

2009 Annual Report

Submit to Nancy Barr by February 1, 2010

Project Title: 900907 High Resolution Near-Surface Seismic Refraction Tomography

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Project Manager: David Caress

Project Team: David Caress, Rich Henthorn, Mark Chaffey, Paul McGill, Bill Kirkwood

Collaborators: (Include affiliation)

PROJECT SUMMARY

The goal of the High Resolution Refraction project is to develop a high-resolution seismic refraction capability to image the shallow structure of the seafloor subsurface. The basic concept is to combine a swept-frequency (chirp) acoustic source operated on or near the seafloor with multiple ocean bottom hydrophones (OBHs) as receivers to observe acoustic signals that propagate through the shallow subsurface. To conduct an experiment, we deploy the OBHs in a desired configuration, run profile lines along the seafloor while pinging the source, and then recover the OBHs. The OBH data is match filtered (“dechirped”) using the source signal to yield seismic refraction record sections. Once refracted arrivals are identified and travel times are picked, these observations can be used to constrain models of subsurface compressional seismic velocity structure. If arrays of receivers are deployed, tomographic inversion can be used to yield 2D or 3D models of the subsurface structure.

During 2009 we tested the acoustic chirp refraction concept by assembling a working chirp source (Figure 1) to be operated mounted on an ROV and purchasing two hydrophone receivers (Figures 2 and 3). We performed at-sea tests from the Point Lobos on May 27, June 24, and September 22 in which ROV Ventana first deployed the hydrophones and then ran the refraction profiles. These tests accomplished the following:

- Used the source to generate an arbitrarily designed signal in the 1 kHz to 6 kHz band. At full power, this source outputs acoustic signals at approximately 200 dB re 1 uPa at 1 m.
- Recorded the source waveforms with minimal interference and distortion by positioning the ROV and hydrophones in the midwater, allowing us to match filter using the actual signal as produced by the source and recorded by the hydrophones.
- Used the hydrophone receivers to record acoustic data continuously with sensitivity in the 16 Hz – 9 kHz band.
- Successfully generated 1-6 kHz sweep chirp signals of various durations while running ROV transects
- Successfully match filtered the hydrophone data, resolving direct arrivals in the correlated signal. The time resolution of direct and reflected water column arrivals is about 0.3 msec, close to the theoretical ideal resolution of 0.25 msec (Figures 4 and 5).

Although the match filtered data clearly resolved both direct and reflected arrivals from the water column, we did not resolve any arrivals refracting through the subsurface. Spectral analysis of the hydrophone data (Figures 7-8) demonstrate that ROV Ventana's hydraulic systems produce high levels of noise in the band of interest. An interesting feature of the Ventana noise is that it is dominated by a fundamental tone at around 550 Hz and harmonics of that tone extending all the way up to 6 kHz. Essentially, Ventana resonates like a musical instrument.

We also deployed a hydrophone in the path the Mapping AUV on June 25. Figure 9 presents a spectrogram of the AUV acoustic noise, which proves to be about 50 dB less than ROV Ventana in the band of interest. We conclude that the Mapping AUV would be a much more suitable platform for the acoustic chirp refraction source than ROV Ventana, or any hydraulic ROV.

In 2010, the focus of the High Resolution Refraction project will be to reconfigure for an AUV-based experimental configuration. In particular, we are upgrading the Edgetech subbottom profiler sonar to use a 1-6 kHz sweep, both to achieve greater subbottom penetration and to allow the AUV to serve as the refraction acoustic chirp source platform. We will also replace the initial two hydrophone packages with five higher-gain units that will be fitted with acoustic release systems so that they can be deployed over-the-side from R/V Zephyr during Mapping AUV operations.

GRAPHICS

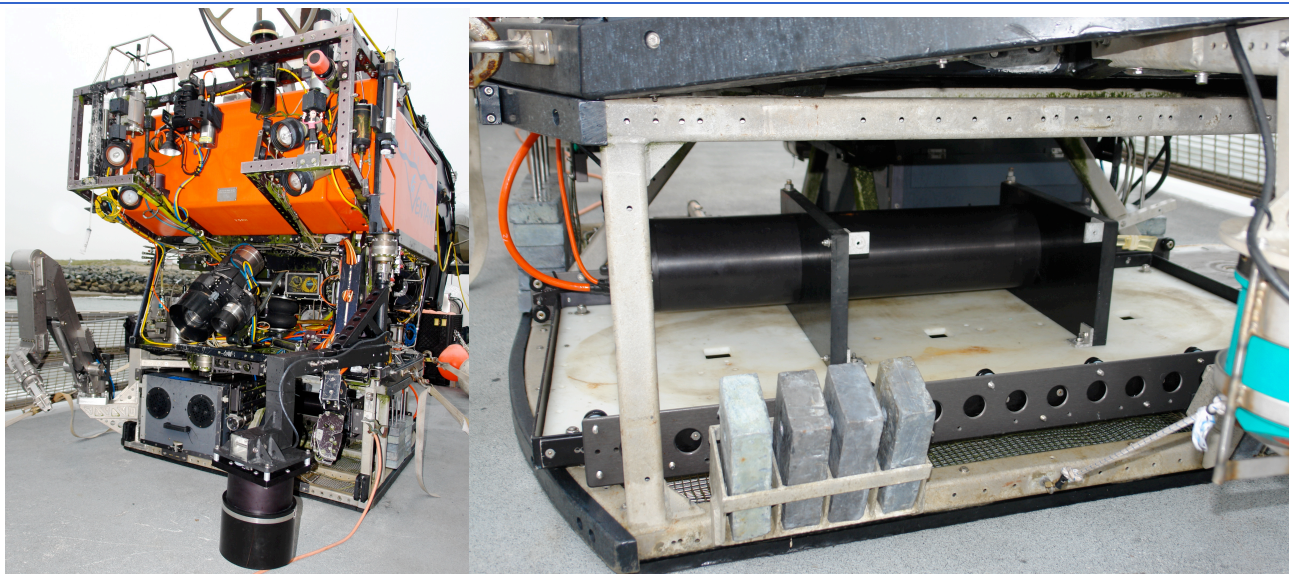


Figure 1. Acoustic source on ROV Ventana. (left) The transducer is mounted on the swing arm. (right) The electronics housing is mounted in the rear of the tool sled.



Figure 2. Hydrophone configuration used for initial testing. The two hydrophones (Acousonde B0003A from Greeneridge Sciences) are attached to a 1 m long poly line attached a homer pro beacon and float to a lead ball anchor. The sondes are quite small: 22 cm long and 3.2 cm in diameter. Each can record 16 Hz to 9 kHz acoustic data sampled at 27 kHz for 42 hours.

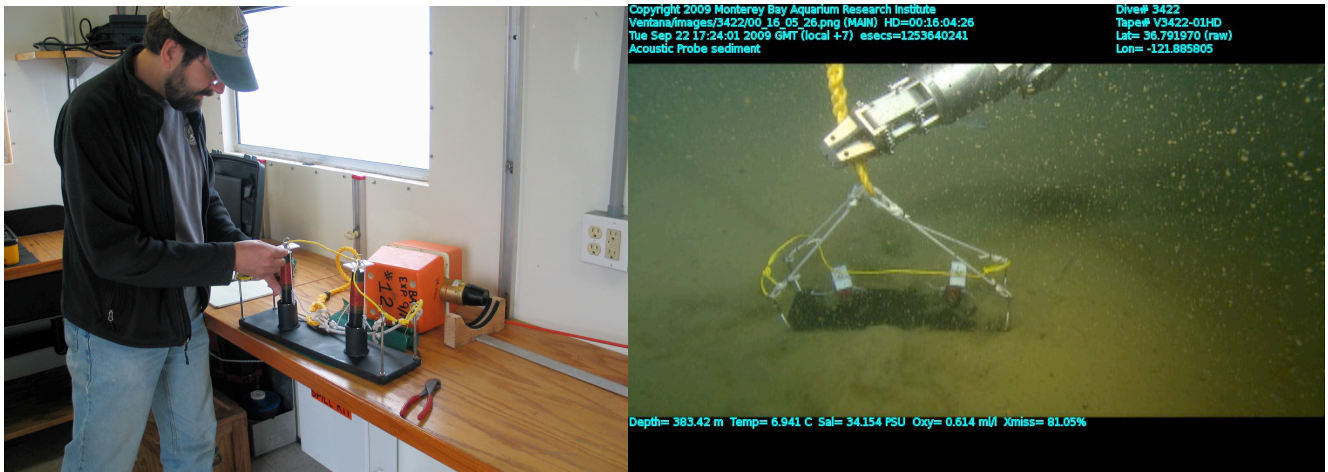
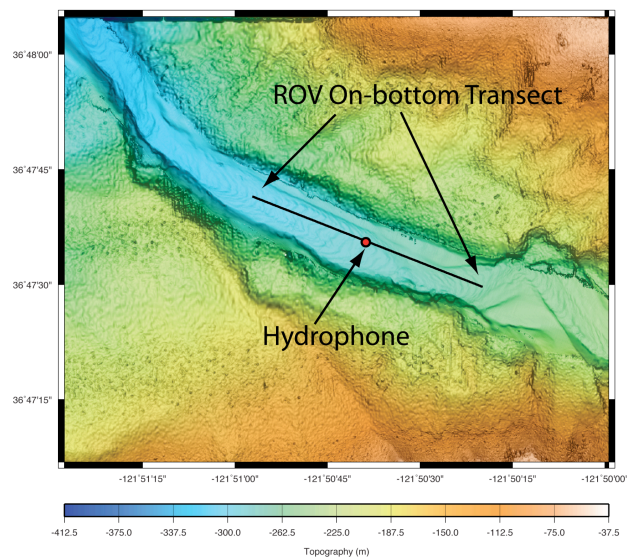


Figure 3. Hydrophone configuration used in September tests. Here the sondes are pushed into the seafloor mud by tensioned shock cord to provide physical coupling to the seafloor.



Example of chirp refraction tests using ROV Ventana in Monterey Canyon on June 24, 2009.
 (Left) The hydrophone was deployed along the canyon axis at a depth of 300 m (avoiding surface reflection interference), and the ROV ran transects from the hydrophone to ranges of 500 m both up and down canyon.
 (Top right) Record section of raw data recorded by a hydrophone as the ROV first maneuvered adjacent to the hydrophone and then drove 500 m away at an altitude of 1 m. The 25 msec duration chirp signal is largely buried in the broadband noise produced by ROV Ventana.
 (Bottom right) Application of chirp match filtering resolves the direct arrival to about 0.3 msec, consistent with a theoretical ideal resolution of 0.25 msec.

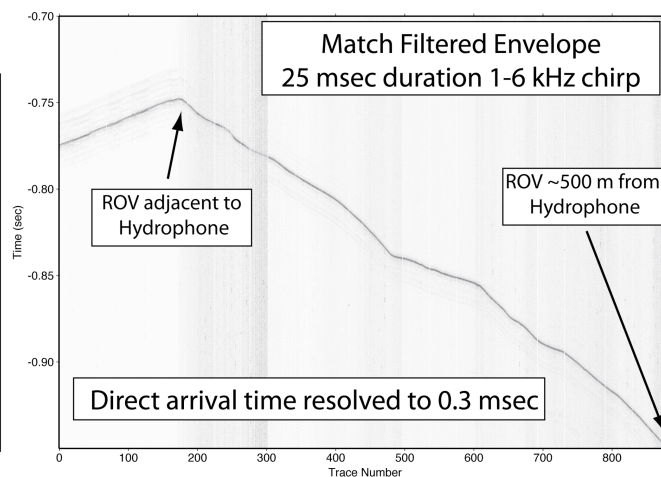
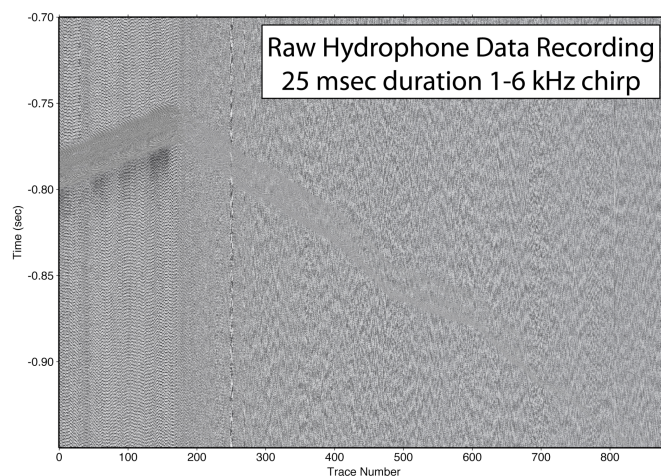


Figure 4. Example results from first chirp refraction tests.

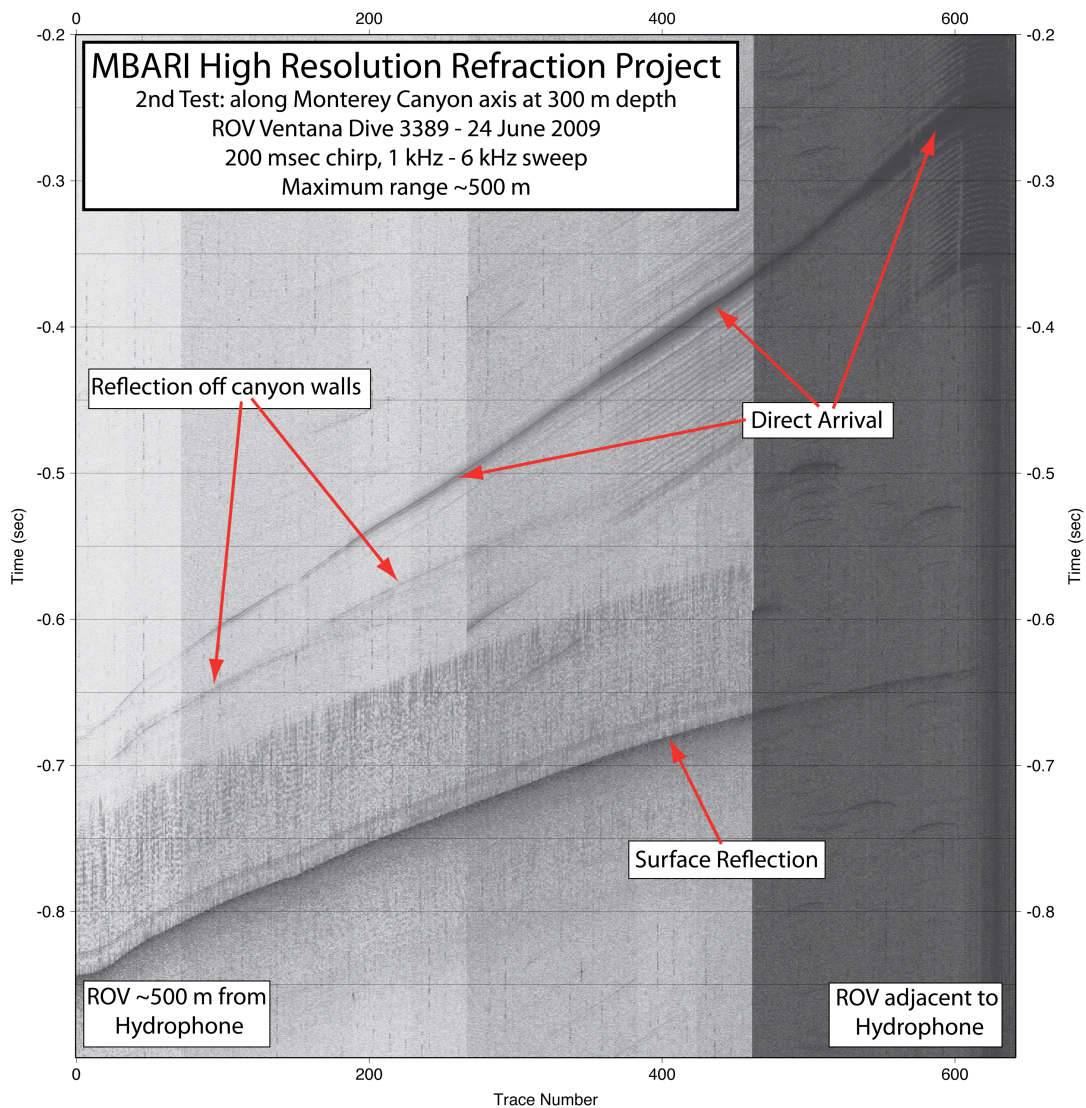


Figure 5. Match filtered record section from test profile along canyon axis using a longer, 200 msec chirp signal. The longer duration improves signal-to-noise, allowing us to resolve additional features – in this case, reflections off the canyon walls. However, no subsurface refracted arrivals are observed.

High Resolution Refraction Testing (22 September 2009)

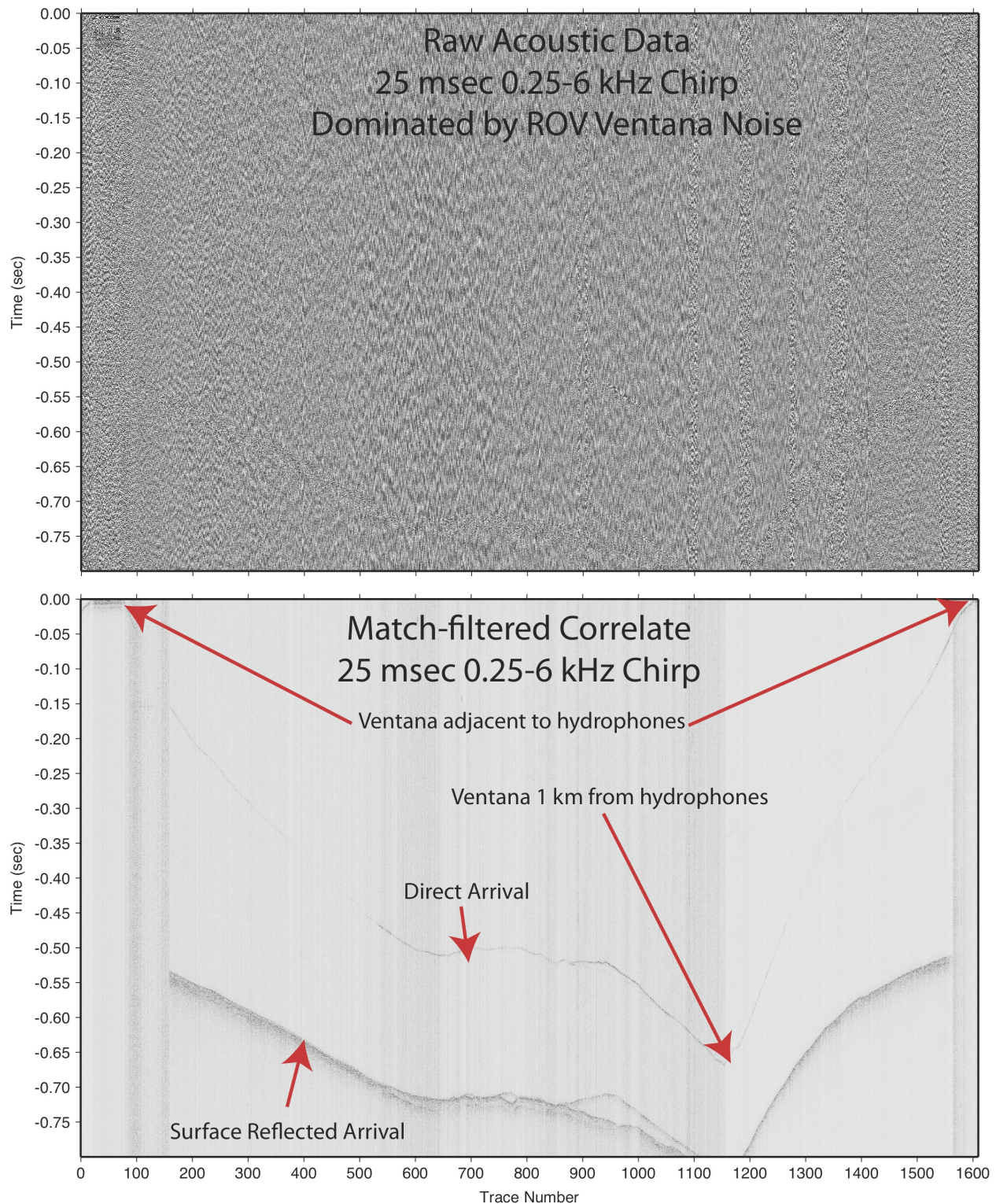


Figure 6. Match filtering of hydrophone data from September 22 testing. Again, water-borne arrivals are well resolved but no subsurface refractions are observed.

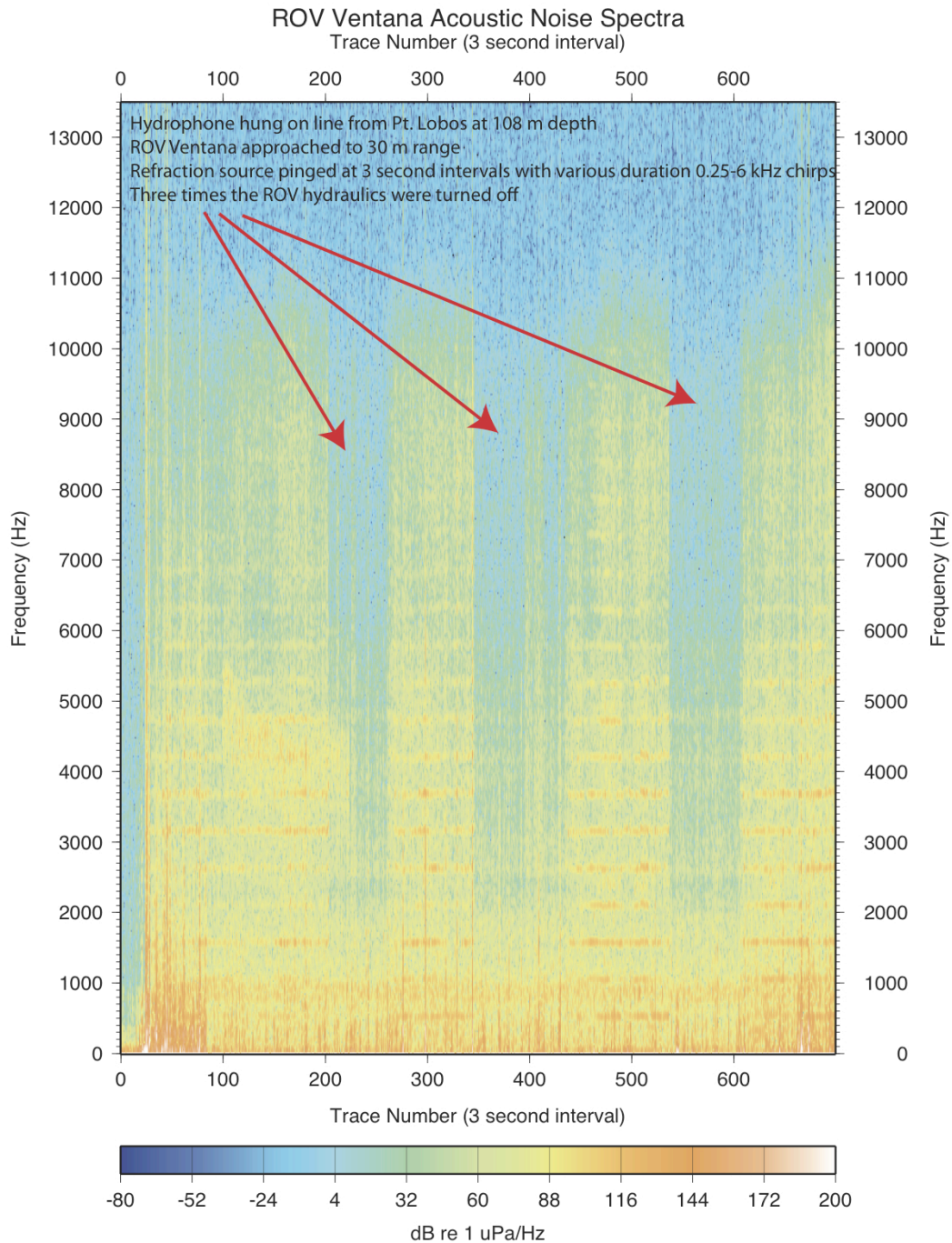


Figure 7. Spectrogram of hydrophone data during midwater observation of chirp waveforms. ROV Ventana's hydraulic systems produce very high levels of noise with an interesting pattern: there is a fundamental tone at about 550 Hz and then prominent harmonics to over 6 kHz.

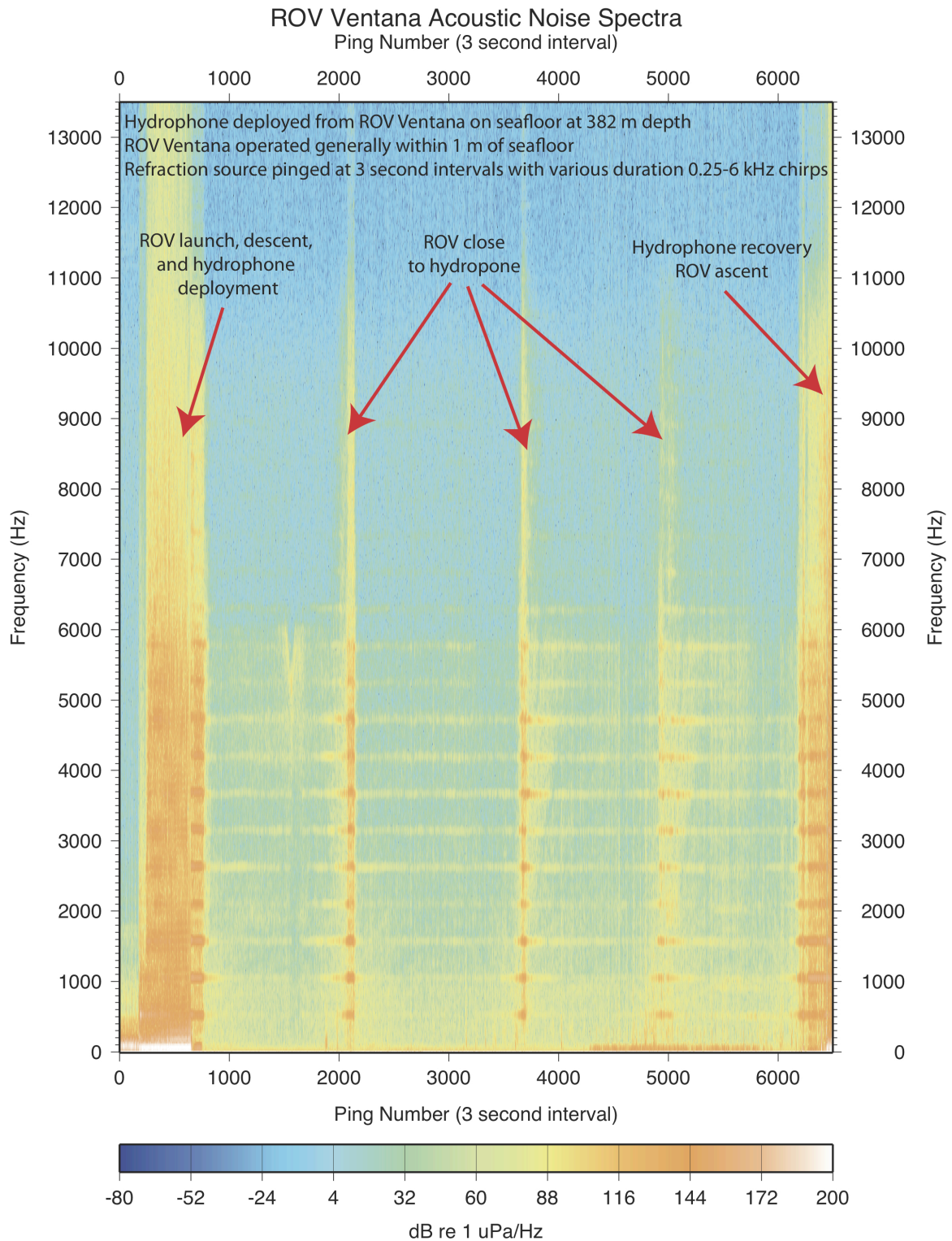


Figure 8. Spectrogram of hydrophone data during on-bottom refraction profiles. The ROV hydraulic noise dominates the recording. We hypothesize that the high noise levels within the band of interest preclude observations of low amplitude refracted arrivals.

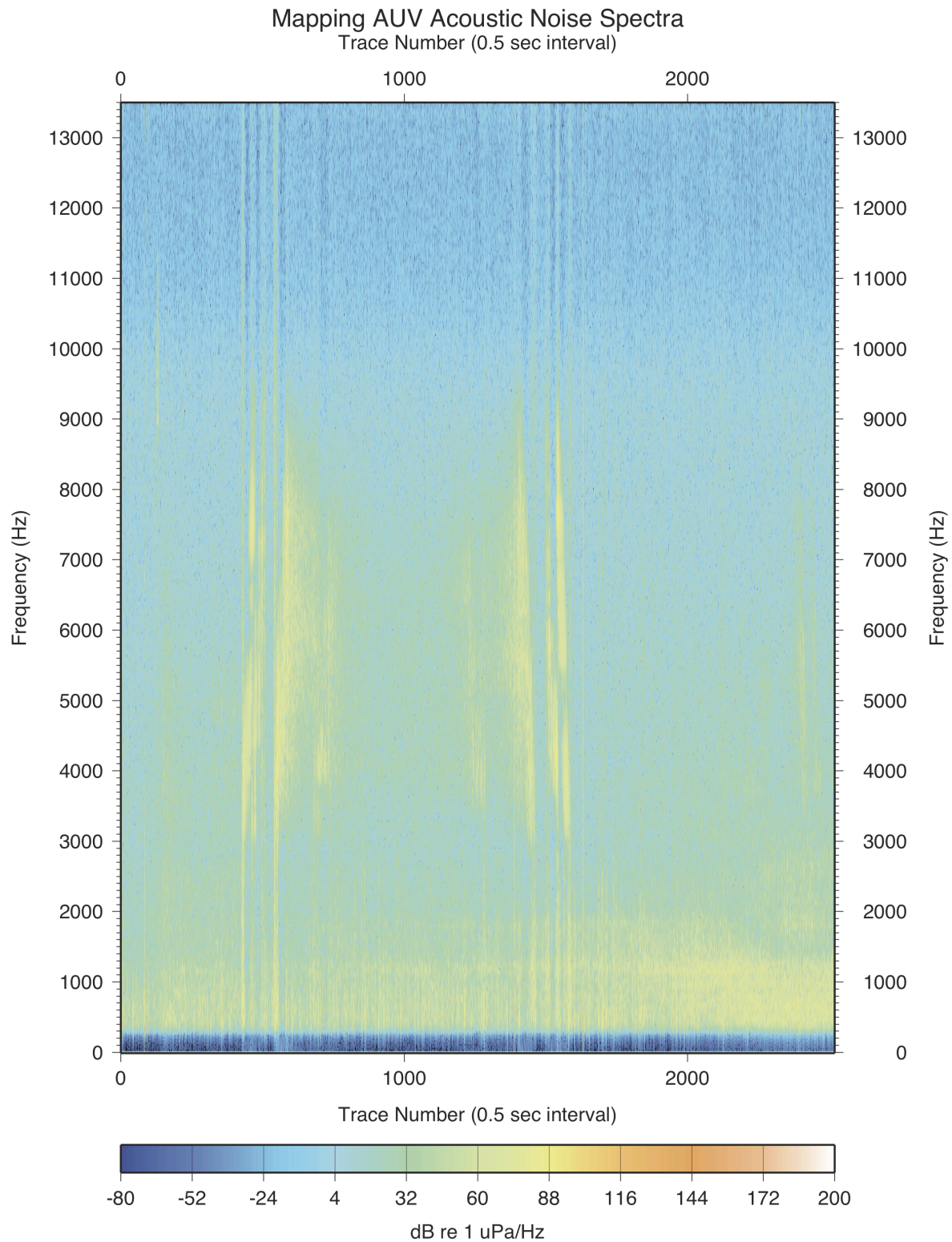


Figure 9. Spectrogram of the Mapping AUV observed by a hydrophone moored 1 m above the seafloor. The signal is low pass filtered below 250 Hz to eliminate strumming of the mooring line. The AUV is on the order of 50 dB less noisy than ROV Ventana in the band of interest.

ADDENDA

If unsure what to include in the addenda, please refer to the 2007 or 2006 annual reports

AWARDS:

DEGREES AWARDED TO ANY MEMBERS OF YOUR GROUP:

PATENTS ISSUED:

INVITED LECTURES:

MENTORSHIPS:

EDUCATION AND OUTREACH EFFORTS (THESE ARE FOR INTERNAL USE; THEY WILL NOT BE PRINTED IN THE ANNUAL REPORT):

PEER-REVIEWED PUBLICATIONS:

TECHNICAL PUBLICATIONS:

MEETING ABSTRACTS:

Henthorn, R., Caress, D.W., Chaffey, M.R., McGill, P.R., Kirkwood, W.J., Burgess, W.C., "Development of a High-Resolution Shallow Seismic Refraction Tomography System at the Monterey Bay Aquarium Research Institute", Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract OS21A-1148, 2009.

Deadline: February 1, 2010. Please submit to Nancy Barr.