
Marine Physical Laboratory

Seismic Properties of Shallow-Water Sediments: A Component of the STRATAFORM Program

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**SEISMIC PROPERTIES OF SHALLOW-WATER SEDIMENTS:
A component of the STRATAFORM Program**

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ABSTRACT

The goal of this proposal is to determine some of the seismic properties of the top few tens of meters of the sedimentary fan off Northern California in the STRATAFORM (STRATA FORMation on Margins) test area, and to attempt to relate them to the the multi-sensor detection problem.

In 1995, we participated in a field program in collaboration with Will Avera, Wayne Kinney, and Dale Bibee of NRLSSC. SIO provided 6 Ocean-Bottom Seismometers (OBSs) and fired four seafloor shots of a half-pound of high explosives each. These were recorded on 4 of the SIO instruments and the NRLSSC DOSIS (bottom-penetrating) OBS. Subsequent funding supported replacement of a sensor lost to a local trawler as well as some analysis.

This scientific problem is interesting in several aspects. The first is in the context of the STRATAFORM project, whose goal is the elucidation of the processes which control the formation of the distinctive geological formations which characterize continental margin sediments. This is major task, since the continental margin sediments comprise most of the volume of the all marine sediments, and most of the sediments now on continents were, in fact, formed in the shallow marine environment. Thus we can say, arguably, that continental margin sediments comprise the source of most of the earth's geology.

In the context of today's Navy, which is finding renewed interest in the shallow-water environment, the complexity and variability of shallow-water sediments acts to complicate the detection problem, and to require local, rather than basin-wide solutions to the task of surveillance. The tasks which this proposal addresses are seismo-acoustic surveillance and mine warfare (both burial and sweeping). We have obtained dispersion data which is useful for several purposes. For scientific purposes, we extract the surficial shear velocity. The dispersed waveform is also the Green's function characterizing seismic propagation from a near-bottom seismic source. In addition to recording signals from the explosions,

we recorded background noise, which forms the interference against which we must detect signals from intruders.

BACKGROUND AND RELATIONSHIP TO OTHER WORK

The shear velocity is more variable, in terms of percentage variation, than compressional velocity. This is at once a blessing and a curse. It is a curse in that it helps turn the seismo-acoustic detection problem into a range and azimuth dependent one. But it also means that there is the potential for single-point range and azimuth detection because the lateral variability breaks the near-perfect range and azimuth symmetry common in the deep oceans.

In the geological context, the greater variability of sedimentary shear-wave velocities allows more geological information to be extracted from velocity information. In the case of compressional velocities, many rock types are indistinguishable on the basis of compressional velocity, but additional separation is possible when both P and S velocities are known, and even more information can be extracted if the anisotropy can be determined.

Figure 1 shows the general locations of two areas studied. The region to the east spans the "sand-mud" transition and the region to the northwest is a region of gassy sediments

Figure 2 and 3 show the positions of instruments and sources in the two areas. The overall quality of the data from this experiment was poor. The weather was rough, handling instruments and sources was difficult. The swell in shallow water increased the background noise the instruments had to contend with.

Figures 4 and 5 respectively, show seismograms from the two sites. The shallow-water (60m) silt-sand site shows little dispersion, while the deeper (200m) mud site shows prominent dispersion of the fundamental Scholte mode.

Analysis of the gassy mud site yields the shear velocity structure shown in Figure 6. This model was obtained in two steps. First, the shear velocity structure was adjusted manually so that the group velocity dispersion curve from the model matched the dispersion in the sonogram of figure 5 reasonably well. The structure was then refined by waveform matching using the methods described in Nolet and Dorman, 1996. Figure 7 shows a comparison of the observed and modeled waveforms. The overall structure of the seismogram is modeled fairly well in terms of the gross fit of the envelope and the frequency content of the waveform. Exact cycle-by-cycle matching of the waveforms is not, however, achieved. This can be due to multipath propagation, which is not modeled, or not enough effort in the fitting process.

The SIO/ONR OBSs are equipped with newly-developed water flowmeter/samplers, developed in collaboration with Professor Kevin Brown of SIO in part under ONR support. These devices use the OBS anchor as a fluid collector to measure fluid flow into or out of the seafloor. Figure 3 shows the fluid flow recorded during our participation in the STRATAFORM experiment. The abrupt increase at day 14 is coincident with a bottom explosion at a distance of 850 meters. The inferred fluid flux out of the sea floor changes from 0.012 mm/day to 0.071 mm/day. The precise mechanism causing this flux change is unknown at present. It is easy to imagine that the OBS frame was jarred sharply by the half-pound shot, and settled further into the seafloor, squeezing water out of the sediments. The flow seems to be constant for the five remaining days of the deployment though, rather than returning to the previous value.

COMPARISON WITH OTHER WORK

Recent work in shallow water in the Gulf of Mexico by Bibee; on the New Jersey margin by Ewing, Sutton and Stoll; and off Southern California by Dorman, have shown the utility of Scholte wave surveys in determining the near-surface shear velocity structure of the seafloor.

Work off San Diego, for which this program was a foundation, showed that shear velocities lower than we have observed heretofore. Using a newly developed implosive source (supported by NSF) we found surficial shear velocities of 16 and 26 meters/second. This area had been studied previously by pioneers Ed Hamilton and others (1970) using a manned submersible. Our results indicate velocities lower by a factor of 6-10 than the 70-200 m/s they found.

Note that this is a multiplicative factor, not a percentage. Investigation of the analysis revealed that the seafloor had been modeled by a half-space, rather than allowing a strong gradient. This yields velocities of the higher modes, which represent structure tens of meters deep, rather than the surficial velocity.

FIGURE CAPTIONS

Figure 1. The STRATAFORM test area (after Nittrouer and Kravitz, 1995; Riter, Goff and Mayer, 1995). The OBS field work was carried out across the sand-silt boundary at about 70 meters water depth (the eastern box) and at about 200 meters water depth (western box), an area containing gassy sediments.

Figure 2 shows the positions of the instruments and sources in the eastern (silt-sand) area. The OBSs are indicated by OBXX where XX is the OBS number. DOSI is the Dale Bibee's DOSIS bottom-penetrator. EXP? represents the positions of the half-pound shots. AGXX are bottom airgun shots.

Figure 3 shows the single OBS and shot in the area of gassy sediments.

Figure 4 is a seismogram and dispersion sonogram for shot 2 observed on instrument 1. The predominant frequency is 4 Hz. The dispersion is slight, indicated by the upward tilt of the contour lines as time increases. The velocity is a little faster than 200 m/s. The water depth is 60 meters. .IP

Figure 5 is the seismogram and dispersion plot for the gassy area. The signal is contaminated by a near-monotone at about 12 Hz. The dispersion of the fundamental mode is, however, clear. The signal is in the 2-7 Hz range. The water depth is 200 meters.

Figure 6 (velocity-depth plot, Figure 1 from other report)

Figure 7 (observed and modeled seismograms, Figure 2 from other report)

BOTTOM SEISMIC EXPERIMENTS

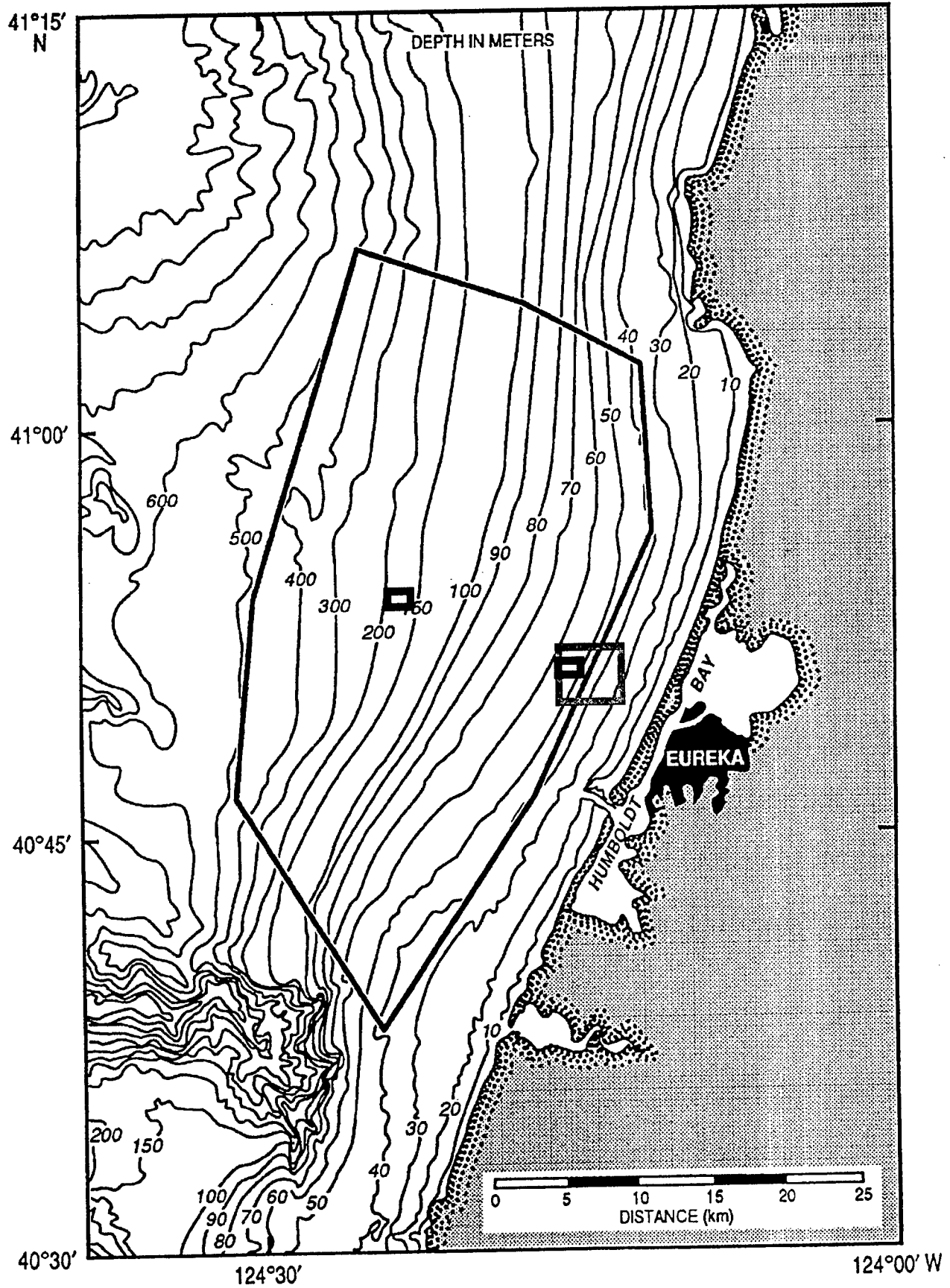


Figure 1

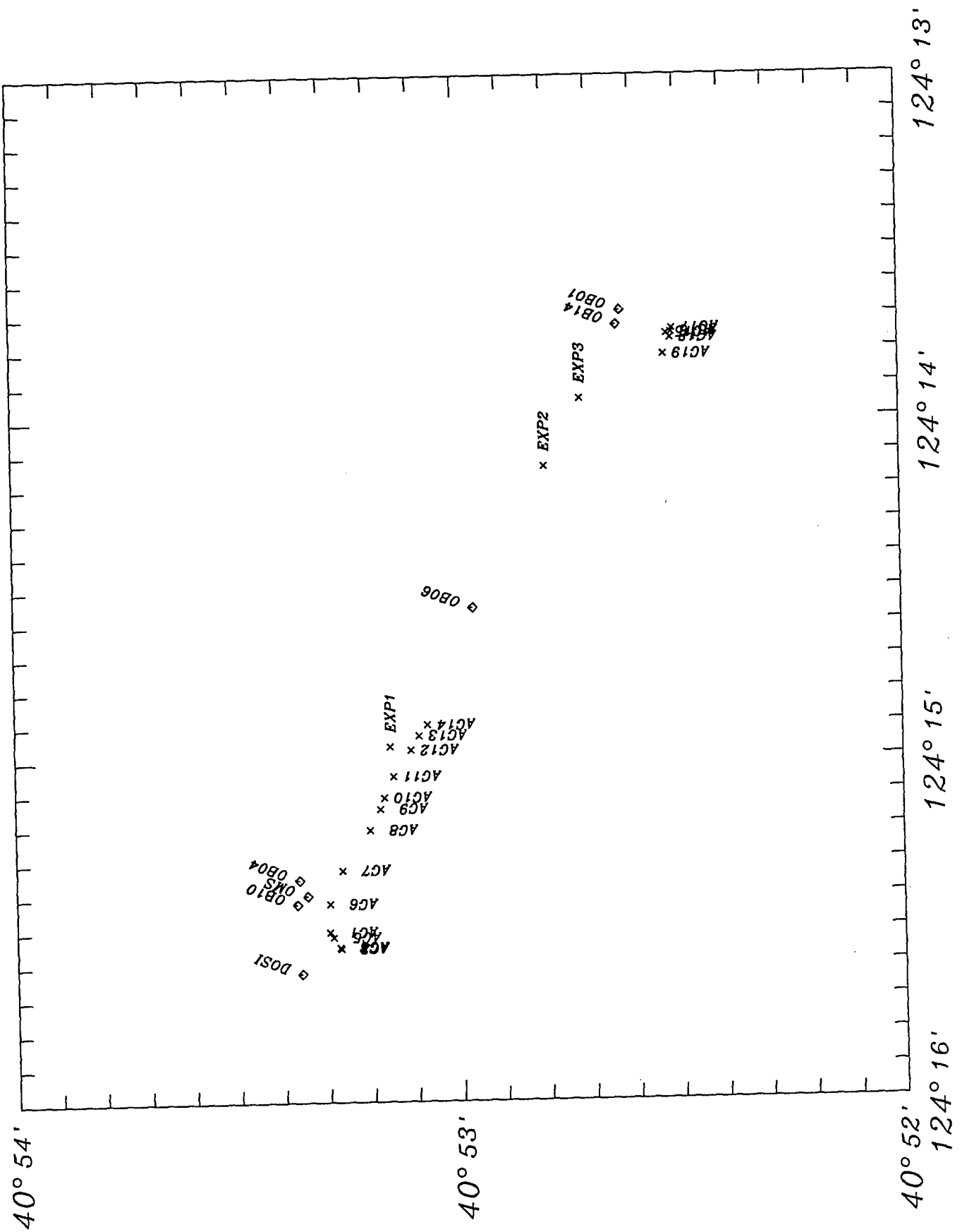


Figure 2

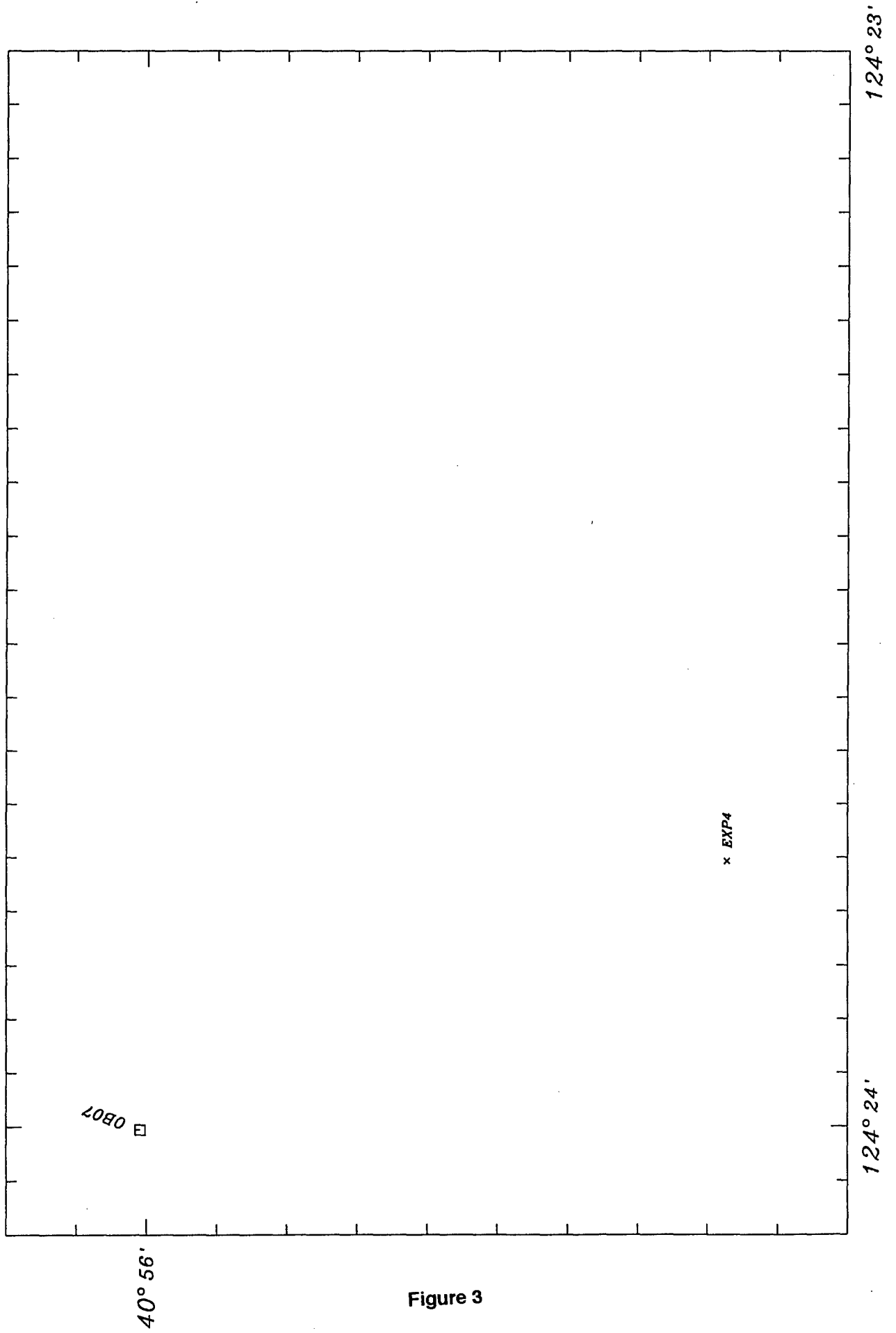
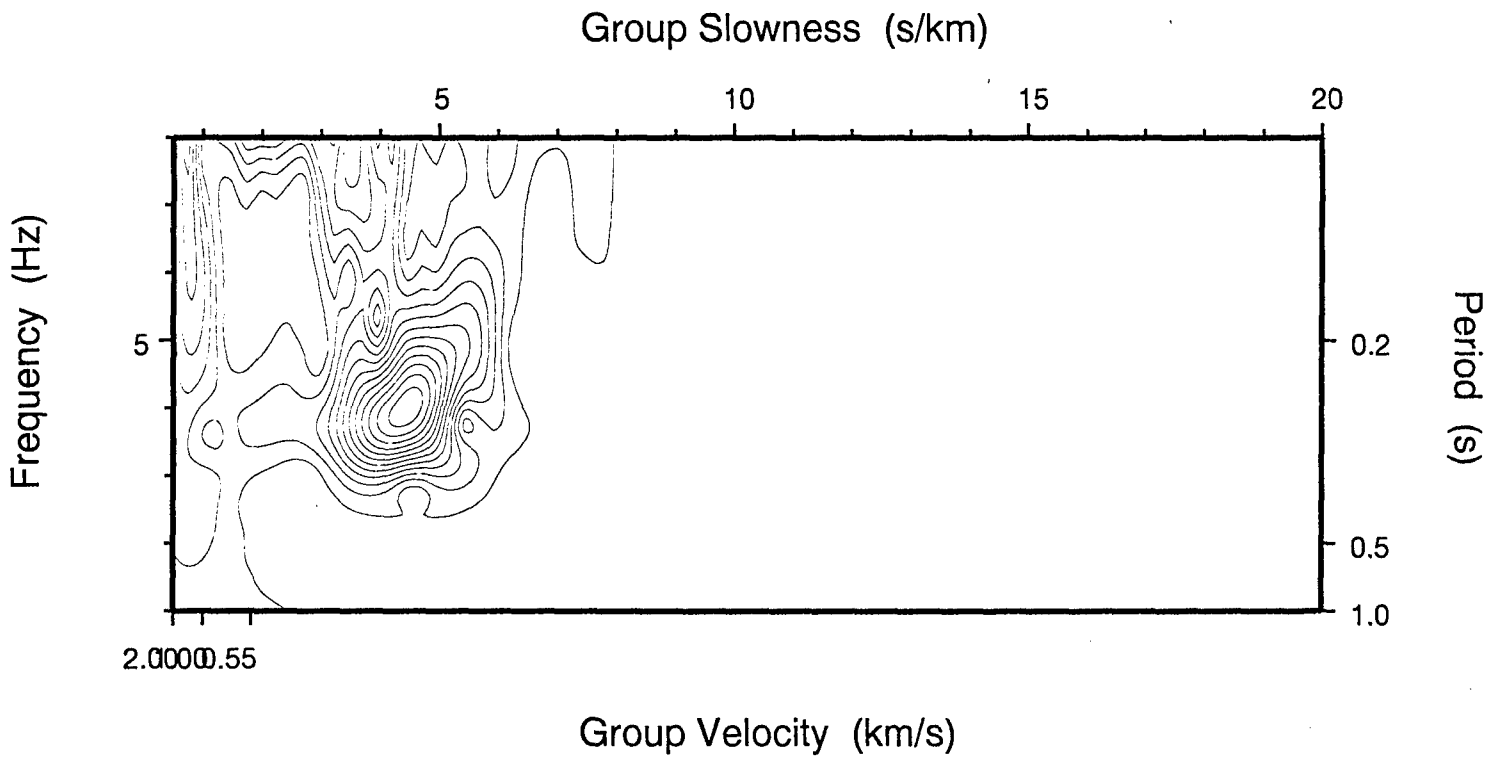
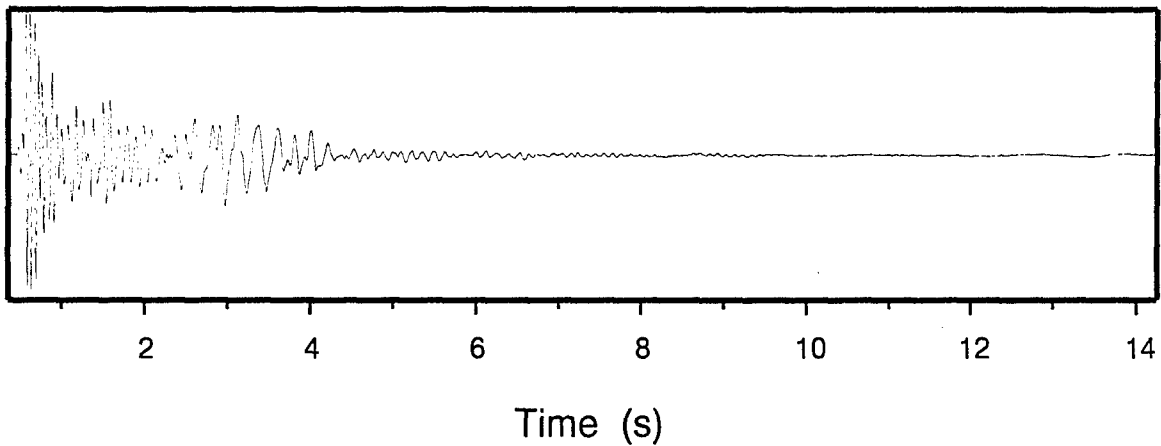


Figure 3

Instrument 1 Event 2 Component 1

Range 0.713 km



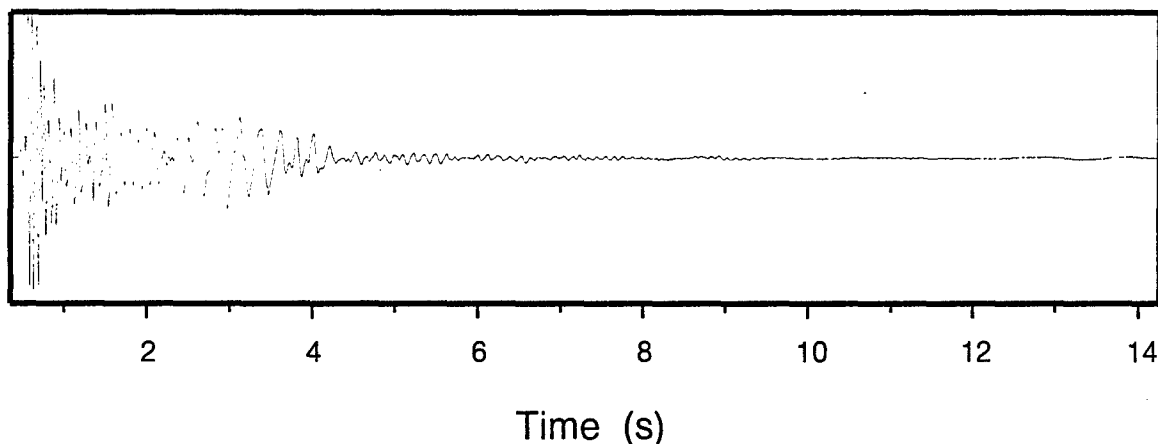
AMPLITUDE

Contour interval 2.0e+06

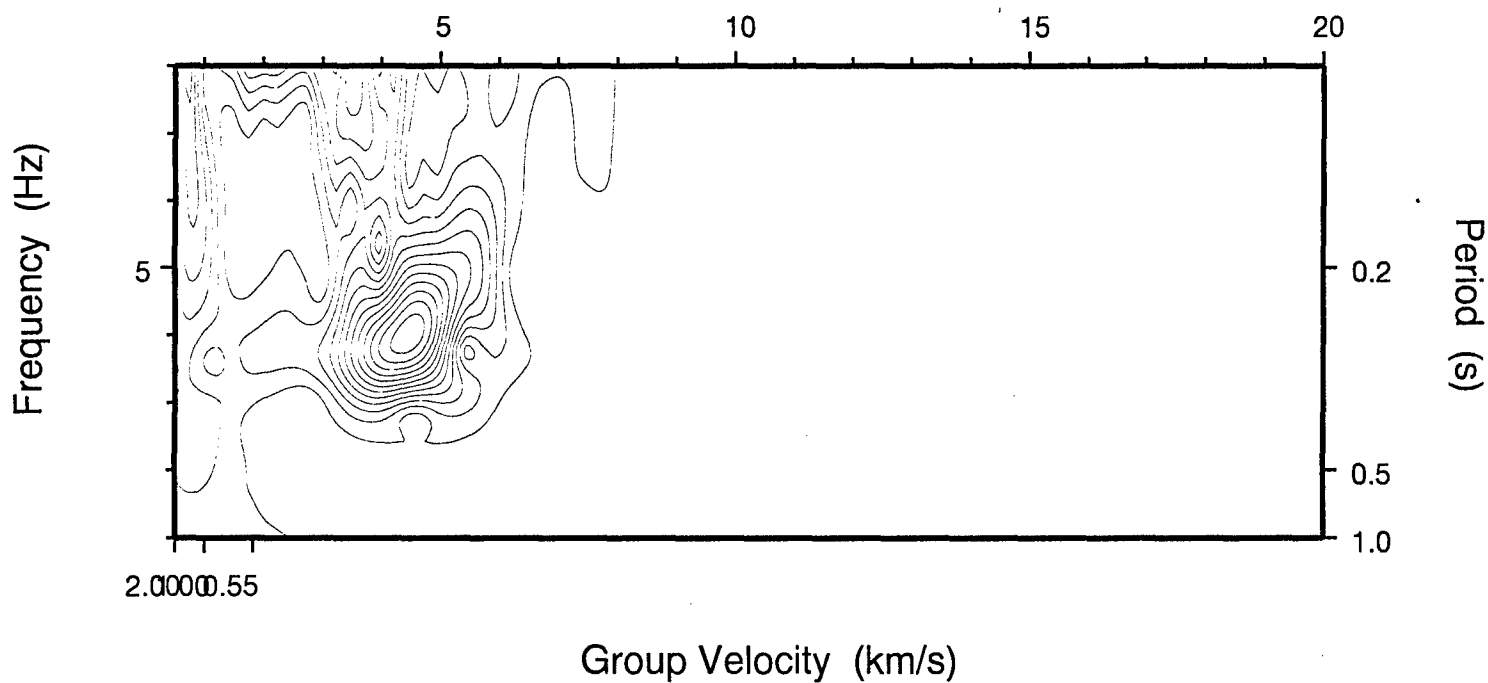
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Figure 4

Instrument 1 Event 2 Component 1
Range 0.713 km



Group Slowness (s/km)



AMPLITUDE

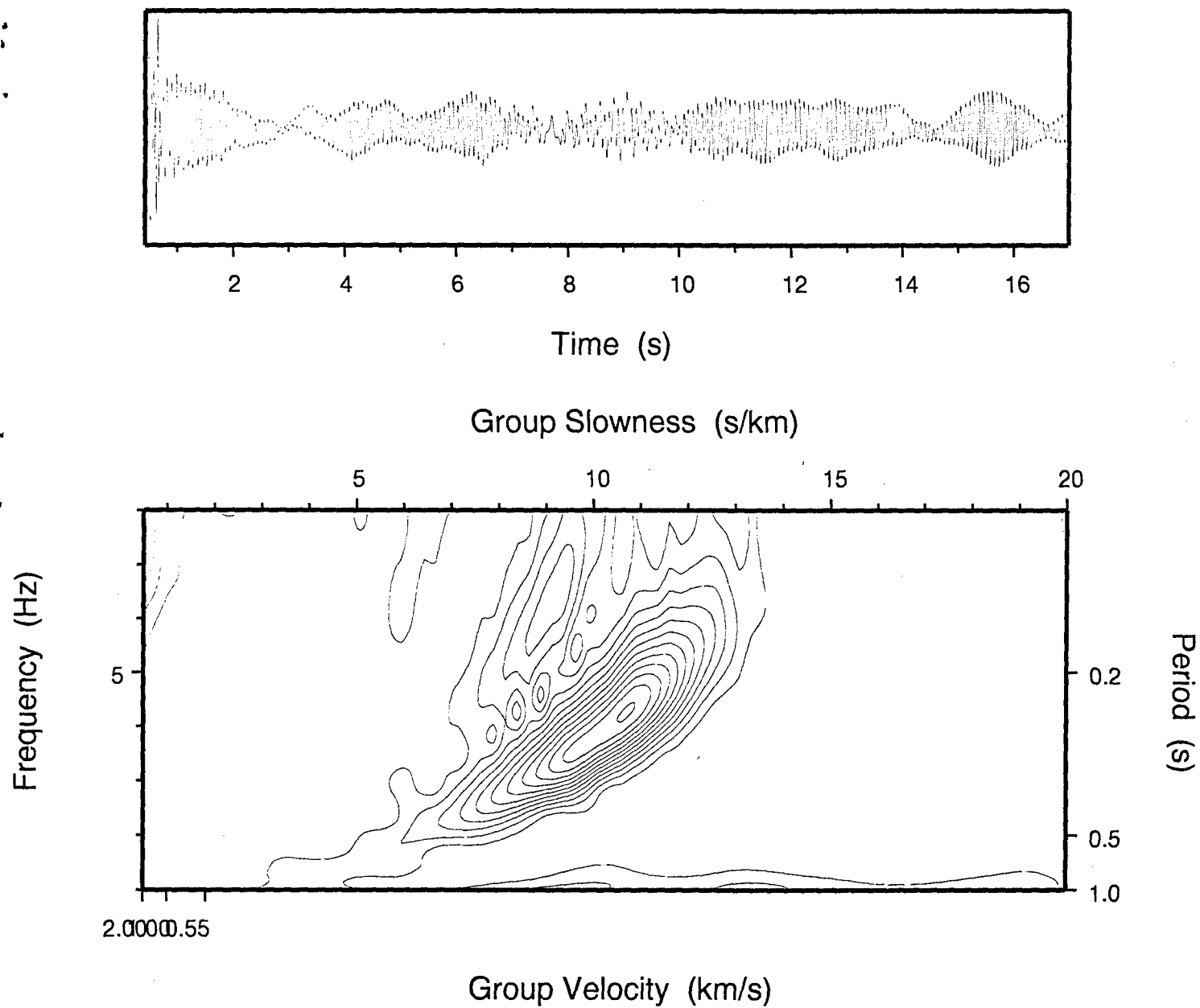
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Filter parameters: Alpha 20.0, Relative bandwidth

Figure 5

Instrument 7 Event 4 Component 1

Range 0.849 km



AMPLITUDE

Contour interval 1.0e+05

Filter parameters: Alpha 20.0, Relative bandwidth

Figure 6

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