

Dr. 1372

I-9121

①

UCID-19778

UCID--19778

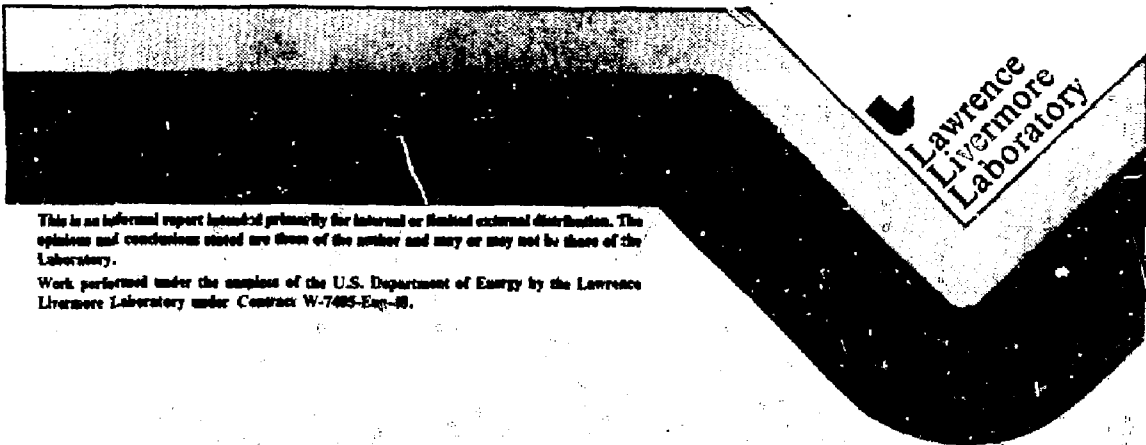
DE83 011215

MASTER

MEASUREMENT OF SEISMIC MOMENTS AT THE RSTN
STATION RSSD FOR NTS EXPLOSIONS

Steven R. Taylor
and
Howard J. Patton

April 5, 1983



Lawrence
Livermore
Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under Contract W-7405-Eng-48.

ABSTRACT

We have estimated the seismic moment for two Nevada Test Site (NTS) explosions (Nebbiolo, 6/24/82; Atrisco, 8/5/82) at the Regional Seismic Test Network (RSTN) station in South Dakota (RSSD; distance from NTS \sim 1280 km). The moments are calculated from the vertical component mid-period channel for the Rayleigh waves and the merged mid- and short-period band for the P waves. The moment estimates from surface waves give values of 1.0×10^{23} and 2.0×10^{23} dyn-cm for Nebbiolo and Atrisco, respectively. The body-wave moments obtained at 0.5 Hz are approximately five times greater than those from surface waves and give values of 4.8×10^{23} and 1.0×10^{24} dyn-cm for Nebbiolo and Atrisco, respectively. The apparent discrepancy between the body and surface-wave moments can be resolved if there is overshoot (of 5:1) in the explosion source spectrum. As a check on the absolute value of the surface-wave moments, we compared them to moment values predicted from empirical moment-yield relationships for different emplacement media at NTS (Patton, 1983). We found that the agreement between observed and predicted values is satisfactory, within the measurement error on the moments at the one sigma level.

As a result of this work, we have gained additional familiarity with the effects of the RSTN passbands on the analysis of regional seismic data. Because the frequency spectrum for most regional seismic events spans both the mid- and short-period passbands, we recommend that the two bands be accurately merged prior to analysis. From the nature of the explosion source spectrum (Aki et al, 1974; Murphy, 1977; Peppin, 1976), it is evident that the merging process is crucial to the study of explosions at regional distances, particularly in the 10-100 kt range.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

NOTICE
PORTIONS OF THIS REPORT ARE ILLEGIBLE¹

It has been reproduced from the best available copy to permit the broadest possible availability.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

slg

INTRODUCTION

The work described in this report is part of an ongoing effort addressing the validation of RSTN capabilities. A number of specific seismological studies are currently underway at the Lawrence Livermore National Laboratory. In addition to producing scientific results, these studies provide insight into RSTN system properties that may enhance or detract from the accuracy or ease of study. In this report, seismic moments from two underground nuclear explosions (see Table 1) at NTS are estimated at the RSTN station RSSD in South Dakota using both Pn and Rayleigh wave data. Our analysis of the P-waves brings out the importance of band merging, which we believe should be carried out routinely for many types of analysis.

SEISMIC MOMENT FROM RAYLEIGH WAVES

We used a 275 sec time window of signal determined from the expected group arrival times of fundamental mode Rayleigh waves (Fig. 1). The signal was tapered, Fourier transformed and corrected for the mid-period filter response (Rodgers and Hummel, 1981). We then corrected the ground displacement spectrum for geometric spreading and for anelastic attenuation using a Basin and Range decay rate (Patton and Taylor, 1982). The observed spectrum for Nebbiolo showed evidence of some complications, perhaps due to multipath interference, for frequencies between 0.1 and 0.14 Hz. Both observed spectra showed a narrow peak centered at 0.16 Hz, possibly related to multipathing or perhaps due to body-wave signals in the window that was Fourier analyzed (Figs. 2 and 3).

Each observed spectrum was fitted with a theoretical spectrum for an isotropic explosion source. A von Seggren - Blandford source-time function with B of 2 and K of 1000 was assumed. It should be noted that the overshoot parameter, B , does not affect the Rayleigh-wave spectrum at low frequencies where the fit is most crucial for estimating the moment. Figs. 2 and 3 show comparisons between observed and theoretical spectra for Nebbiolo and Atrisco,

respectively. From the fits, we estimated seismic moments of 1.0×10^{23} and 2.0×10^{23} dyne-cm for Nebbiolo and Atrisco respectively, using spectral amplitudes at frequencies below 0.06 Hz. Complications due to adverse propagation effects do not appear to affect the spectral amplitudes used to estimate the moment. On the other hand, source effects, related to tectonic strain release accompanying the detonation of the explosive, can affect spectral amplitudes. It is not possible to determine the extent to which non-isotropic radiation patterns have affected the moment estimates on the basis of this preliminary analysis alone.

SEISMIC MOMENT FROM P WAVES

The seismic moments for Nebbiolo and Atrisco were also calculated following the approach described by Hanks and Wyss (1972) using the instrument-corrected P wave. The P waves shown in Fig. 4 were obtained from the merged mid- and short-period vertical components using the technique described in Nakanishi et al., (1983). The merged deconvolution of the RSTN data provides a flat response to ground velocity between approximately 0.02-10 Hz.

The moment estimate was made from the long-period level of the displacement spectrum calculated from a 5-second time window around the P-wave. The long-period spectral amplitude was corrected for geometrical spreading and a Q of 150 using the relation given in Hanks and Wyss (1972). The displacement spectra for both explosions are shown in Fig. 5. For Nebbiolo, the long-period level was estimated to be $0.6-2.0 \times 10^{-5}$ cm-s for corner frequencies of 2.0 and 0.5 Hz, respectively. These values give a moment range of $1.3-4.8 \times 10^{23}$ dyne-cm. As with the surface waves, the spectrum from Atrisco appeared to be smoother than Nebbiolo, and the corner frequencies were selected at 1.4 Hz and 0.5 Hz giving a long-period spectral levels of $1.0-4.5 \times 10^{-5}$ cm-s and a range of moments from $2.0-10.0 \times 10^{23}$ dyne-cm. The high frequency falloff for both explosions is variable and depends on the corner frequency selected.

Because of the short time window, the presence of spectral overshoot for many explosions, and effects of the free surface, the estimation of the long-period spectral level and corner frequency is quite subjective and not without

problems (cf. Langston, 1978). From the explosion source spectrum calculated for Oscuro (detonated in Yucca tuff and of similar magnitude to Nebbiolo and Atrisco), Aki et al. (1974) estimated an overshoot ratio of 4 to 5 with a corner frequency of approximately 0.5 Hz (see their Fig. 10). Interestingly, the ratio of body-wave moments measured at 0.5 Hz to surface-wave moments for both explosions is 5:1. This may be due to the spectral overshoot in both cases and is very similar to that observed for Oscuro by Aki et al. (1974).

From the scaling relationships for explosions (Aki et al., 1974; Peppin, 1976; and Murphy, 1977) the spectral peak and corner frequency occur around 1 Hz for yields between 10-100 kt. Because of the sharp corner in the mid-period response at 1.3 Hz, the estimation of the seismic moments and corner frequencies from the mid-period P-waves would have been difficult. Thus, for this and many other types of seismic analysis, data from the mid- and short-period channels should be merged. We recommend that an accurate and fast method for merging the mid- and short-period passbands be routinely applied to the RSTN data.

To summarize, our analysis of surface wave spectra at the South Dakota RSTN station gave seismic moment estimates of 1.0×10^{23} and 2.0×10^{23} dyne-cm for Nebbiolo and Atrisco, respectively, and our analysis of P-wave spectra at 0.5 Hz gave moment estimates approximately five times greater than those from the surface waves. As a check on the absolute value of the surface-wave moments, we compared them to moment values predicted on the basis of empirical moment-yield relationships for different emplacement media at NTS (Patton, 1983). Nebbiolo was fired in rhyolite on Pahute Mesa and Atrisco in Yucca Tuff. We found that the estimated moments of 1.0×10^{23} and 2.0×10^{23} dyn-cm agree within 17% and 60% of the predicted values for Nebbiolo and Atrisco, respectively. It should be noted that there is an error of about a factor of 1.5 -2.0 at the one sigma level (i.e. one standard deviation) for both the measured and predicted moment values. This error is mostly due to the effect of the anisotropic component of the explosion source which has not been corrected for in the present analysis nor in the moment-yield relationship. A study of the Rayleigh and Love waves at other stations including stations in the RSTN could lead to refinement of the explosion moments by accounting for anisotropic radiation for these two explosions. Similarly, work is underway

to refine the moment-yield relationships by incorporating the effect of source anisotropy. In light of the uncertainties in the present analysis the agreement found above between measured and predicted moments is considered to be satisfactory.

CONCLUSIONS

Seismic moments have been calculated for two NTS explosions at the RSTN station RSSD using both P- and Rayleigh-waves. For both explosions, the body wave moment estimated at 0.5 Hz is approximately five times greater than that obtained from surface waves (1.0×10^{23} and 2.0×10^{23} dyn-cm for Nebbiolo and Atrisco, respectively). The apparent discrepancy between body-wave and surface-wave moments can be resolved if there is large overshoot of (5:1) in the explosion source spectrum. As a check on the absolute value of the surface wave moments, we compared them to moment values predicted from empirical moment yield relationships for different emplacement media at NTS. We found that the agreement between observed and predicted values is satisfactory, within the measurement error on the moments at the one sigma level.

The importance of accurately merging the mid- and short-period bands is also evident, particularly for studies involving the analysis of body waves and high frequency crustal phases such as Lg.

ACKNOWLEDGMENTS

The authors would like to thank Keith Nakanishi, Jim Hannon, Pete Rodgers and Al Smith for helpful comments on the manuscript.

FIGURE CAPTIONS

- Fig. 1 Rayleigh waves recorded on the mid-period band at RSSD from Nebbiolo and Atrisco. (amplitude units in volts).
- Fig. 2 Comparison of attenuation-corrected spectrum for Rayleigh-waves at RSSD from Nebbiolo with theoretical spectra for an explosion using a von-Seggren - Blandford source-time function with $B=2$, $K=1000$ and $M_0 = 1.0 \times 10^{23}$.
- Fig. 3 Same as Fig.2 for Atrisco for $M_0 = 2.0 \times 10^{23}$.
- Fig. 4 Vertical component P-waves from Nebbiolo and Atrisco recorded at RSSD. Signals were obtained by merging mid- and short-period bands and vertical scale is in cm/s.
- Fig. 5 Instrument corrected P-wave spectrum at RSSD for (a) Nebbiolo and (b) Atrisco using a 5-second window around signals shown in Fig. 4. Also shown are ranges of long-period spectral levels, corner frequency, and high frequency asymptote.

REFERENCES

- Aki, K., M. Bouchon, and P. Reasenber, Seismic source function for an underground nuclear explosion, *Bull. Seism. Soc. Am.*, 64, 131-148, 1974.
- Hanks, T.C. and M. Wyss, The use of body-wave spectra in the determination of seismic-source parameters, *Bull. Seism. Soc. Am.*, 62,561-589, 1972.
- Langston, C.A., Moments, corner frequencies, and the free surface, *J. Geophys. Res.*, 83,3422-3426, 1978.
- Murphy, J.R., Seismic source functions and magnitude determinations for underground nuclear detonations, *Bull. Seism. Soc. Am.*, 67,135-158, 1977.
- Nakanishi, K.K., S.R. Taylor, N.C. Burr, and P.W. Rodgers, Broadband signals from the Regional Seismic Test Network, Lawrence Livermore National Laboratory, CA, UCID (in preparation), 1983.
- Patton, H.J., Moment-Yield relationships for underground nuclear explosions, UCRL (in preparation), 1983.
- Patton, H.J. and S.R. Taylor, Q-structure of the Basin and Range from surface waves, *Trans. Am. Geophys. Un.*, 63,372, 1982.
- Peppin, W.A., P-wave spectra of Nevada Test Site events at near and very near distances for a near-regional body wave-surface wave discriminant, *Bull. Seism. Soc. Am.*,66,803-825, 1976.
- Rodgers, P.W. and M. Hummell, National Seismic Stations transducers and filters, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53098, 23pp, 1981.

TABLE 1

EPICENTRAL DATA FOR UNDERGROUND EXPLOSIONS USED IN MOMENT STUDY

NAME	DATE	LAT.	LONG.	DEPTH (M)	MEDIA	mb	Ms
NEBBIOLO	6/24/82	37.236N	116.370W	640	RHYOLITE	5.6	4.3
ATRISCO	8/5/82	37.084N	116.007W	640	TUFF	5.7	4.2

RAYLEIGH WAVES AT RSSD. MID-PERIOD

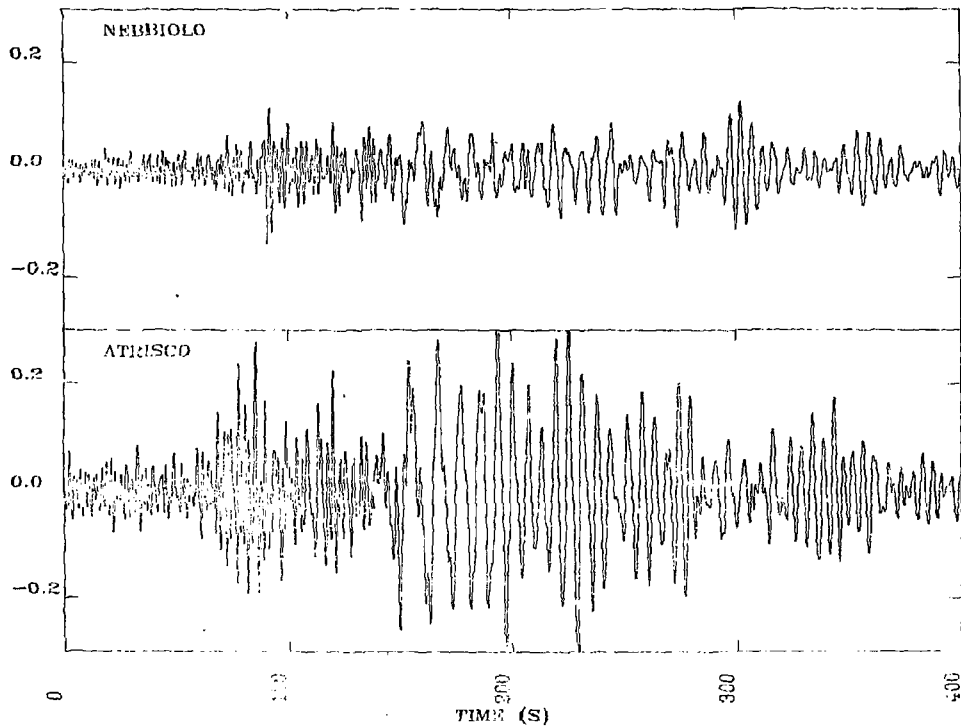


Figure 1

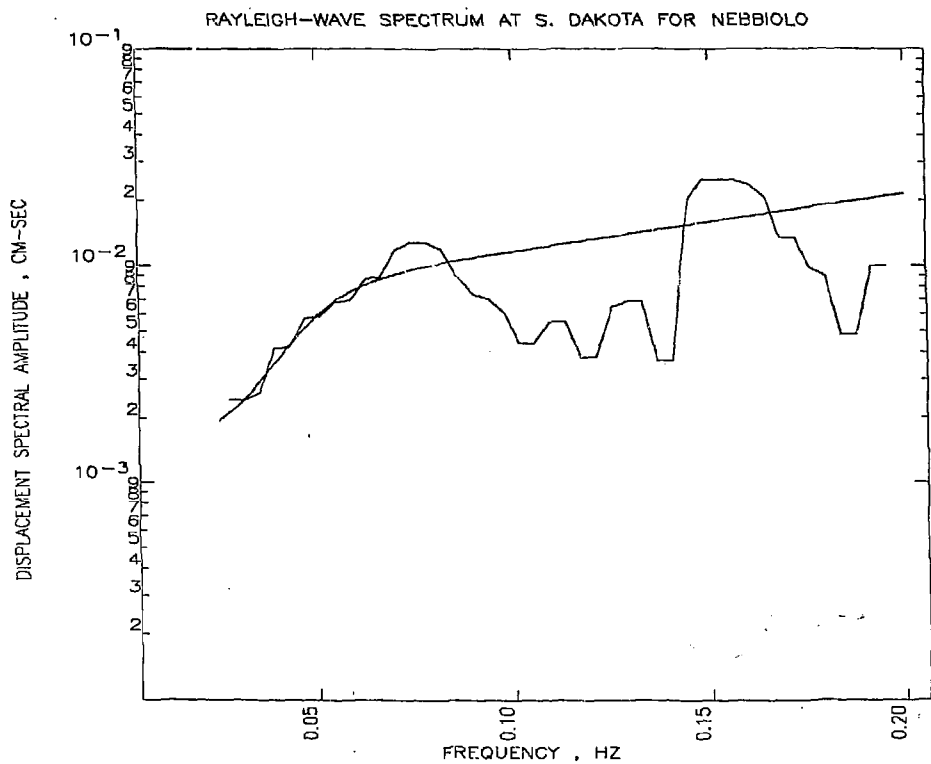


Figure 2

RAYLEIGH-WAVE SPECTRUM AT S. DAKOTA FOR ATRISCO

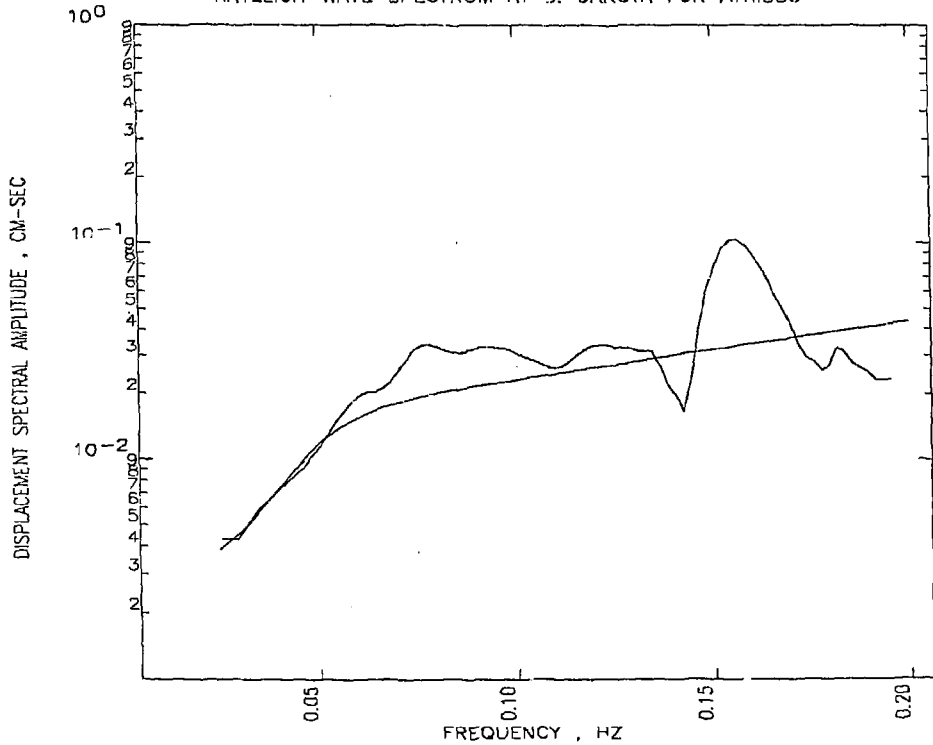


Figure 3

MERGED P-WAVES AT RSSD

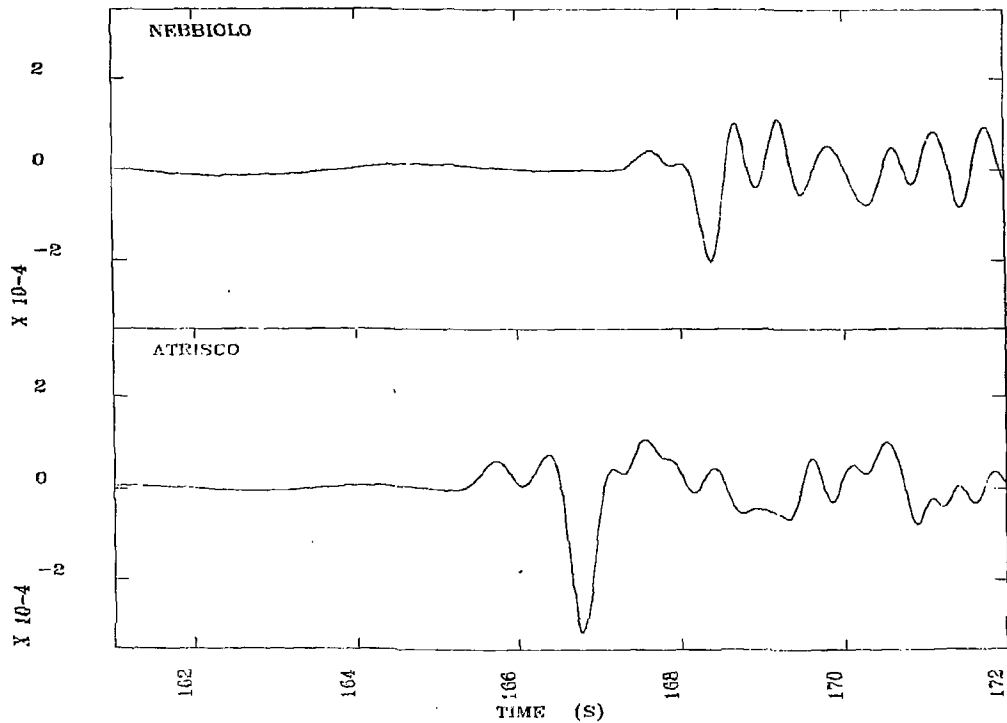


Figure 4

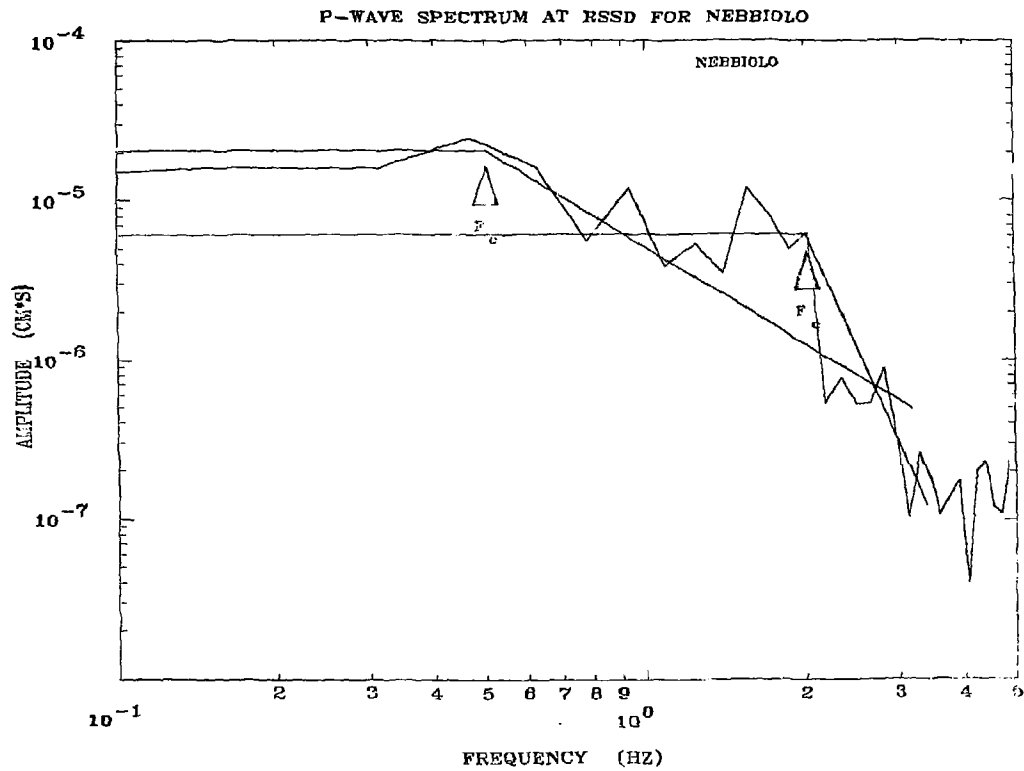


Figure 5a

P-WAVE SPECTRUM AT RSSD FOR ATRISCO

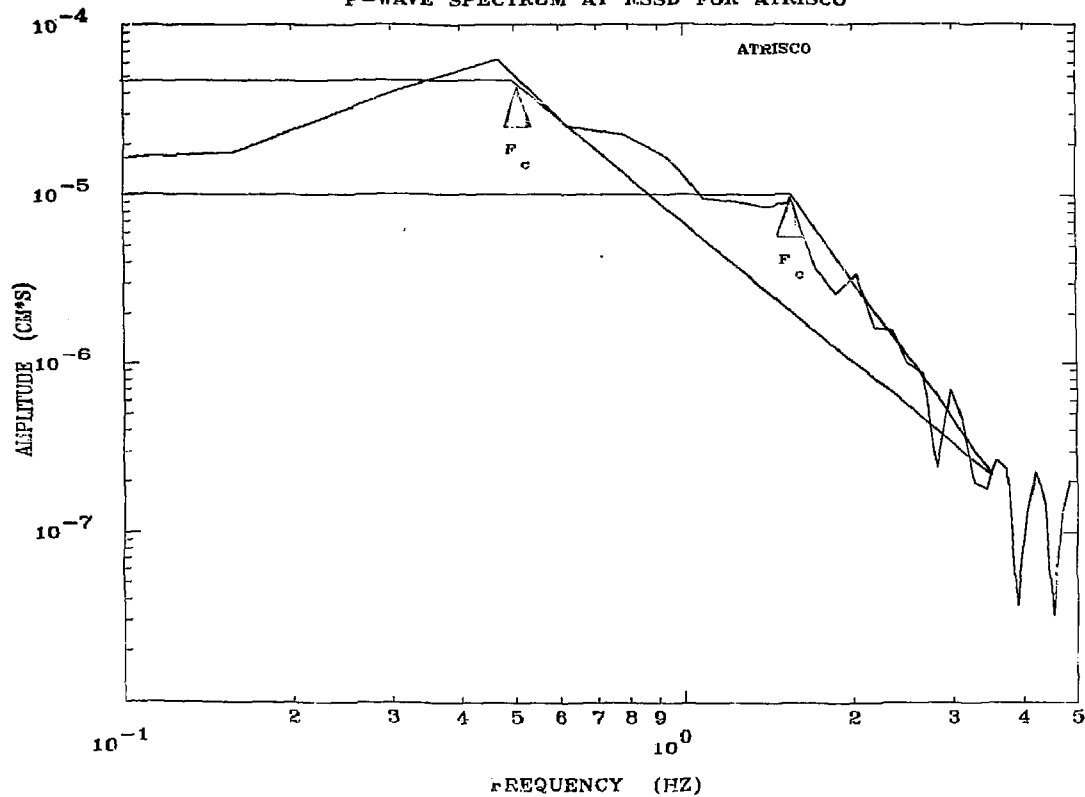


Figure 5b

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government thereof, and shall not be used for advertising or product endorsement purposes.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
585 Post Royal Road
Springfield, VA 22161
Price: Printed Copy \$: Microfilm \$4.50

<u>Page Range</u>	<u>Domestic Price</u>	<u>Page Range</u>	<u>Domestic Price</u>
001-025	\$ 7.00	326-350	\$ 26.50
026-050	8.50	351-375	28.00
051-075	10.00	376-400	29.50
076-100	11.50	401-426	31.00
101-125	13.00	427-450	32.50
126-150	14.50	451-475	34.00
151-175	16.00	476-500	35.50
176-200	17.50	501-525	37.00
201-225	19.00	526-550	38.50
226-250	20.50	551-575	40.00
251-275	22.00	576-600	41.50
276-300	23.50	601-up ¹	
301-325	25.00		

¹Add 1.50 for each additional 25 page increment, or portion thereof from 601 pages up.