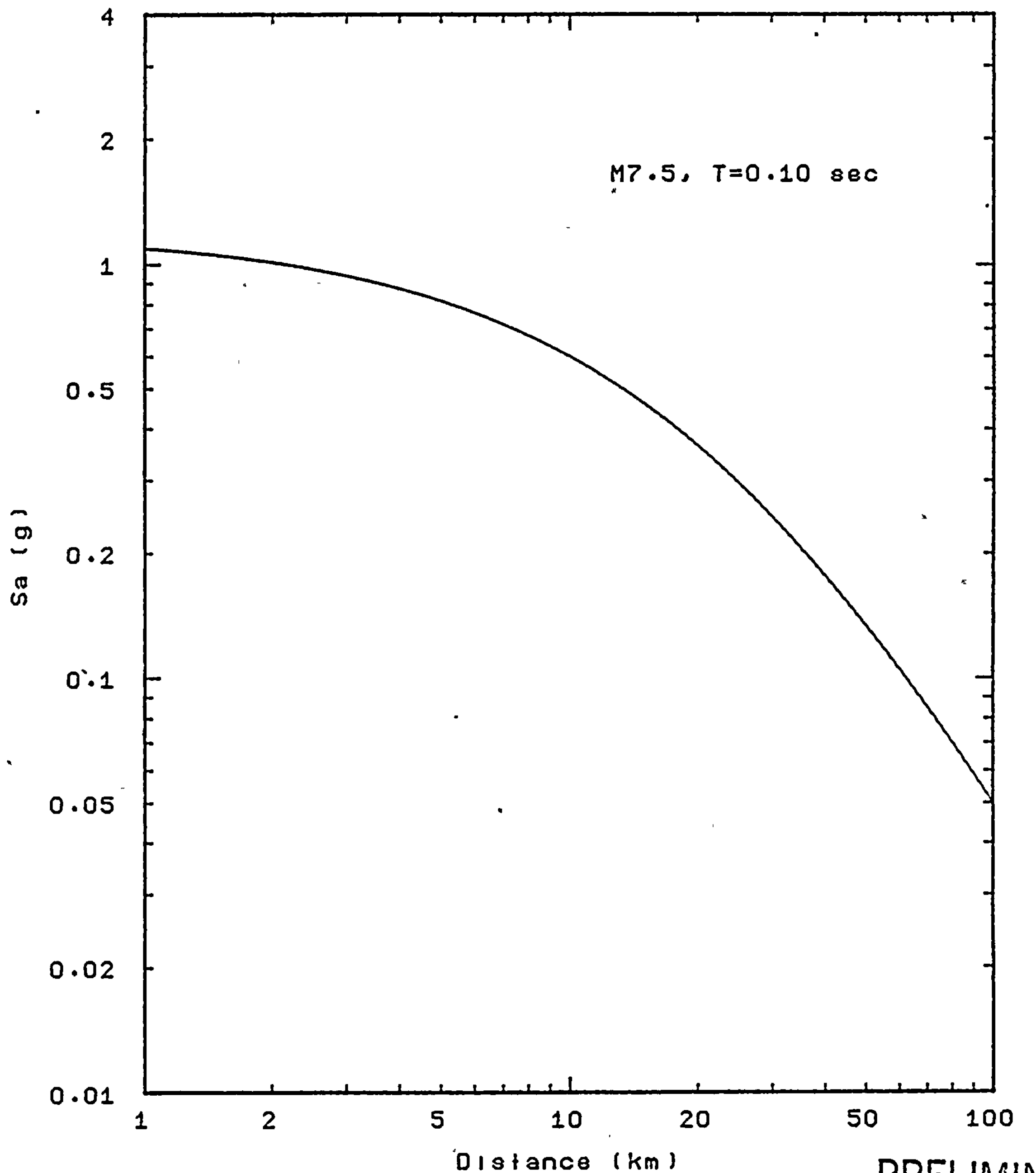
PRELIMINARY
OCT 23 1986



PRELIMINARY
OCT 23 1986

Campbell (1983)

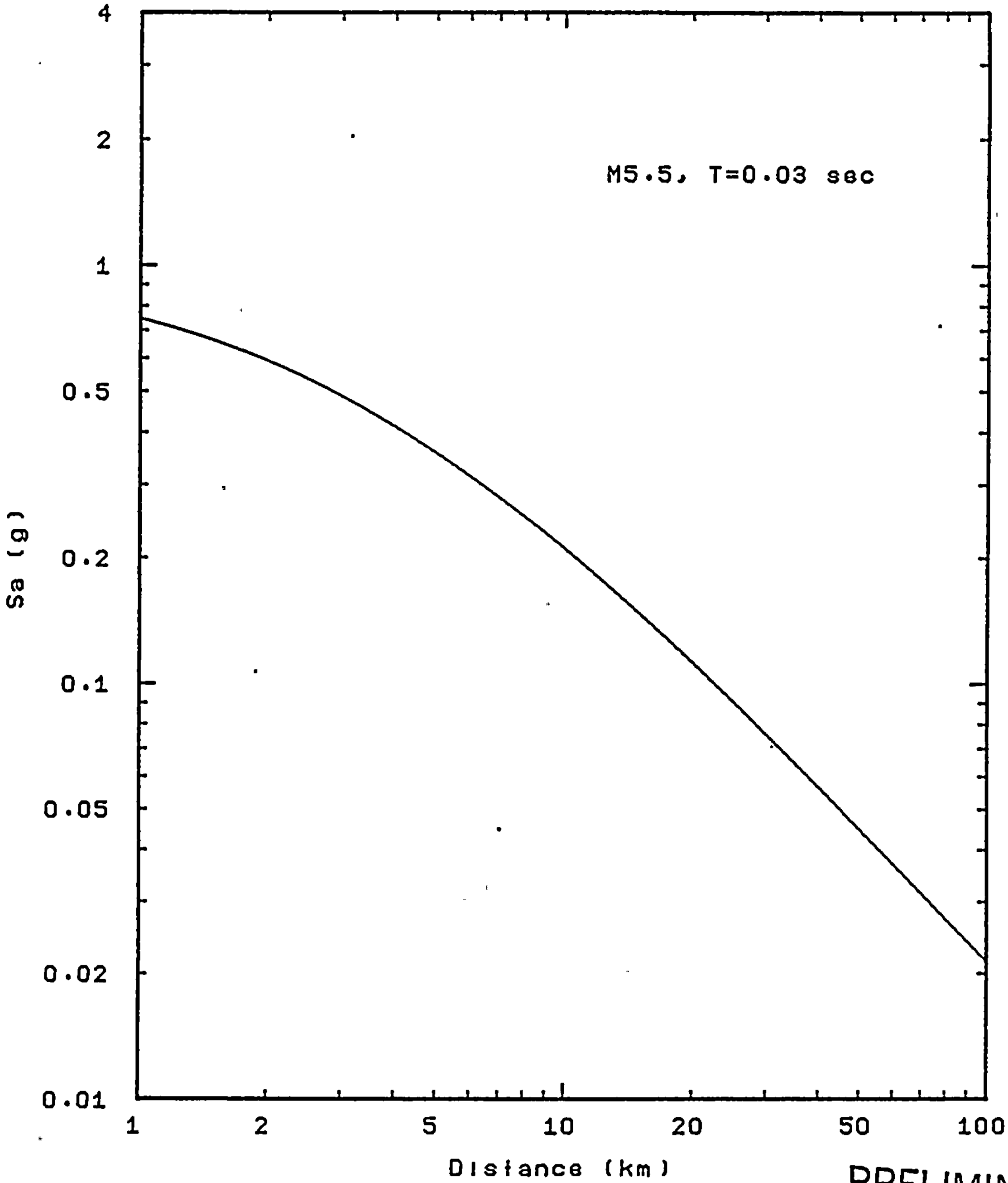
V-27



Campbell (1983)

V-28

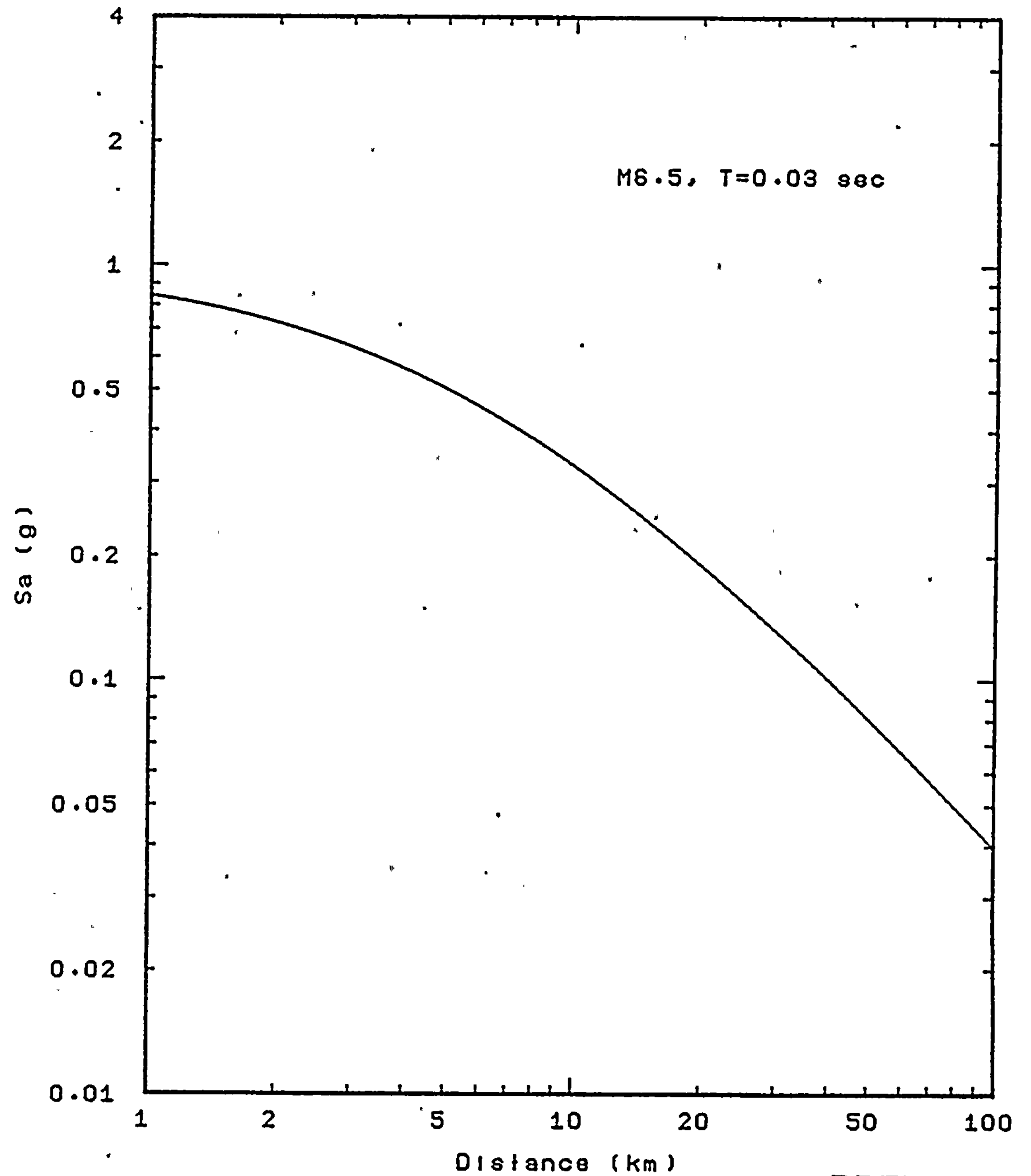
PRELIMINARY
OCT 23 1986



Campbell (R) (1983)

V-29

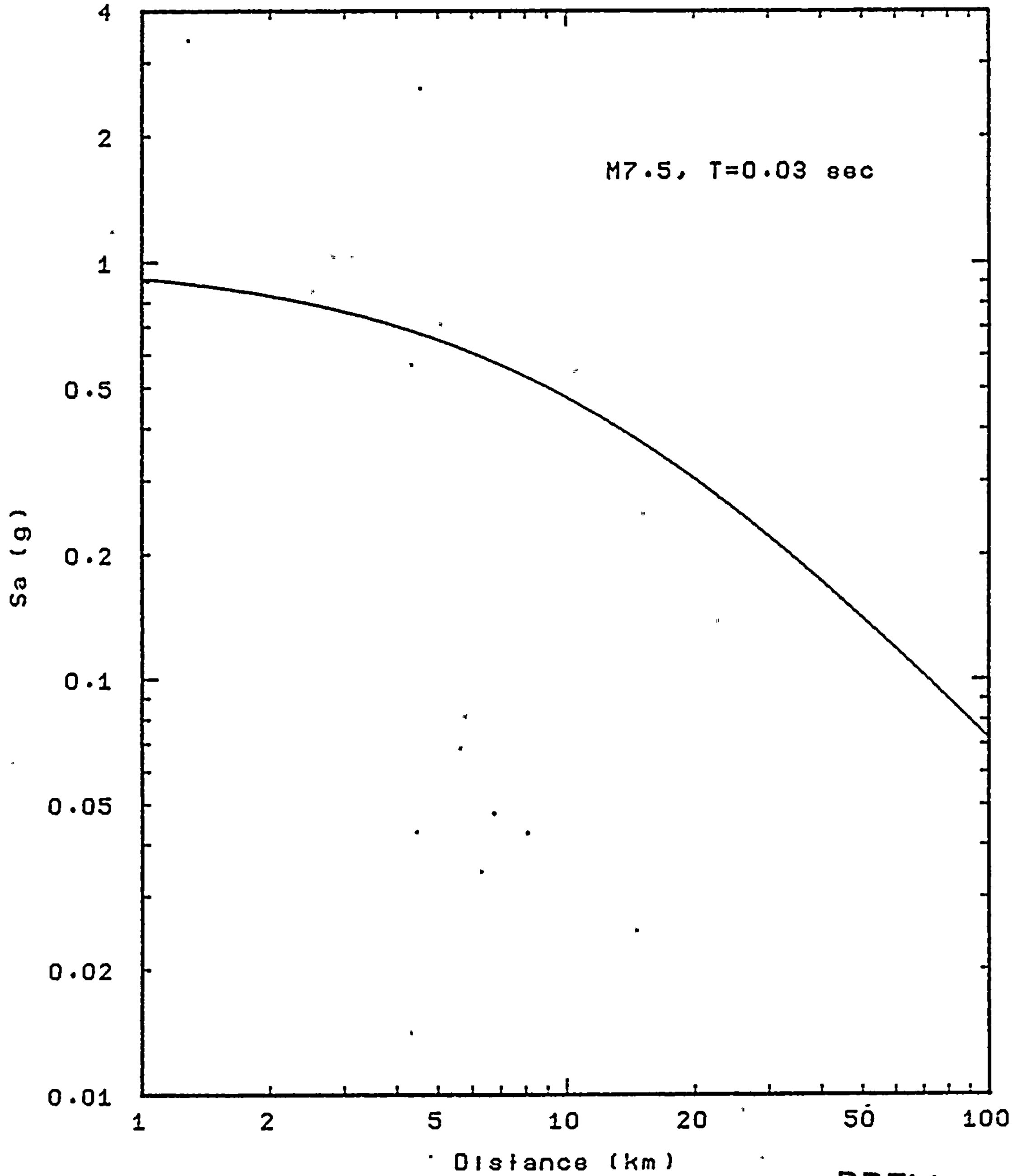
PRELIMINARY
OCT 23 1986



Campbell (R) (1983)

V-30

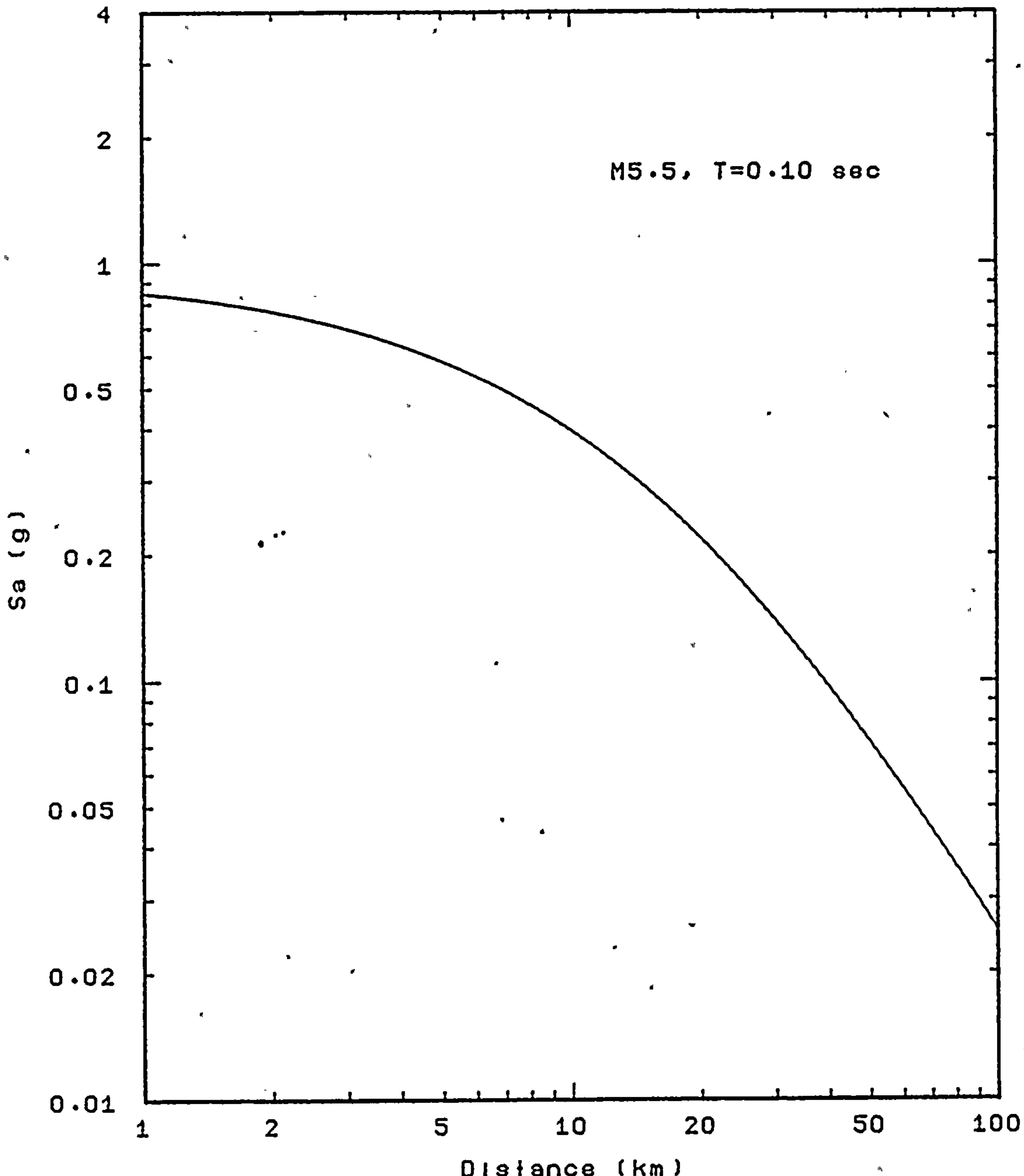
PRELIMINARY
OCT 23 1986



Campbell (R) (1983)

PRELIMINARY
OCT 23 1986

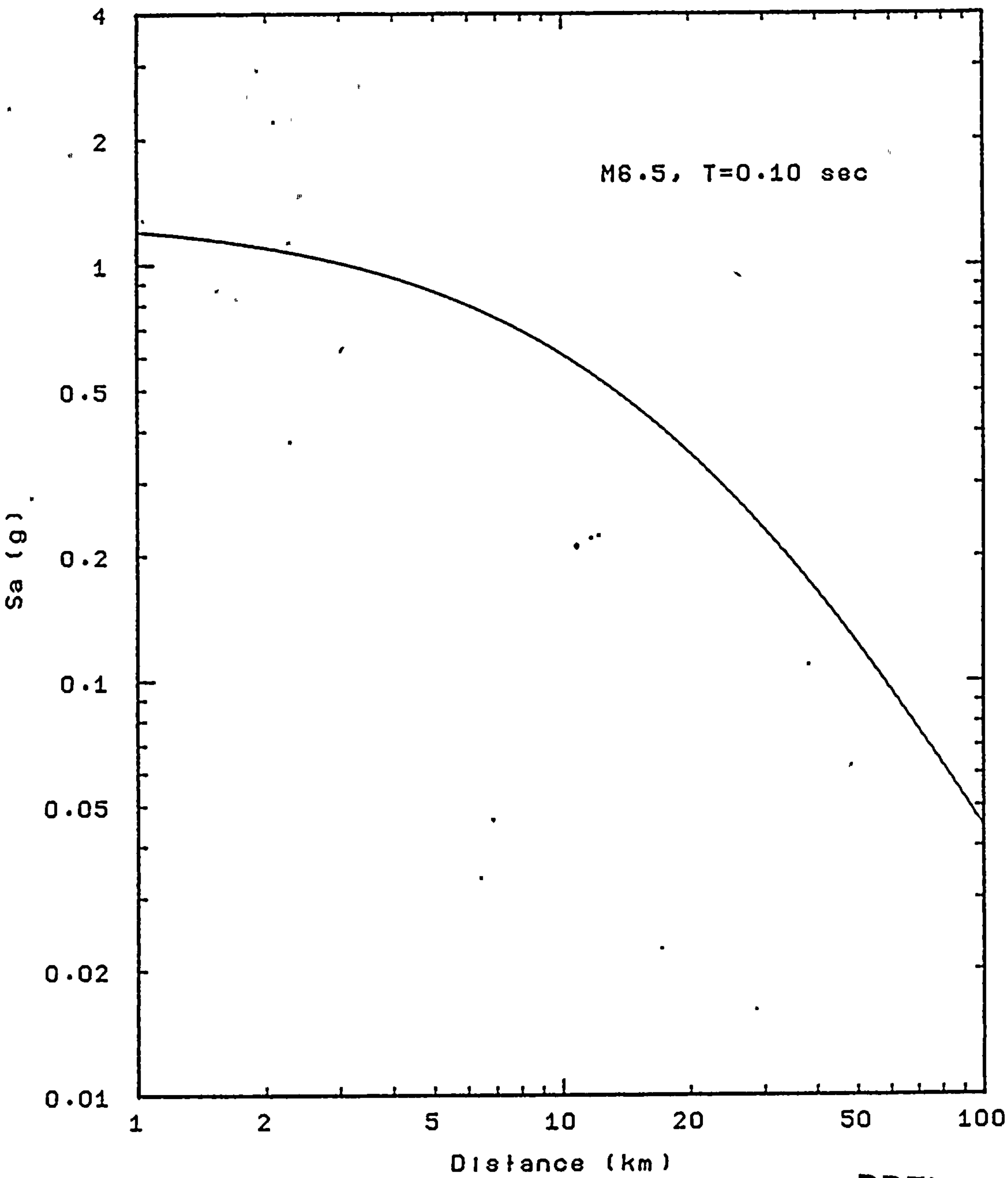
V-31



Campbell (R) (1983)

V-32

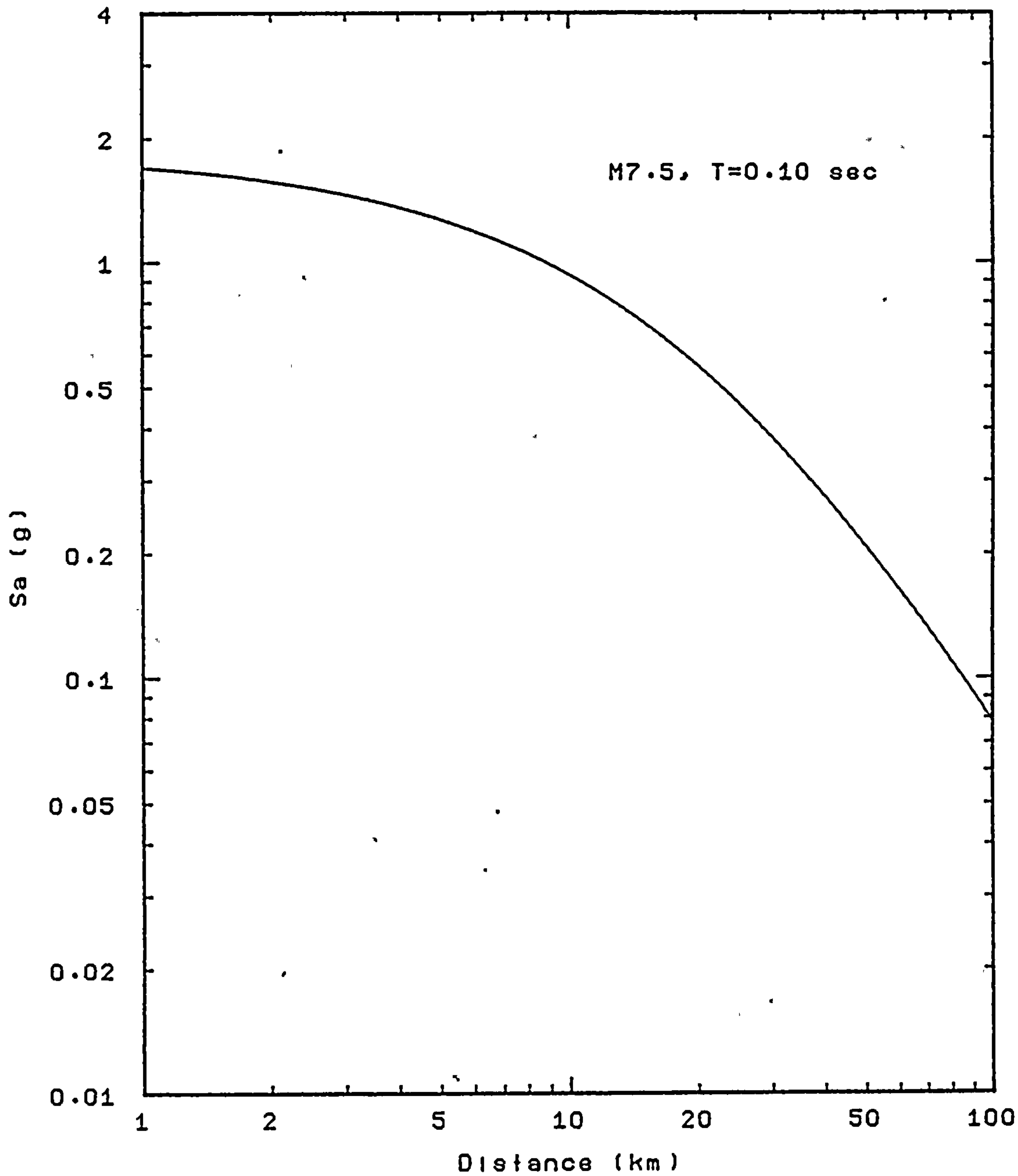
PRELIMINARY
OCT 23 1986



Campbell (R) (1983)

V-33

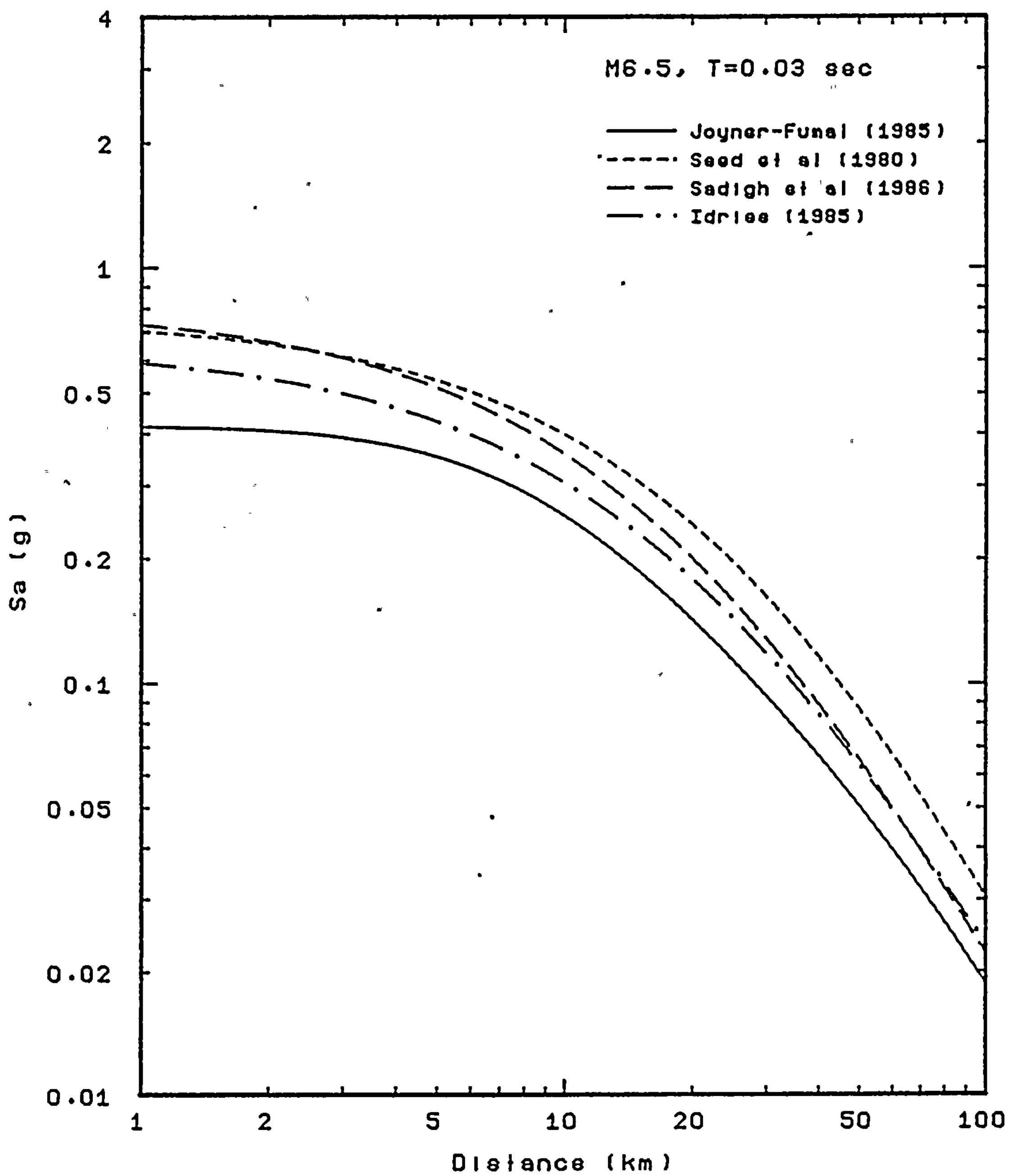
PRELIMINARY
OCT 23 1986



Campbell (R) (1983)

V-34

PRELIMINARY
OCT 23 1986



Attenuation Relationship Comparison

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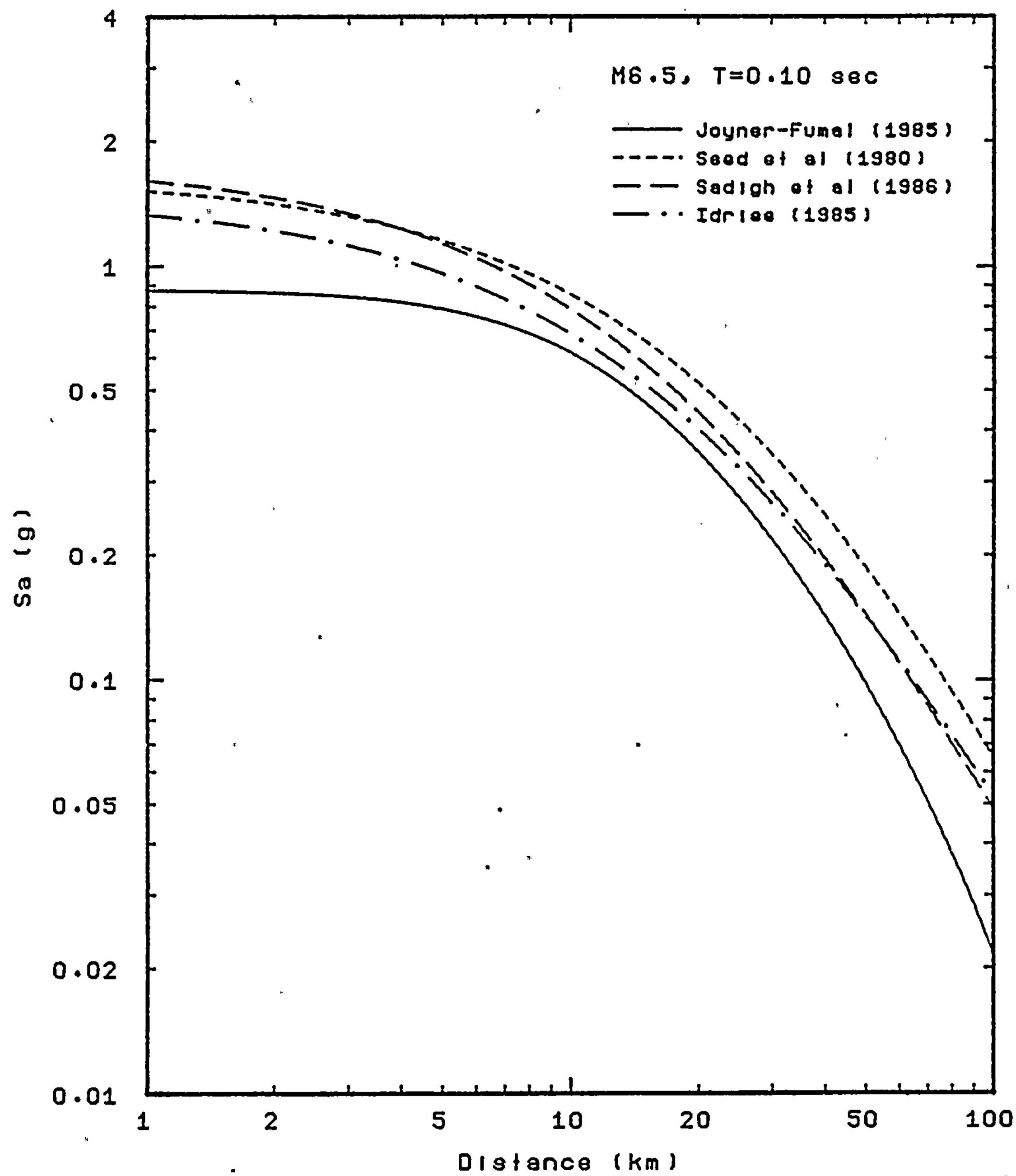
F-V-35



Attenuation Relationship Comparison

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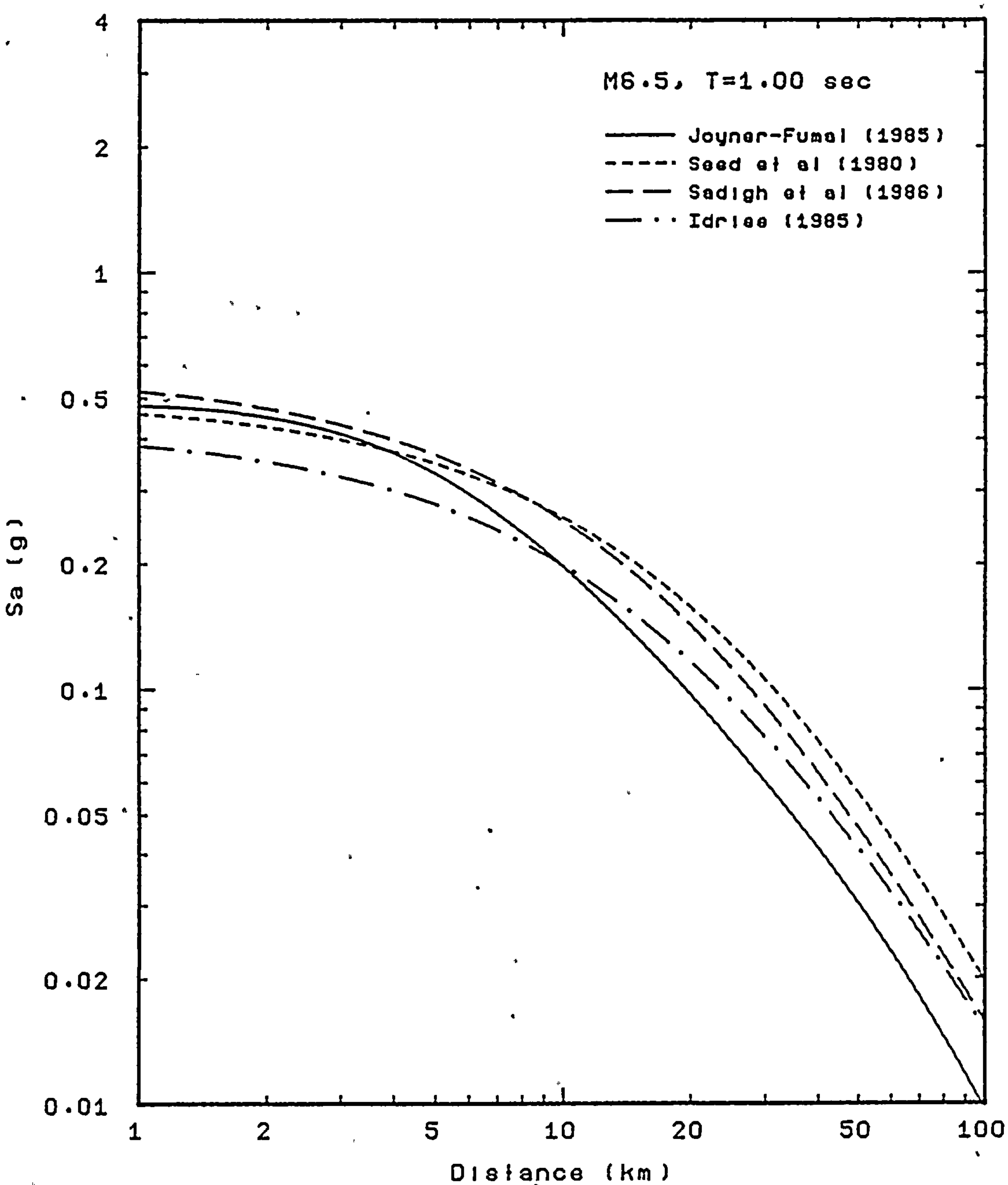
IV-36



Attenuation Relationship Comparison

PRELIMINARY
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V-37

GROUND-MOTIONS INPUT TO PHASE IIIB STUDIES

SCHEDULE REQUIREMENTS AND APPROACHES

DATE	APPLICATION	GROUND-MOTIONS PRODUCTS	APPROACHES
FEBRUARY 1987	SSI ANALYSIS	REFINED TIME HISTORIES	EMPIRICAL & NUMERICAL
		REFINED WAVE CHARACTERISTICS	NUMERICAL & EMPIRICAL
		SPATIAL COHERENCY	SITE RECORDS & NUMERICAL
MAY 1987	SEISMIC HAZARD ANALYSIS	REFINED RESPONSE SPECTRA	EMPIRICAL & NUMERICAL

YBT:hw
10/13/86

PG&E Diablo Canyon Power Plant
Long Term Seismic Program (LTSP)

Empirical Ground Motion Study

Input to Phase IIIB Studies
Work in Progress

EXAMINATION OF APPARENT SEISMIC WAVE INCIDENCE DIRECTION

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VII-1

EMPIRICAL GROUND MOTION STUDY

EVALUATION OF APPROXIMATE INCIDENCE ANGLES FOR SOIL-STRUCTURE INTERACTION ANALYSES

- Estimate direction of original earthquake fault rupture strike

- Rotate horizontal components at recording station into directions normal (longitudinal) and parallel (transverse) to fault rupture strike

- calculate the resultant component of the rotated motions in the vertical-longitudinal plane. and the instantaneous approximate incidence angle

- Estimate the approximate predominant incidence angle for motions in the vertical-longitudinal plane

- Estimate the median incidence angle and its range of variation for eight selected records

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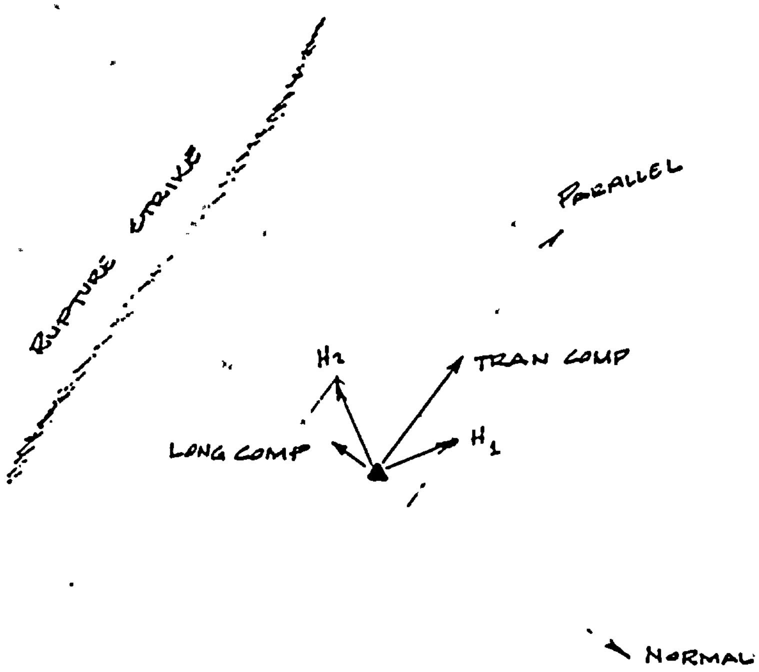
RESOLUTION OF HORIZONTAL COMPONENTS OF RECORDING STATION ALONG DIRECTIONS NORMAL AND PARALLEL TO FAULT RUPTURE STRIKE



LONG = component rotated along direction normal to fault strike.

TRAN = component rotated along direction parallel to fault strike.

PRELIMINARY
OCT 23 1986

TABLE 2: ROTATION OF HORIZONTAL COMPONENTS ALONG DIRECTION NORMAL AND PARALLEL TO ORIGINAL EARTHQUAKE FAULT STRIKE

Record	Direction of Normal (Longitudinal) Component (clockwise from north)
Gazli	10°
Tabas*	74°
Dayhook	49°
Pacoima	180°
El Centro No. 4	50°
Diff Array	230°
P.V. Pump STN	24°

*Record received with components already along radial (longitudinal) and tangential (transverse) directions of motion

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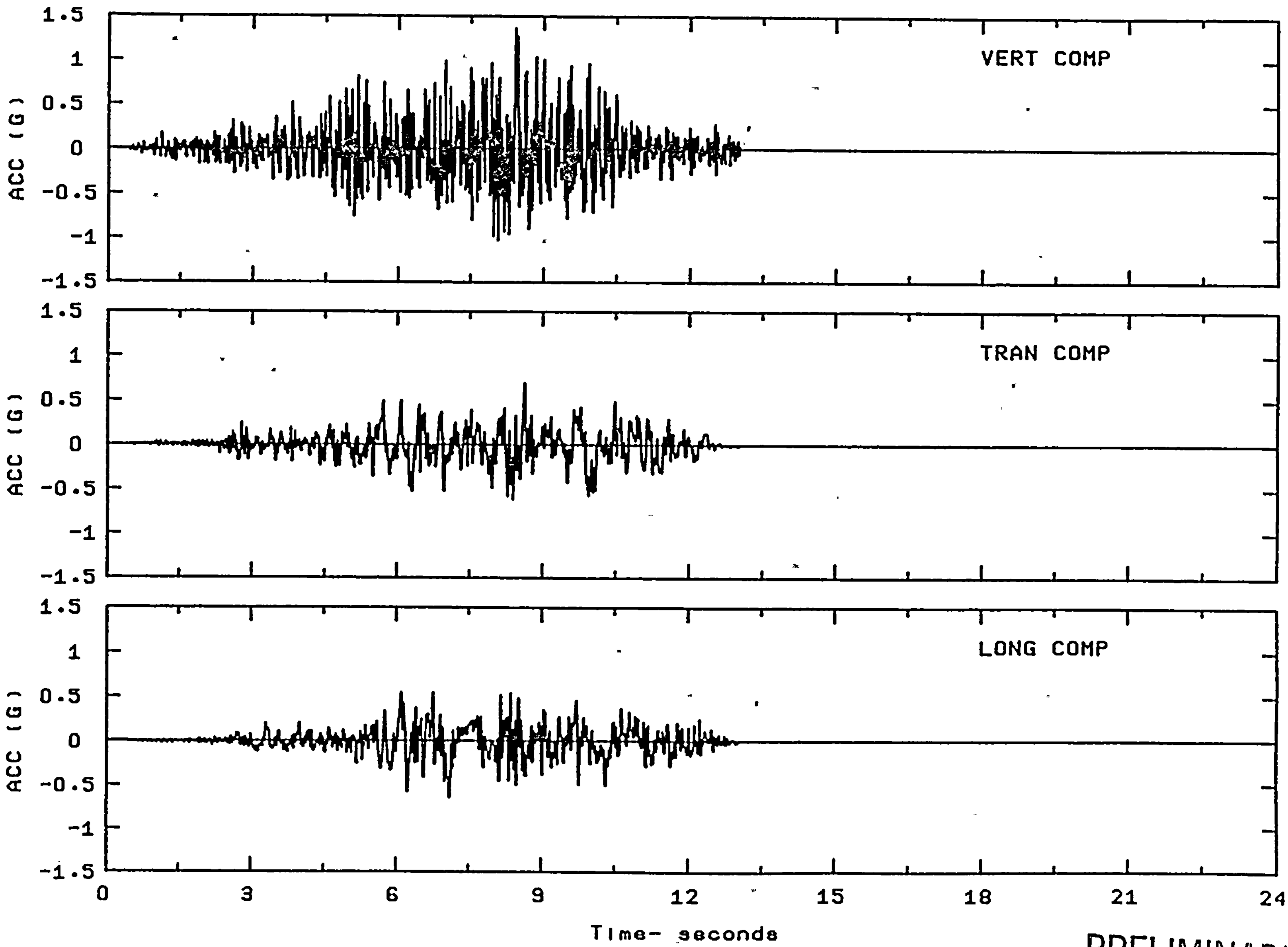
S-IIIA



GAZLI LONG AND TRAN COMP

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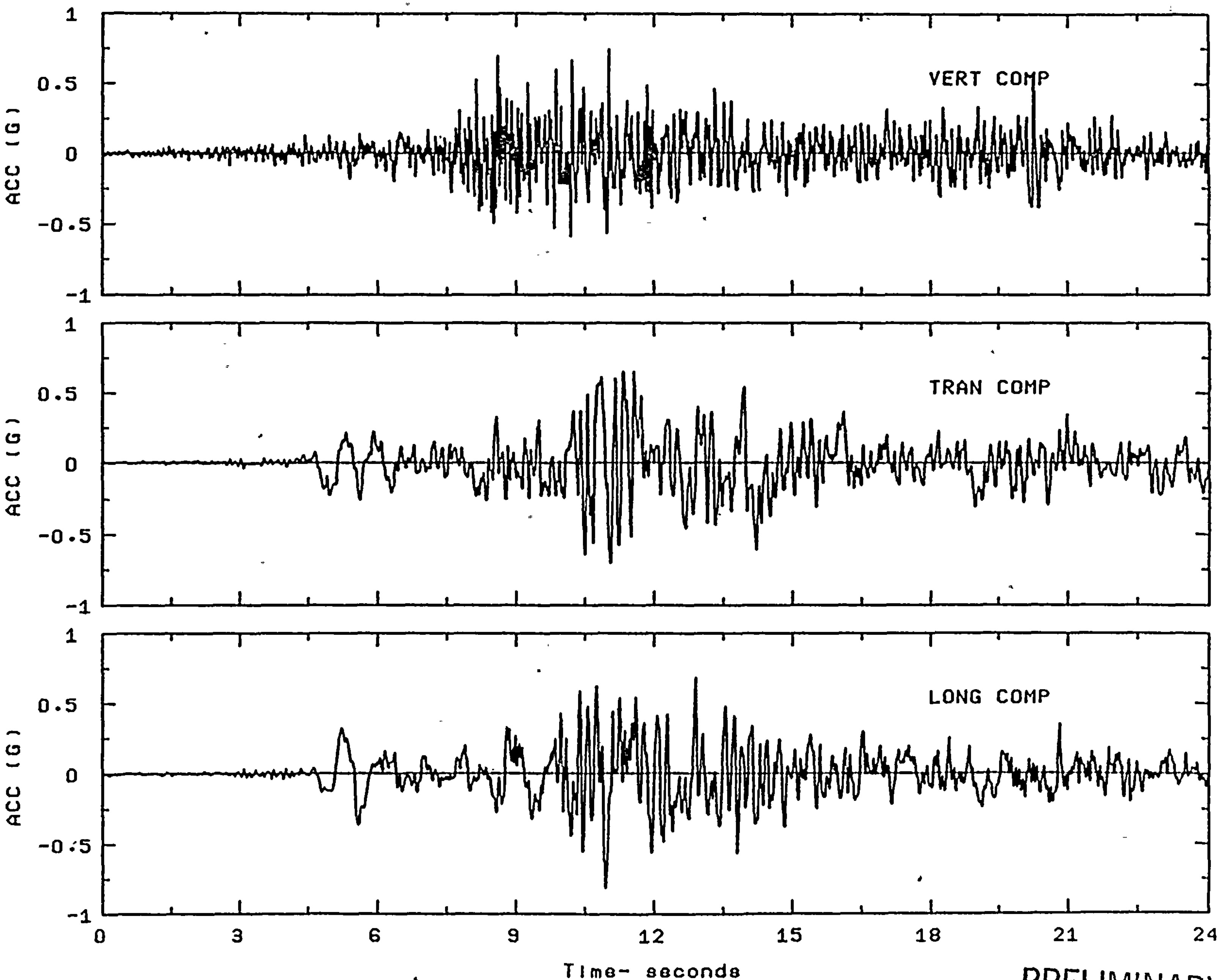
9-III



TABAS (THREE COMP)

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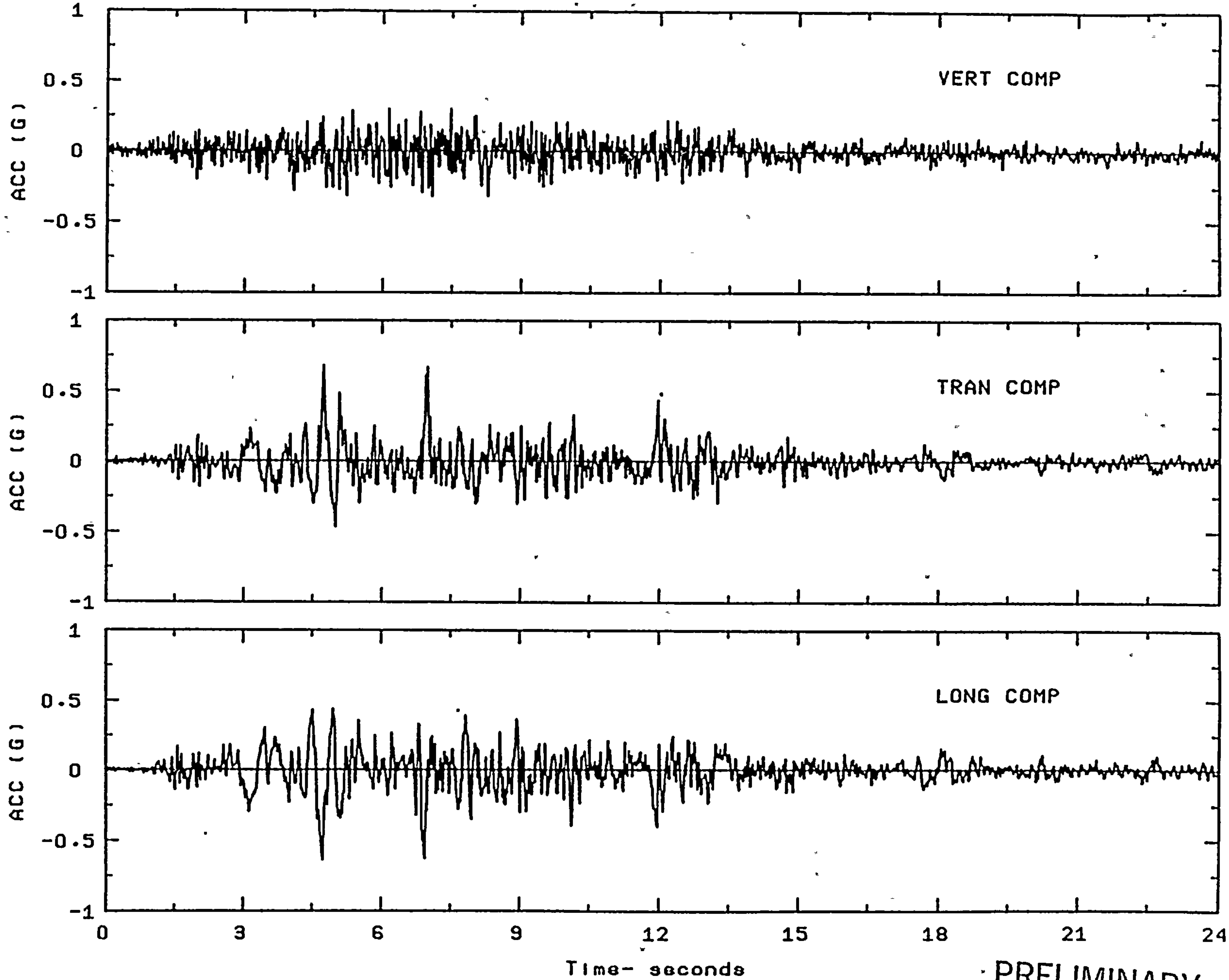
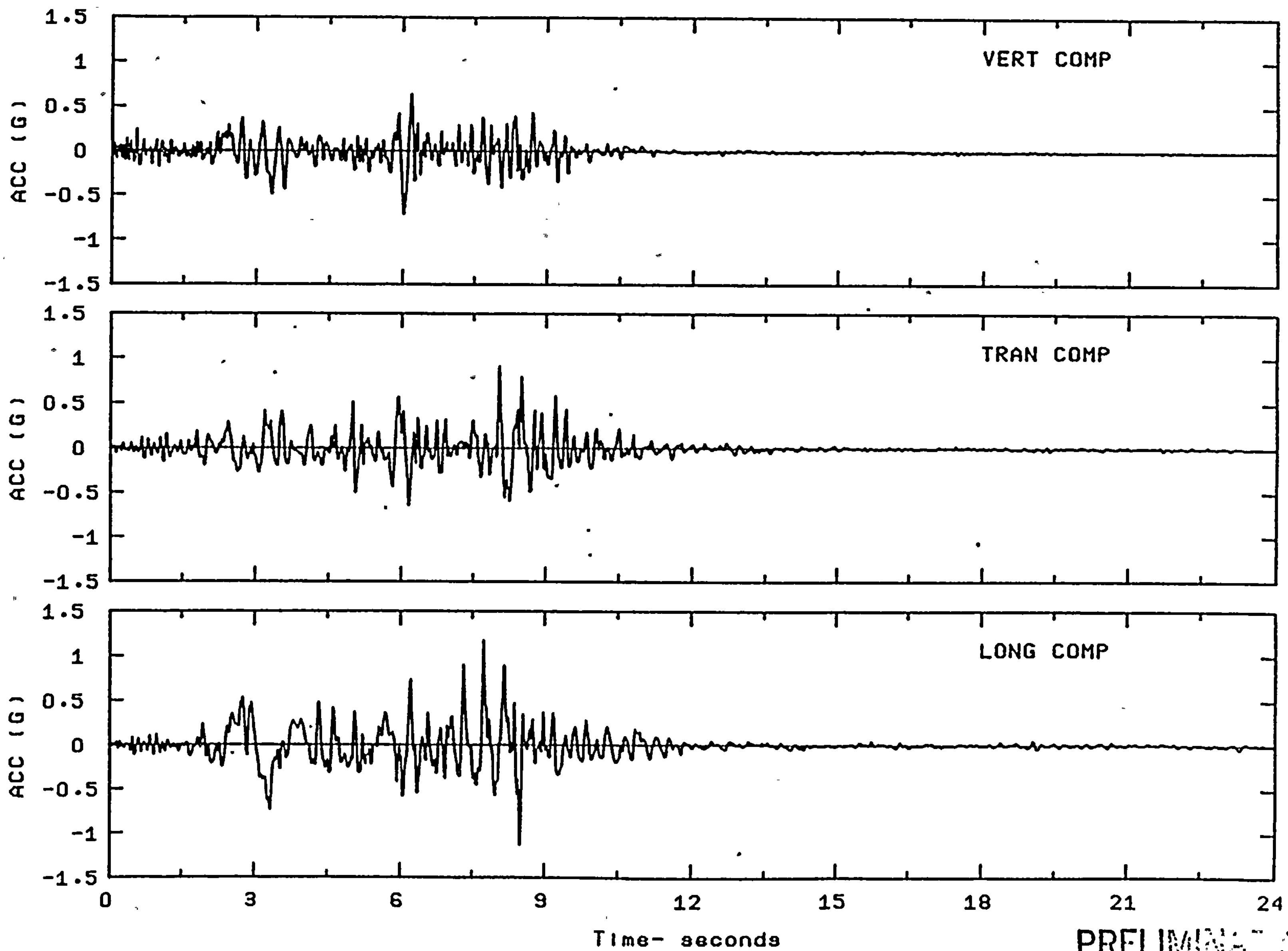
L-III



dayhook(THREE COMP)

PRELIMINARY
OCT 23 1986

8-III



PACOIMA (THREE COMP)

PRELIMINA
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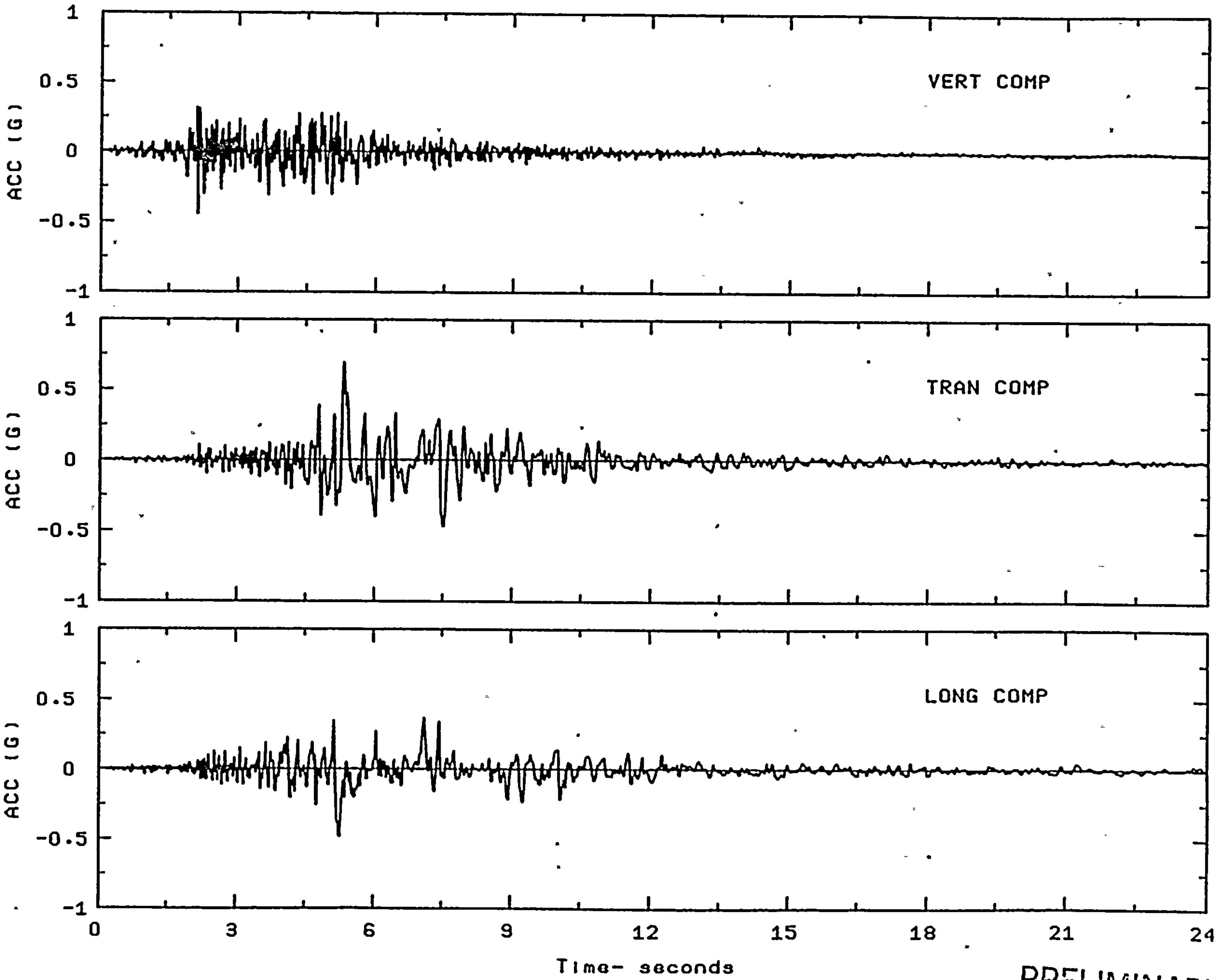
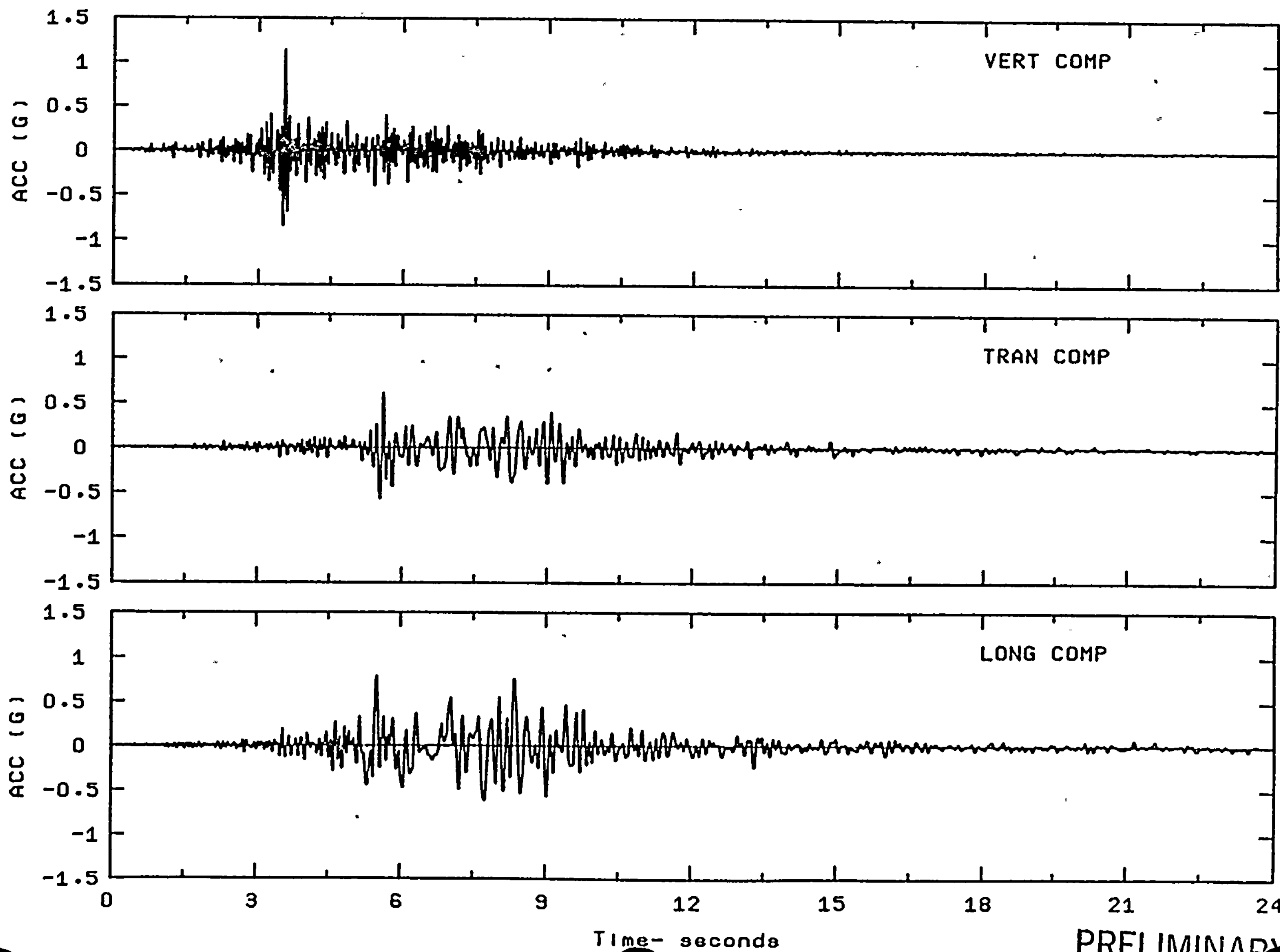
6-III



IMP V EC NO 4 (THREE COMP)

PRELIMINARY
OCT 23 1986

III-10



IMP V DIFF ARRAY (THREE COMP)

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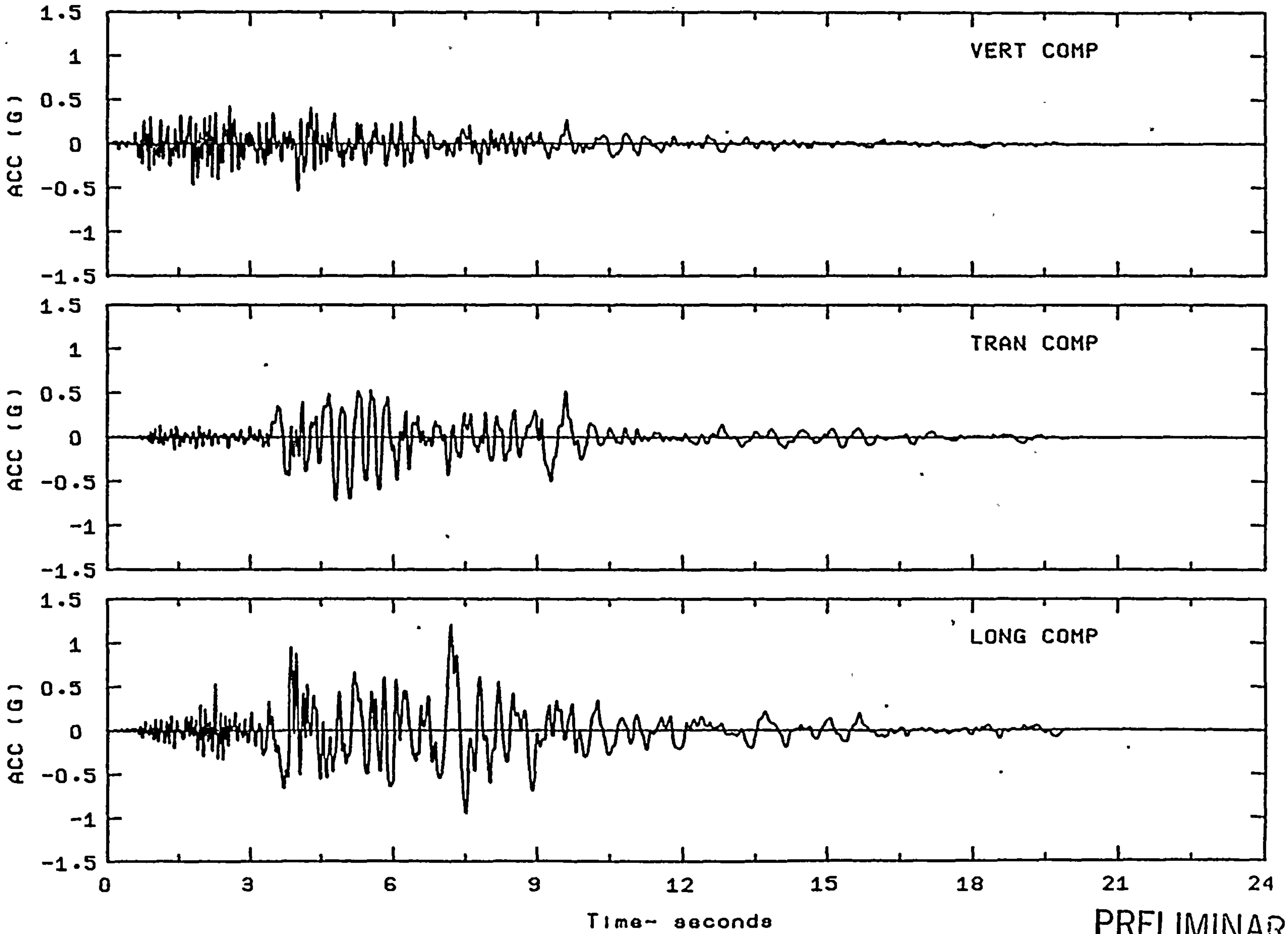
II-III



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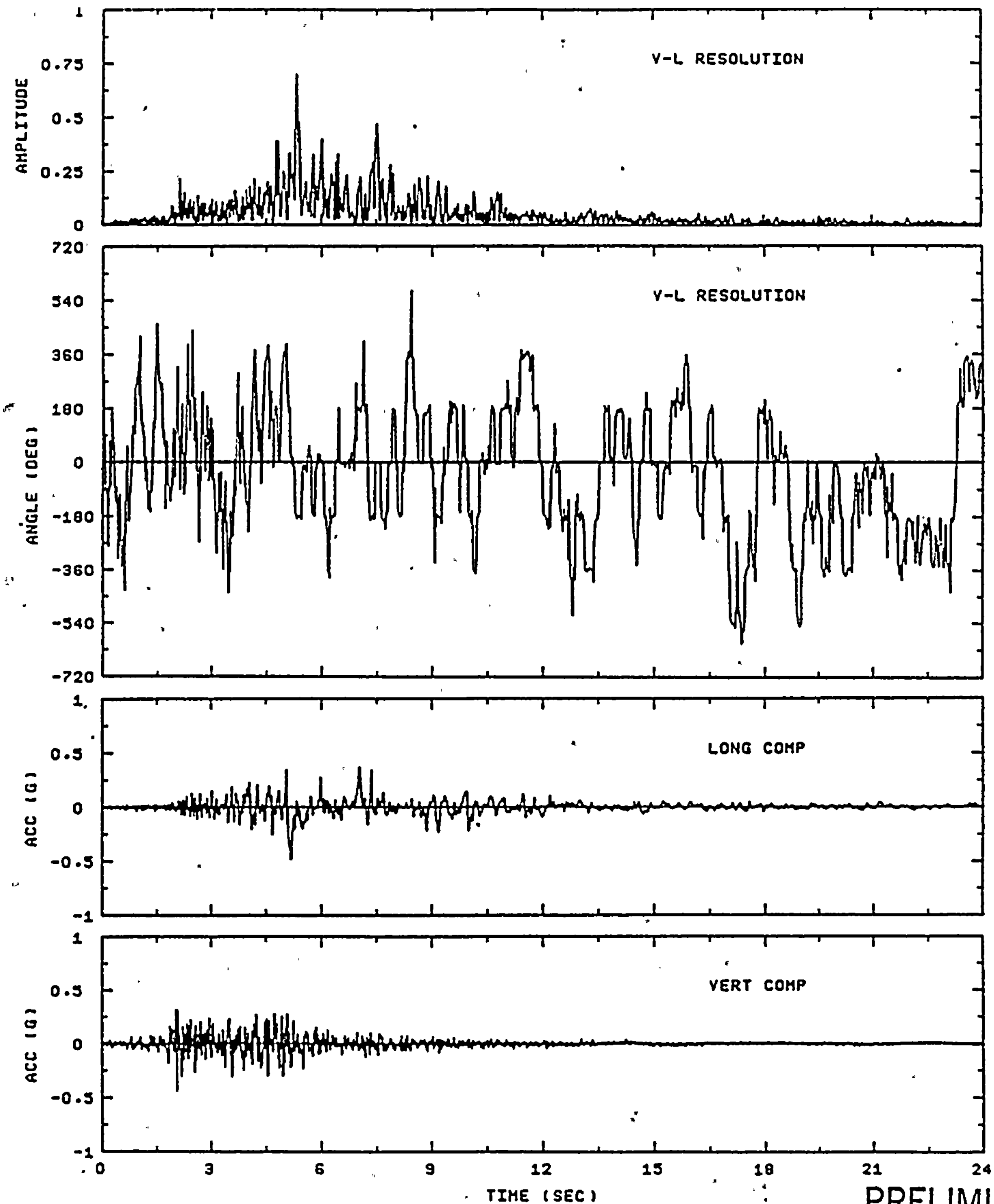
COALINGA PL V PUMP STN (THREE COMP)



IV EC4 VERT LONG (Acc)

VII-12

PRELIMINARY
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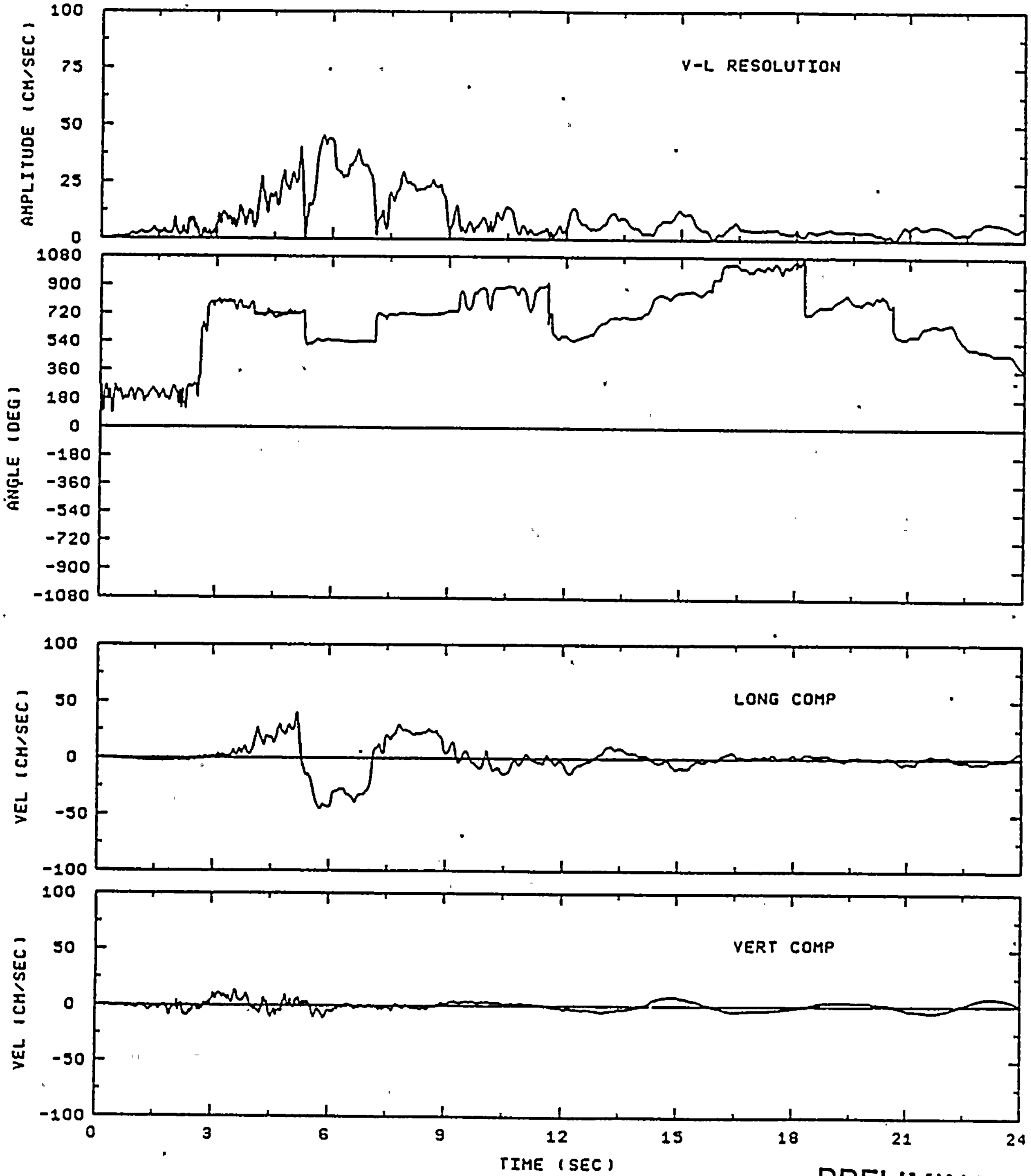
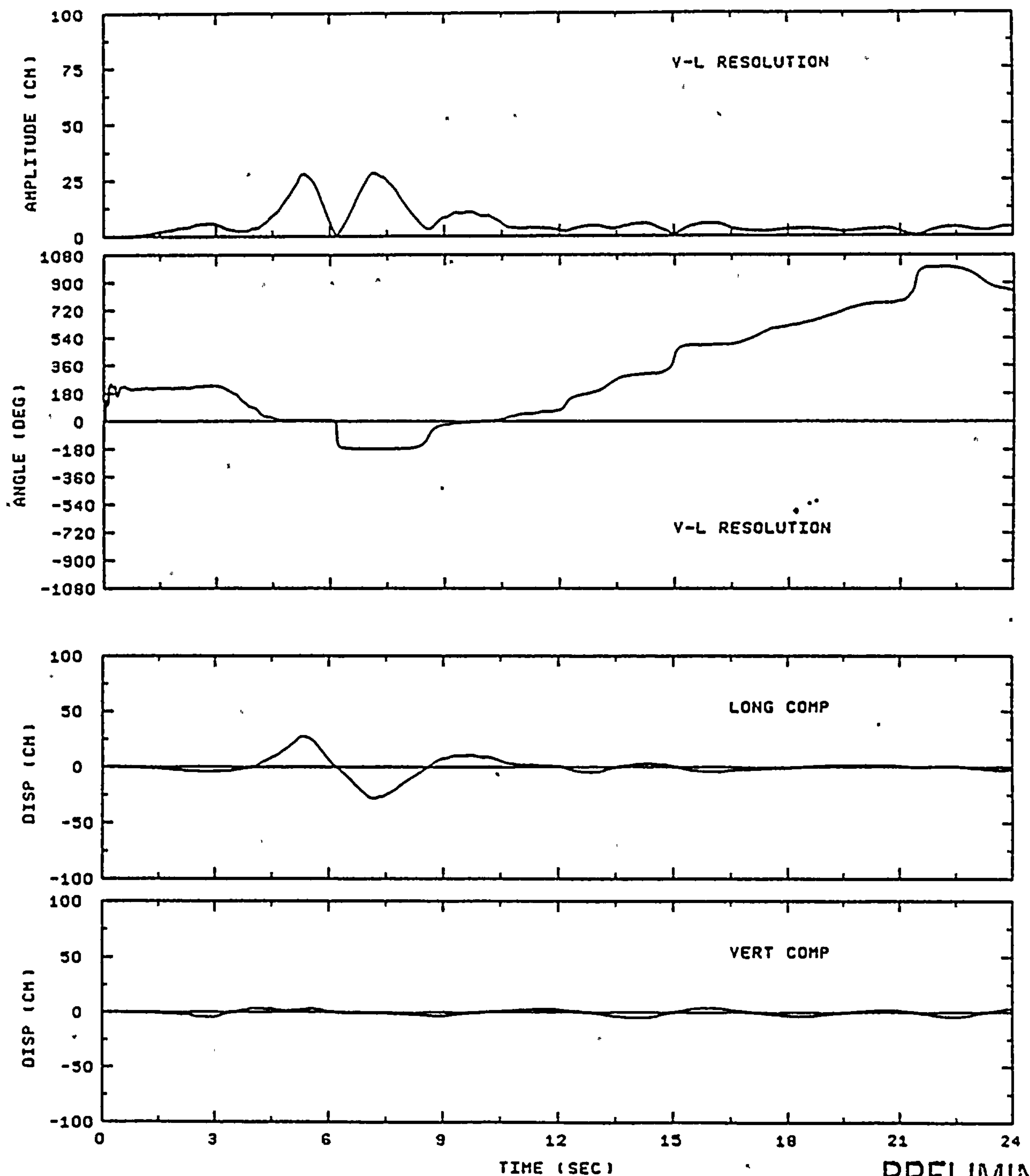


IV EC4 VERT LONG - VELOCITIES

VII-13

PRELIMINARY
OCT 23 1986



IV EC4 VERT LONG - DISPLACEMENTS

PRELIMINARY
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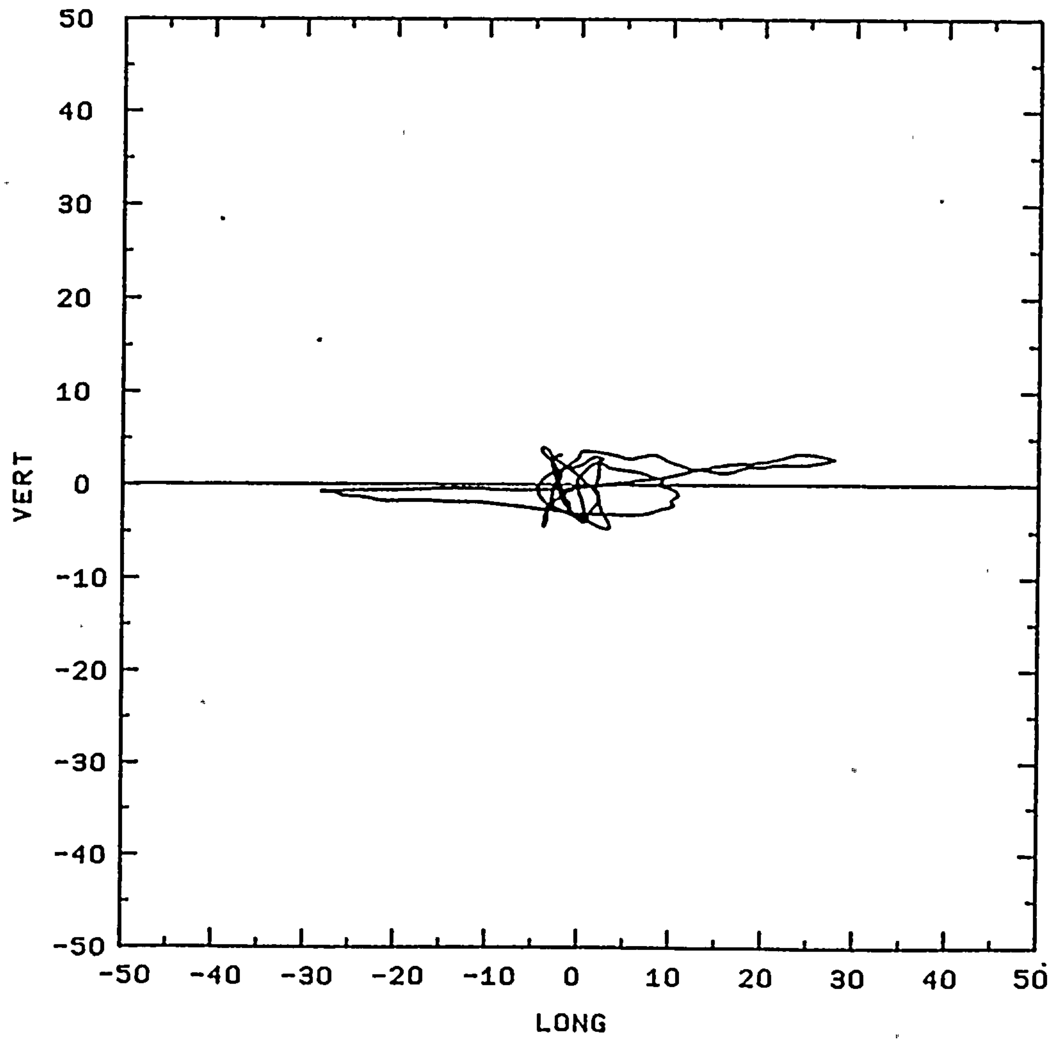
51 - III



IV-EC4 LONG VERT PARTICLE MOTION

PRELIMINARY
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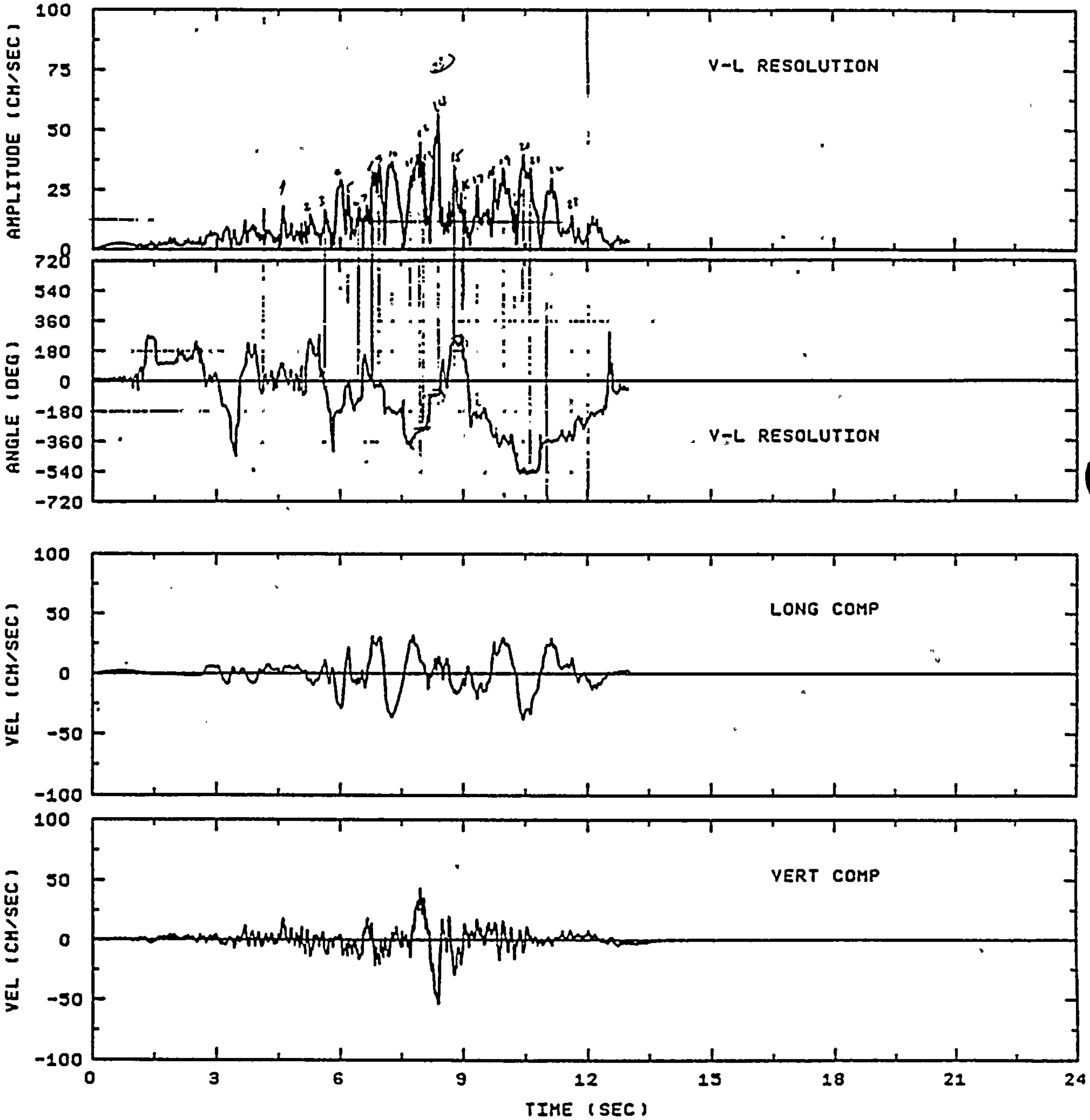

Fig 30: GAZLI VERT LONG - VELOCITIES

PRELIMINARY
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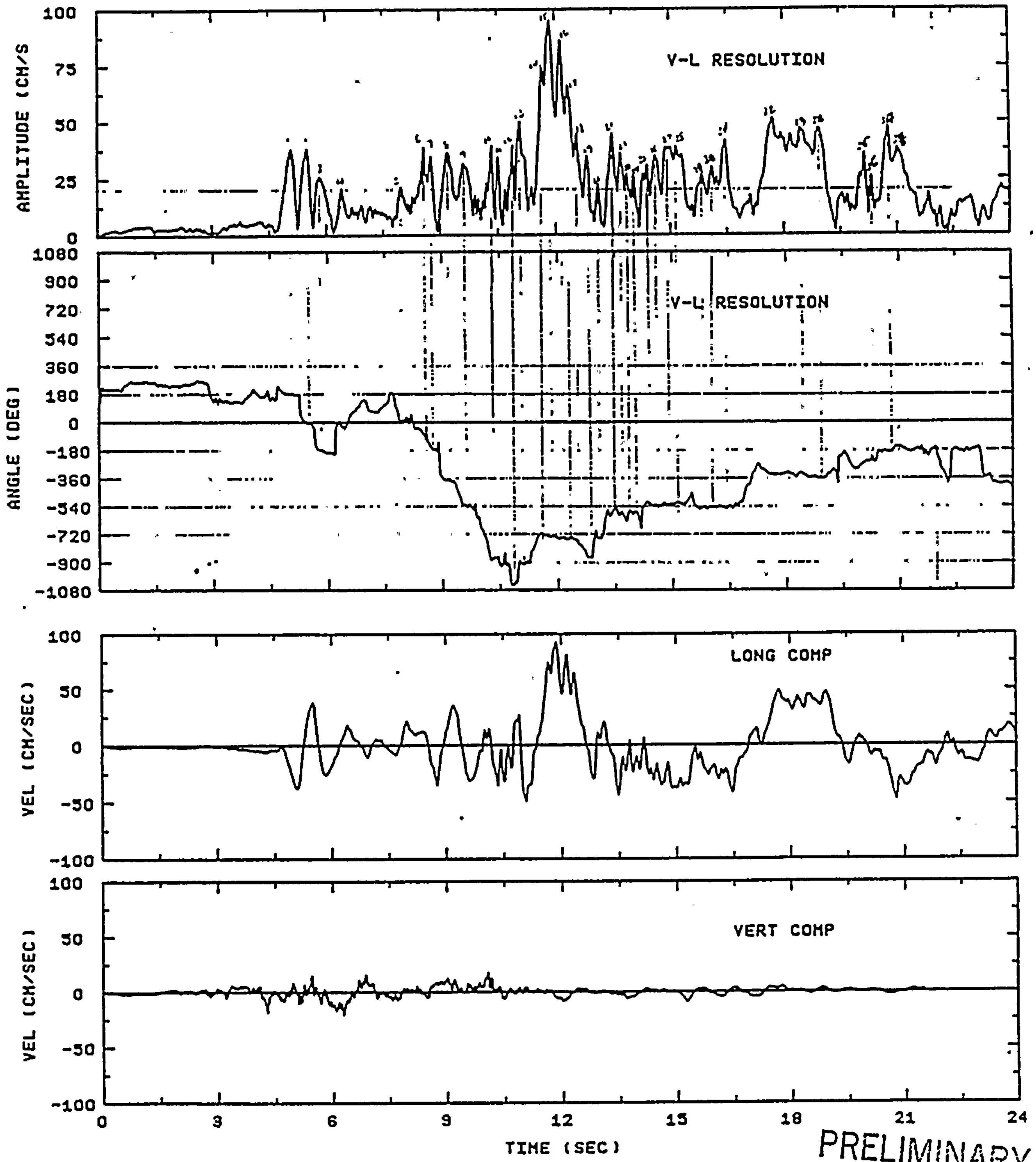

PRELIMINARY
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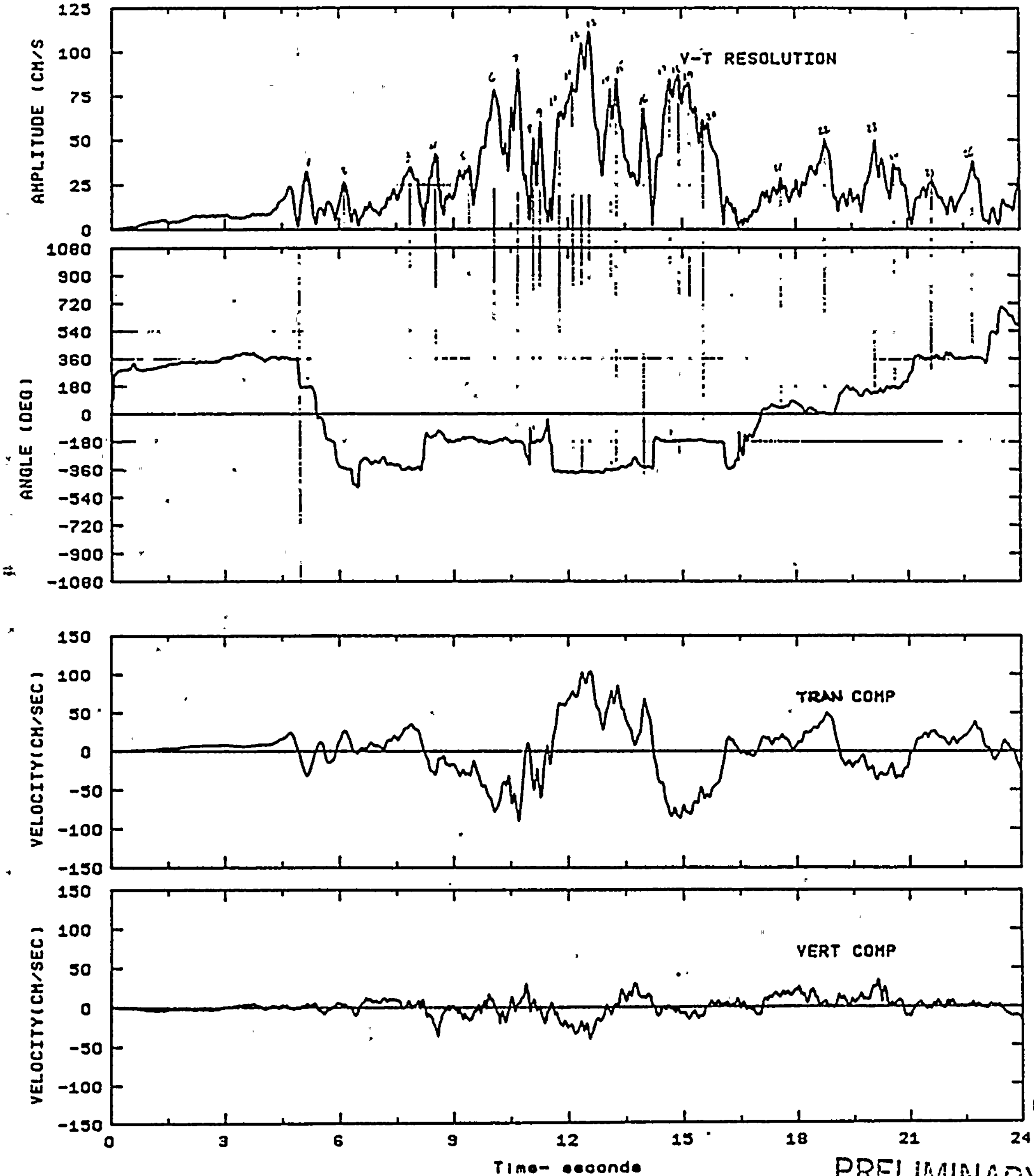
Fig 22: TABAS VERT LONG - VELOCITIES

VII-17



TABAS VERT-TRAN (VELOCITIES)

VII-18

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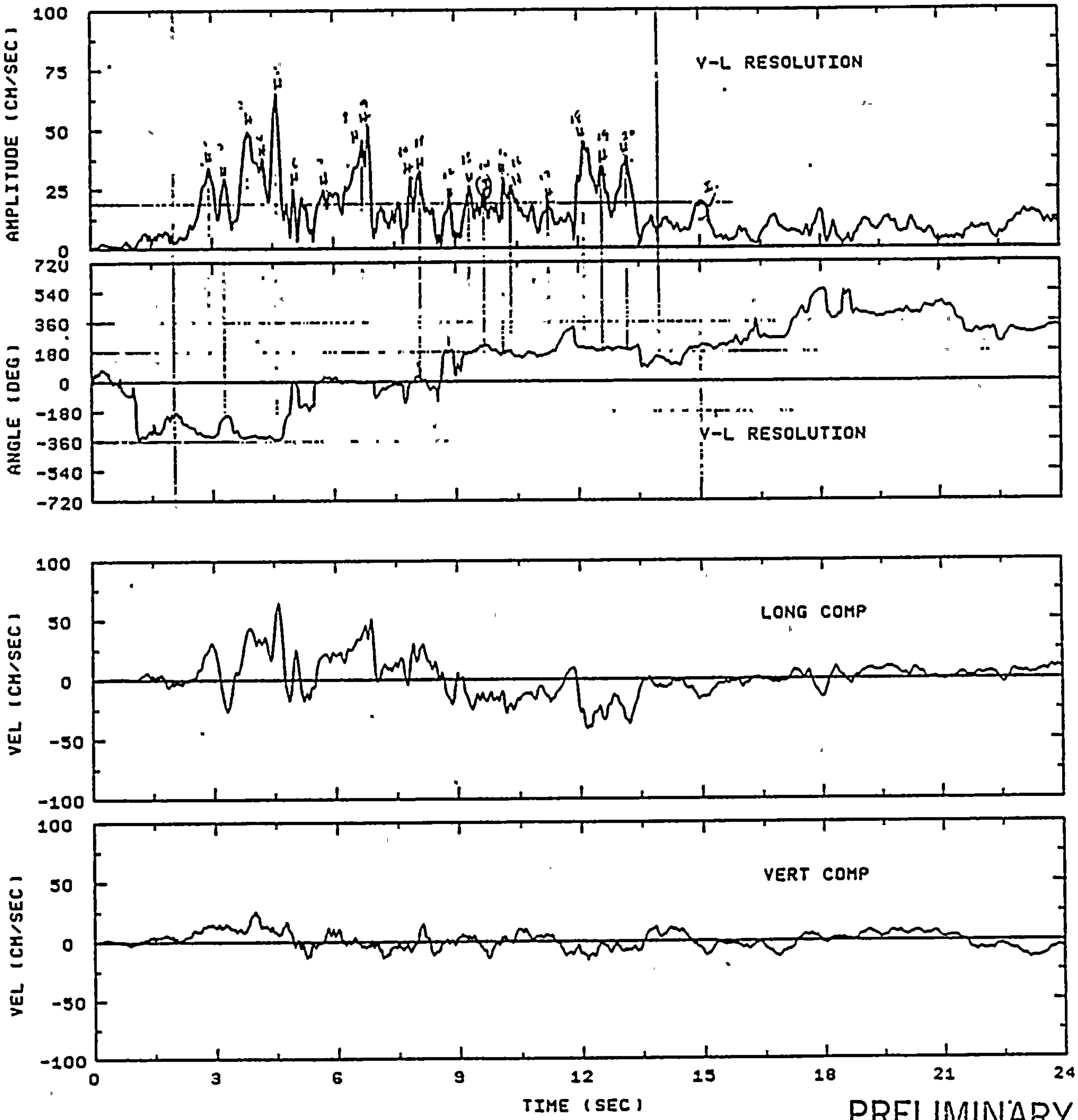

Fig 34 DAYHOOK VERT LONG - VELOCITIES

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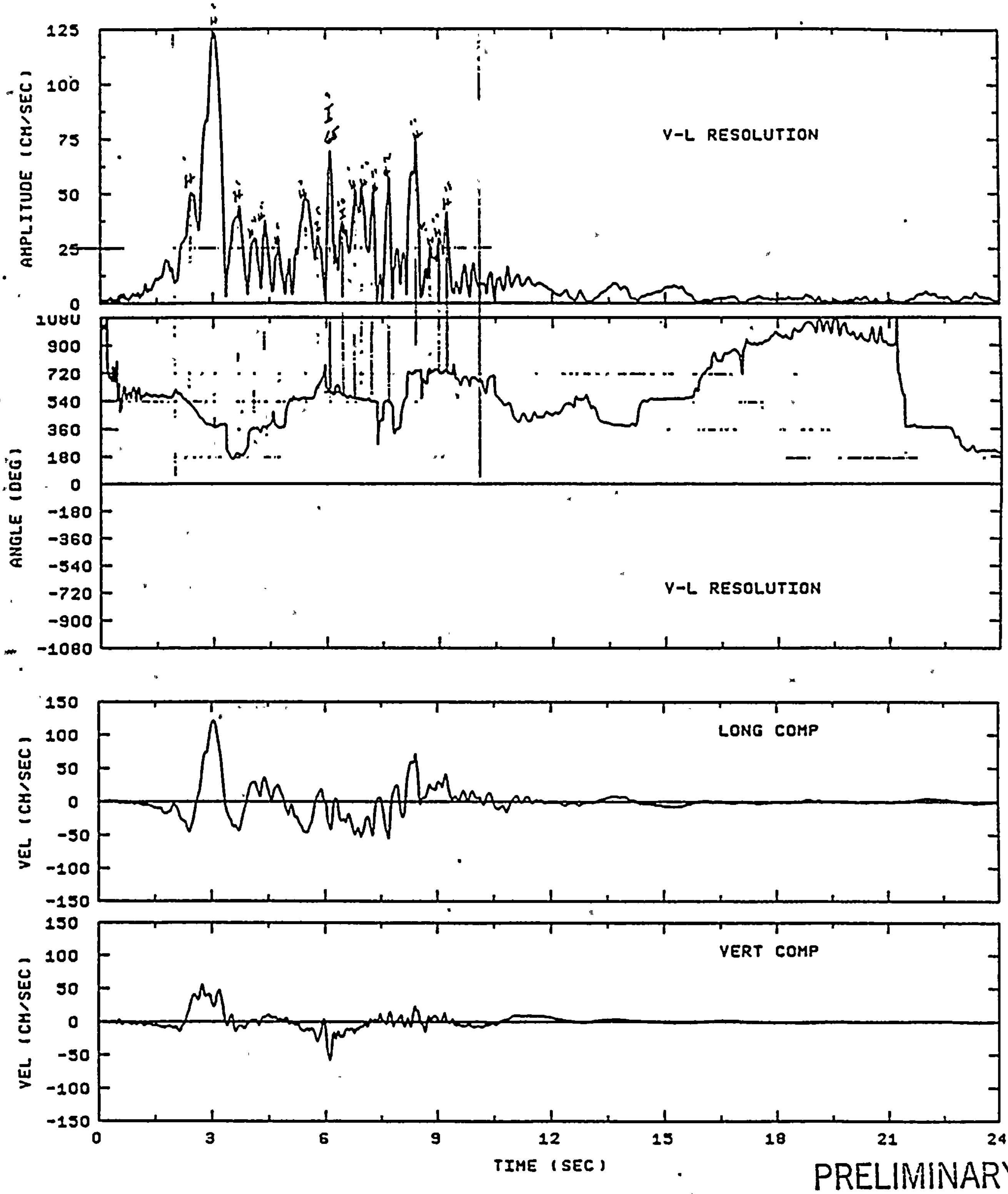

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Fig. 36: SFPAC VERT LONG - VELOCITIES

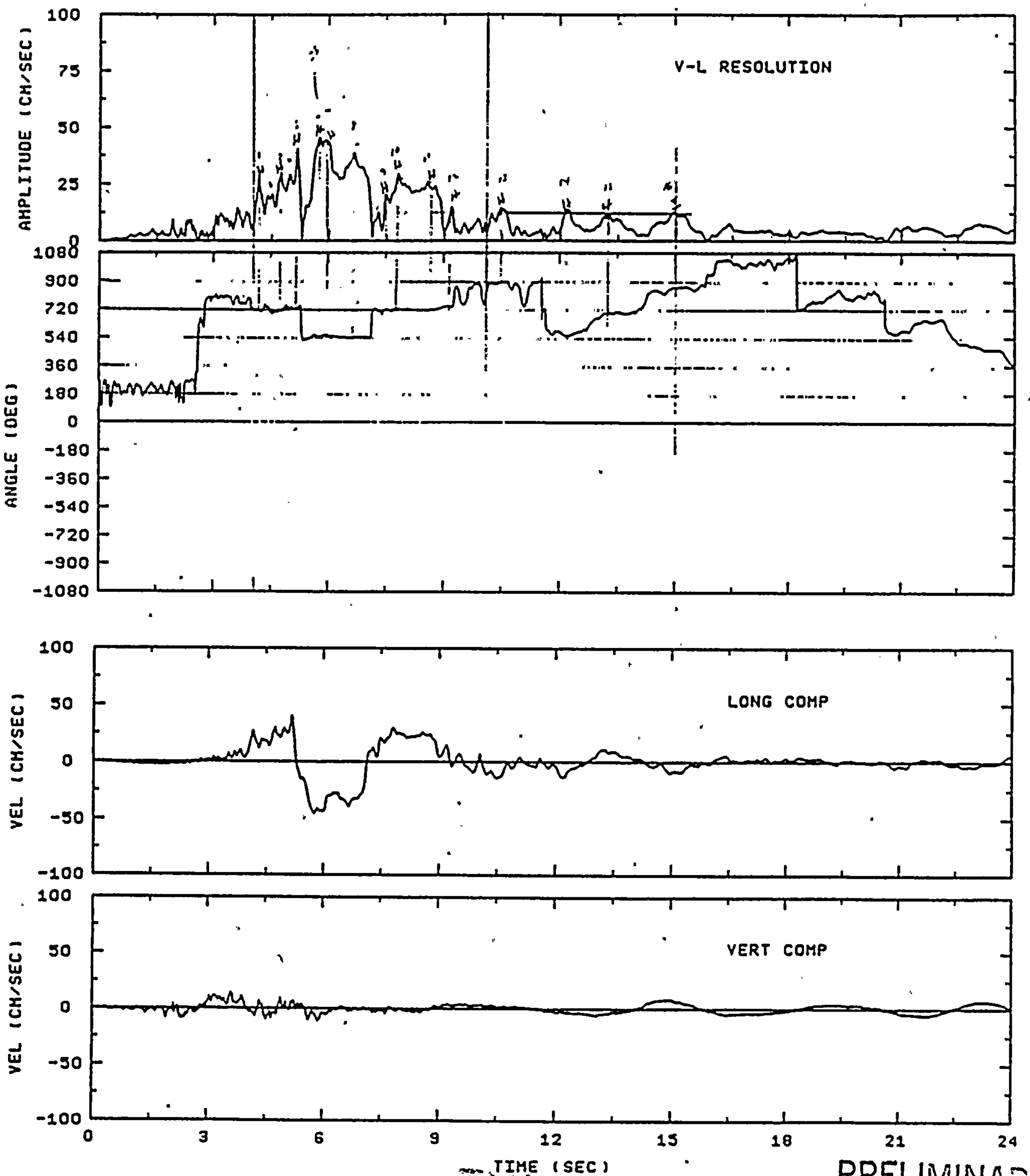

Fig 38 : IV EC4 VERT LONG - VELOCITIES

PRELIMINARY
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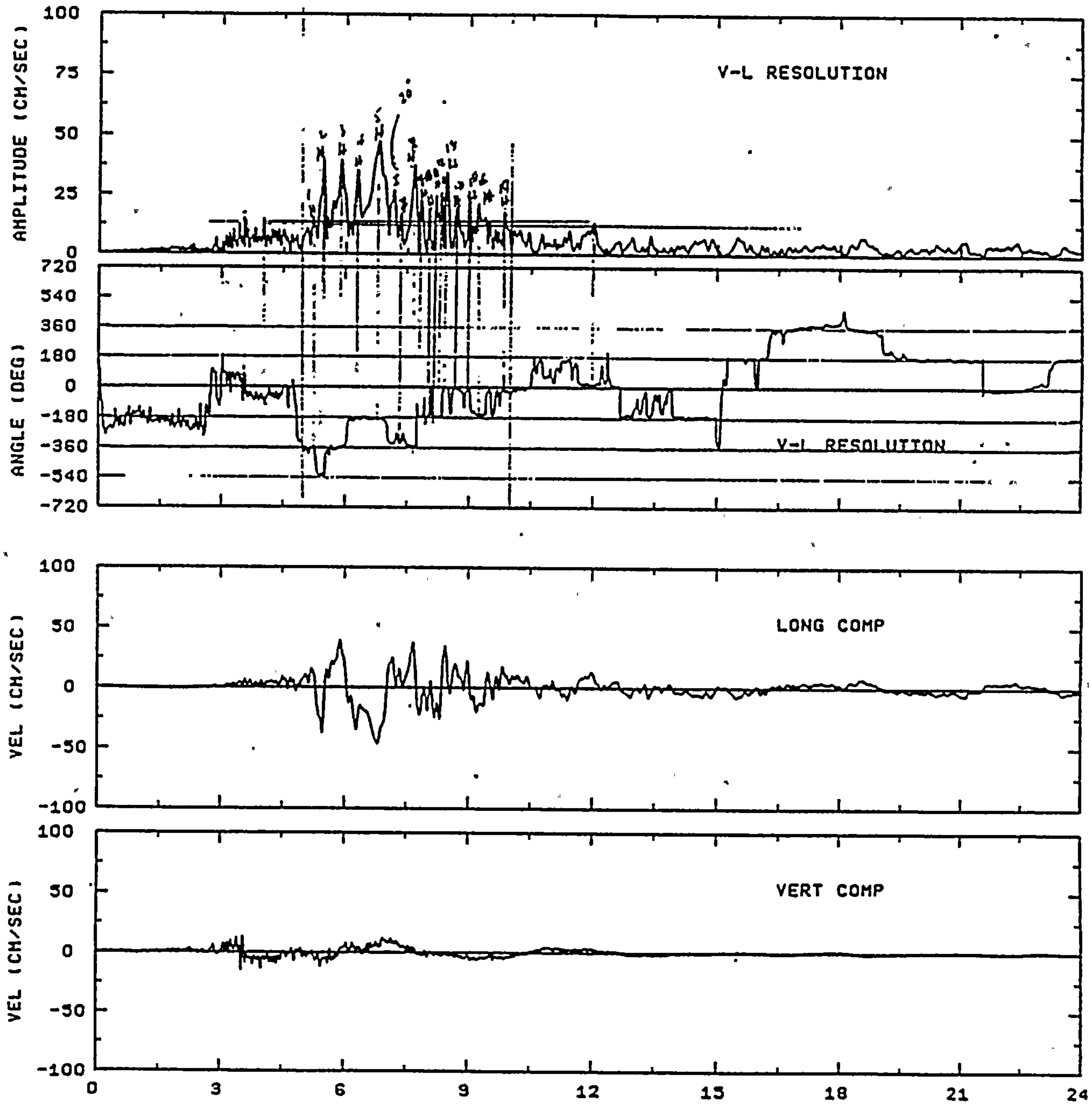

PRELIMINARY
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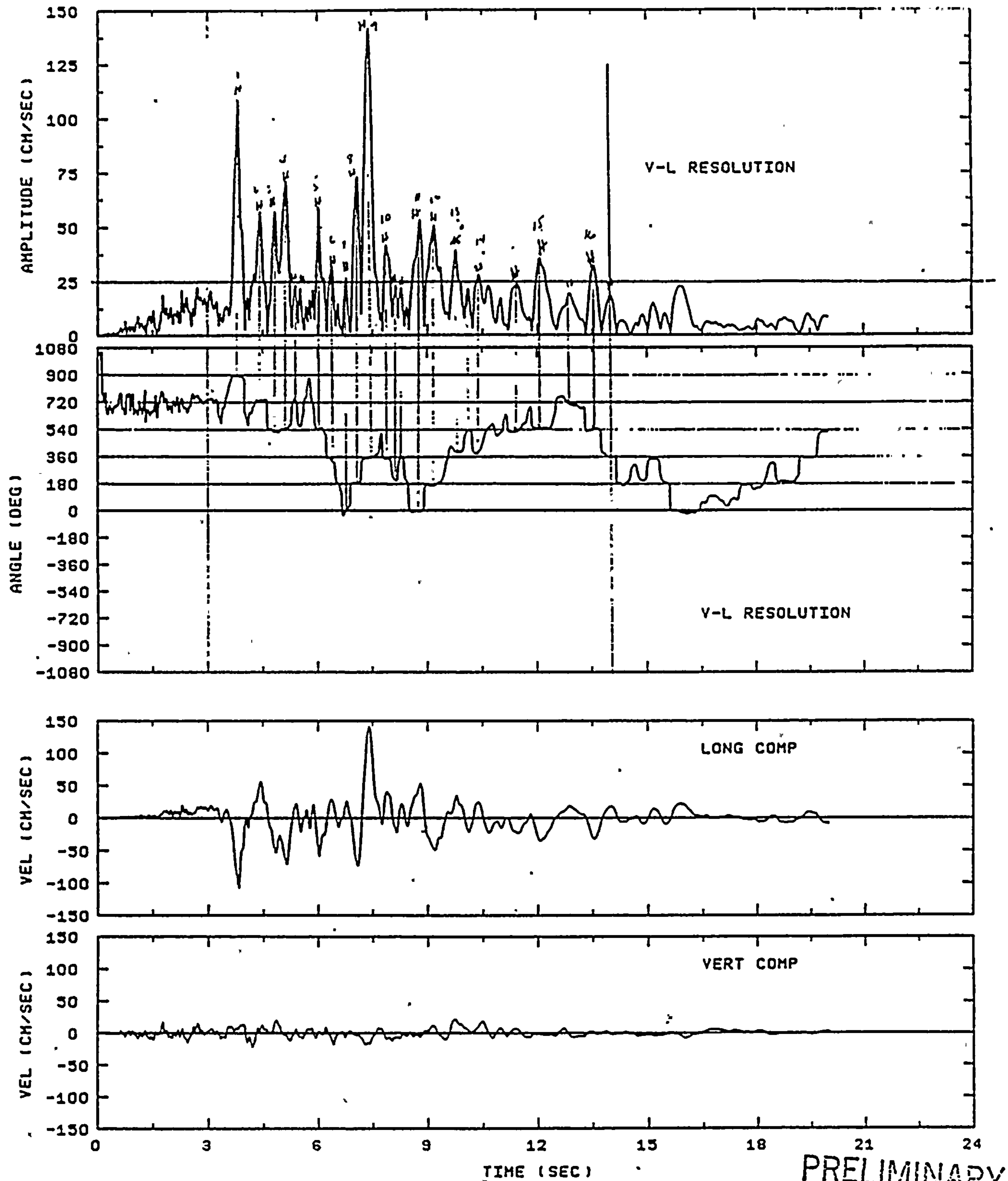
Fig 40: IM V-OA VERT LONG - VELOCITIES



PRELIMINARY
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Fig 42 : CGA PV VERT LONG - VELOCITIES

TABLE 3: ESTIMATION OF APPROXIMATE PREDOMINANT INCIDENCE ANGLE FOR MOTIONS IN THE VERTICAL-LONGITUDINAL PLANE

Record	Interval of Strong shaking	Total No. of Peaks	Approx. Predominant Incid. Angle (degrees from vertical) median value	std. deviation
Gazli	4-12 sec	23	30°-35°	45°
Tabas (vert-long)	5-22 sec	38	15°-20°	15°
Tabas (vert-tran)	5-22 sec	26	5°-10°	10°
Dayhook	3-15 sec	20	5°-10°	20°
Pacoima	2-10 sec	18	15°-20°	20°
El Centro No. 4	4-15 sec	16	0°-5°	5°
Diff Aray	5-10 sec	17	0°-5°	20°
P.V. Pump STN	3-14 sec	16	0°-5°	20°

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GEOMATRIX

PG&E Diablo Canyon Power Plant
Long Term Seismic Program (LTSP)

Empirical Ground Motion Study

Input to Phase IIIB Studies
Work in Progress

DEVELOPMENT OF ATTENUATION RELATIONSHIPS

PRELIMINARY
OCT 23 1986

VIII-1

EMPIRICAL GROUND MOTION STUDY
DEVELOPMENT OF ATTENUATION RELATIONSHIP
FOR USE IN PHASE IIIB STUDIES

PRODUCTS

The objective of the empirical ground investigations is to develop ground motion attenuation relationships based on detailed regression analyses of currently available strong motion recordings. Products of the Phase IIIB empirical ground motion studies are as follows:

1. Attenuation relationships for horizontal PGA
2. Attenuation relationships for vertical PGA
3. Attenuation relationships for horizontal PGV
4. Attenuation relationships for vertical PGV
5. Attenuation relationships for horizontal S_a (5% damping)
6. Attenuation relationships for vertical S_a (5% damping)
7. Relative damping effect (2%, 4%, 7%, 10% relative to 5%) on response spectral ordinates

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APPROACH

The steps involved in developing the product attenuation relationships are summarized below.

1. Development of Strong Motion Data Base: Attenuation relationships will be developed for rock and/or rock-like local subsurface site conditions.

   o Magnitude range considered is $M \geq 5$
   o Distance range considered is $R \leq 100$ km

2. Earthquake Parameters: The earthquake parameters being utilized are magnitude and focal mechanism.

   o It is intended that magnitude be defined in terms of moment magnitude (in the absence of moment magnitude determinations, M_L will be used for $M \lesssim 6$ and M_s will be used for $M \gtrsim 6$).

   o Effect of focal mechanism (style of faulting) will be examined and quantified.

3. Ground Motion Parameters: Both horizontal components and the vertical component for each recording will be used.

4. Source-to-Site Distance: Distance definition utilized will be the closest distance to rupture surface.

5. Attenuation Model: Key features of the model include:

   o Near-field distance saturation of ground motion characteristics.

   o Nonlinear magnitude scaling to allow for saturation of ground motion with magnitude.

   o Far field rates of attenuation appropriate to specific ground motion parameters (e.g. PGA, PGV, $S_a(T)$).

PRELIMINARY
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<u>NUMERICAL MODELING - PHASE IIIB</u>

INITIAL OBJECTIVE: CALIBRATION OF NUMERICAL MODELING METHOD

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MODIFICATIONS IN EMPIRICAL GREEN'S FUNCTION SUMMATION APPROACH

- INTRODUCE DETERMINISTIC REPRESENTATION OF ASPERITIES

  (BY ASSOCIATING ASPERITIES WITH FAULT SLIP DISTRIBUTION)

- REDUCE DEGREE OF RANDOMNESS, I.E. STOCHASTIC REPRESENTATION OF ASPERITIES

  (BY CHANGING FROM WHITE TO GAUSSIAN RANDOM NUMBERS)

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CALIBRATION APPROACH

- COMPARISON OF SIMULATIONS WITH RECORDED STRONG MOTIONS
- DEMONSTRATE THE ABILITY TO SIMULATE THE VELOCITY TIME HISTORIES ON WHICH THE ASPERITY MODELS ARE BASED
- DEMONSTRATE THAT THE ASPERITY MODELS PRODUCE ACCELEROGRAMS THAT ARE SIMILAR TO THE RECORDED DATA
- USE TIMING OF CONTRIBUTIONS FROM DIFFERENT PARTS OF THE FAULT TO ANALYSE ASPERITY MODELS

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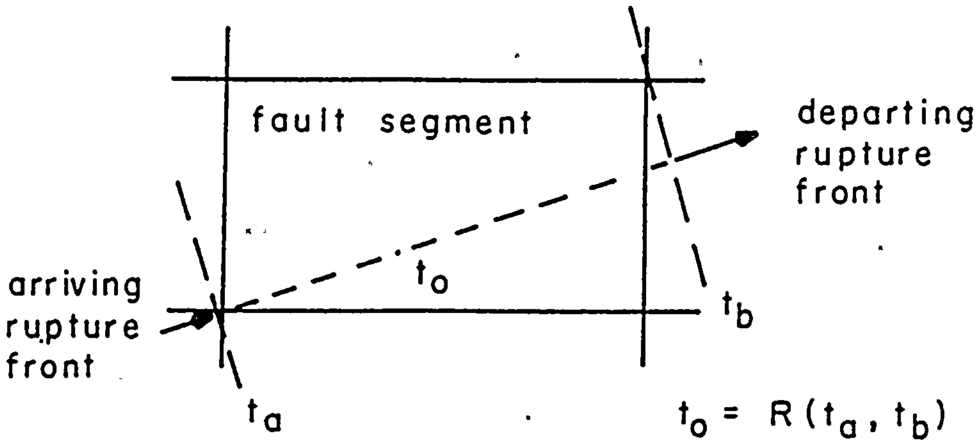
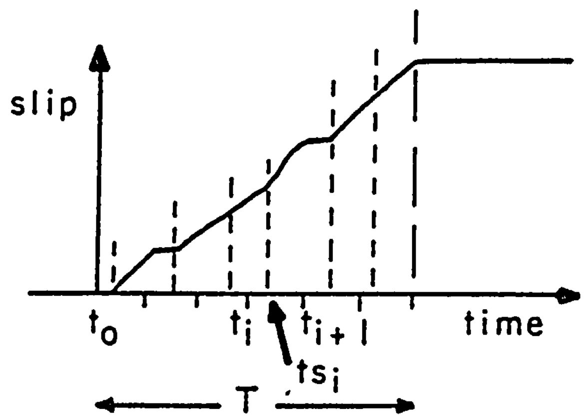
Randomization Of Rupture Velocity



$t_o = R(t_a, t_b)$

Randomization Of Slip Time Function



$ts_i = R(t_i, t_{i+1})$

$(i = 1, n_T)$

$R(x,y)$ = Gaussian random number, $x, y = \mp 2\sigma$

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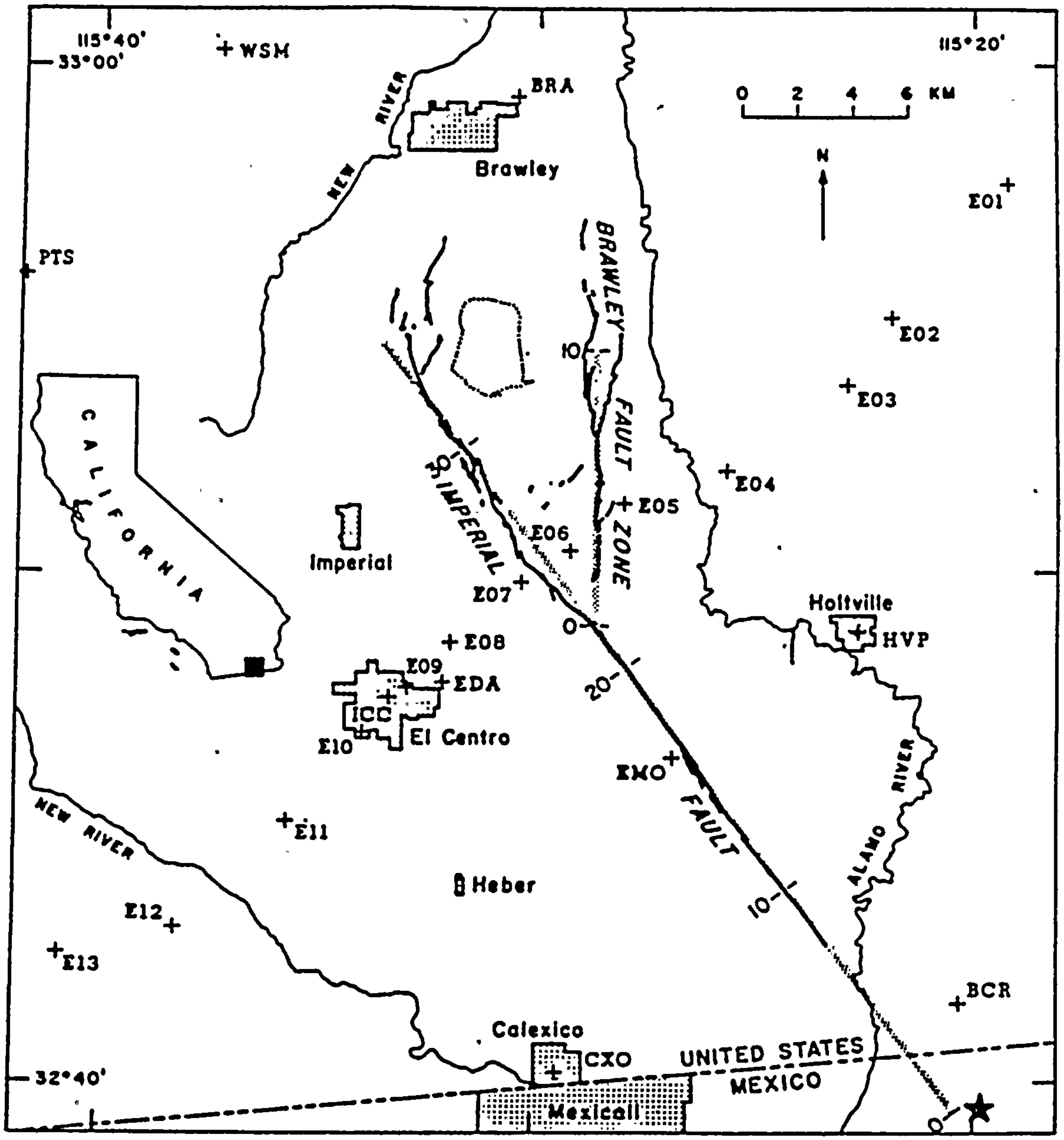

PRELIMINARY
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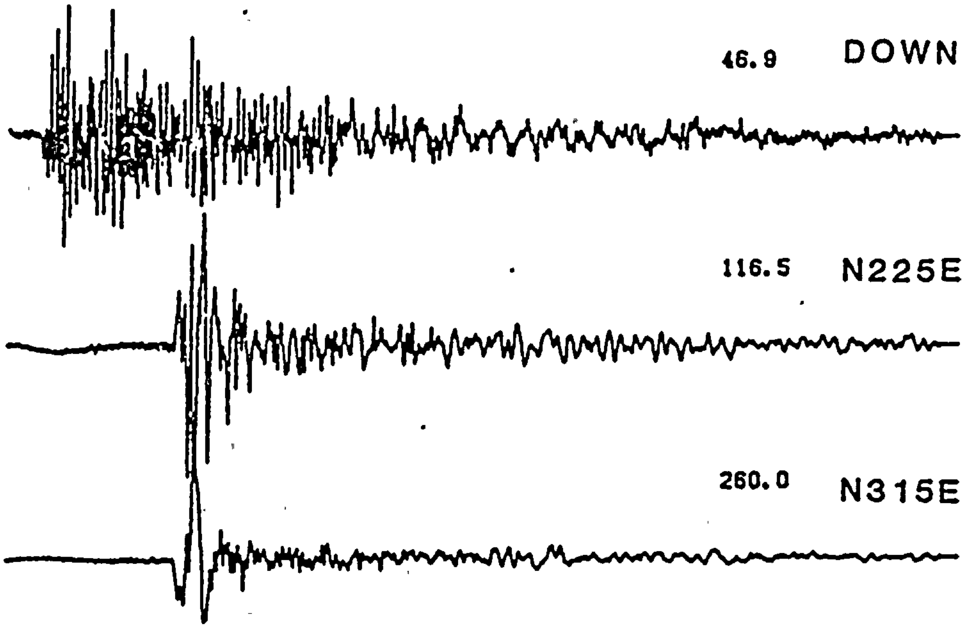
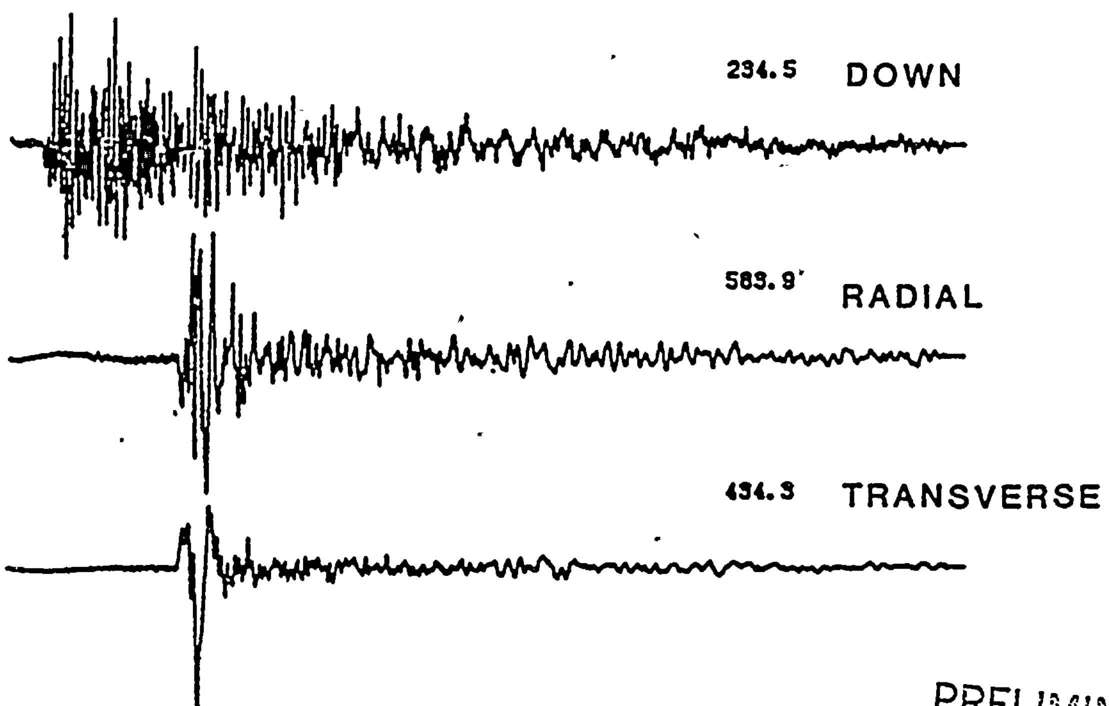
IX-5

ACCELEROGRAM OF IMPERIAL VALLEY AFTERSHOCK RECORDED AT HOLTVILLE

RECORDED DATA



AFTER ROTATION AND RADIATION PATTERN CORRECTION



PRELIMINARY
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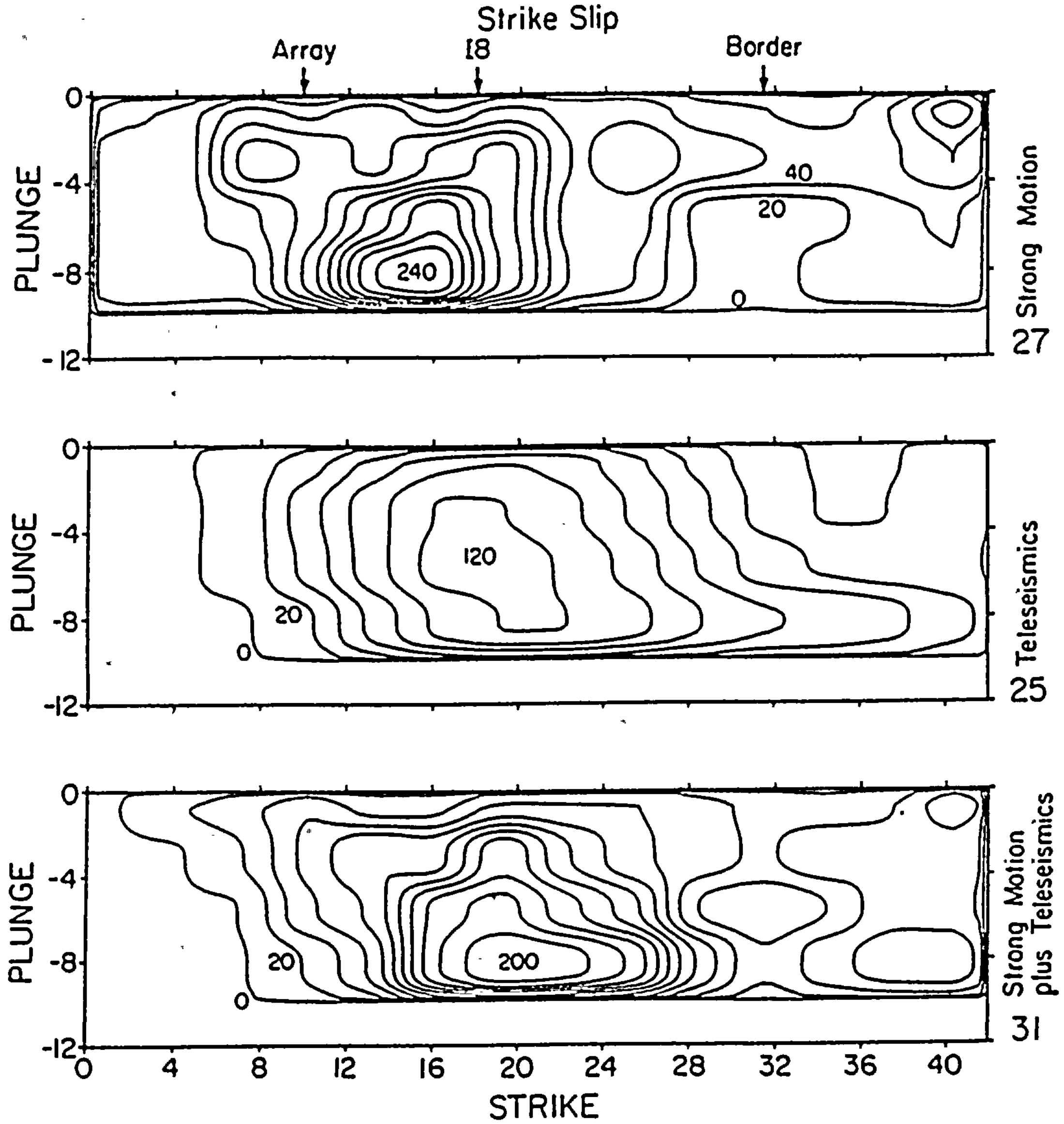
HARTZELL AND HEATON - ASPERITY MODEL OF 1979 IMPERIAL VALLEY EQ

(DETERMINED FROM STRONG MOTION AND TELESEISMIC VELOCITY DATA - PERIODS AROUND 1 SEC.)



FAULT SLIP IN CM. CONTOURED ON FAULT PLANE

PRELIMINARY
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IX-7

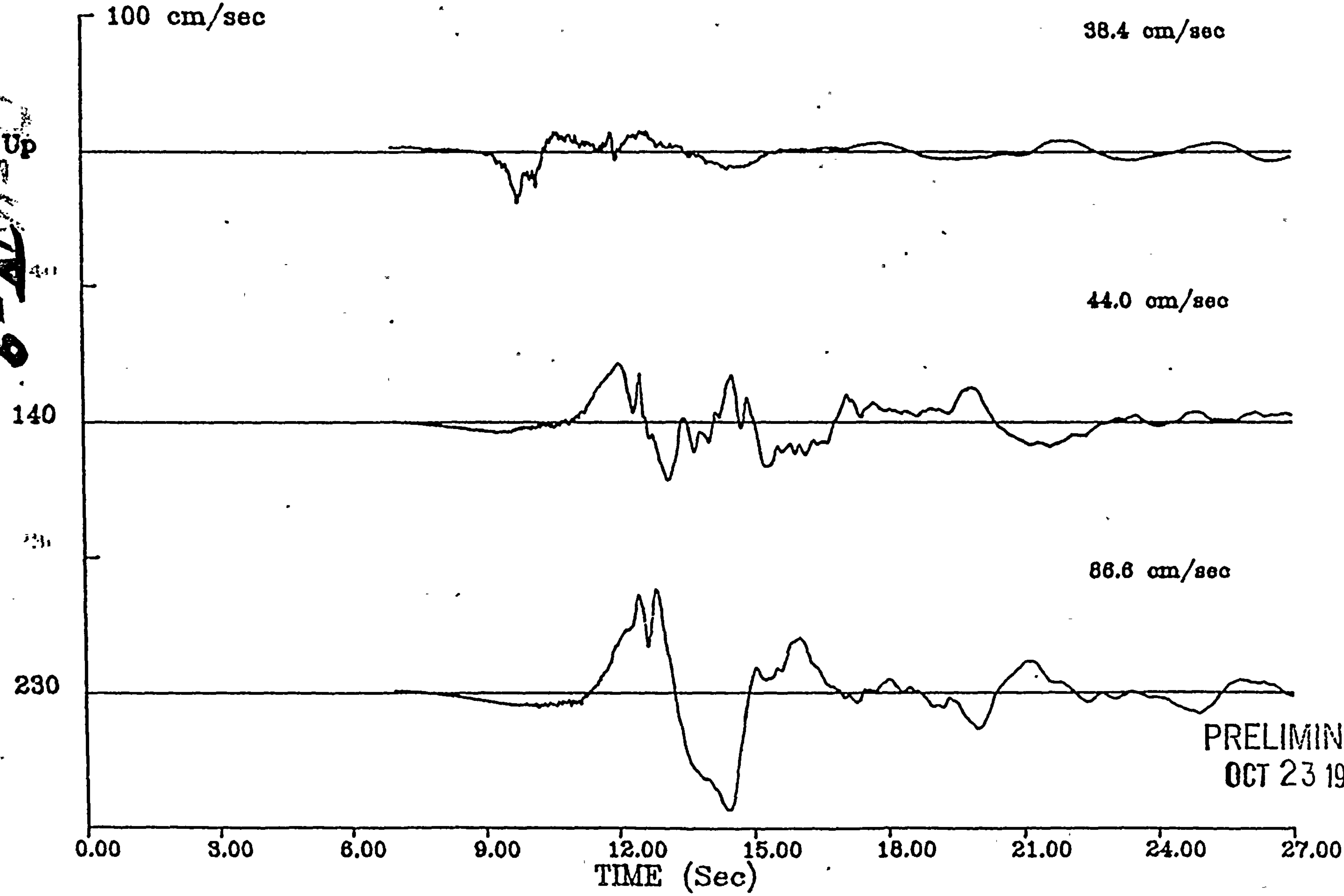
CALIBRATION - 1979 IMPERIAL VALLEY EARTHQUAKE - ARRAY #5

VELOCITY - RECORDED DATA
- SIMULATION - ASPERITY MODEL
- SIMULATION - SMOOTH MODEL

ACCELERATION - RECORDED DATA
- SIMULATION - ASPERITY MODEL
- SIMULATION - SMOOTH MODEL

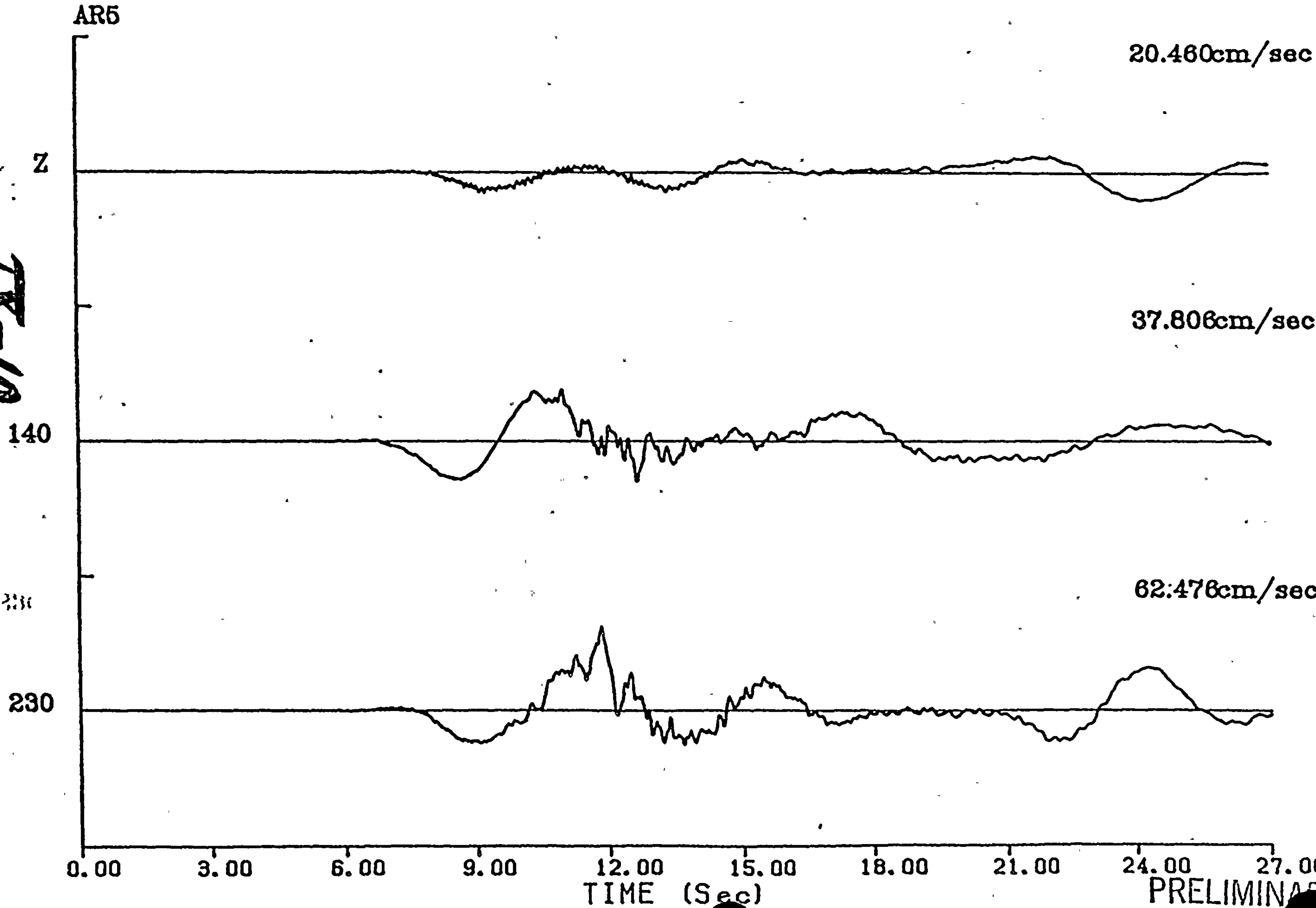
PRELIMINARY
OCT 23 1986

Imperial Valley, 2317 UTC, El Centro Array 5, James Road
Origin time = 23:16:54.4; Trigger time = 23:17:01.39



PRELIMINARY
OCT 23 1986

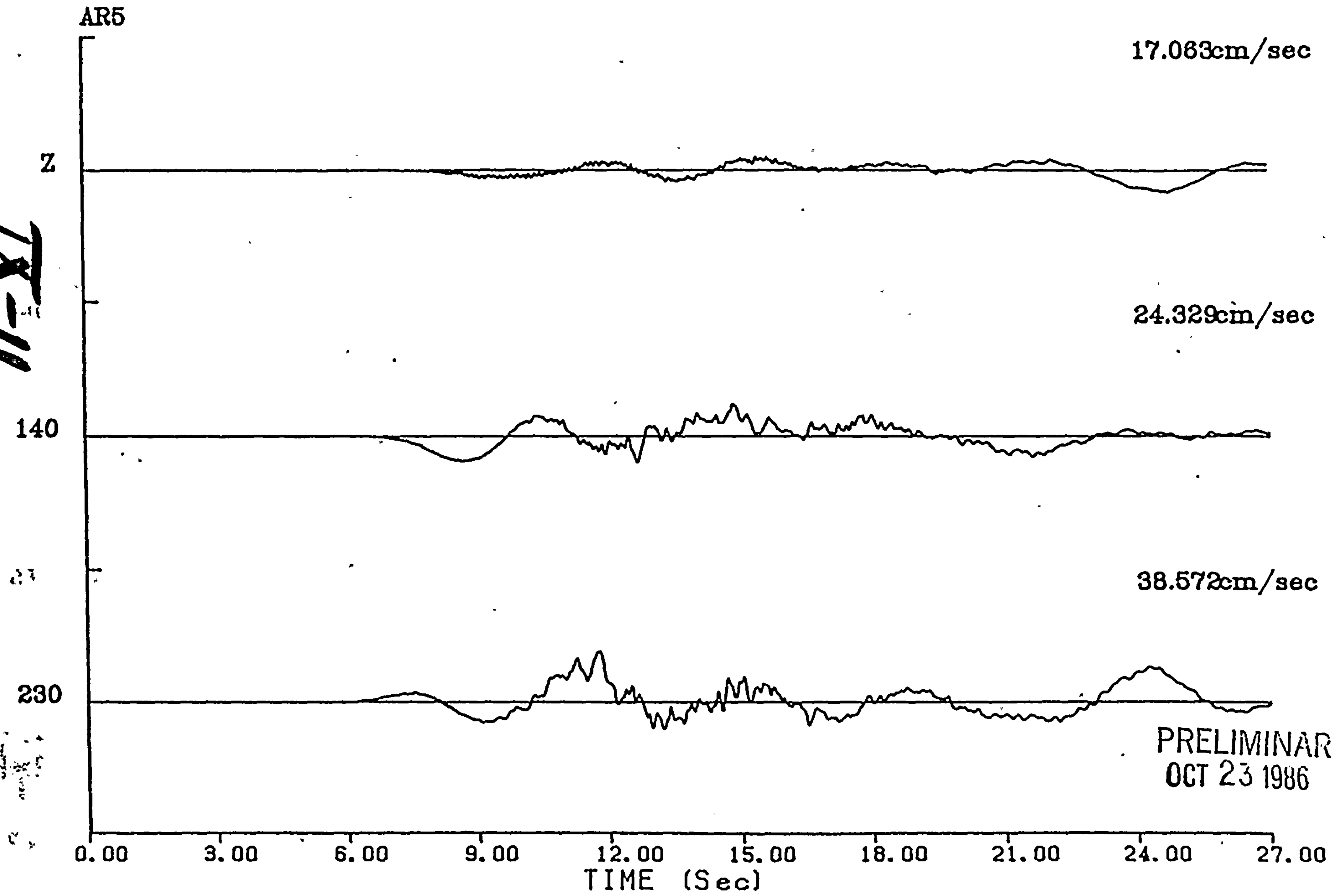
VELOCITY (ASPERITY MODEL) FROM FILTERED GREEN'S (fo=.03,fc=.17)



IX-10

PRELIMINARY
OCT 23 19

SMOOTH MODEL Vr=2.5,Vs=3.1,RAND.GAUS.1,RT=1.5s VELOCITY



IX-11

PRELIMINARY
OCT 23 1986

Imperial Valley, 2317 UTC, El Centro Array 5, James Road
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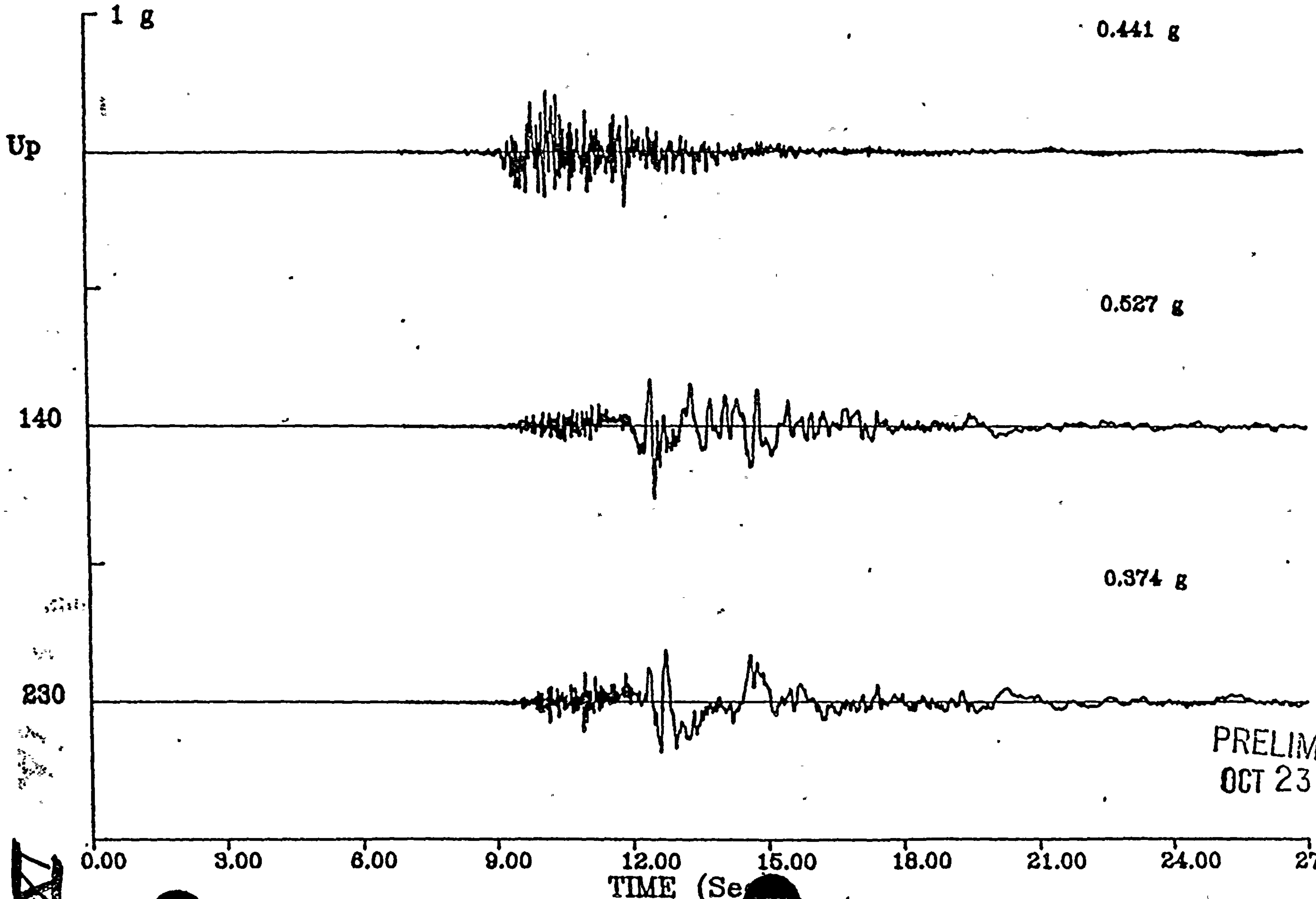
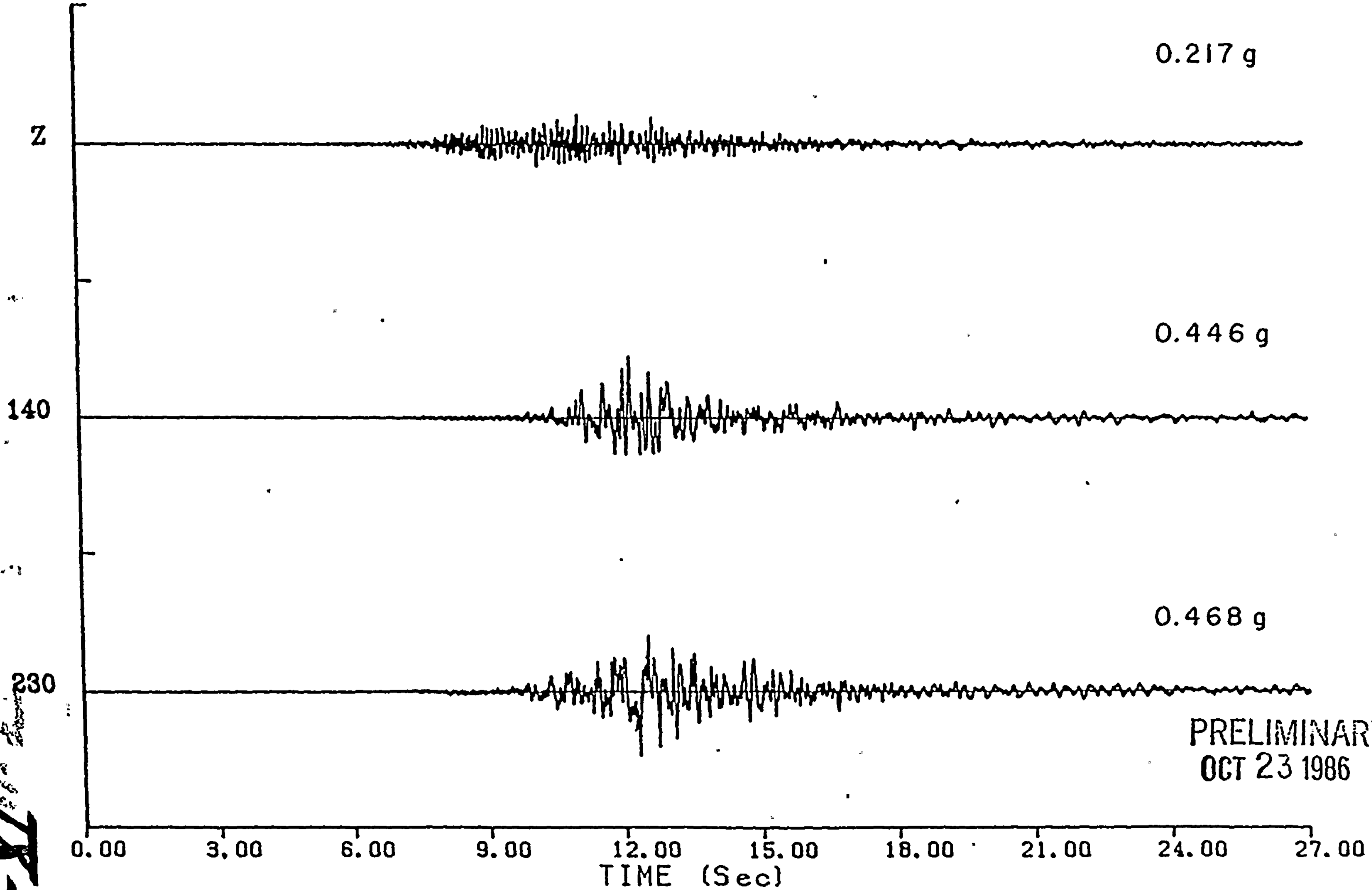


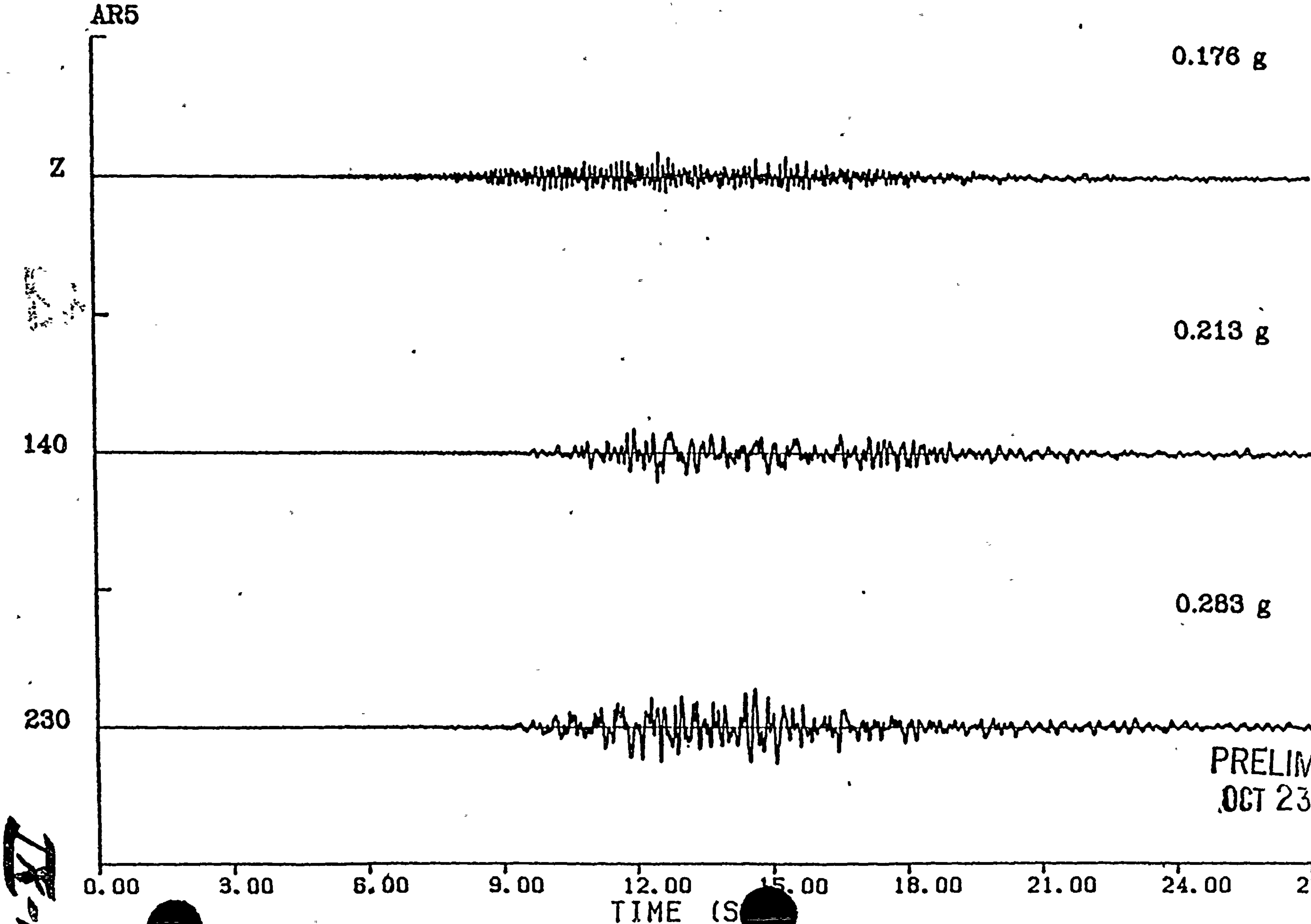
IMP. VALLEY (HARTZELL Vr=2.5,Vs=3.1) GAUSSIAN RAND. RT 1.5s

AR5



PRELIMINARY
OCT 23 1986

IMP. VALLEY (SMOOTH Vr=2.5,Vs=3.1) RAND.GAUS.1,RT 1.5s



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COMPARISON OF PEAK GROUND MOTION VALUES - EL CENTRO ARRAY #5

		OBSERVED	ASPERITY MODEL	SMOOTH MODEL
PEAK VELOCITY (CM/SEC)	VERT	38	20	17
	140°	44	38	24
	230°	87	62	38
PEAK ACCELERATION (G)	VERT	.44	.22	.18
	140°	.53	.45	.21
	230°	.37	.47	.28

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CONCLUSION FROM ANALYSIS OF VELOCITY AND ACCELERATION AT ARRAY #5

THE ASPERITY MODEL PROVIDES A BETTER FIT TO BOTH THE VELOCITY AND ACCELERATION TIME HISTORIES THAN DOES THE SMOOTH RUPTURE MODEL

PRELIMINARY
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ANALYSIS OF ASPERITY MODEL USING EL CENTRO (TRANSVERSE) ARRAY

COMPONENTS:

FAULT PARALLEL
FAULT NORMAL
VERTICAL

ARRAY PLOTS:

RECORDED ACCELERATION

SIMULATION - ASPERITY MODEL

SIMULATION - SMOOTH RUPTURE MODEL

NOTE:

ON SIMULATIONS FOR ASPERITY MODEL, MOVEOUTS OF TWO ARRIVALS ARE SHOWN:

SOLID LINE : ARRIVAL FROM ASPERITY

DOTTED LINE : ARRIVAL FROM CLOSEST FAULT SEGMENT

PRELIMINARY
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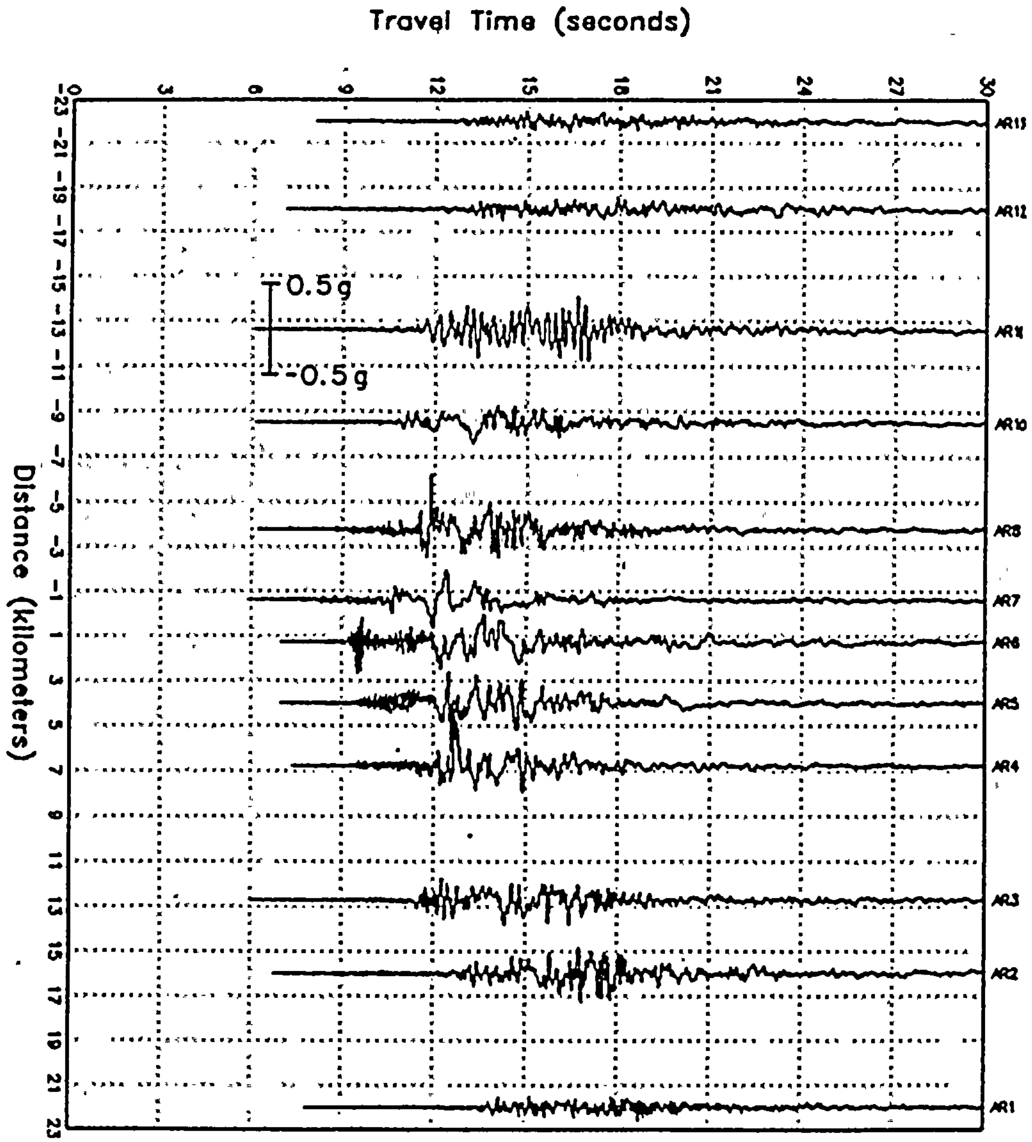
IMPERIAL VALLEY
MAIN SHOCK

OBSERVED DATA
FAULT PARALLEL COMPONENTS (140)
WITH EXECPTION OF:
ARY9 = NORTH
ARY10 = 320

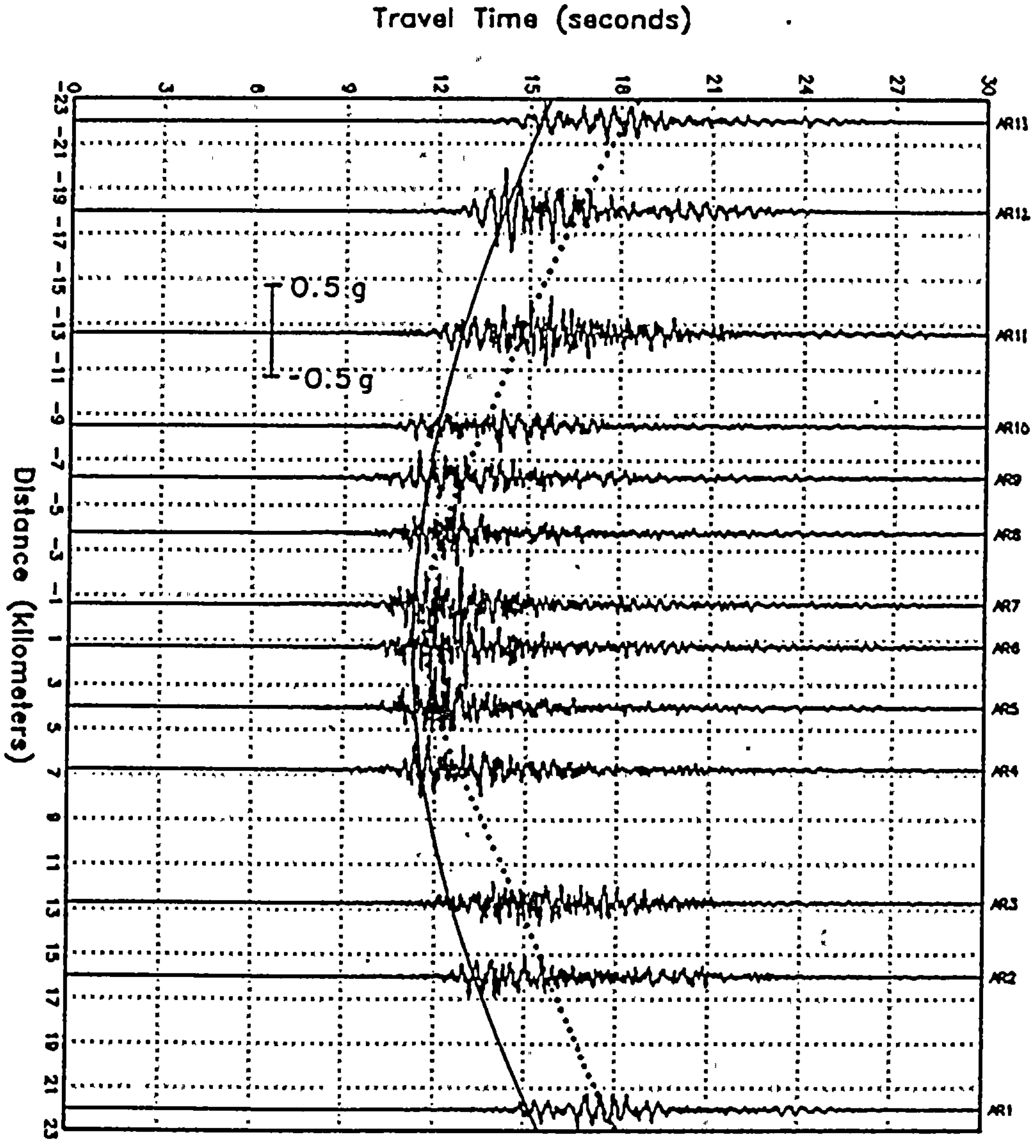


PRELIMINARY
OCT 23 1986

IX-18

IMPERIAL VALLEY
MAIN SHOCK

SIMULATION (ASPERITY MODEL)
FAULT PARALLEL COMPONENTS (140)
WITH EXECPTION OF:
AR9 = NORTH
AR10 = 320



PRELIMINARY
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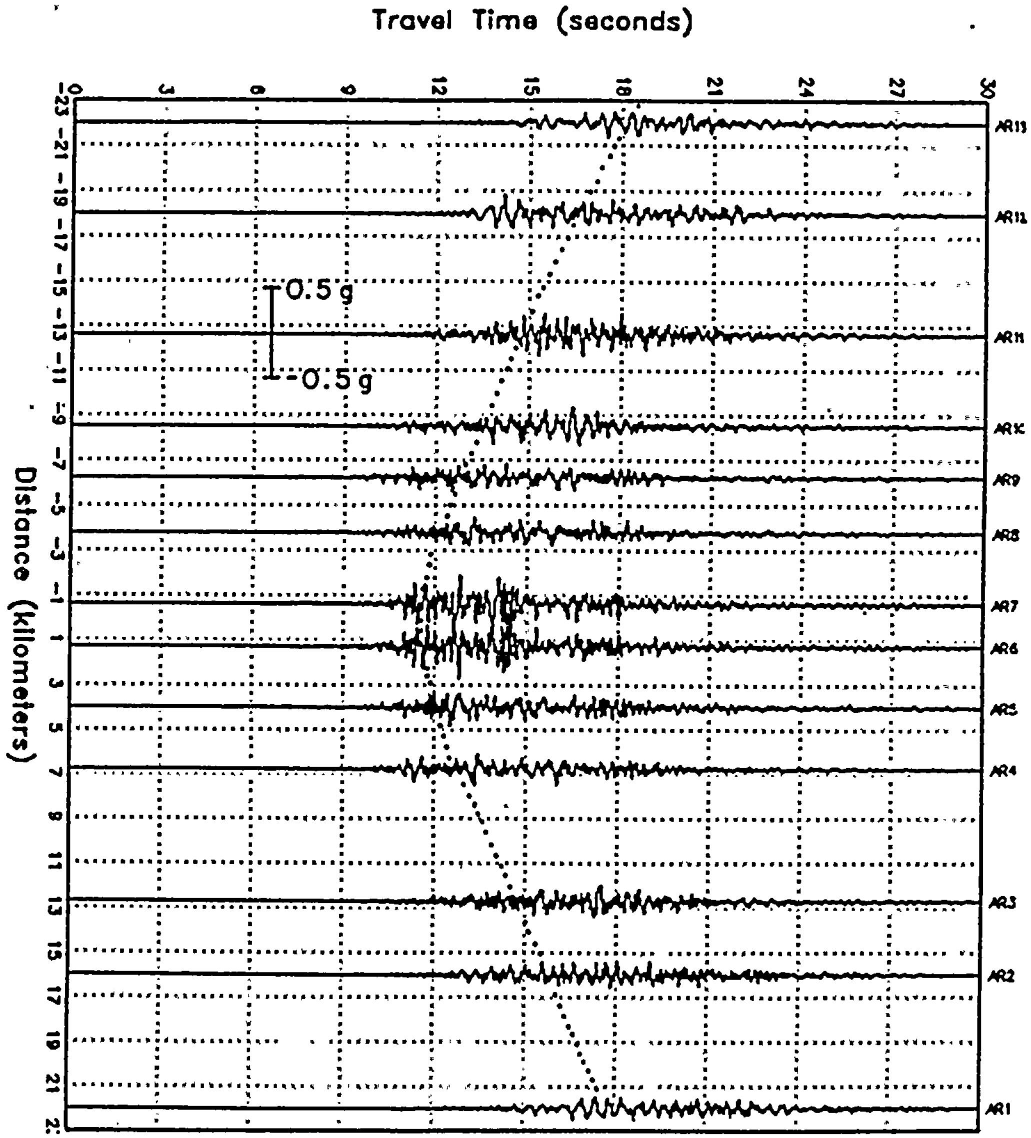
IMPERIAL VALLEY
MAIN SHOCK

SIMULATION (SMOOTH RUPTURE)
FAULT PARALLEL COMPONENTS (140)
WITH EXECPTION OF:
AR9 = NORTH
AR10 = 320

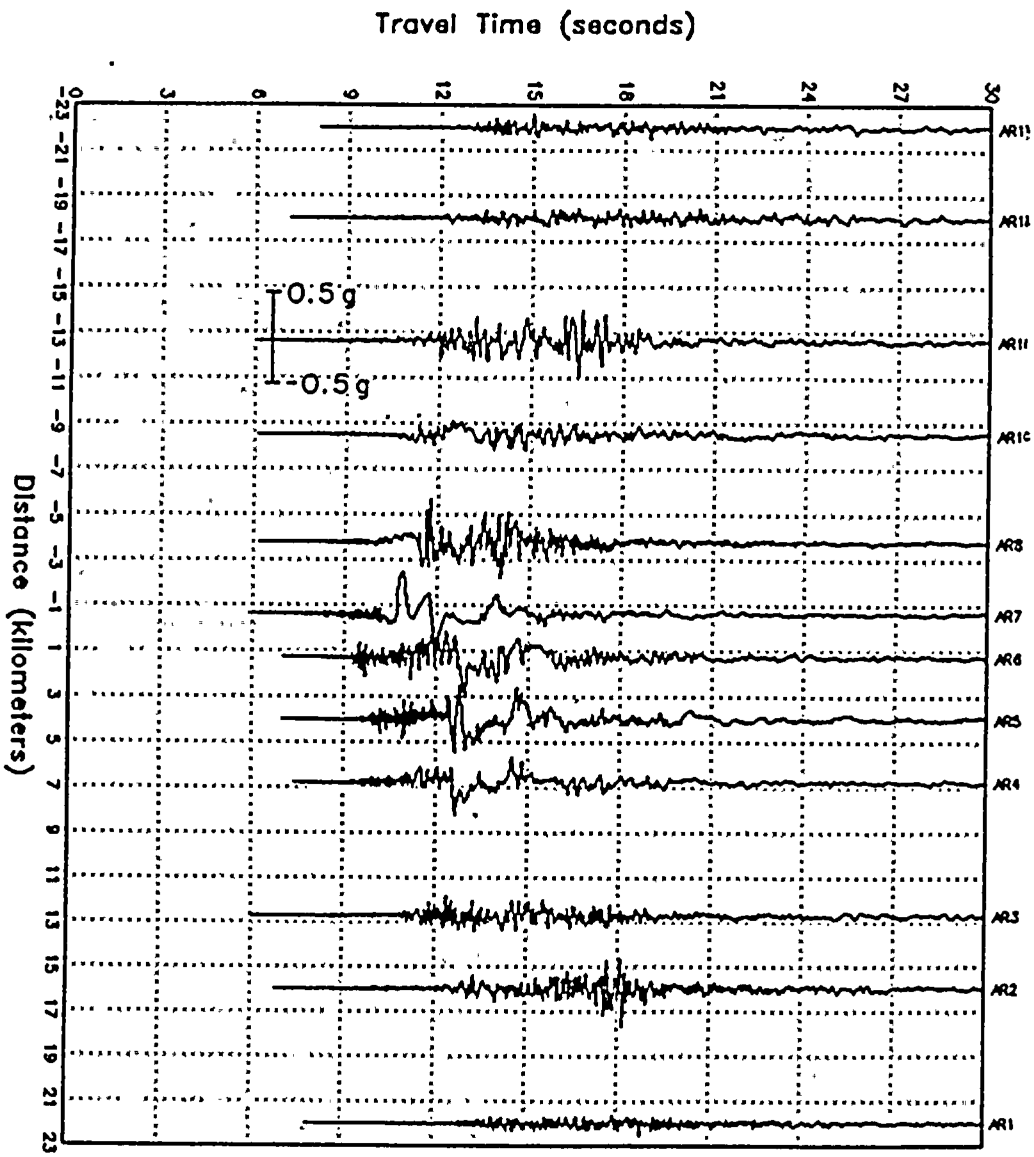


PRELIMINARY
OCT 23 1986

IX-20

IMPERIAL VALLEY
MAIN SHOCK

OBSERVED DATA
FAULT NORMAL COMPONENTS (230)
WITH EXECPTION OF:
AR9 = EAST
AR10 = 50

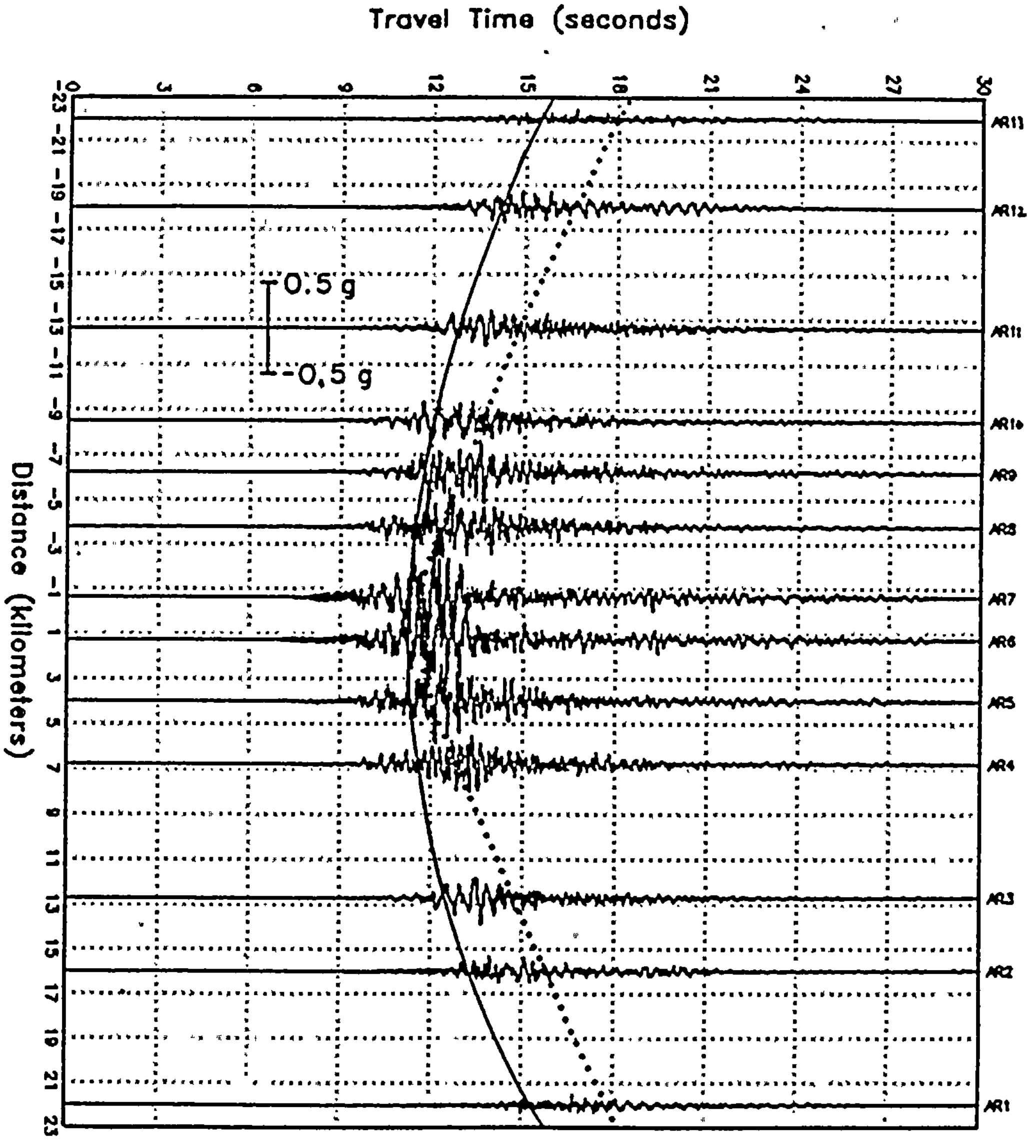


PRELIMINARY
OCT 23 1986

IX-21

IMPERIAL VALLEY
MAIN SHOCK

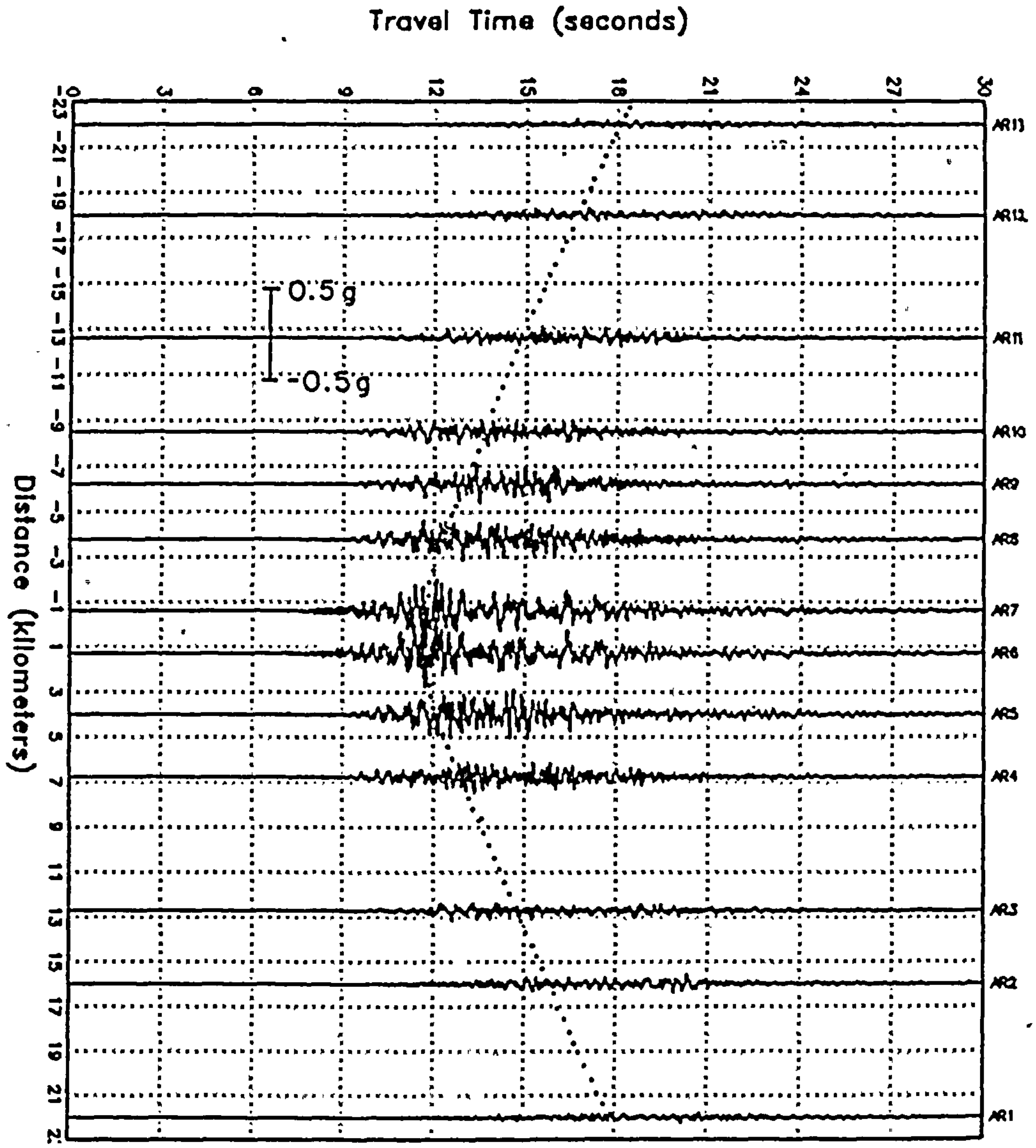
SIMULATION (ASPERITY MODEL)
FAULT NORMAL COMPONENTS (230)
WITH EXCEPTIONS OF:
AR9 – EAST
AR10 – 50



PRELIMINARY
OCT 23 1986

IMPERIAL VALLEY
MAIN SHOCK

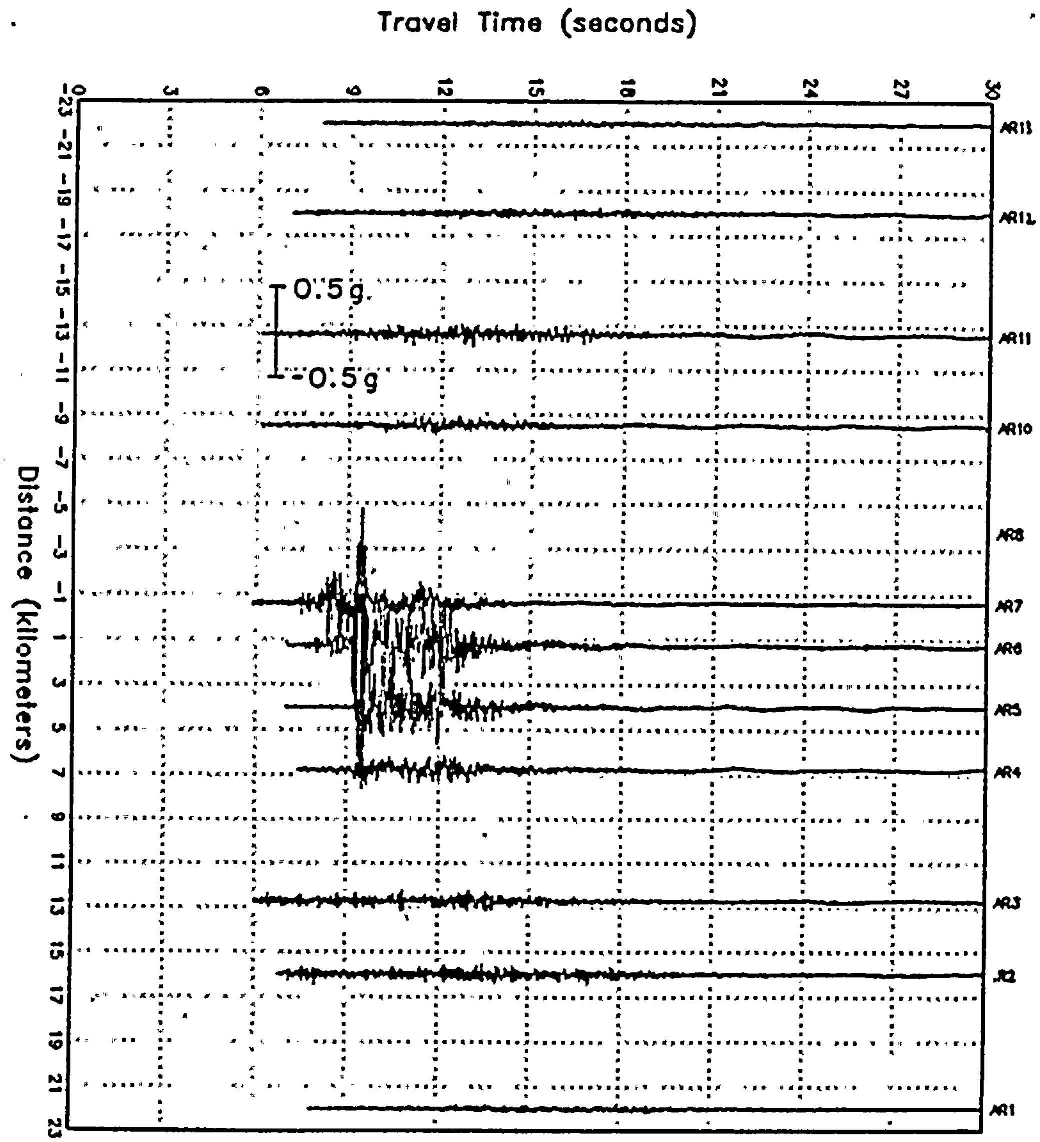
SIMULATION (SMOOTH RUPTURE)
FAULT NORMAL COMPONENTS (230)
WITH EXCEPTIONS OF:
AR9 – EAST
AR10 – 50



PRELIMINARY
OCT 23 1986

IMPERIAL VALLEY
MAIN SHOCK

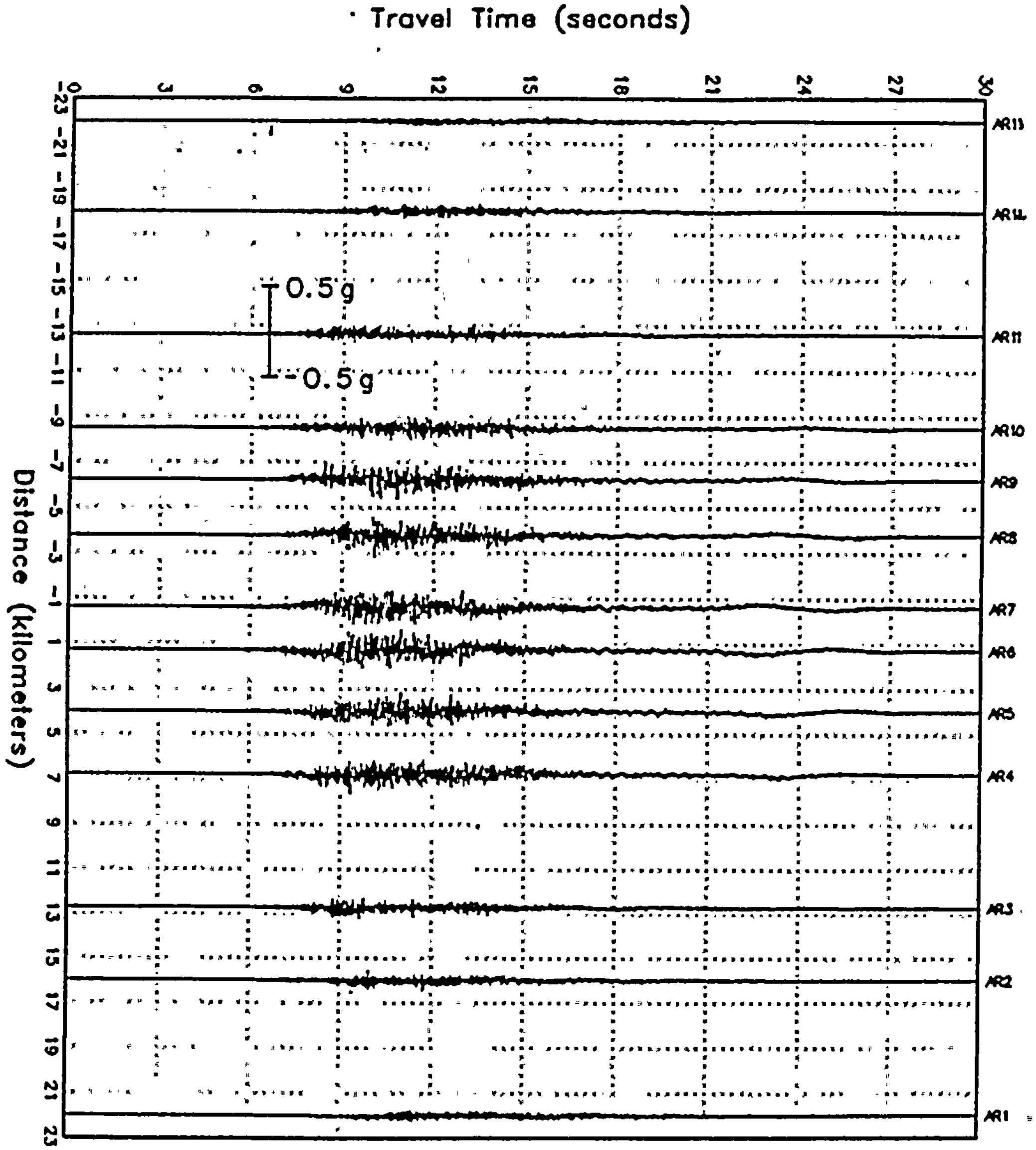
OBSERVED ACCELERATION
VERTICAL COMPONENTS



PRELIMINARY
OCT 23 1986

IMPERIAL VALLEY
MAIN SHOCK

ACCELERATION SIMULATION
(ASPERITY MODEL)
VERTICAL COMPONENT

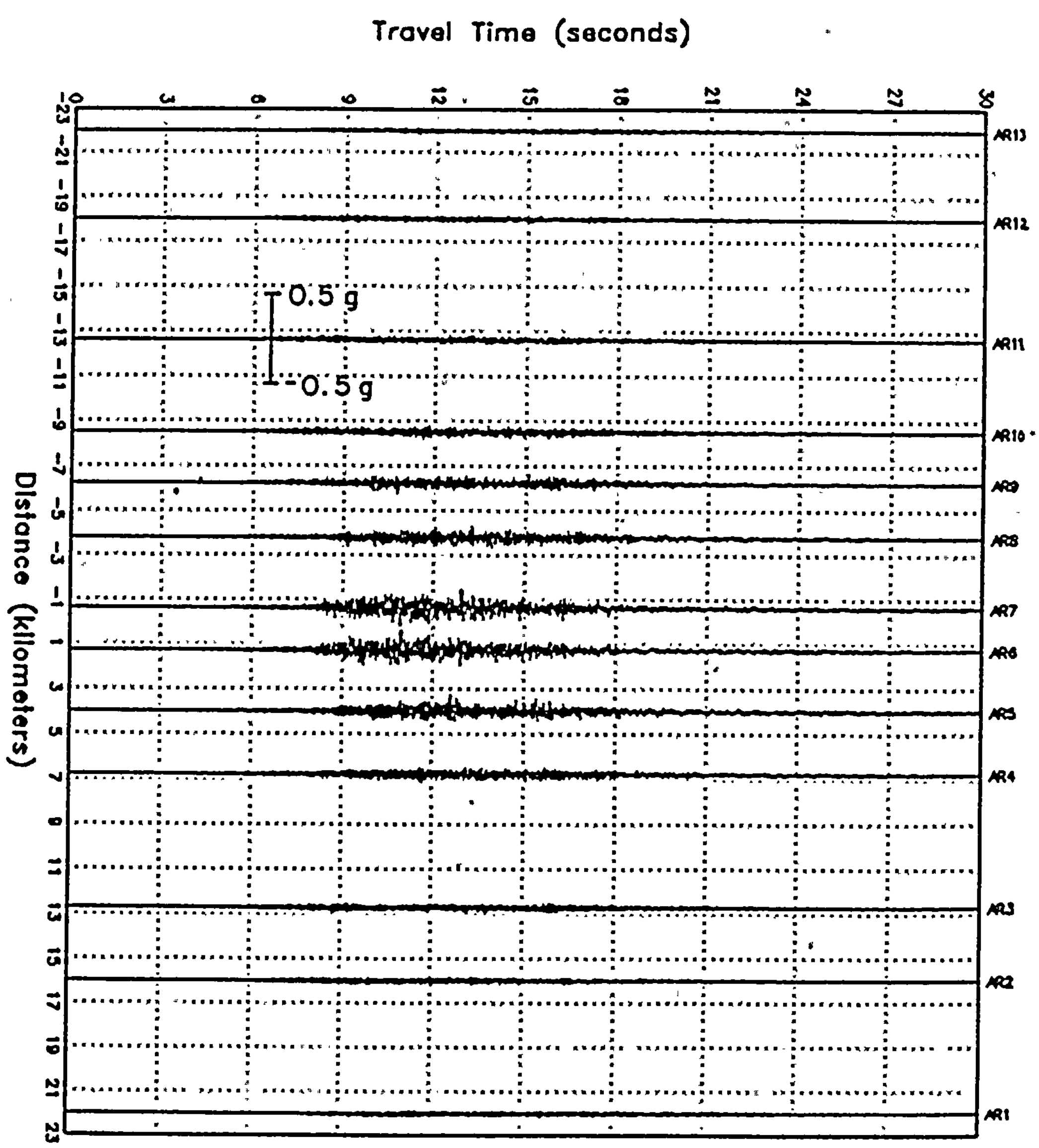


PRELIMINARY
OCT 23 1986

IX-25

IMPERIAL VALLEY
MAIN SHOCK

SIMULATION (SMOOTH RUPTURE)
VERTICAL COMPONENTS



PRELIMINARY
OCT 23 1986

IX-26

CONCLUSION FROM ANALYSIS OF EL CENTRO ARRAY

- THE TIMING OF THE INITIAL LARGE S-WAVE ENERGY ON THE ACCELEROGRAMS IS CONSISTENT WITH THEM HAVING ORIGINATED AT THE LARGE ASPERITY OF THE HARTZELL AND HEATON MODEL

- THE ASPERITY MODEL PROVIDES A BETTER FIT TO THE OBSERVED DATA THAN THE SMOOTH RUPTURE MODEL

PRELIMINARY
OCT 23 1986

ANALYSIS OF ASPERITY MODEL USING LONGITUDINAL ARRAY

STATIONS:

ARRAY #4, HOLTVILLE, BOND'S CORNER

PLOTS FOR EACH STATION:

OBSERVED ACCELERATION

SIMULATION - CENTRAL ASPERITY MODEL (HARTZELL AND HEATON, 1983)

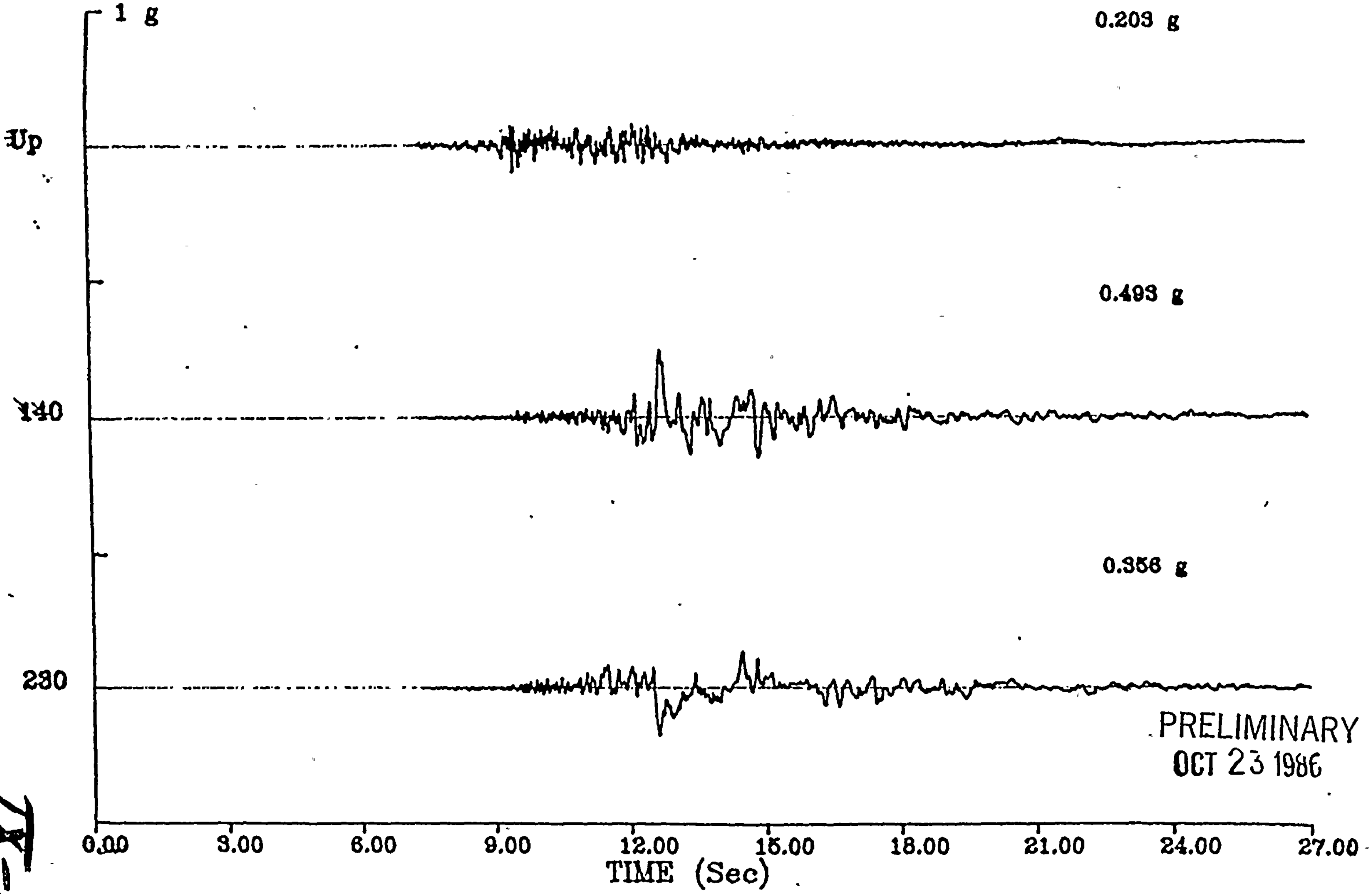
SIMULATION - SMOOTH RUPTURE MODEL

SIMULATION - NORTHERN ASPERITY MODEL

SIMULATION - SOUTHERN ASPERITY MODEL

PRELIMINARY
OCT 23 1986

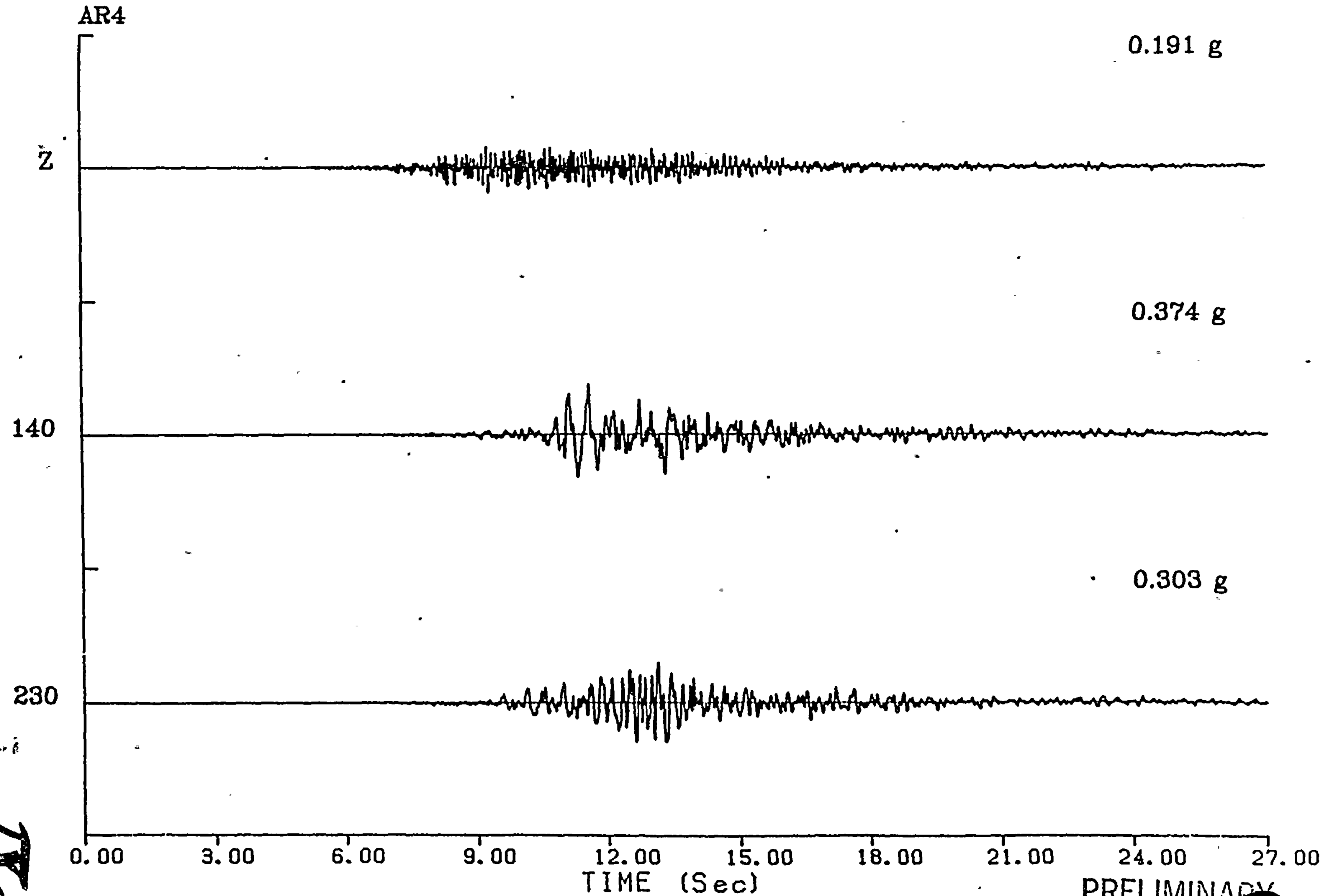
Imperial Valley, 2317 UTC, El Centro Array 4, Anderson Road
Origin time = 23:16:54.4; Trigger time = 23:17:01.78



PRELIMINARY
OCT 23 1986

V-29

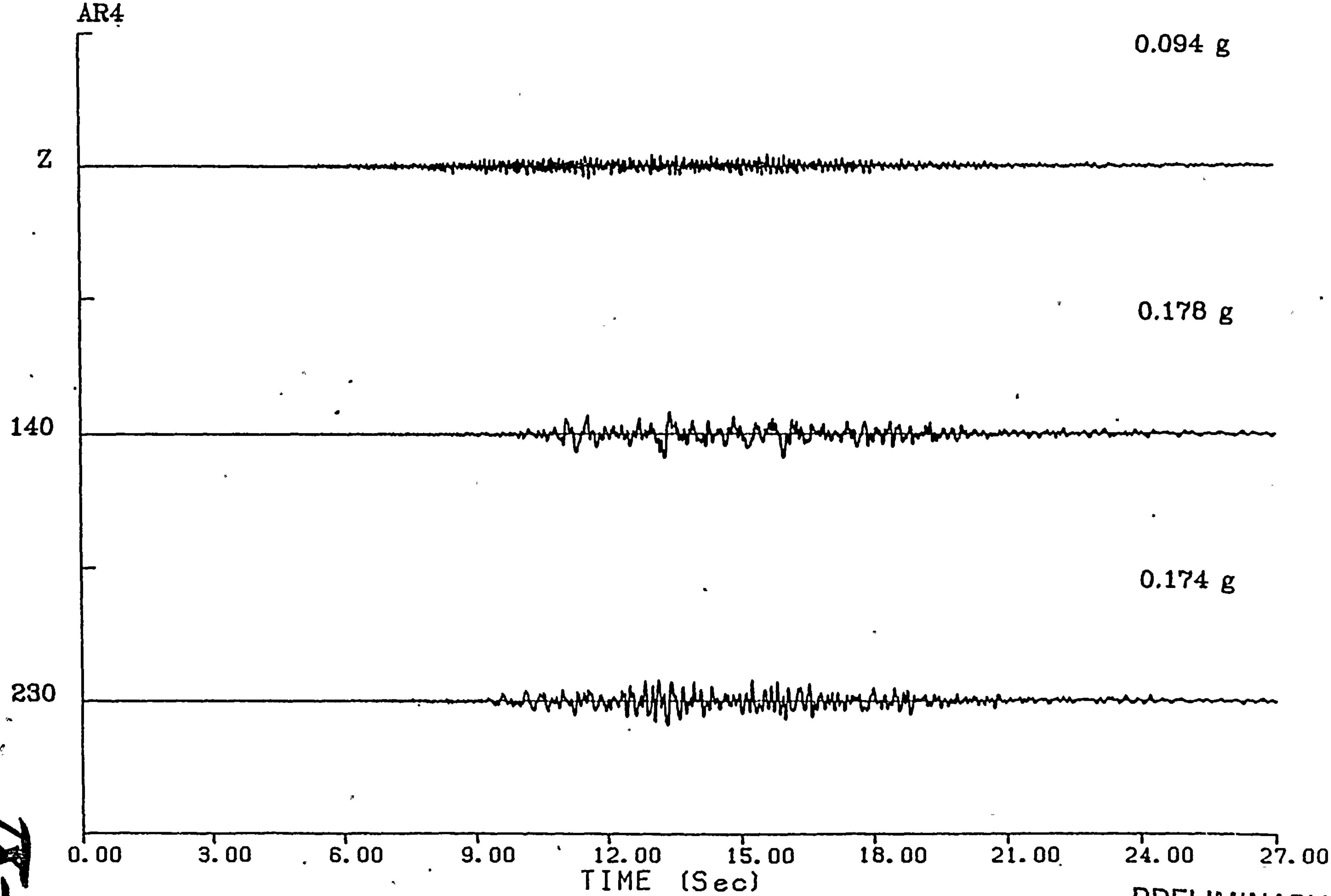
IMP. VALLEY CENTRAL ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT= 1.5



PRELIMINARY
OCT 23 1986

XI-30

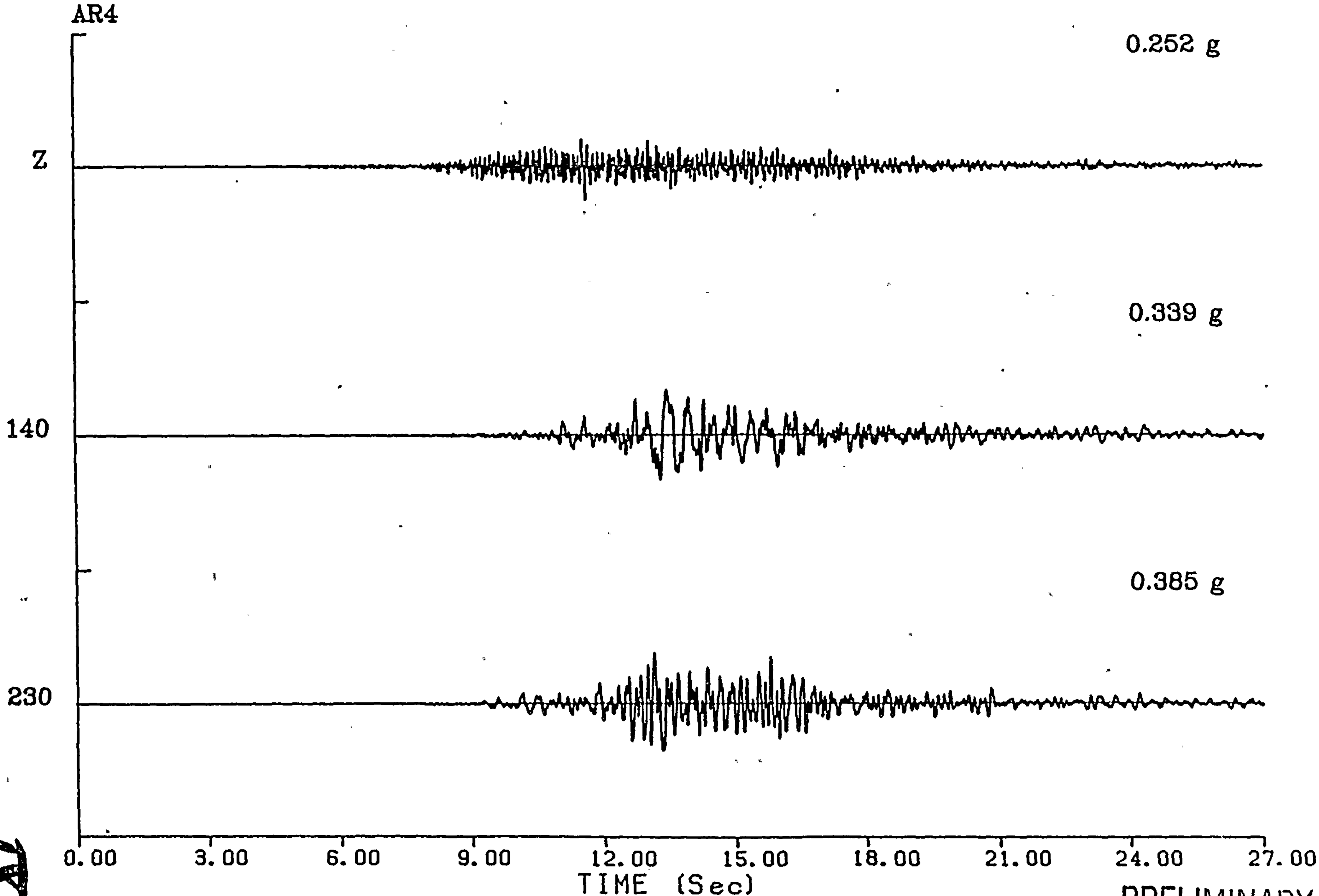
IMP. VALLEY SMOOTH RUPTURE (HARTZELL Vr=2.5,Vs=3.1) RT= 1.5



PRELIMINARY
OCT 23 1986

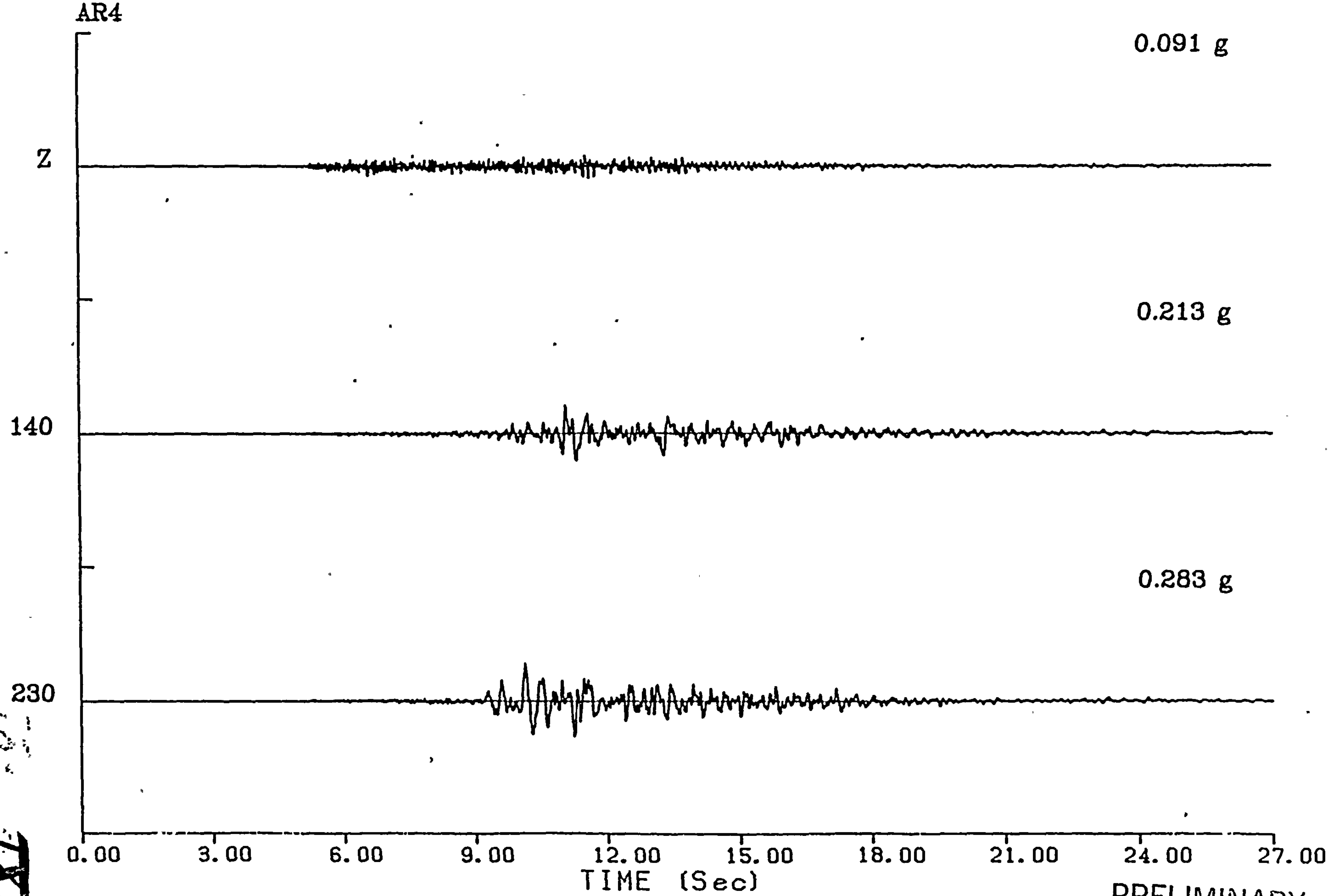
IV-31

IMP. VALLEY NORTH ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT 1.5



PRELIMINARY
OCT 23

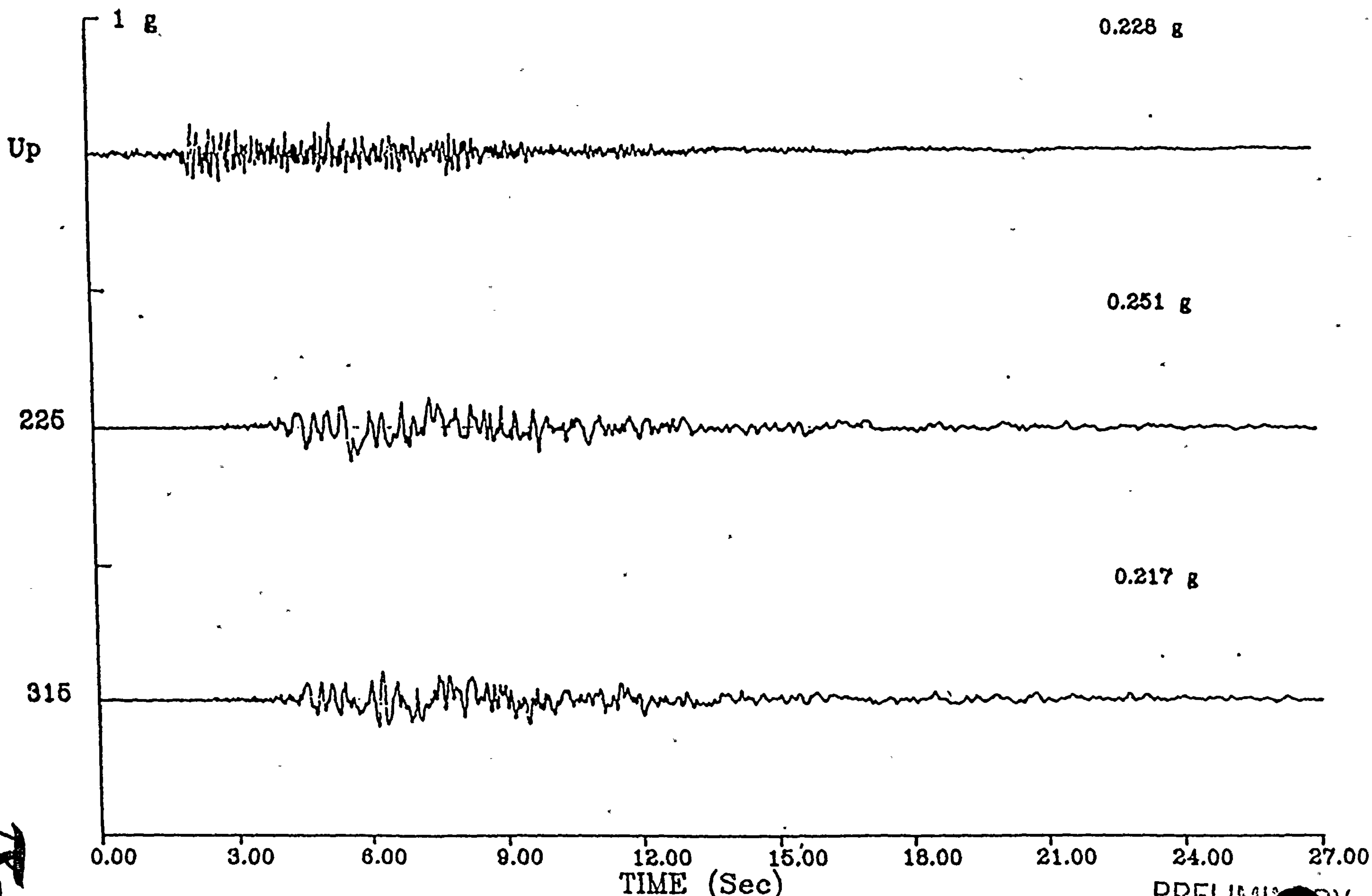
IMP. VALLEY SOUTH ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT 1.5



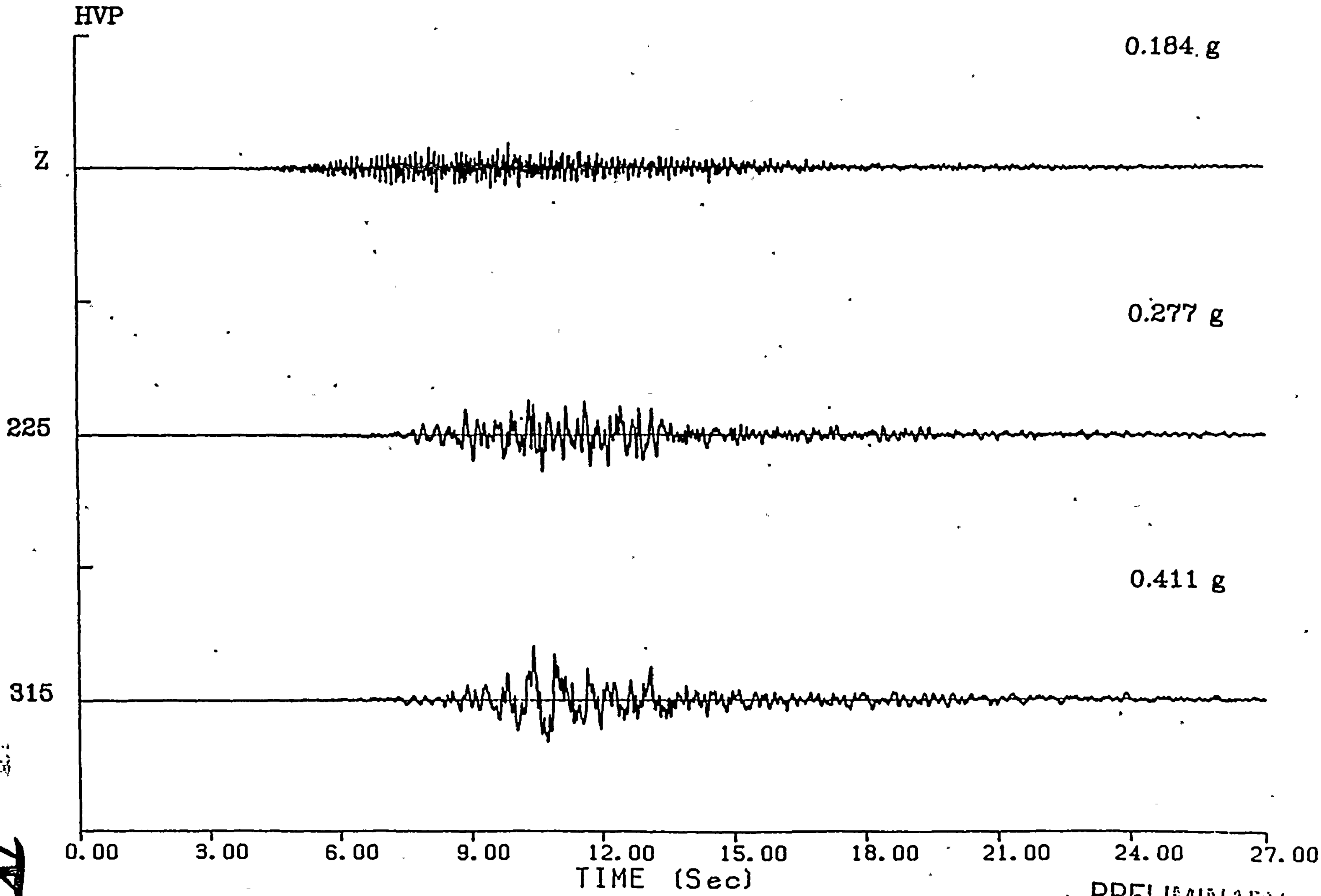
PRELIMINARY
OCT 23 1986

IX-53

Imperial Valley, 2317 UTC, Holtville Post Office
Origin time = 23:16:54.4; Trigger time =No Absolute Time



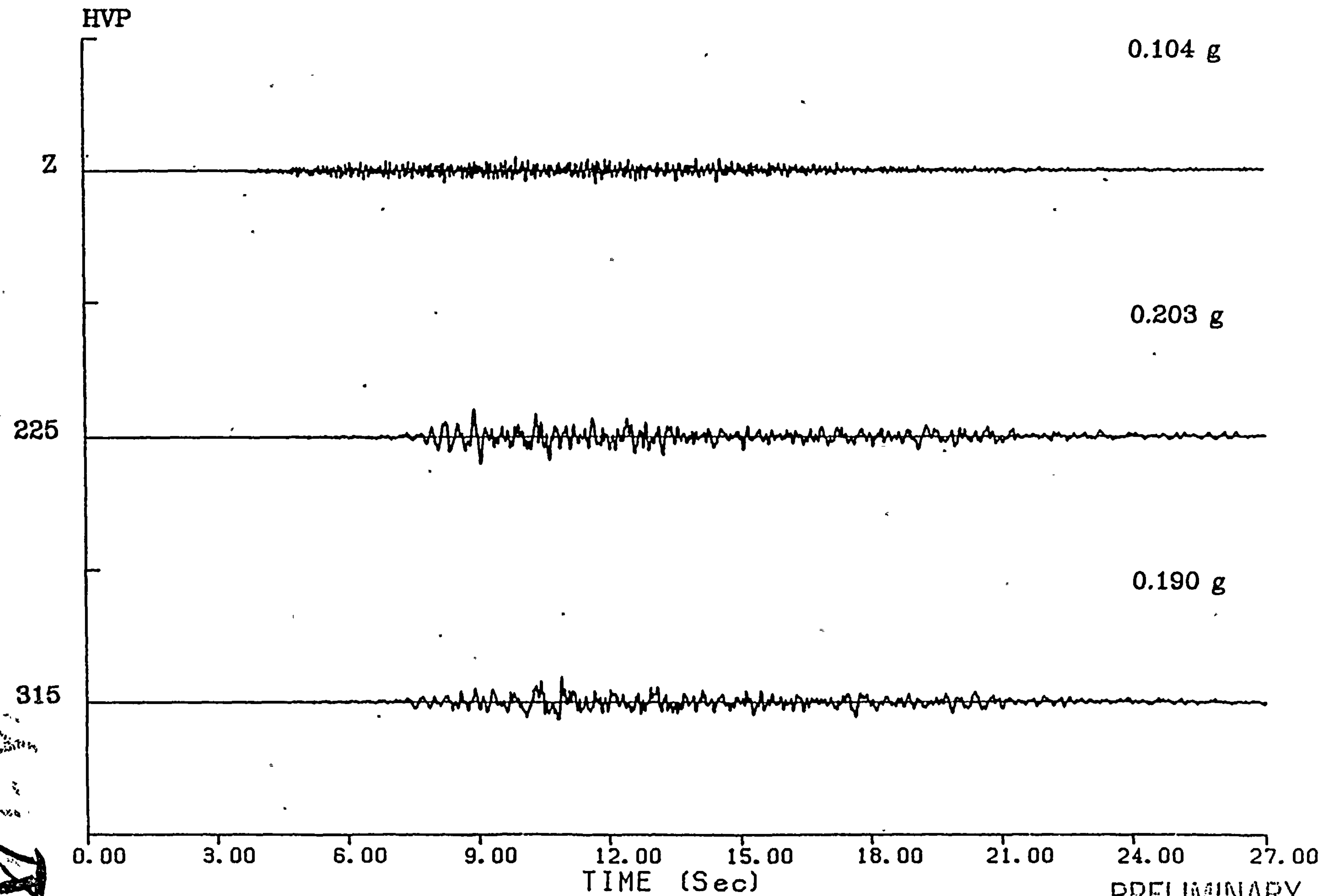
IMP. VALLEY CENTRAL ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT= 1.5



PRELIMINARY
OCT 23 1986

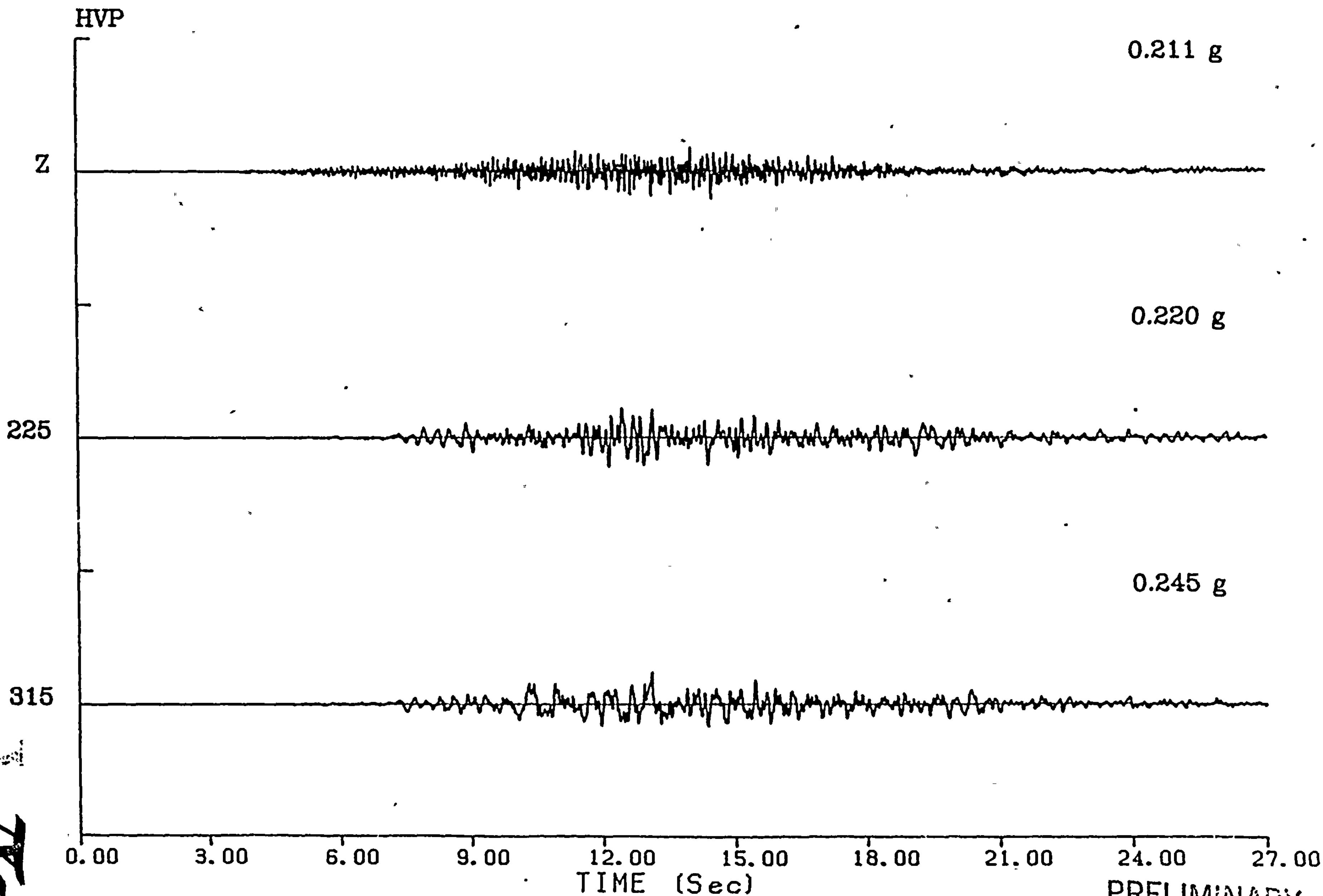
II-355

IMP. VALLEY SMOOTH RUPTURE (HARTZELL Vr=2.5,Vs=3.1) RT= 1.5



PRELIMINARY
OCT 23 198

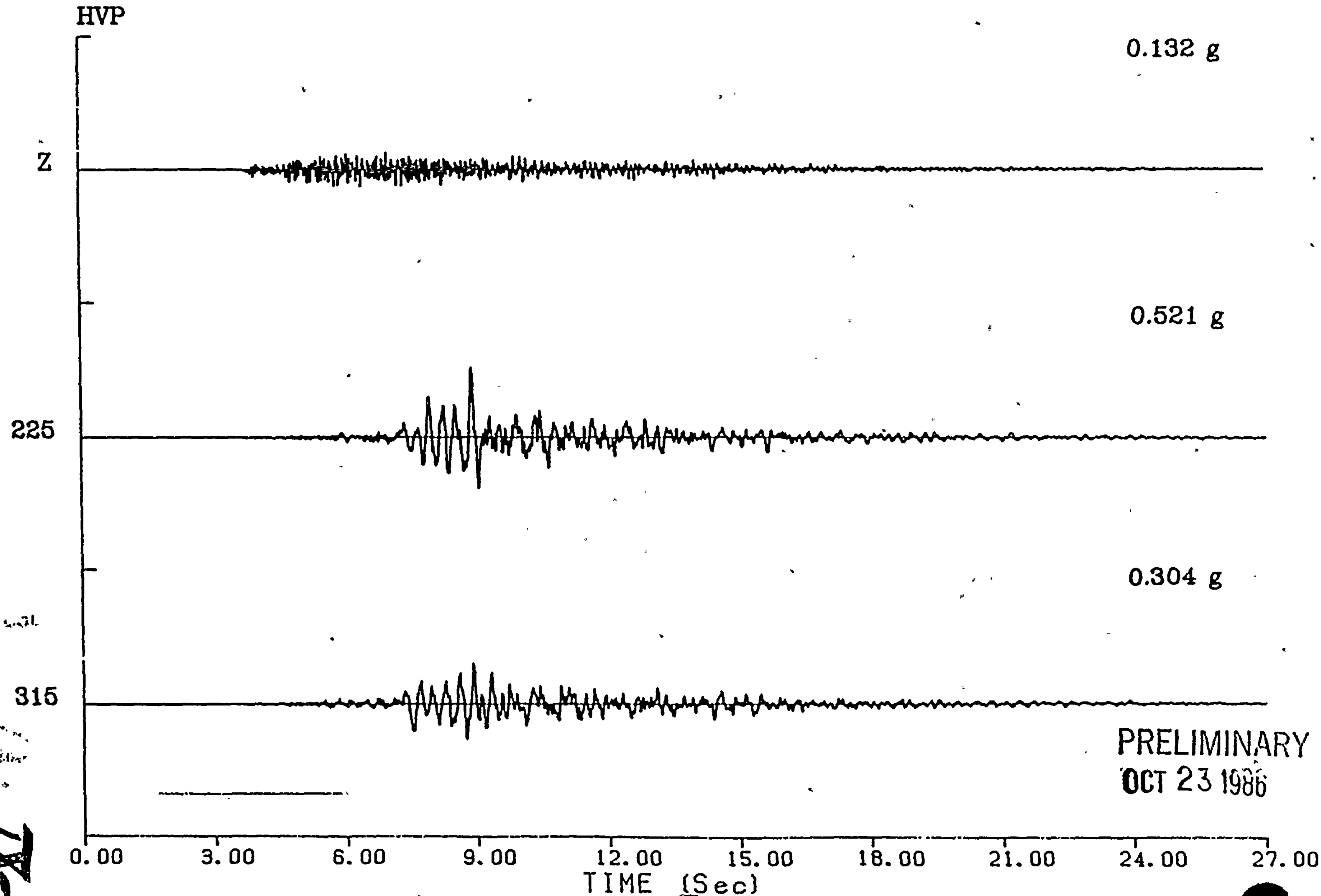
IMP. VALLEY NORTH ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT 1.5



PRELIMINARY
OCT 23 1980

II-37

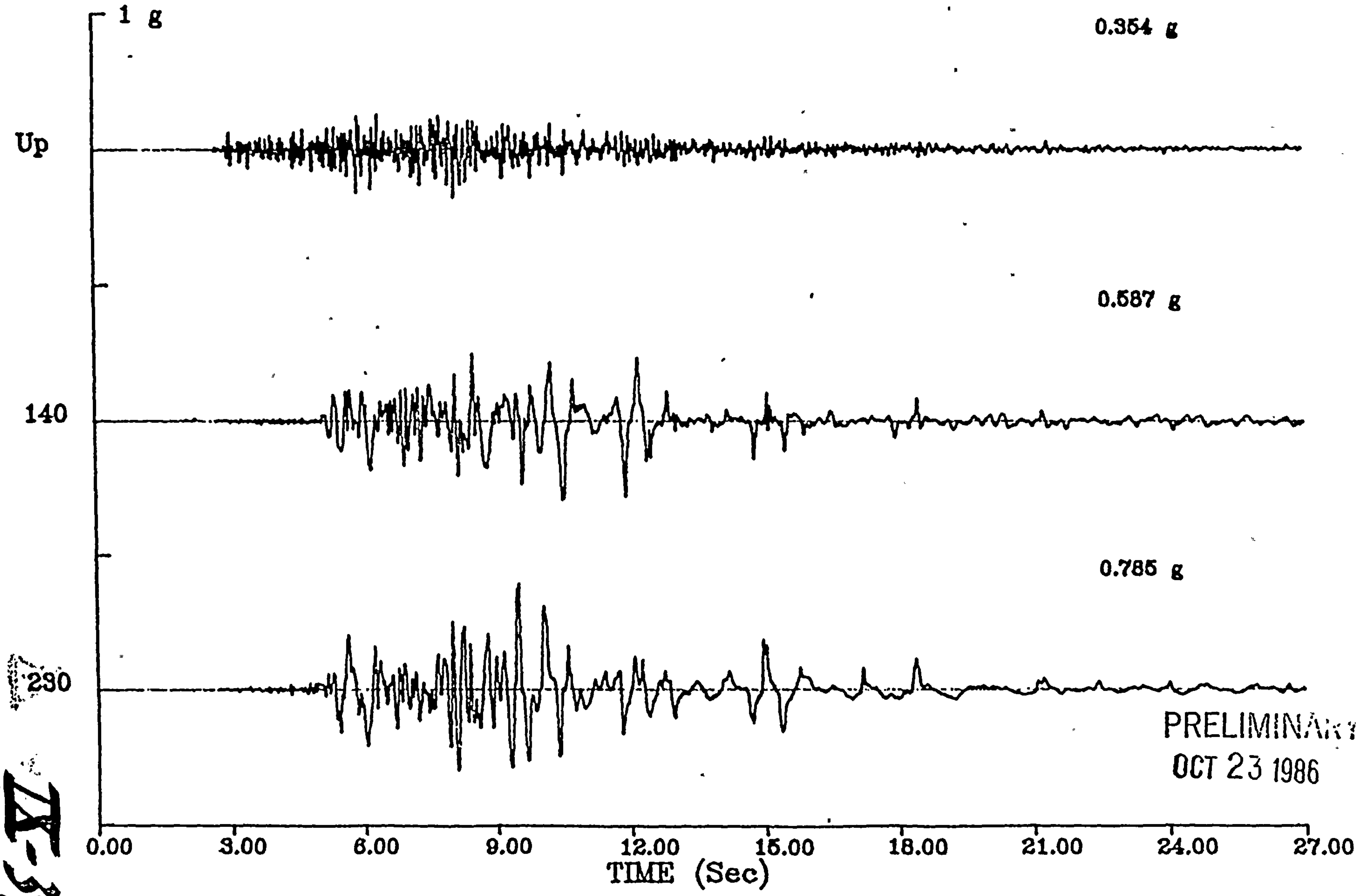
IMP. VALLEY SOUTH ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT 1.5



PRELIMINARY
OCT 23 1986

55-II

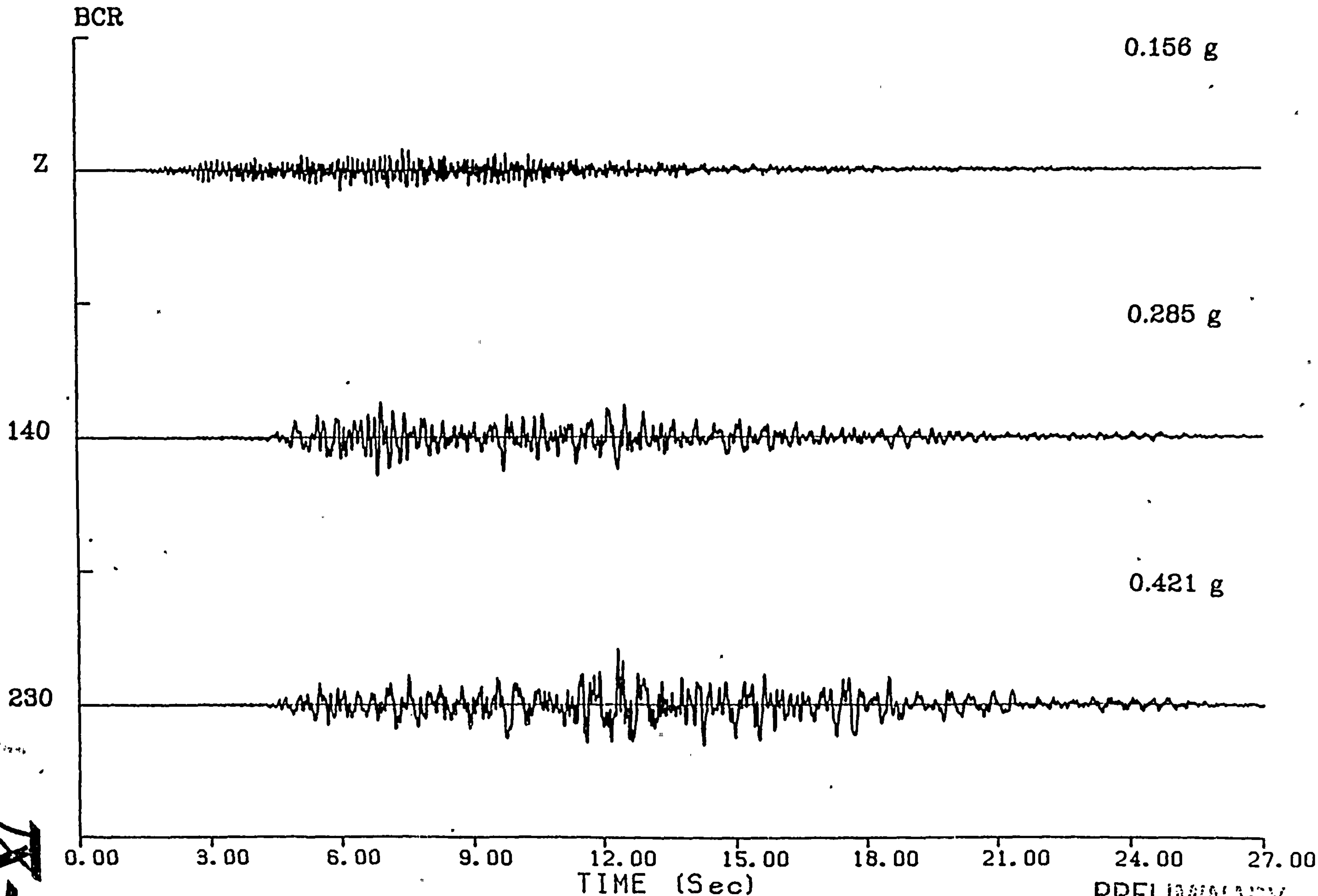
Imperial Valley, 2317 UTC, El Centro Bonds Corner
Origin time = 23:16:54.4; Trigger time = 23:16:57.11



PRELIMINARY
OCT 23 1986

IX-39

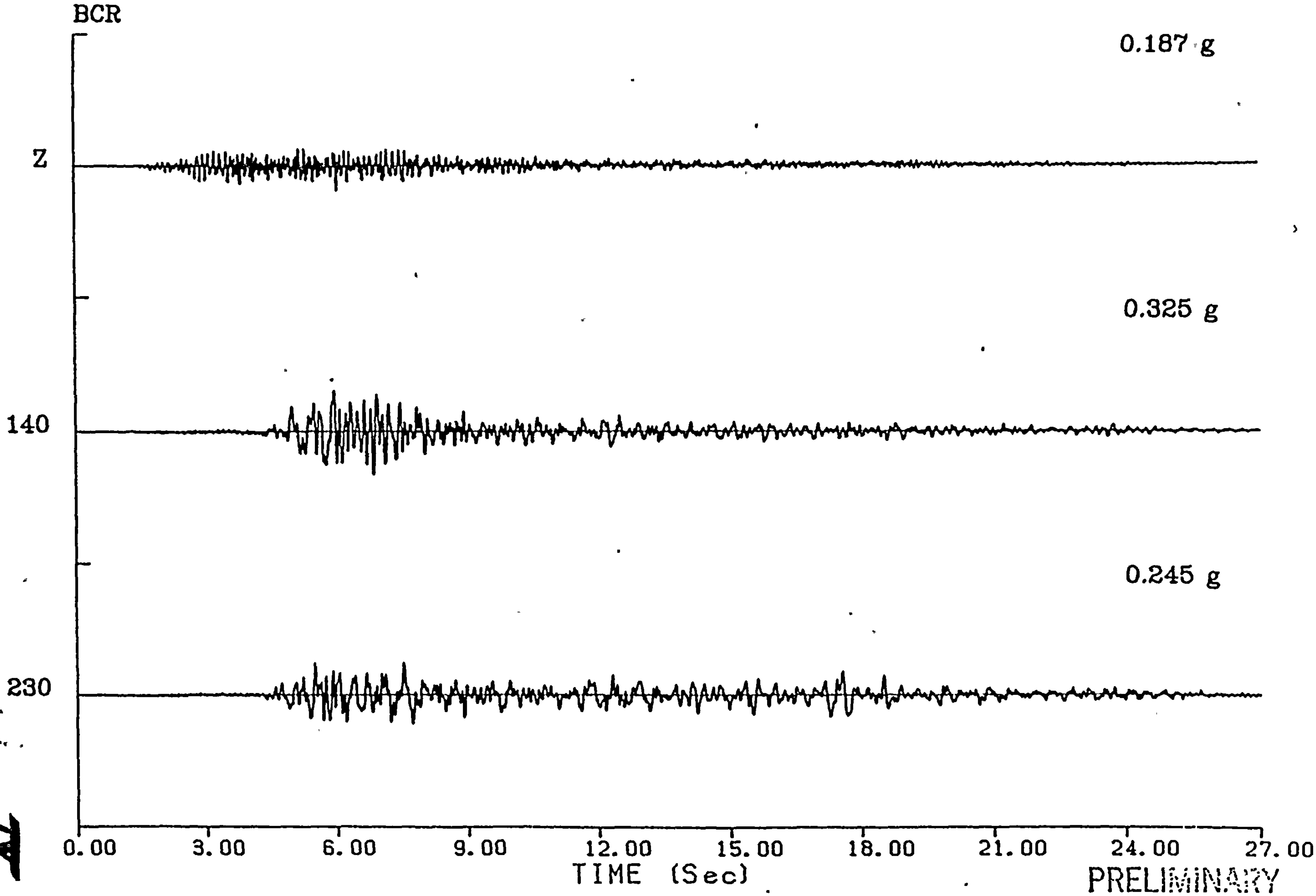
IMP. VALLEY CENTRAL ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT= 1.5



IX-40

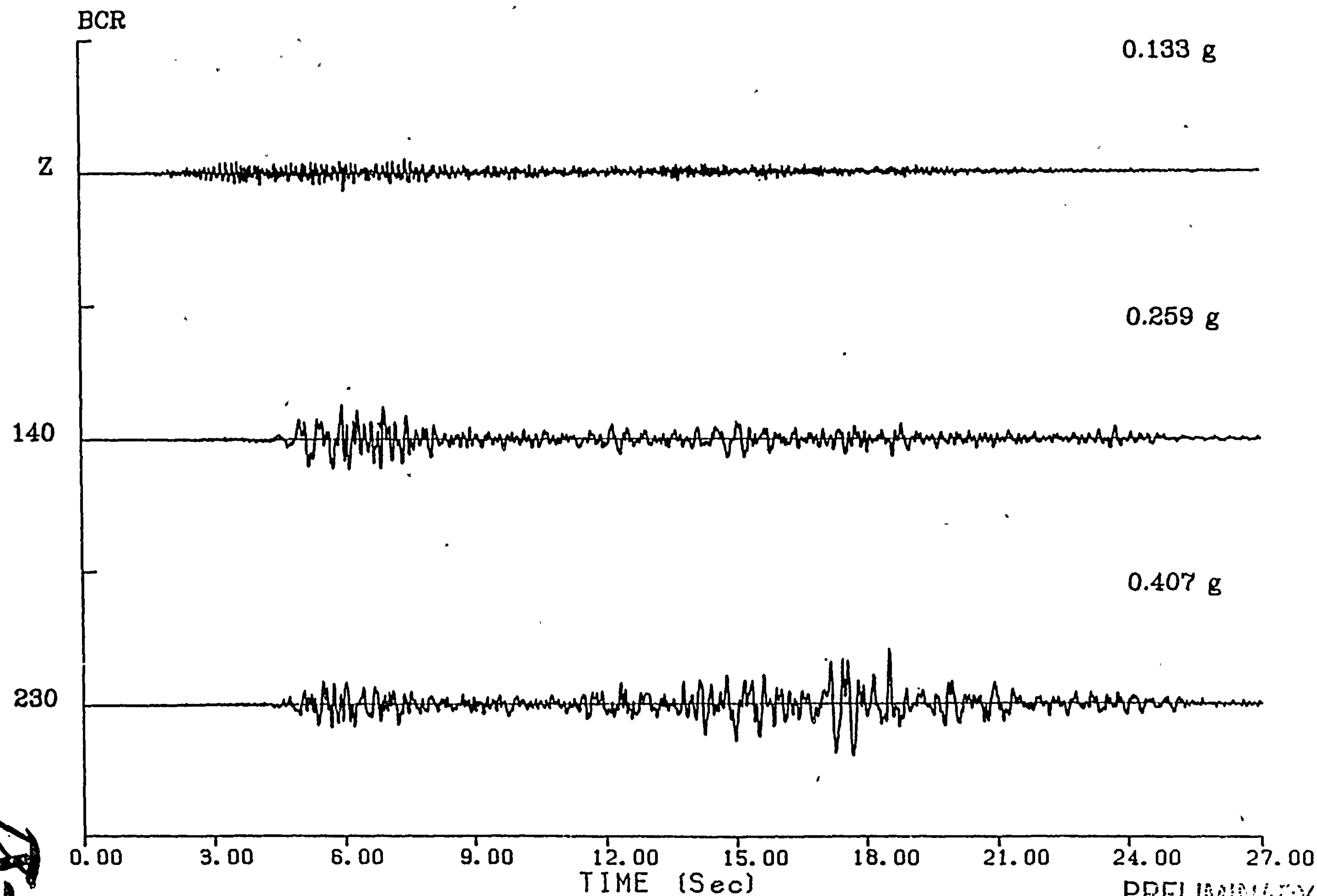
PRELIMINARY
OCT 23 198

IMP. VALLEY SMOOTH RUPTURE (HARTZELL Vr=2.5,Vs=3.1) RT= 1.5



PRELIMINARY
OCT 23 1986

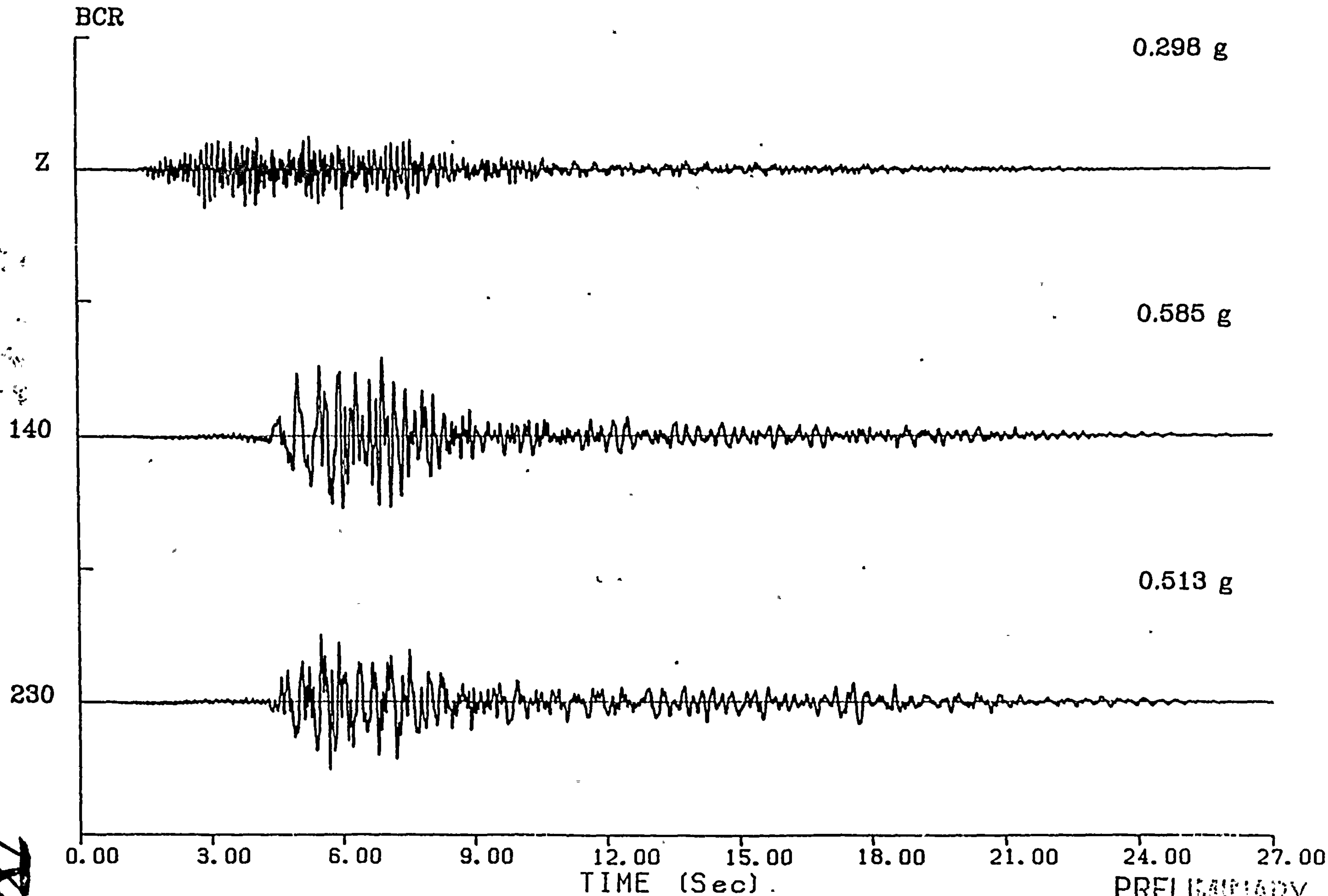
IMP. VALLEY NORTH ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT 1.5



PRELIMINARY
OCT 23

B-42

IMP. VALLEY SOUTH ASPERITY (HARTZELL Vr=2.5,Vs=3.1) RT 1.5



PRELIMINARY
OCT 23 1986

IX-43

CONCLUSION REGARDING MODELING OF ASPERITIES AT HIGH FREQUENCIES

THE HARTZELL & HEATON (1983) ASPERITY MODEL, WHEN APPLIED TO HIGH FREQUENCY RADIATION, PROVIDES BETTER AGREEMENT BETWEEN OBSERVED AND SIMULATED ACCELEROGRAMS THAN SMOOTH RUPTURE MODELS OR MODELS HAVING ASPERITIES IN OTHER LOCATIONS.

PRELIMINARY
OCT 23 1986

ATTENUATION OF PEAK MOTION AMPLITUDE WITH DISTANCE

PEAK MOTIONS:

- ACCELERATION
- VELOCITY

COMPONENTS:

- VERTICAL
- FAULT NORMAL (H1)
- FAULT PARALLEL (H2)

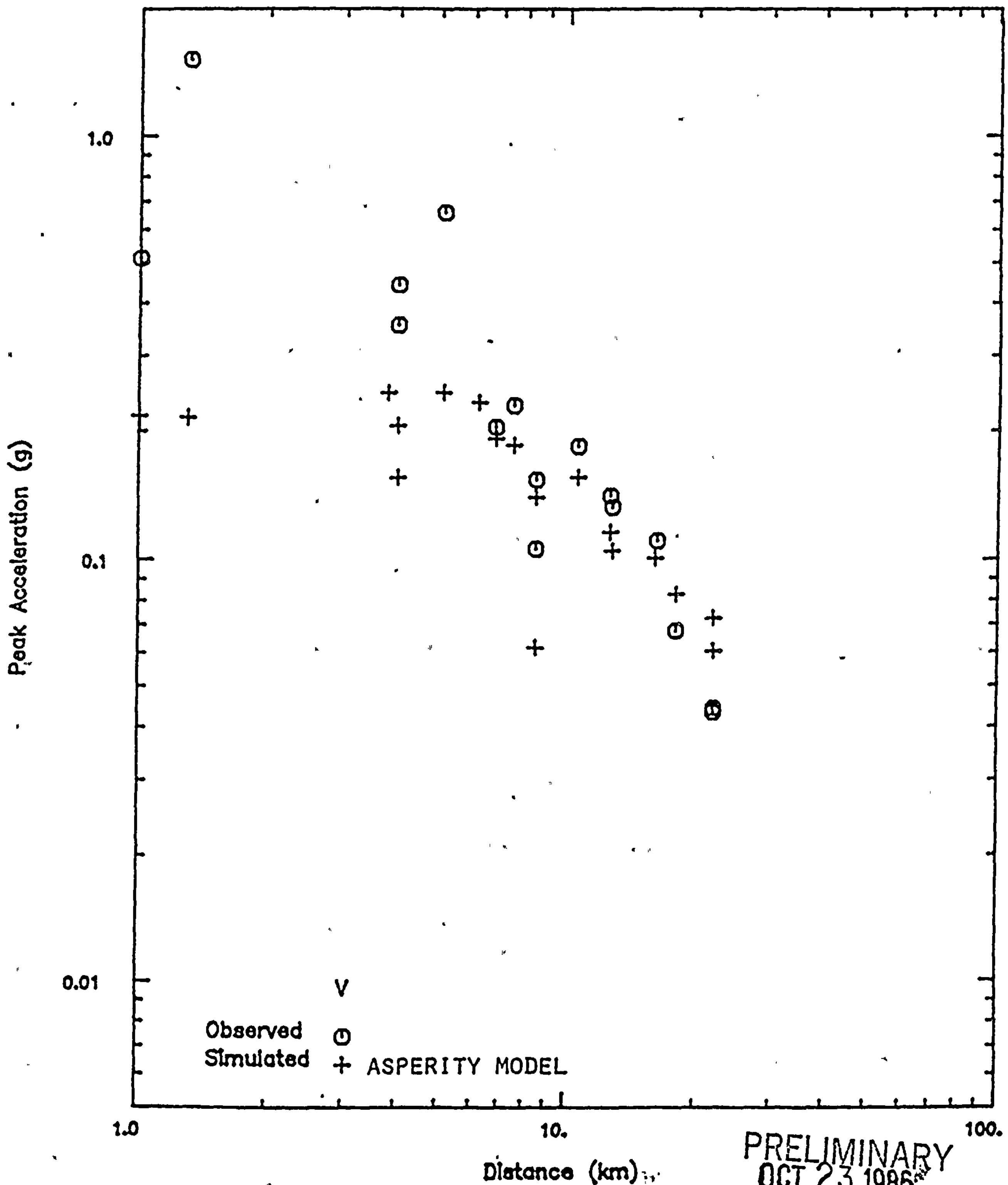
FAULT MODELS:

- ASPERITY
- SMOOTH RUPTURE

PRELIMINARY
OCT 23 1986

Imperial Valley Main Shock 1979

ASPERITY MODEL

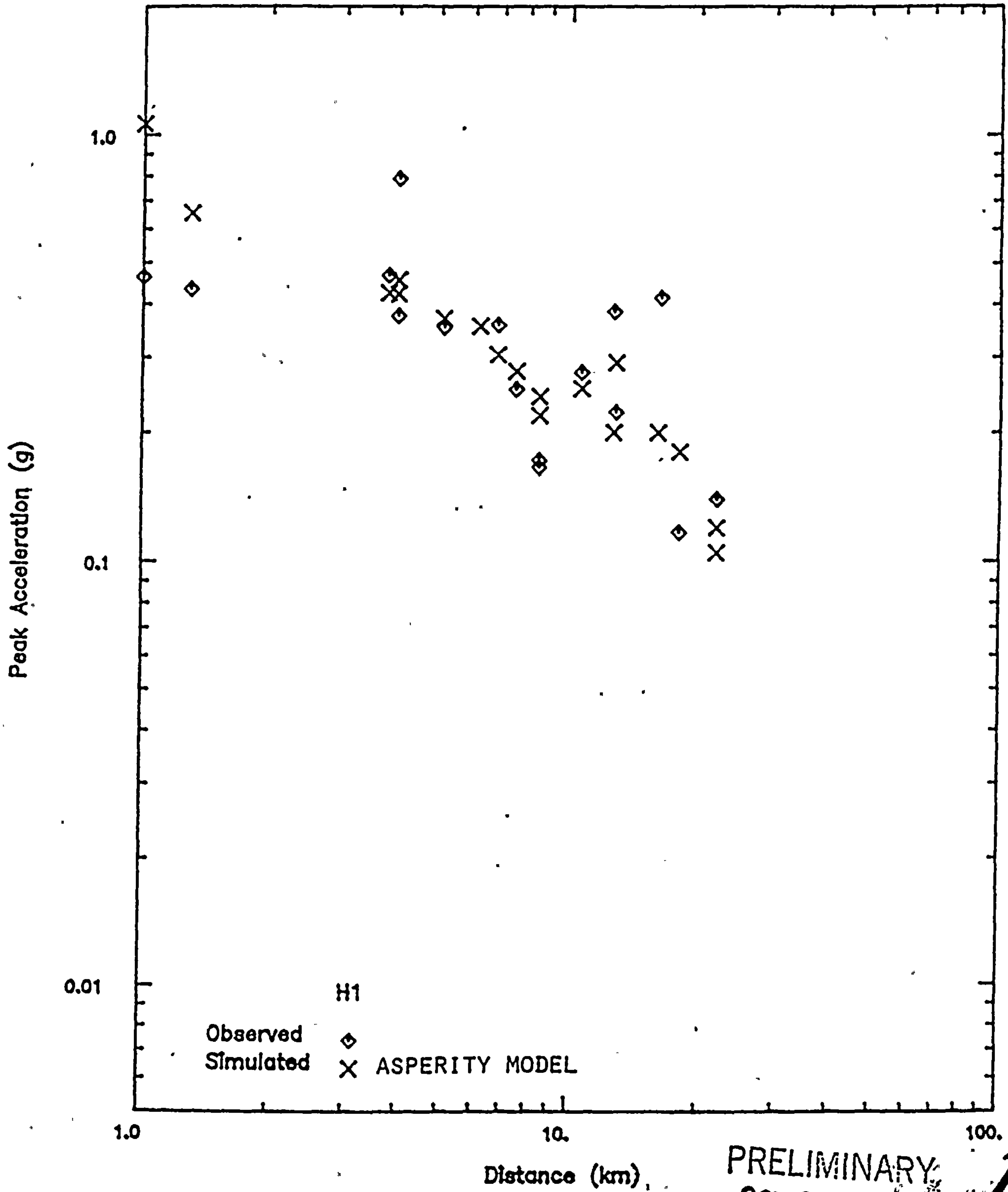


PRELIMINARY
OCT 23 1986

IX-46

Imperial Valley Main Shock 1979

ASPERITY MODEL

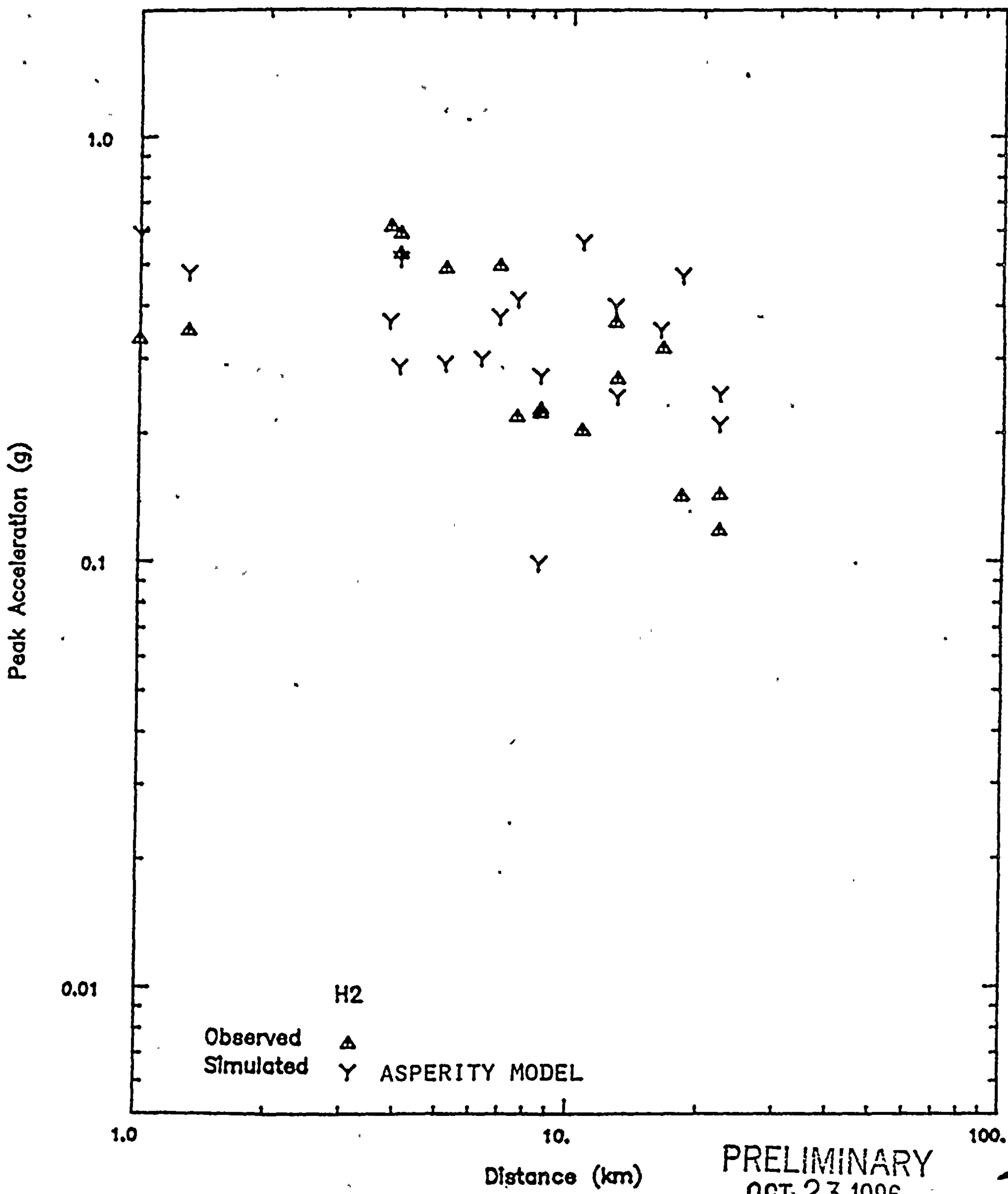


PRELIMINARY
OCT 23 1986

IX-47

Imperial Valley Main Shock 1979

ASPERITY MODEL

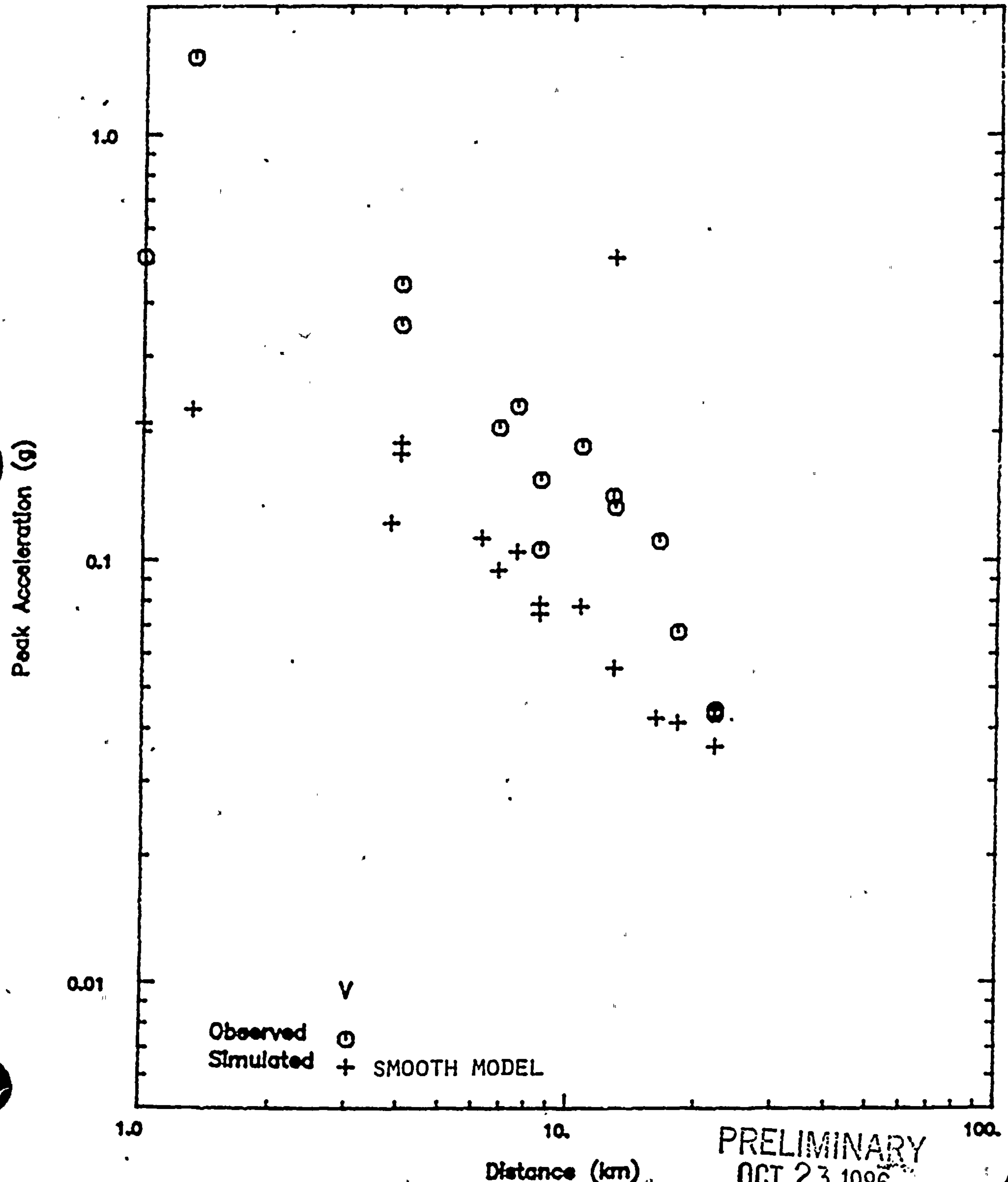


PRELIMINARY
OCT 23 1986

IX-98

Imperial Valley Main Shock 1979

SMOOTH MODEL

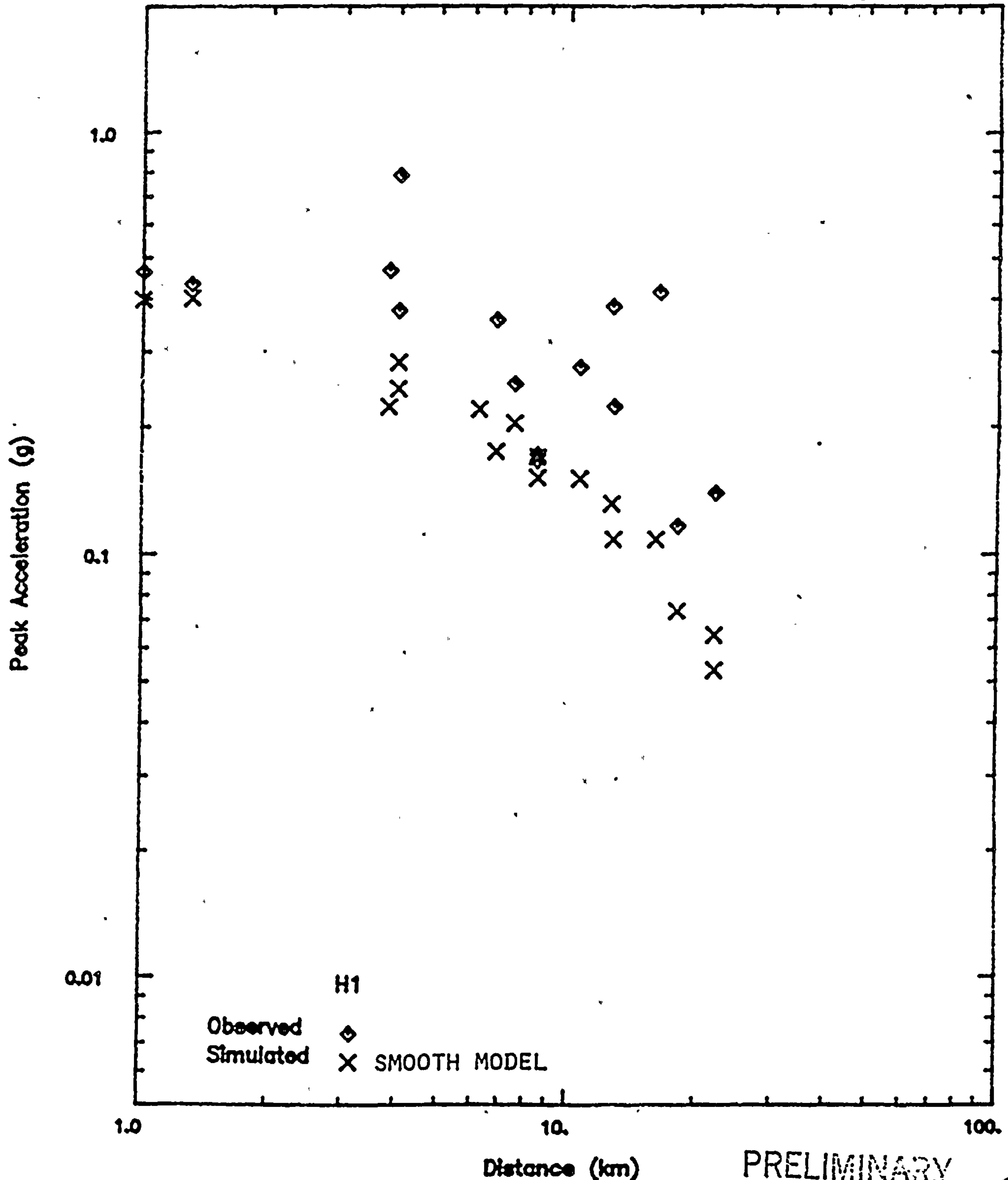


PRELIMINARY
OCT 23 1986

IX-49

Imperial Valley Main Shock 1979

SMOOTH MODEL

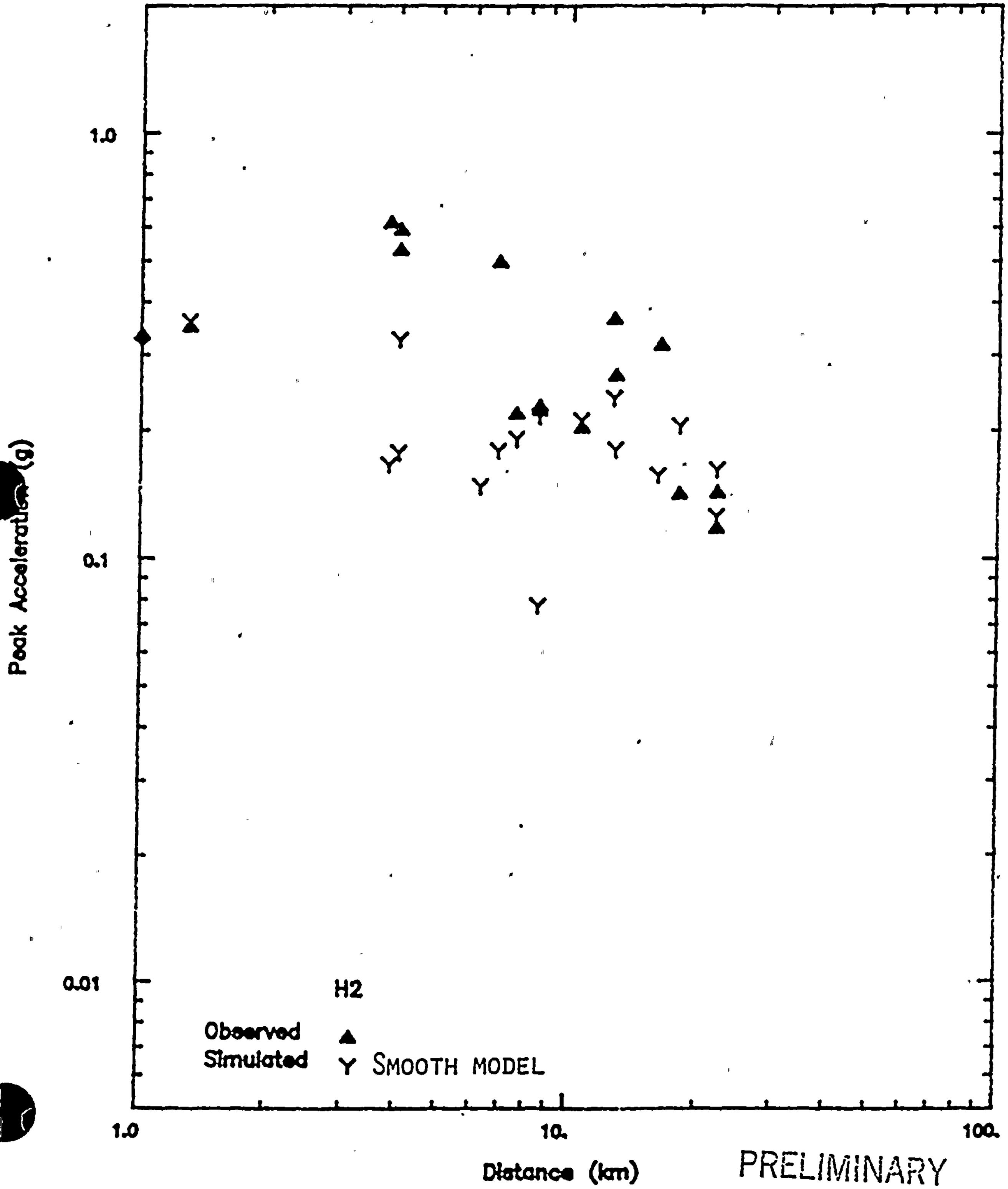


PRELIMINARY
OCT 23 1986

IX-50

Imperial Valley Main Shock 1979

SMOOTH MODEL

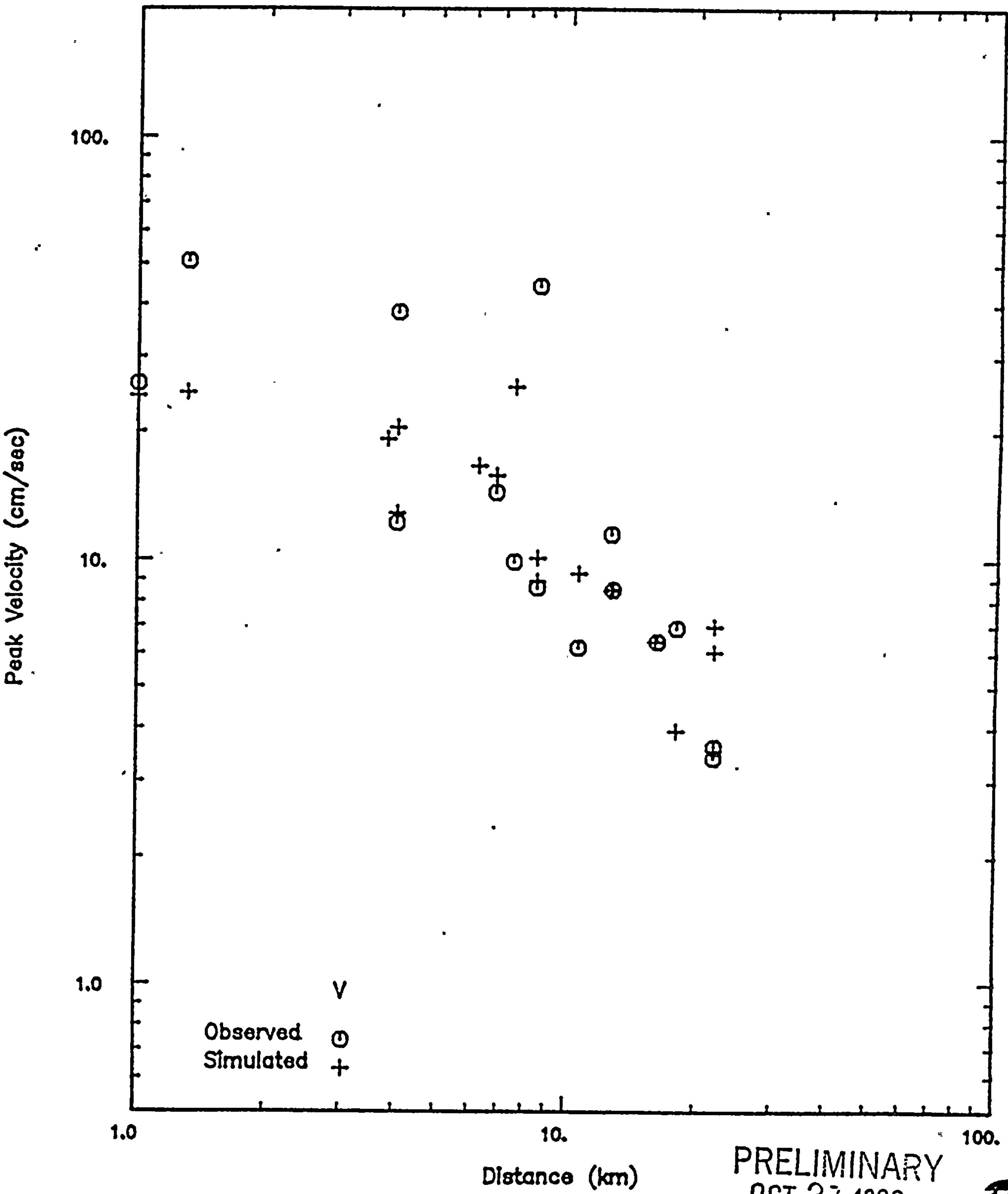


PRELIMINARY
OCT 23 1986

IX-51

Imperial Valley Main Shock 1979

ASPERITY MODEL

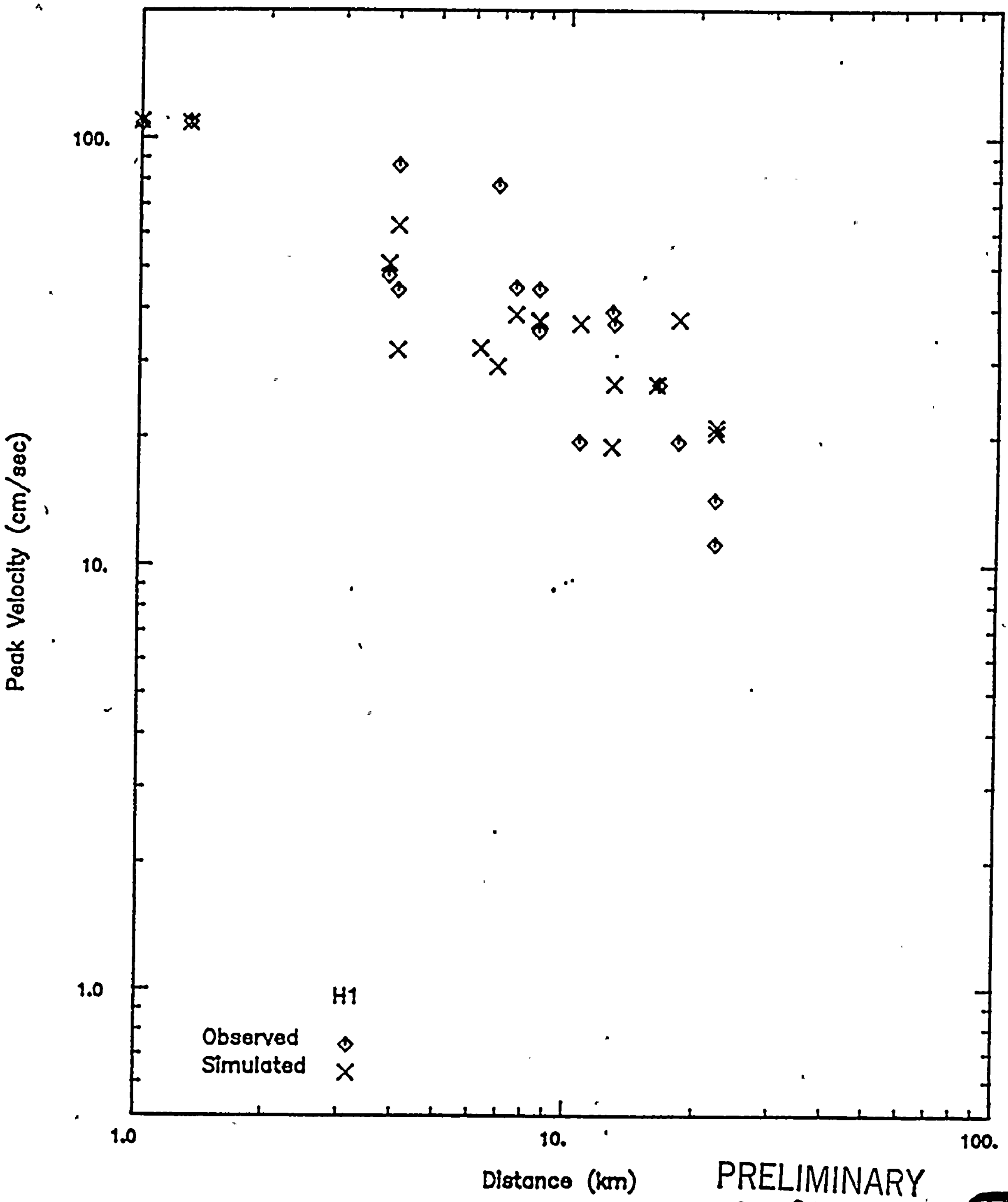


PRELIMINARY
OCT 23 1986

IX-52

Imperial Valley Main Shock 1979

ASPERITY MODEL

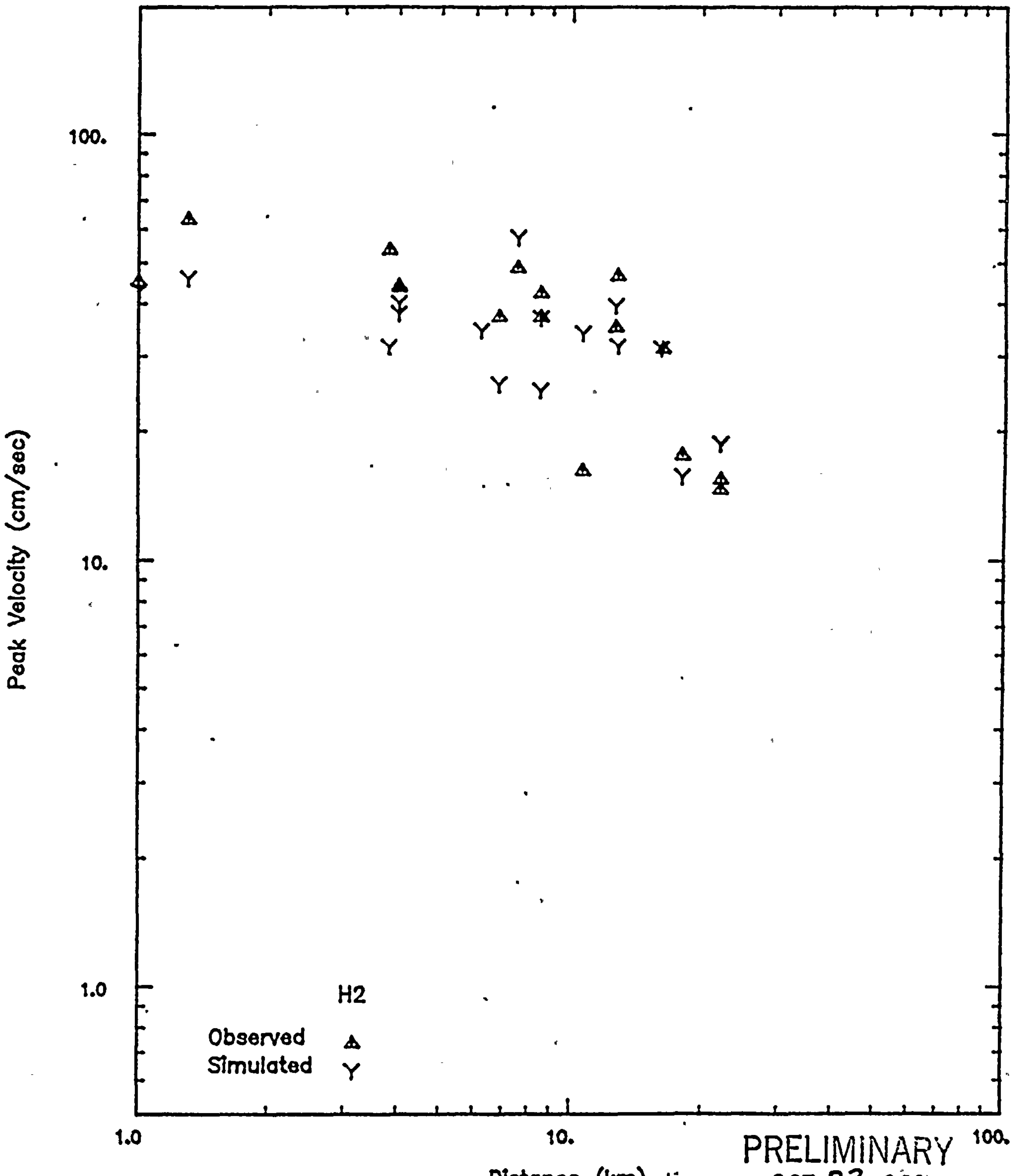


PRELIMINARY
OCT 23 1986

IX-53

Imperial Valley Main Shock 1979

ASPERITY MODEL

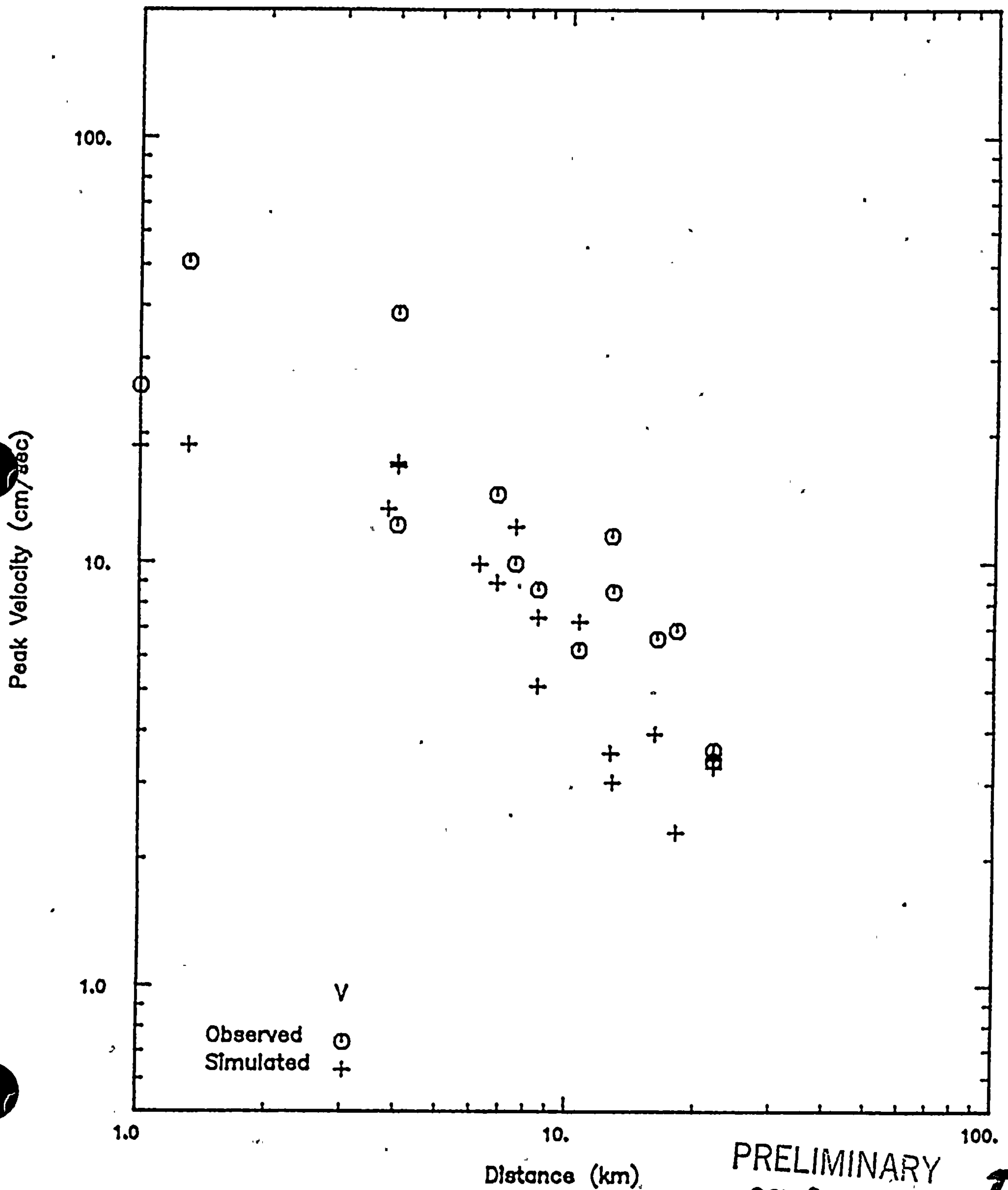


PRELIMINARY
OCT 23 1986

IX-54

Imperial Valley Main Shock 1979

SMOOTH MODEL

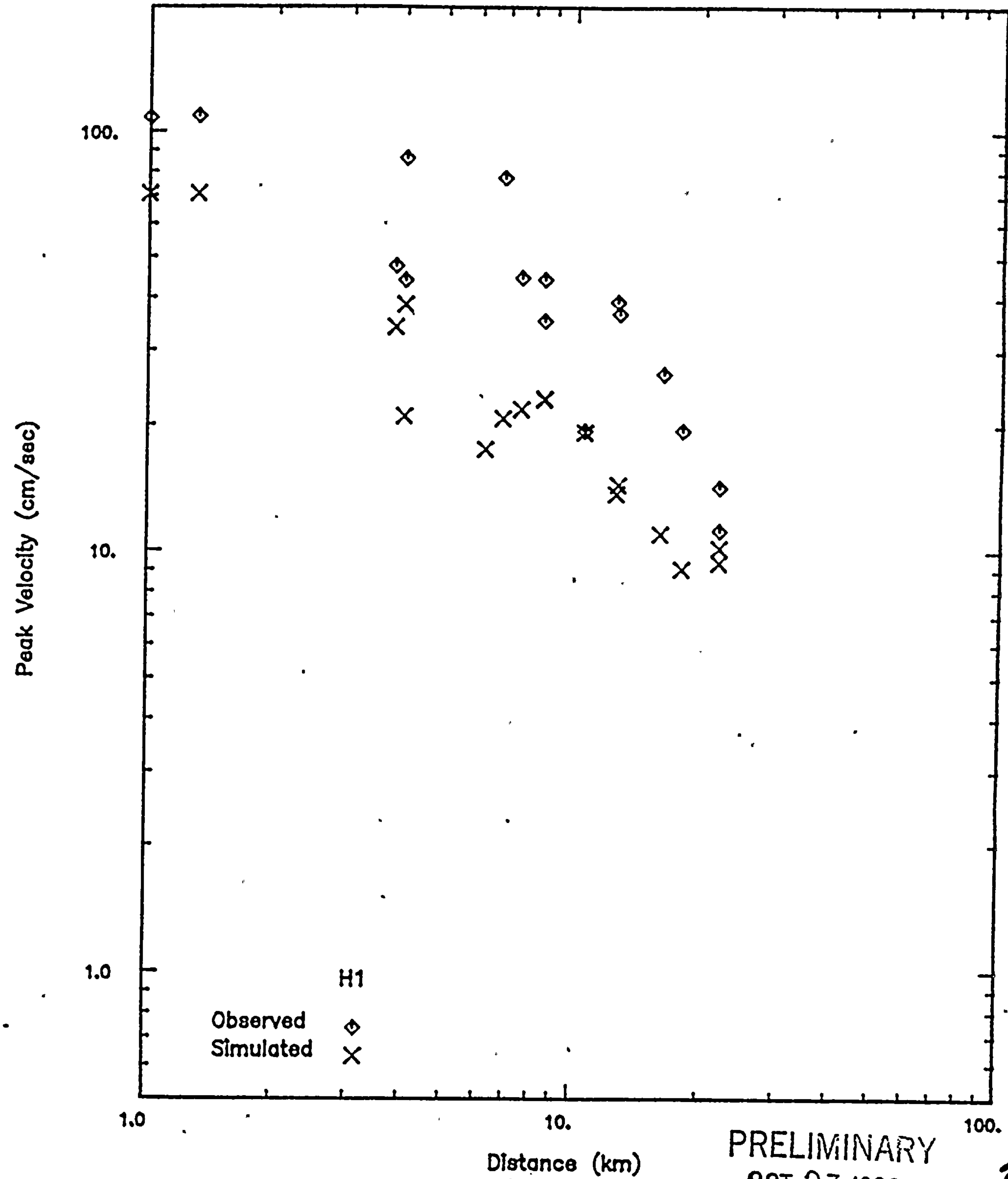


PRELIMINARY
OCT 23 1986

IX-55

Imperial Valley Main Shock 1979

SMOOTH MODEL

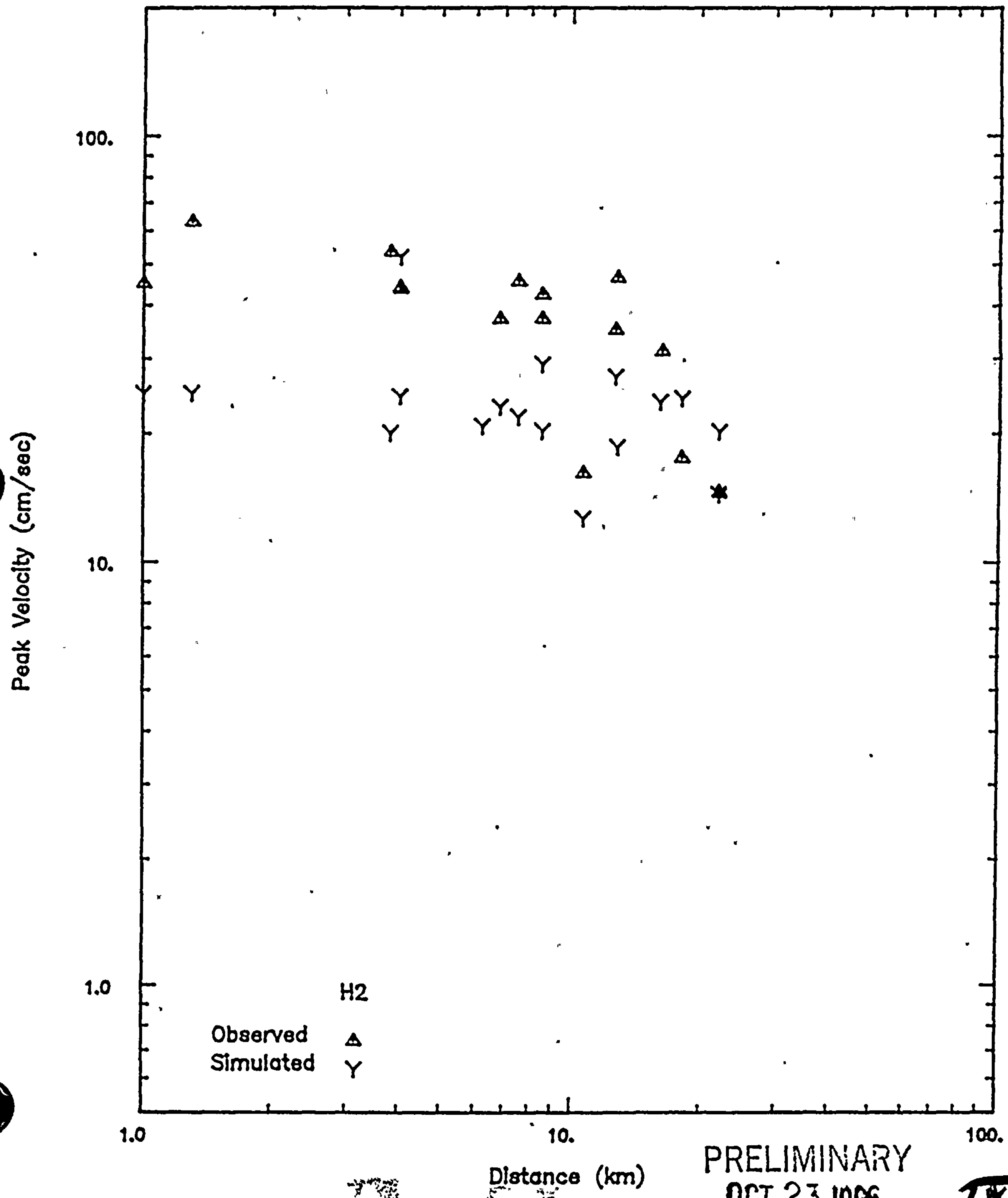


PRELIMINARY
OCT 23 1986

IX-56

Imperial Valley Main Shock, 1979

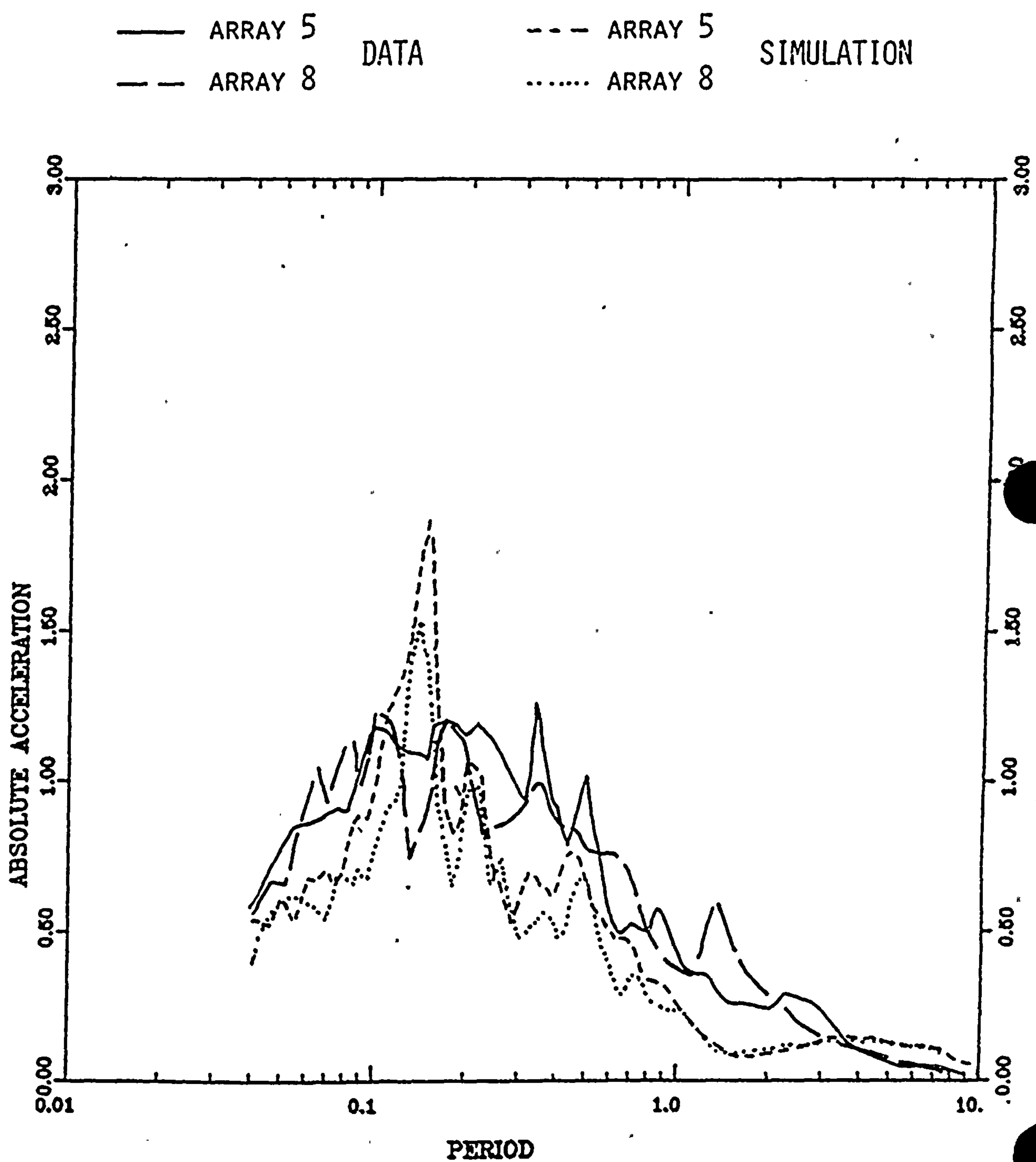
SMOOTH MODEL



PRELIMINARY
OCT 23 1986

IX-57

RESPONSE SPECTRA 5% DAMPING COMPONENT 140

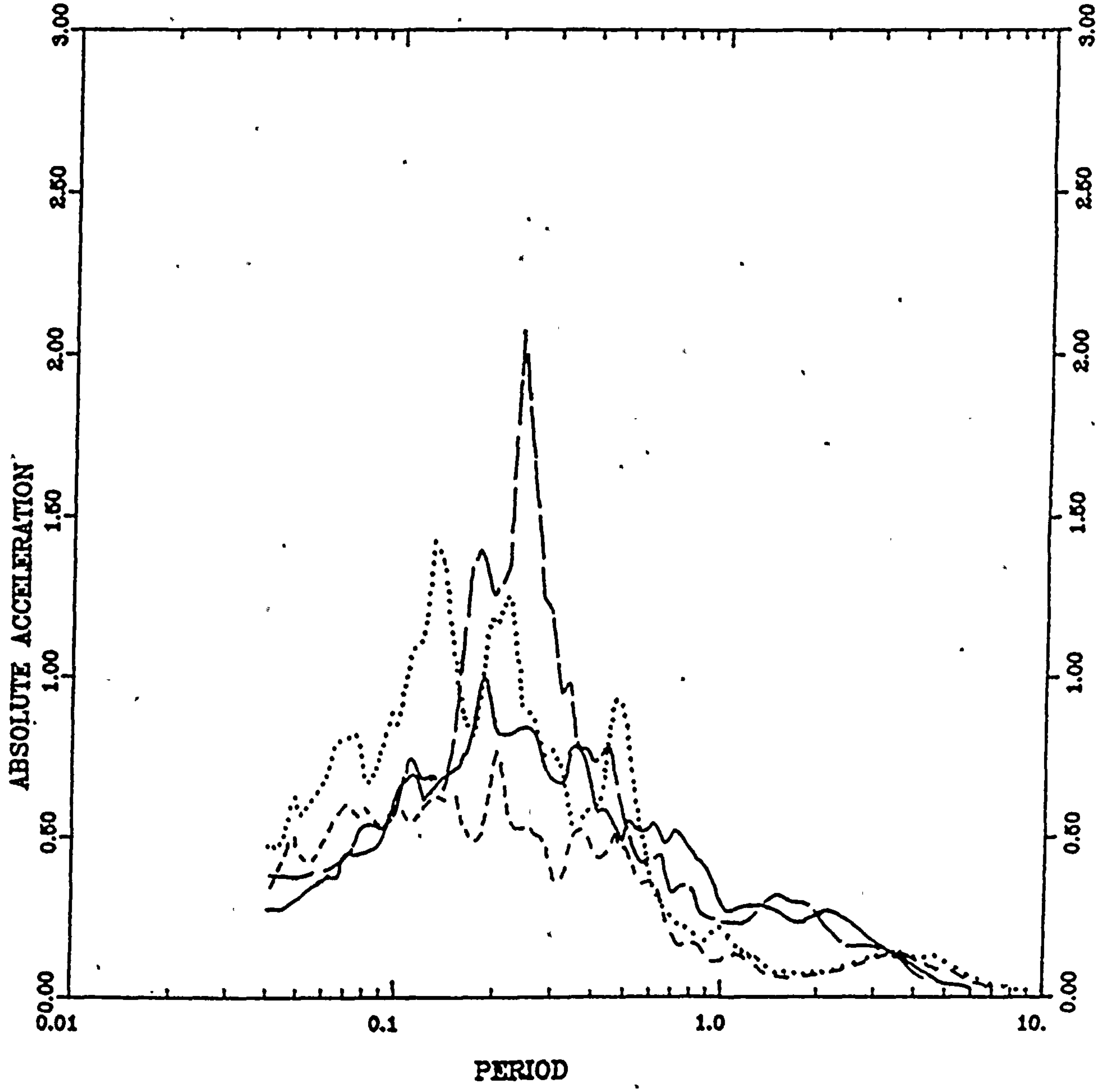


PRELIMINARY
OCT 23 1986

IX-58

RESPONSE SPECTRA 5% DAMPING COMPONENT 140

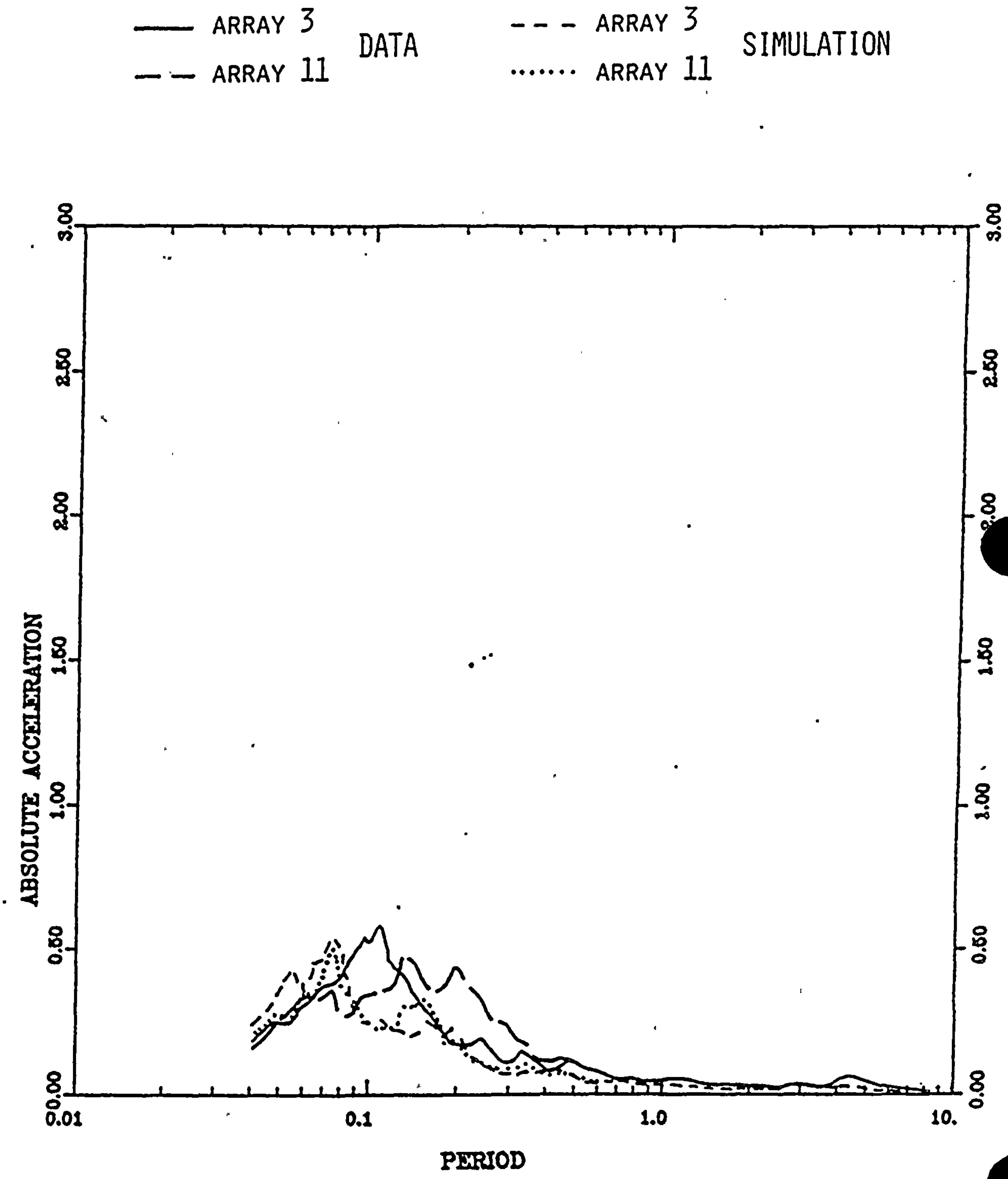
—— ARRAY 3 DATA --- ARRAY 3 SIMULATION
— — ARRAY 11 .... ARRAY 11



PRELIMINARY
OCT 23 1986

IX-59

RESPONSE SPECTRA 5% DAMPING COMPONENT VERTICAL



PRELIMINARY
OCT 23 1986

IX-60

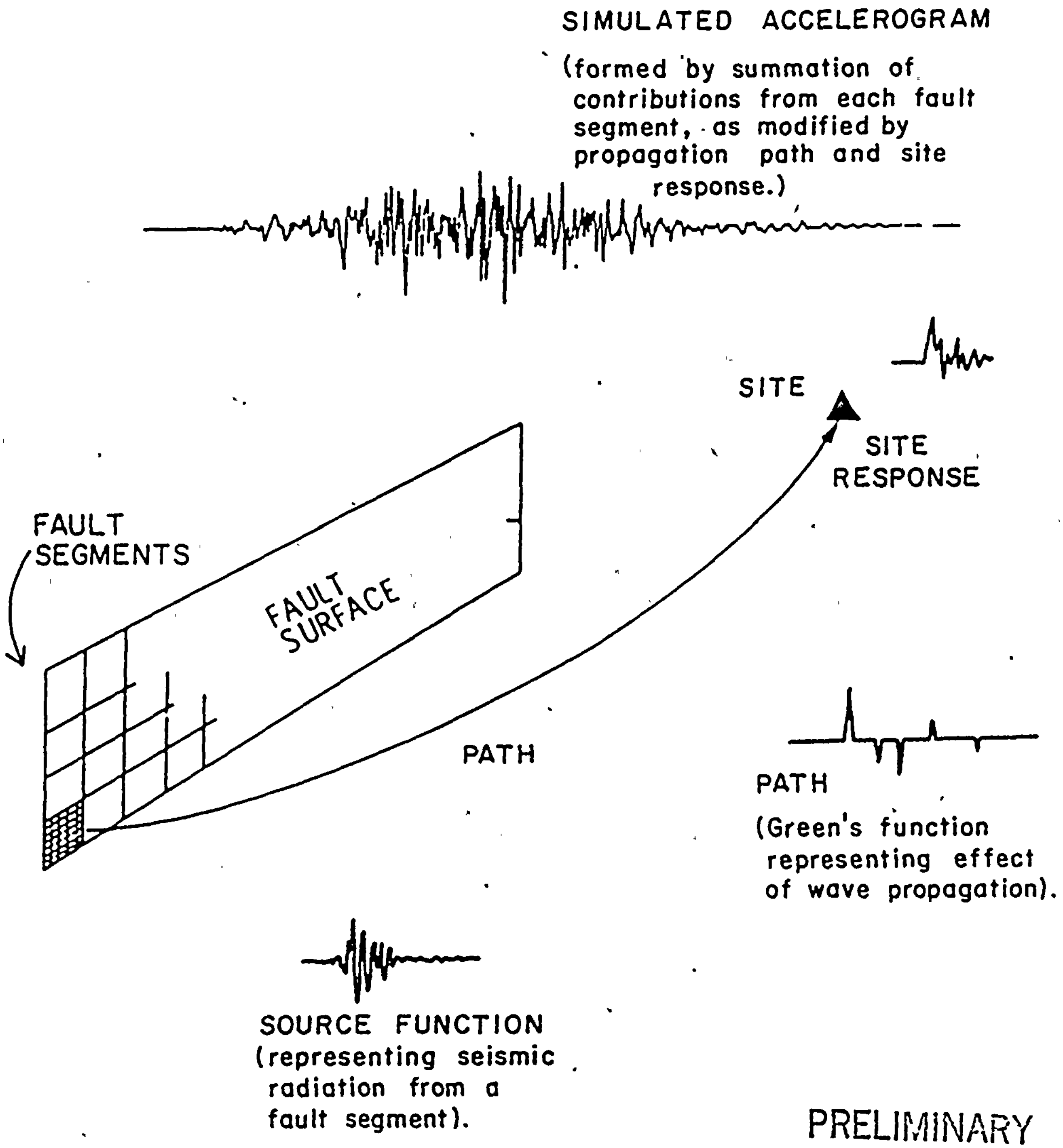
CONCLUSIONS REGARDING THE EMPIRICAL GEEEN'S FUNCTION APPROACH

THE EMPIRICAL GREEN'S FUNCTION SUMMATION APPROACH SUCCESSFULLY PREDICTS THE OVERALL CHARACTERISTICS OF THE STRONG MOTION RECORDINGS OF THE 1979 IMPERIAL VALLEY MAINSHOCK FROM THE AFTERSHOCK RECORDINGS.

PRELIMINARY
OCT 23 1986

EMPIRICAL/THEORETICAL SIMULATION PROCEDURE

(HADLEY, HELMBERGER & ORCUTT, 1982)



PRELIMINARY
OCT 23 1986

ASPECTS OF THE EMPIRICAL/THEORETICAL SIMULATION PROCEDURE

- METHODS FOR GREEN'S FUNCTION CALCULATIONS
- SEISMIC VELOCITY AND ATTENUATION MODELS
- SELECTION AND SCALING OF EMPIRICAL SOURCE FUNCTION
- REPRESENTATION OF DECREASING COHERENCE OF RADIATION PATTERN WITH INCREASING FREQUENCY

PRELIMINARY
OCT 23 1986

ADDITIONAL SITE RECORDS AND INSTRUMENTS

PROCESSING OF ADDITIONAL SITE RECORDS

INSTALLATION OF ADDITIONAL GROUND-MOTIONS INSTRUMENTS
AT DCPP SITE

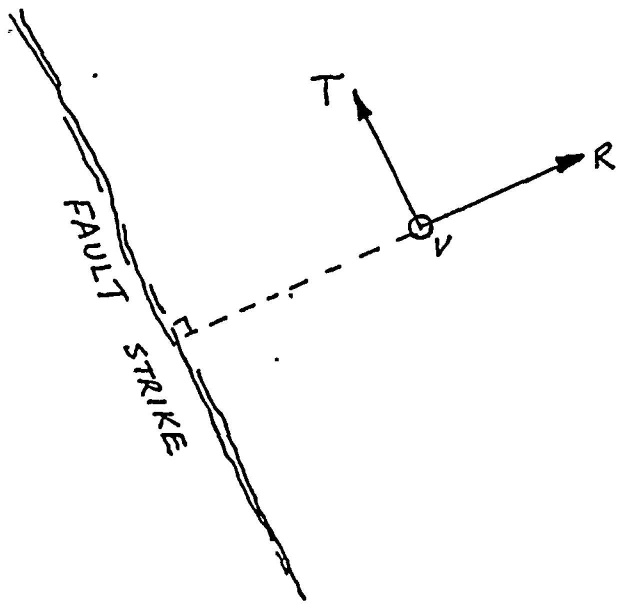
- COHERENCE ARRAY
- TOPOGRAPHIC ARRAY

PRELIMINARY
OCT 23 1986

GROUND MOTION RESULTS PROVIDED FOR SSI ANALYSES

- 3-COMPONENT EARTHQUAKE GROUND ACCELERATION TIME HISTORIES TRANSFORMED INTO THE DIRECTIONS PARALLEL TO (T-AXIS) AND NORMAL TO (R-AXIS) THE FAULT STRIKE, AND THE VERTICAL DIRECTION (V-AXIS) AT THE GROUND SURFACE

- RANGE OF APPARENT INCIDENCE ANGLES (θ FROM VERTICAL) OF DOMINANT MOTION ENERGY.



PRELIMINARY
OCT 23 1986

INCORPORATION OF GROUND MOTION RESULTS FOR SSI ANALYSES

PROCEDURE:

(1) ALIGN THE PRESCRIBED MOTION'S T-AXIS AND R-AXIS WITH THE PLANT'S N-S AND E-W DIRECTIONS, RESPECTIVELY, SINCE THE PLANT'S N-S DIRECTION IS APPROXIMATELY PARALLEL TO THE HOSGRI FAULT STRIKE.

(2) ASSUME THE PRESCRIBED MOTION IS AT THE ROCK SURFACE OF THE PLANT AT EL. 85 FT.; AND THE MOTION COMPONENT ALONG T-AXIS IS CAUSED BY PLANE SH WAVE AND THE MOTION COMPONENTS ALONG R- AND V-AXES ARE CAUSED SIMULTANEOUSLY BY PLANE SV AND P WAVES PROPAGATING AT AN INCIDENCE ANGLE θ FROM THE VERTICAL.

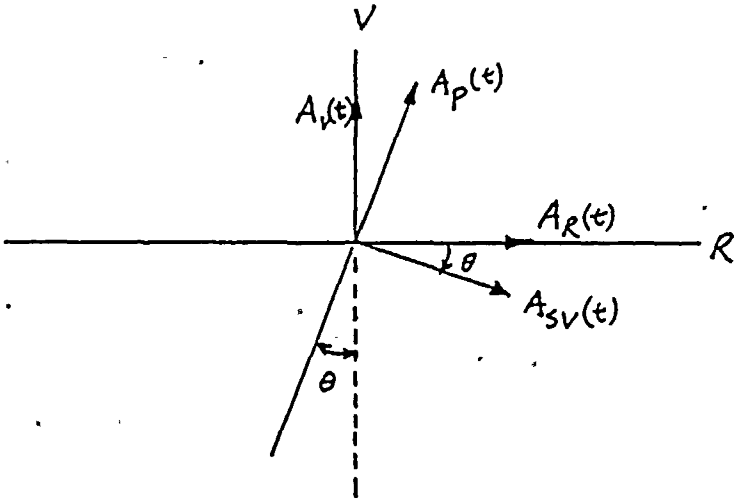
(3) COMPUTE THE ACCELERATION TIME HISTORIES OF SV AND P WAVES FROM THE ACCELERATION TIME HISTORIES OF THE R AND V COMPONENTS OF MOTION.

(4) USE THE P, SV, AND SH WAVE FIELDS AS DERIVED FORM (1), (2), AND (3) FOR CLASSI AND SASSI ANALYSES.

(5) VARY THE INCIDENCE ANGLE WITHIN THE RANGE OF VARIATION TO OBTAIN A RANGE OF SSI RESPONSES.

PRELIMINARY
OCT 23 1986

COMPUTATION OF SV AND P WAVE MOTIONS FROM R AND V MOTION COMPONENTS



$$\begin{Bmatrix} A_R(t) \\ A_V(t) \end{Bmatrix} = \begin{bmatrix} \sin\theta & \cos\theta \\ \cos\theta & -\sin\theta \end{bmatrix} \begin{Bmatrix} A_P(t) \\ A_{SV}(t) \end{Bmatrix}$$

OR

$$\begin{Bmatrix} A_P(t) \\ A_{SV}(t) \end{Bmatrix} = \begin{bmatrix} \sin\theta & \cos\theta \\ \cos\theta & -\sin\theta \end{bmatrix} \begin{Bmatrix} A_R(t) \\ A_V(t) \end{Bmatrix}$$

PRELIMINARY
OCT 23 1986

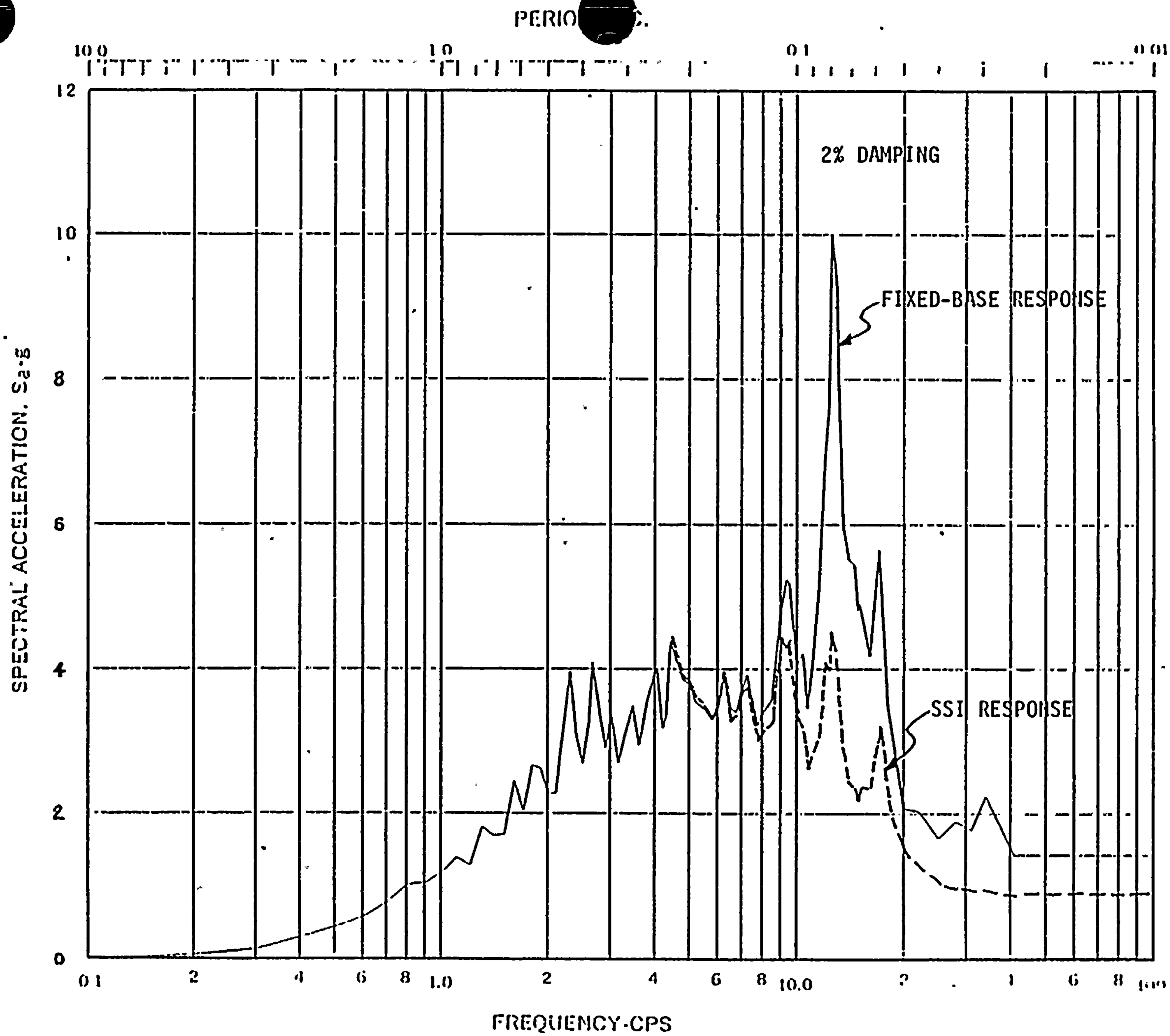
GENERATION OF SSI RESPONSES

- o SUBJECTED TO THE PRESCRIBED GROUND MOTIONS, RESPONSE SPECTRA OF THE SSI RESPONSE ACCELERATION TIME HISTORIES WILL BE CALCULATED FOR THE TOP OF BASEMAT AND SELECTED LOCATIONS IN THE CONTAINMENT STRUCTURE, AUXILIARY BUILDING, AND TURBINE BUILDING.

- o RATIOS OF RESPONSE SPECTRAL ORDINATES WILL BE DEVELOPED BETWEEN THE TOP OF BASEMAT AND THE FREE-FIELD.

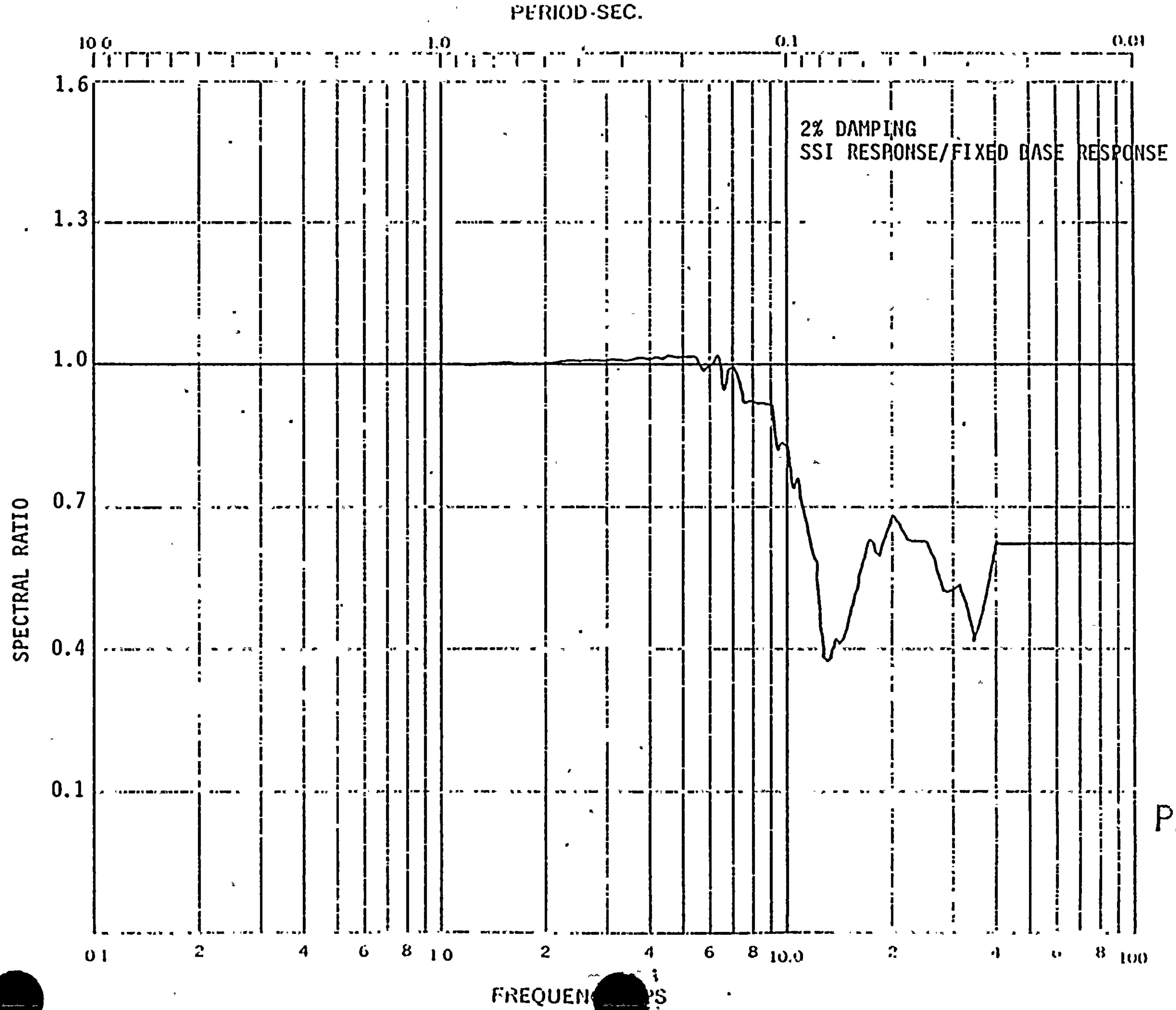
- o RATIOS OF RESPONSE SPECTRAL ORDINATES BETWEEN THE RESPONSE SPECTRA FROM SSI ANALYSES AND THE CORRESPONDING SPECTRA FROM THE FIXED-BASE ANALYSES WILL BE DEVELOPED FOR THE SELECTED BUILDING LOCATIONS.

PRELIMINARY
OCT 23 1986



PRELIMINARY
OCT 23 1986

9-IX



PRELIMINARY
OCT 23 1986