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OBSERVATIONS OF T-PHASE ARRIVALS AT PT SUR AND WAKE ISLAND

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13. ABSTRACT *(Maximum 200 words)*

We have assembled a large suite of T-phase observations recorded on hydrophones located at Point Sur and Wake Island, in an attempt to understand how acoustic energy from underwater earthquakes is coupled to the sound channel and how the sound propagates from source to receiver. The events cover a wide range of locations in the North Pacific. We find that T-phases observable at Point Sur are generated only in a limited number of geographical regions, the Aleutian Islands and Kodiak Island regions, south of Japan, and the southern portion of the Kuril Islands region. Too few records have been assembled to date for Wake Island to discern any pattern in the locations of observable T-phases. A signal to noise (SNR) measure was determined for each event. We found that there was no clear pattern in the SNR vs. magnitude when all the events were examined together. We narrowed the region of study to a small cluster of events in the Andreof Island region of the Aleutian Island chain in order to eliminate variables such as source mechanism, transmission path, and event depth. For this limited data set, we found that the SNR as observed at Pt. Sur was more strongly dependent upon event magnitude, however, there was still a considerable degree of scatter. This scatter is probably due to near source effects, such as the slope of the seafloor in the region of the events.

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CONTENTS

INTRODUCTION

The objective of our research is to analyze hydroacoustic signals from oceanic earthquakes recorded by hydrophones and hydrophone arrays, in order to understand the coupling of energy to the SOFAR channel and the propagation of acoustic energy from source to receiver. The generation of detectable hydroacoustic phases for any underwater event depends on a complicated combinaton of source effects, such as event magnitude and depth and source mechanism; near-source effects, such as the slope and depth of the land/ocean boundary near the source; and path effects, i.e. whether the event lies within a shadow zone for a particular receiver, and source to receiver distance. We plan to integrate theoretical predications of propagation effects with observed acoustic arrivals. Goals include determining the efficiency of coupling of acoustic energy from earthquake sources into the sound channel, and determining the effects of variations in bathymetry and temperature profiles along the travel path on the received signals. This requires the assembly of a suite of hydroacoustic array data from a large number of underwater seismic events, in order to obtain optimal azimuthal coverage from source to receiver, as well as a wide range of source depths and source parameters. In this report, we examine a suite of hydroacoustic data from the North Pacific as recorded by a hydrophone located near Point Sur, and discuss preliminary results from an analysis of T-phase signals recorded near Wake Island.

DATA ANALYSIS

We determined signal-to-noise ratios (SNRs) for a suite of 96 recordings at Point Sur and 35 recordings at Wake Island for events in the North Pacific. The recording were obtained from the Center for Monitoring Research (CMR) for an 8-10 minute band about each expected T-phase arrival. Event parameters were obtained from the near-real-time Earthquake Bulletin, provided by the National Earthquake Information Service (NEIS). We used only events with location accuracies labelled A(good) or B (fair). In order to quantify signal strength, a signal-to-noise ratio (SNR) measure was determined for each recording as follows. Each trace was de-meaned and filtered to 0.1 - 0.5 Hz since most of the T-phases are observable only at the lowest frequencies. For this filtered trace, the signal variance was determined over each 30 second band, with steps of 2 seconds between bands. The square root of the maximum variance divided by the minimum variance is taken as the signal-to-noise ratio. In general, signals were observable for events with calculated SNRs of greater than about 1.6at Pt. Sur and approximately 1.3 at Wake Island. An example of the calculation of the SNR is shown in Figure 1.

In general, it was found that events were observed at Wake Island for a wider range of event locations than at Pt. Sur. We attribute this to the lower noise levels at Wake, although to date, we do not have calibration information for either hydrophone so we can't confirm this. Furthermore, T-phase arrivals tend to have longer duration at Wake than the corresponding arrivals at Pt. Sur. An example of this is shown in Figure 2, which compares low-pass filtered traces recorded at both Wake and Pt Sur from an event located near the Andreof Islands, in the Aleutian chain. The source-receiver distance is approximately 3900km at Wake and 4500km at Pt. Sur, yet the T-phase arrival is nearly twice as long at Wake as at Pt. Sur. This is probably due to bathymetric interaction along the propagation path, resulting in the scattering of the signal. Synthetic responses for the given travel path have yet to be computed to determine whether bathymetric interaction is the cause of the lengthening of the T-phase arrival. The differences in the recorded T-phases illustrates the difficulty in determining source mechanism solely from the traces.

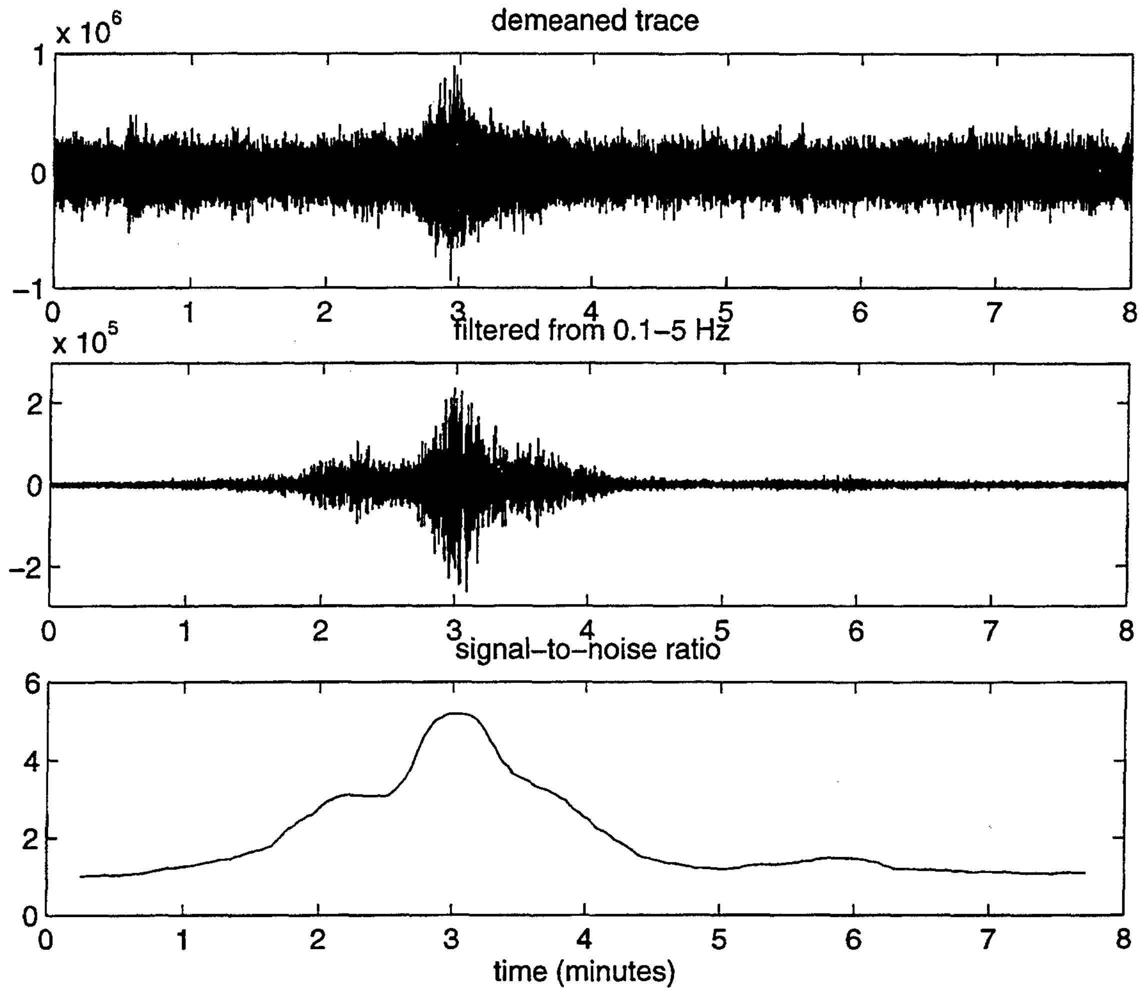

Figure 1. The method of calculation of the SNR is shown here for a trace recorded at Pt. Sur. The de-meaned trace for the Aleution Island event of April 21, 1996 is shown in the top panel. The trace was filtered to 0.1 to 5 Hz, shown in the center panel. The SNR as a function of time is shown in the bottom panel. The method of calculation of the SNR is outlined in the text. The signal-to-noise ratio for this event was determined to be 5.1.

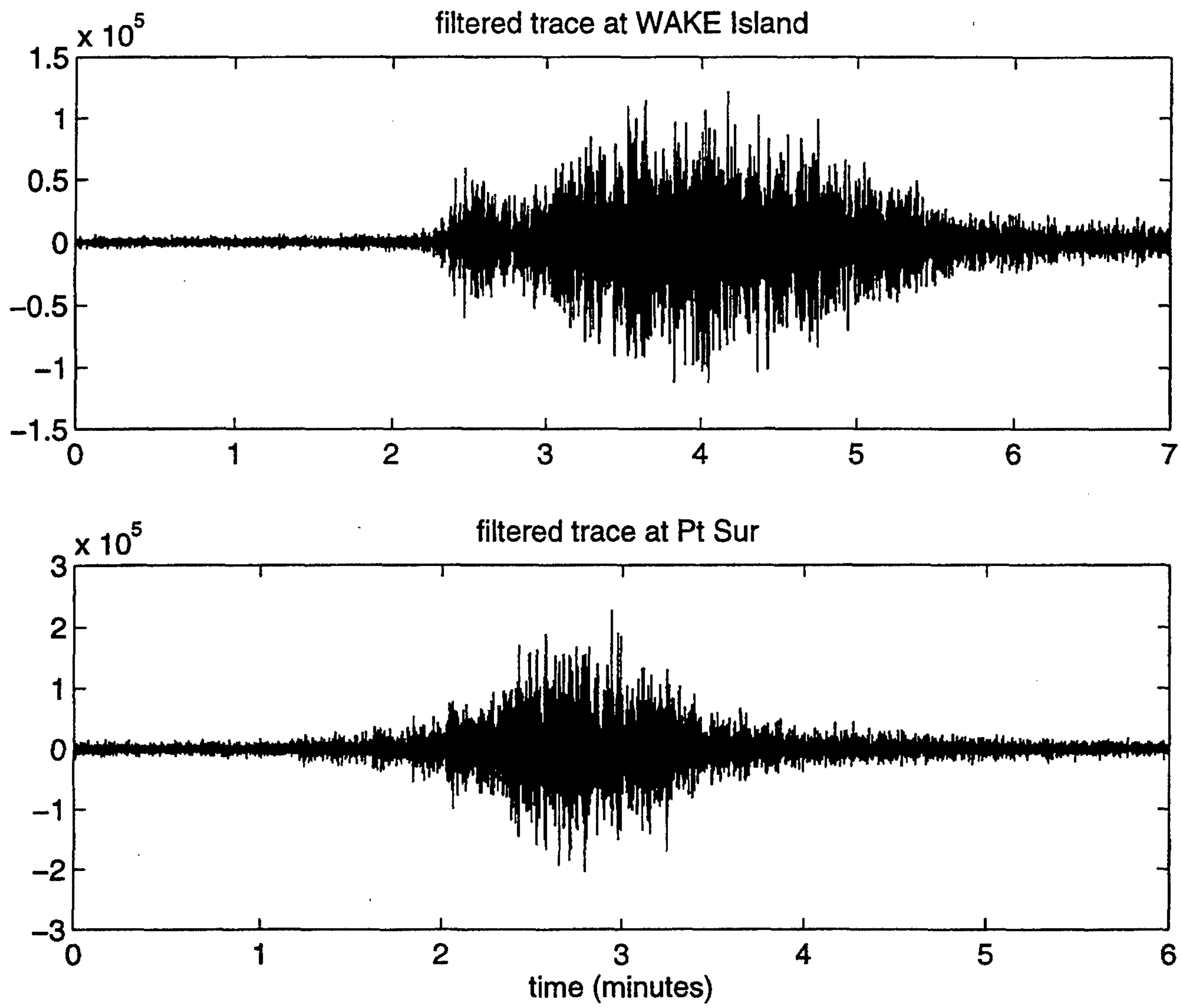

Figure 2. Low pass filtered recordings of T phases generated by an event near the Andreof islands. Note that the length of the T phase arrival at Wake is approximately twice that of Point Sur.

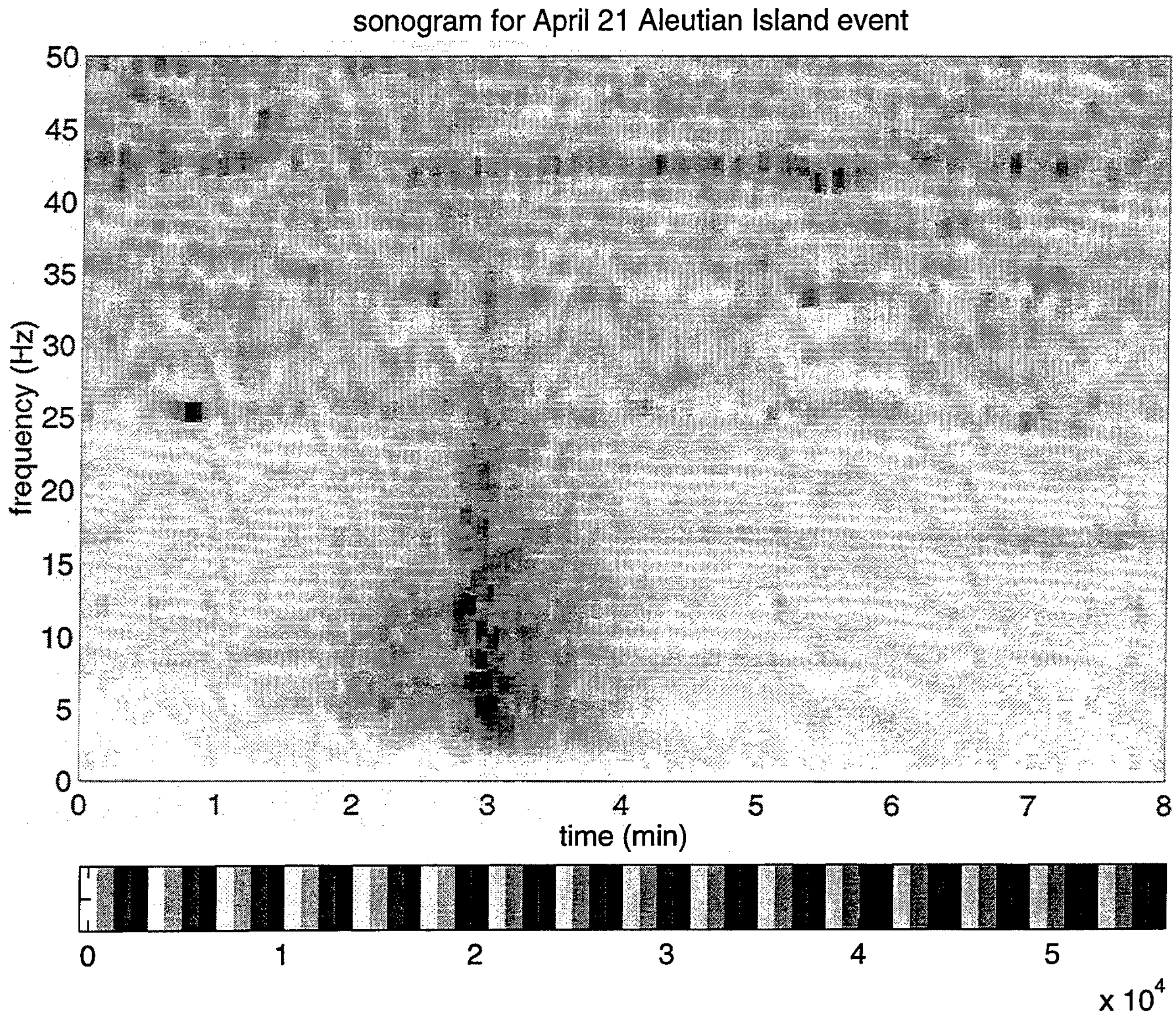

Figure 3. The sonogram for the Aleutian Island event of Figure 1.

Figure 3 shows a sonogram for the trace shown in the top panel of Figure 1 (recorded at Pt Sur). The sonogram confirms that the signal is most clearly observable at the lowest frequencies. At higher frequencies the signal is drowned out by the higher noise levels. For the larger SNR events, such as this one, T-phases are observable at frequencies up to 25-30 Hz.

The SNR ratios were calculated for each event within the suite and are shown as a function of geographic location below for observations at Pt. Sur only. The spatial patterns in the SNR indicates that T-phases observable at the Pt Sur hydrophone are generated in a limited number of geographical regions, the Aleutian Islands and Kodiak Island regions, south of Japan, and the southern portion of the Kuril Islands region.

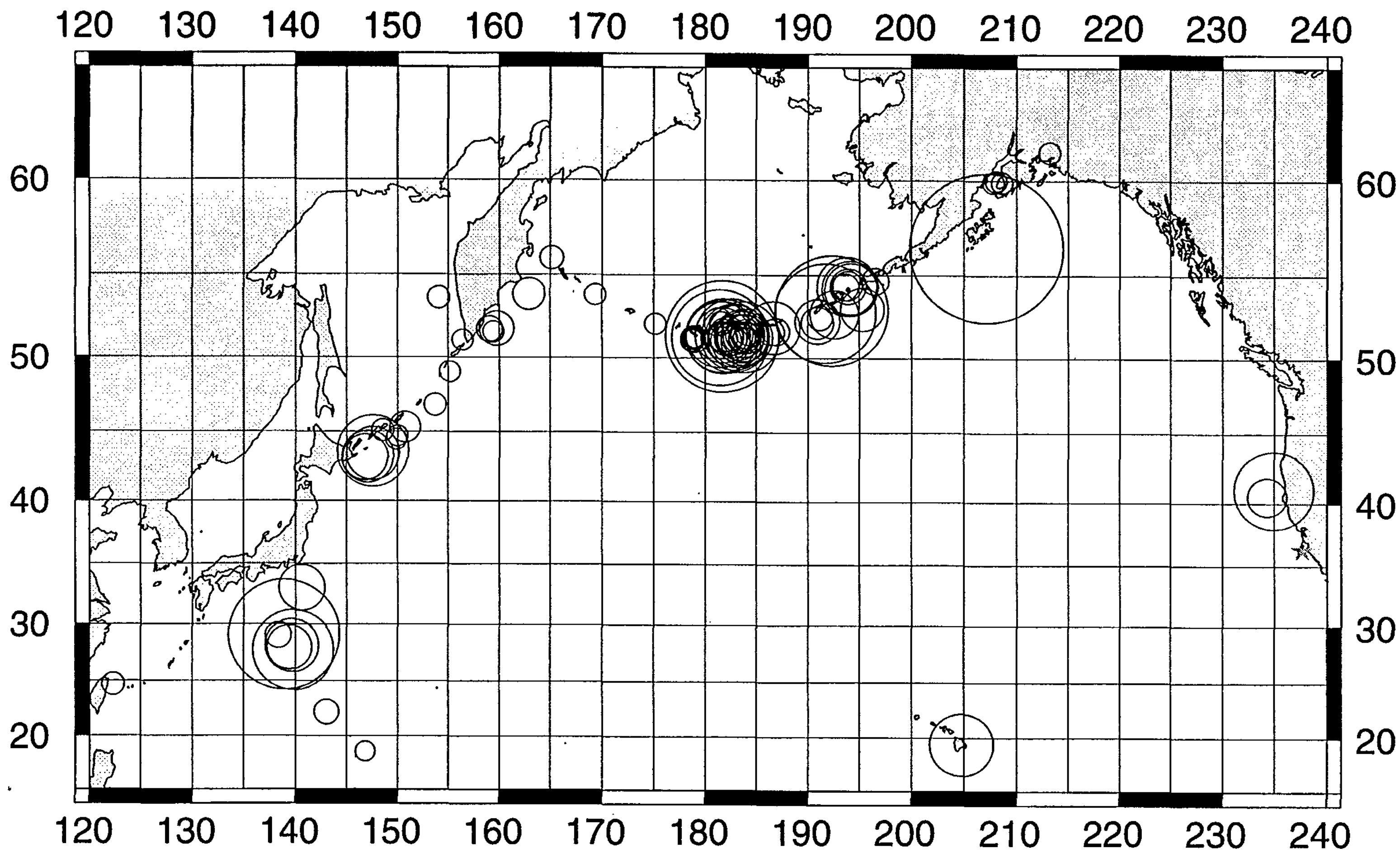

Figure 4. The signal-to-noise ratios (SNR) for T-phases of 96 North Pacific events as recorded at the Pt. Sur hydrophone. All events of the North Pacific that have been examined are shown here, including a number of events for which no signal was observable. The symbol size is proportional to the SNR, which varies from 1 (no signal) to 8 (large signal).

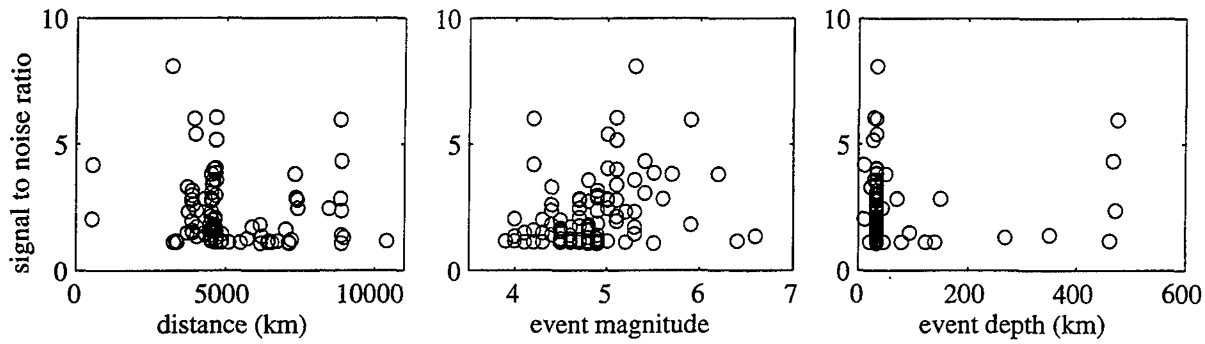

Figure 5. SNR as a function of distance, event magnitude, and event depth.

In Figure 5, we show the SNRs as a function of each of distance, event magnitude, and event depth. No clear patterns are evident in any of these plots. The biggest surprise is in the plot of SNR vs event depth, in that one would not expect *any* T-phases to be observable for deep events. Instead, at least three events generate observable T-phases, all in the region south of Japan.

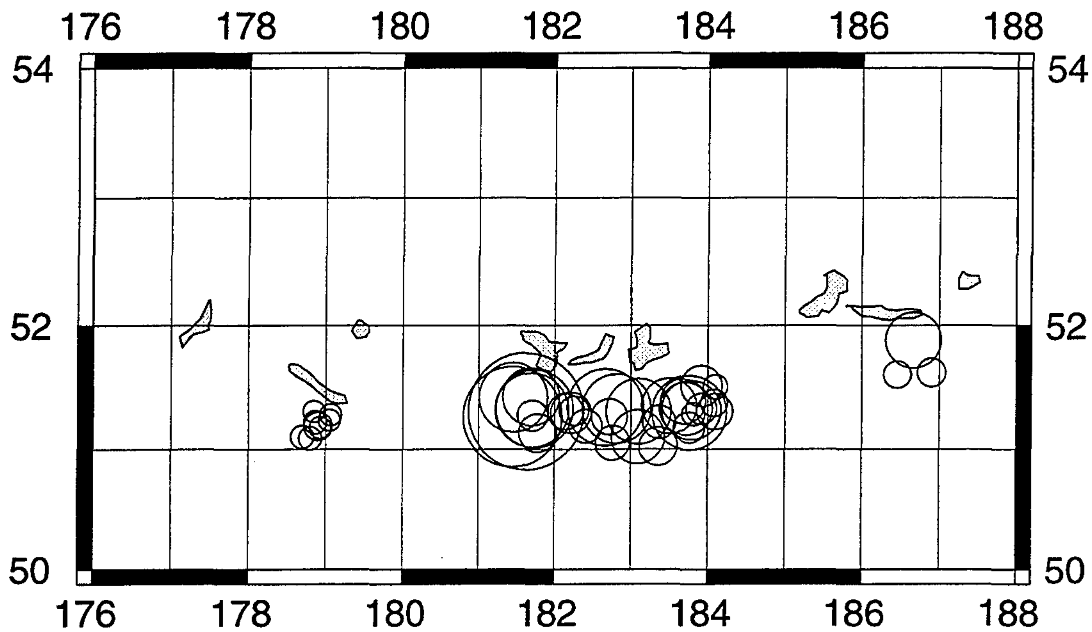

Figure 6. SNRs for the Andreof Island events.

In order to make more sense of the data, we confined our attention to a cluster of events in the Andreof Island region, within the Aleutian Island chain. The SNRs at Pt. Sur for 43 events to the south of the Aleutian Islands are shown in Figure 6 (events to the north of the Islands and thus in the shadow zone were not included). All but one of the events has a given depth between 28 and 33 km. Source mechanisms for all these effects should be the same, ie due to the subduction of the Pacific plate at the Aleutian trench. Thus, we have eliminated complications due to path effects, source mechanism, and event depth. Even at this small scale, a spatial pattern is evident in the SNRs. The events furthest to the east do not generate T-phases that are detectable at Point Sur.

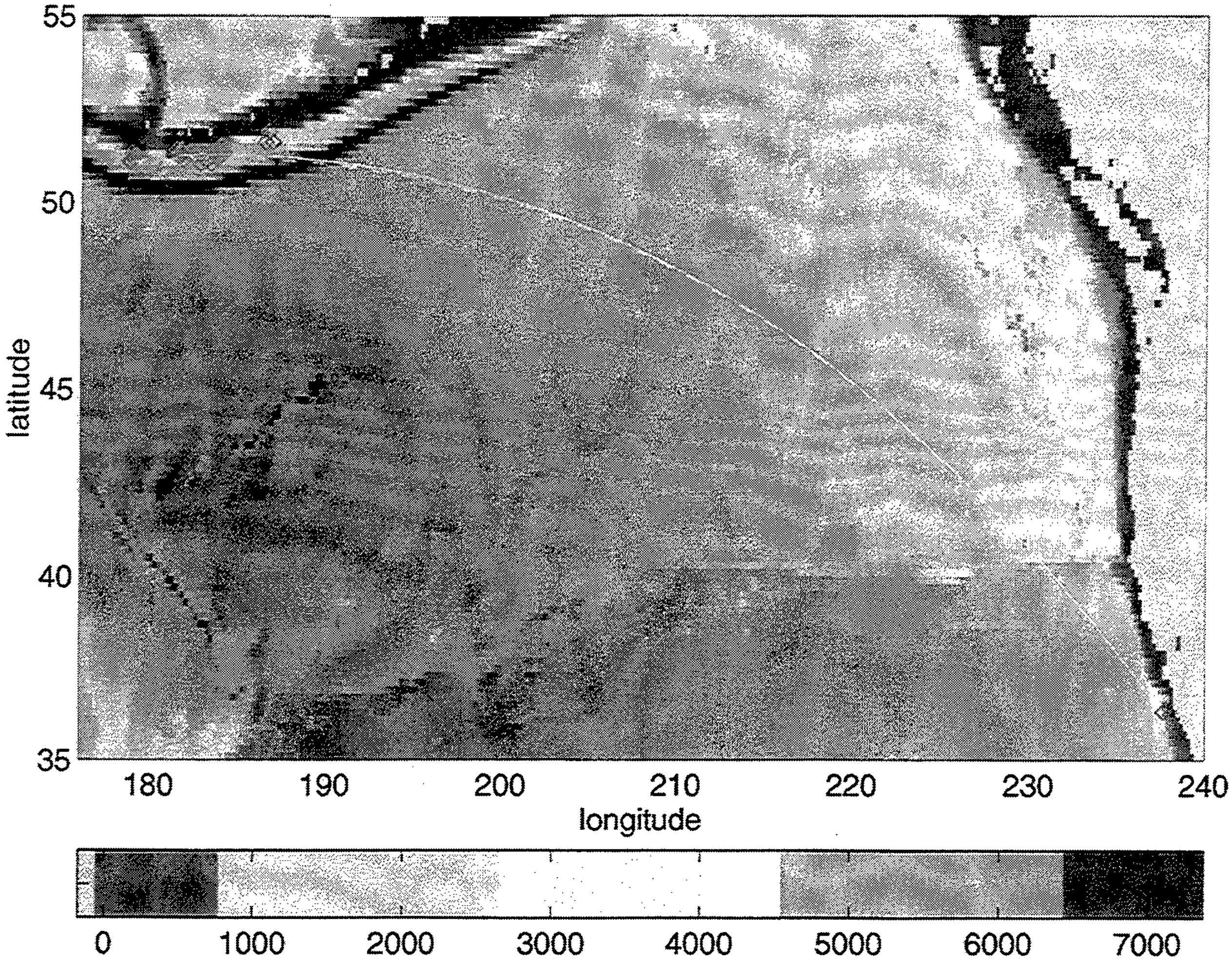

Figure 7. Depth map of the Northeast Pacific showing Andreof Island event locations, including propagation paths for two of the events.

A depth map of the Northeast Pacific showing Andreof Island event locations and geodesic paths for two events is shown in Figure 7. Note that all travel paths follow virtually the same trajectory to Pt. Sur. The solid path is for a magnitude 5.1 event, with SNR of 5.1 at the receiver. The dotted path is for a 5.0 event slightly further to the east with an SNR of 1.4 at the receiver, ie the signal was not observable. In this case, the differences in seismic source to T-phase coupling must be due to near-source effects.

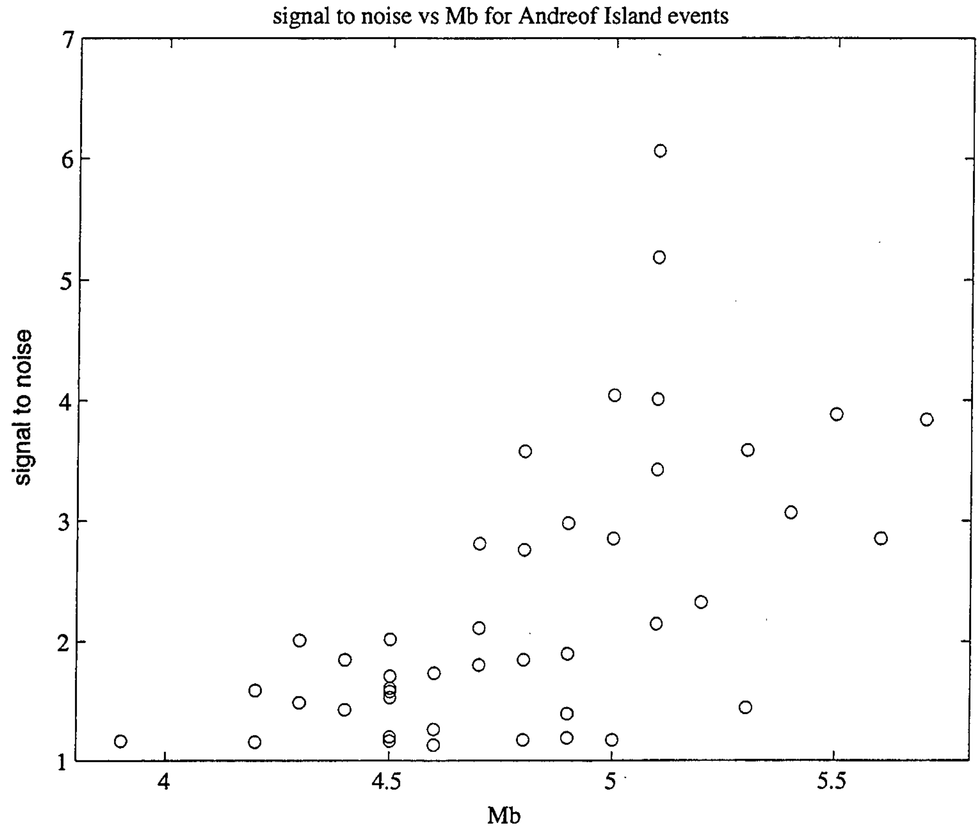

Figure 8 SNR vs magnitude for the Andreof Island events.

A plot of SNR vs magnitude for the Andreof Island events is shown in Figure 8. This plot indicates that larger T-phases are generated by larger events, as expected. However, there is still considerable scatter, possibly due to near-source effects, as mentioned above.

CONCLUSIONS AND FUTURE PLANS

Examination of a widely distributed set of suboceanic events indicates that T-phases are observable at Point Sur for only a limited number of geographical regions. When all these events are examined together, signal strength cannot be determined simply on the basis of event magnitude, depth, or source-receiver distance. Conversion of seismic energy into acoustic energy transmitted in the ocean waveguide is highly complicated, depending on source effects, near-source effects, and path effects. In order to isolate the effects of event magnitude and near-source bathymetry, we narrowed the study to a cluster of 43 events in the Andreof Island region. We found that the T-phase signal strength was more strongly dependent upon event magnitude. However, the scatter within the SNR/event magnitude relation is attributed to near-source bathymetry. More observations are necessary to confirm the conclusions made here. We have begun to examine data from the Wake Island hydrophone, available through CMR. Future plans include integrating land records with hydrophone records. In particular, we wish to examine T-phase arrivals at various island stations within the Pacific to improve coverage. We intend to numerically model coupling of seismic energy (i.e. sources below the ocean floor) into ocean acoustic energy.

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