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A Vertical Hydrophone Array for Imaging the Hydrate Stability Zone

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Introduction

A prototype high-resolution vertical line array (VLA) has been designed and constructed as part of the development of a remote multi-sensor sea-floor observatory to be installed within the gas hydrate stability zone (GHSZ) of the northern Gulf of Mexico.

A net of five such VLAs will form the heart of the station. It is intended that the VLA net will triangulate on and track surface vessels. The noise of the vessels will be recorded and used as an acoustic source for imaging geologic structures within the GHSZ. In this way, temporal changes to the structural configuration can be monitored more-or-less continuously without a survey ship being dedicated to patrolling the area.

Design Details

The design of the prototype VLA is illustrated in fig.1. It has a total length of slightly more than 200m. It is supported in the water column by glass-sphere flotation and is fixed to the sea floor by an expendable concrete anchor.

The upper portion of the VLA consists of 16 acoustic channels evenly spaced at 12.5m intervals. The lower portion accommodates electronic devices in pressure housings. These include a data logger, a battery pack, an acoustic doppler current profiler and acoustic releases to disengage the anchor.

Each acoustic channel comprises a hydrophone and preamplifier. The hydrophone response is flat to within +/-1 db from 5 Hz to 10,000 Hz including the built-in preamplifier with a usable dynamic range of greater than 117 db.

The 16 channels of acoustic signal are analog wired to the data logger which includes a data acquisition and telemetry system (DATS). The signals are further amplified by a programmable gain amplifier before being digitized. A 16-bit, 200 kHz digitizer allows all 16 channels to be digitized at 10,000 samples per second. A record of 2- to 10-second length is stored and transferred. The 16-bit A/D utilizes DMA data transfer to memory in a PC-based microprocessor for both speed and energy conservation. Shot records stored in memory are transferred to a hard drive following each shot.

The DATS is connected to a two-way acoustic modem operating at about 38 kHz and capable of 1200-baud communications. This modem is used to receive a "time-zero" command to start recording data. The modem is also used to monitor DATS house-keeping status, transmit compressed sample record information, provide surface control of acquisition parameters including the gains of the programmable amplifiers, and if requested, to transmit a recording for quality analysis in near-to-real time.

In case communication with the surface should fail, the DATS fail-safe program includes a "record on time" mode that causes the DATS to record continuously for the first 20 minutes of each even hour.

A pressure-compensated battery pack mounted below the data logger provides all system power for up to a 10-day deployment. Energy conservation includes power control of the hydrophone array, signal conditioning circuitry and hard drives.

An acoustic doppler profiling current meter is located below the battery pack. The current profiler is directed upward to aid in determining the geometric configuration of the VLA in the water column. The circuitry provides an option for incorporating tilt meters and compasses along the VLA should they be needed to improve that determination.

Recovery of the system is initiated by activating a pair of acoustic releases that connect the VLA to the expendable concrete anchor. Only one of the two is required to release the anchor successfully. The glass spheres then provide sufficient positive buoyancy to bring the entire system to the sea surface.

Software
The data acquisition software was written in C and includes control of data collection parameters via the acoustic modem once the vertical array is moored to the sea floor. Software control provide a pre-deployment sampling delay, sample rate, shot record duration, 4-channel group amplifier gain adjustment, start and end of line recording, additional start record times, sleep mode and sample fail safe capabilities, and visibility of acquisition house-keeping parameters.

Initial Test Program
During the summer of 2002, the prototype VLA was deployed and recovered successfully three times in 830m of water. During the third deployment, runs were made on it while firing a surface-towed 80in^3 watergun.

Waveforms recorded from one shot of the watergun are shown in fig.2. Acoustic waves in fig.2 are seen to sweep across the array, impinging on the channels at slightly different times. Downward-traveling waves impinge first on the top of the array. Those that impinge first on the bottom are traveling upward.

The left-most wave in fig.2 is propagating downward. It is the wave that has traveled directly from the source to the VLA. It can be seen that the direct wave is "clipped", i.e. its amplitude exceeds the saturation level of the A/D converter. This could have been avoided by reducing the gain applied prior to digitization, but then the amplitudes of later arriving waves may have been unacceptably weak. Rather than take that chance, it was decided onboard ship to accept the direct wave being clipped.

The upward-propagating wave that follows the direct wave is the reflection from the sea floor. The upward-propagating waves that follow the sea-floor reflection are subbottom reflections.

The downward-propagating waves on the right-hand side of fig.2 are first-order multiple reflections in the water layer, i.e. the upward-traveling bottom and subbottom reflections after they have been reflected back downward from the sea surface.

Conclusions and Further Development
Results indicate that the tests were generally successful but it has been concluded that some modifications to the prototype VLA design are desirable.

The clipping of the direct wave is not acceptable for future work because it eliminates some important options for post processing. In particular, the direct wave cannot be used as a source signature for deconvolution or phase conjugation. The difficulty would best be avoided by increasing the dynamic range of the A/D conversion by a few bits. Failing that, channel 16 could be recorded at more that one gain level so an unclipped signature would be available.

Tilt meters and compasses should be installed on future VLAs.

It may be noticed in fig.2 that channels 1 and 13 are dead and that channel 8 is noisy. It is concluded that this did not seriously impair the success of the initial test program.

Immediate plans are to construct two other VLAs to a modified design and to modify the prototype accordingly. The three VLAs will then be deployed to comprise a net for triangulating upon and tracking sounds in the water column. These sounds will be used to monitor possible changes to the geologic structures in the shallow subbottom.

In the long term, it is planned to deploy a net of five VLAs to provide redundancy and error correction for the triangulation/tracking of ship traffic. That will provide the heart of a multi-sensor remote station which will monitor an area of sea floor for a period of three-to-five years. Data will be transmitted to shore via an oil platform or a moored buoy.

Acknowledgments
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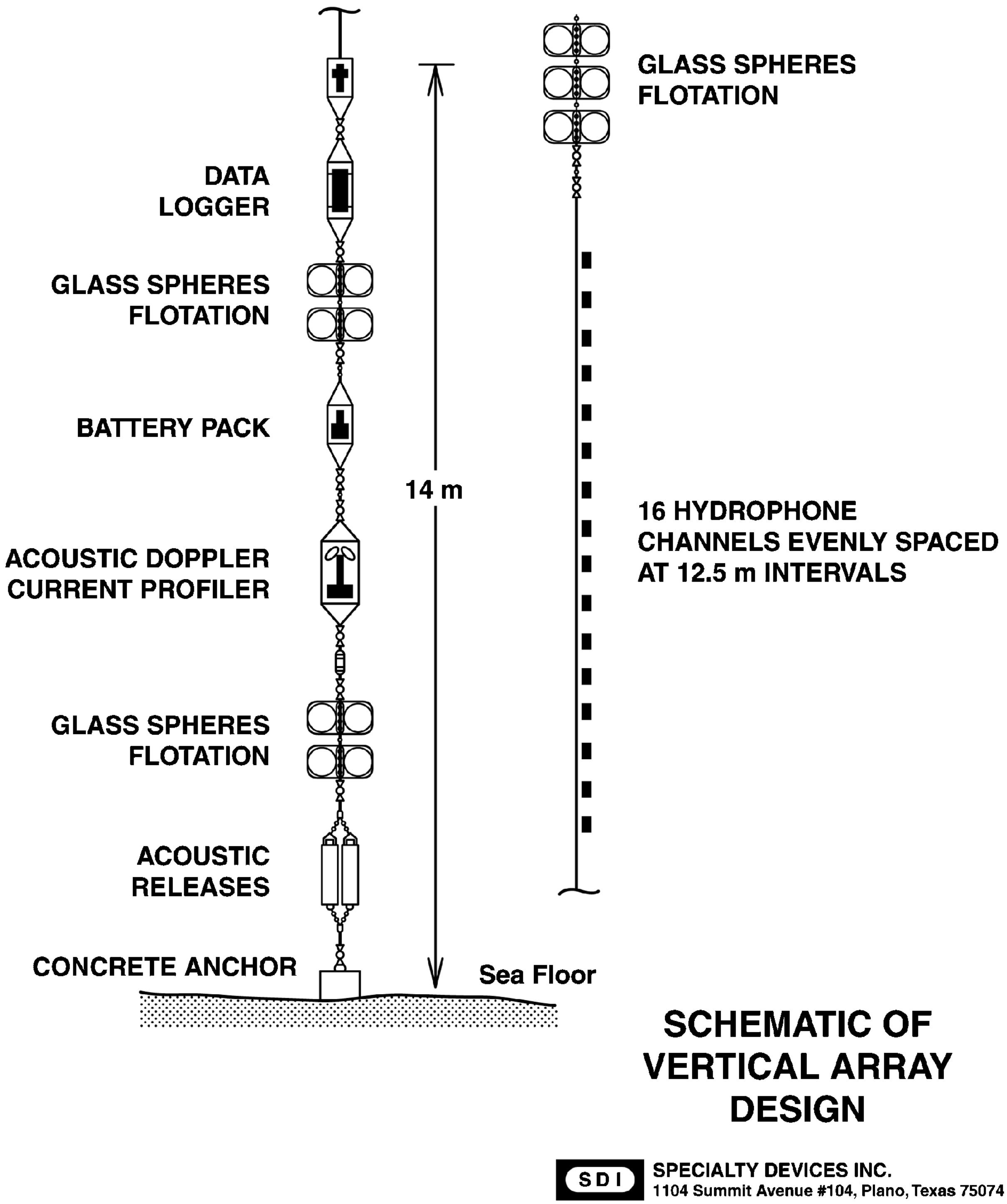

Fig. 1: Layout of Prototype VLA.

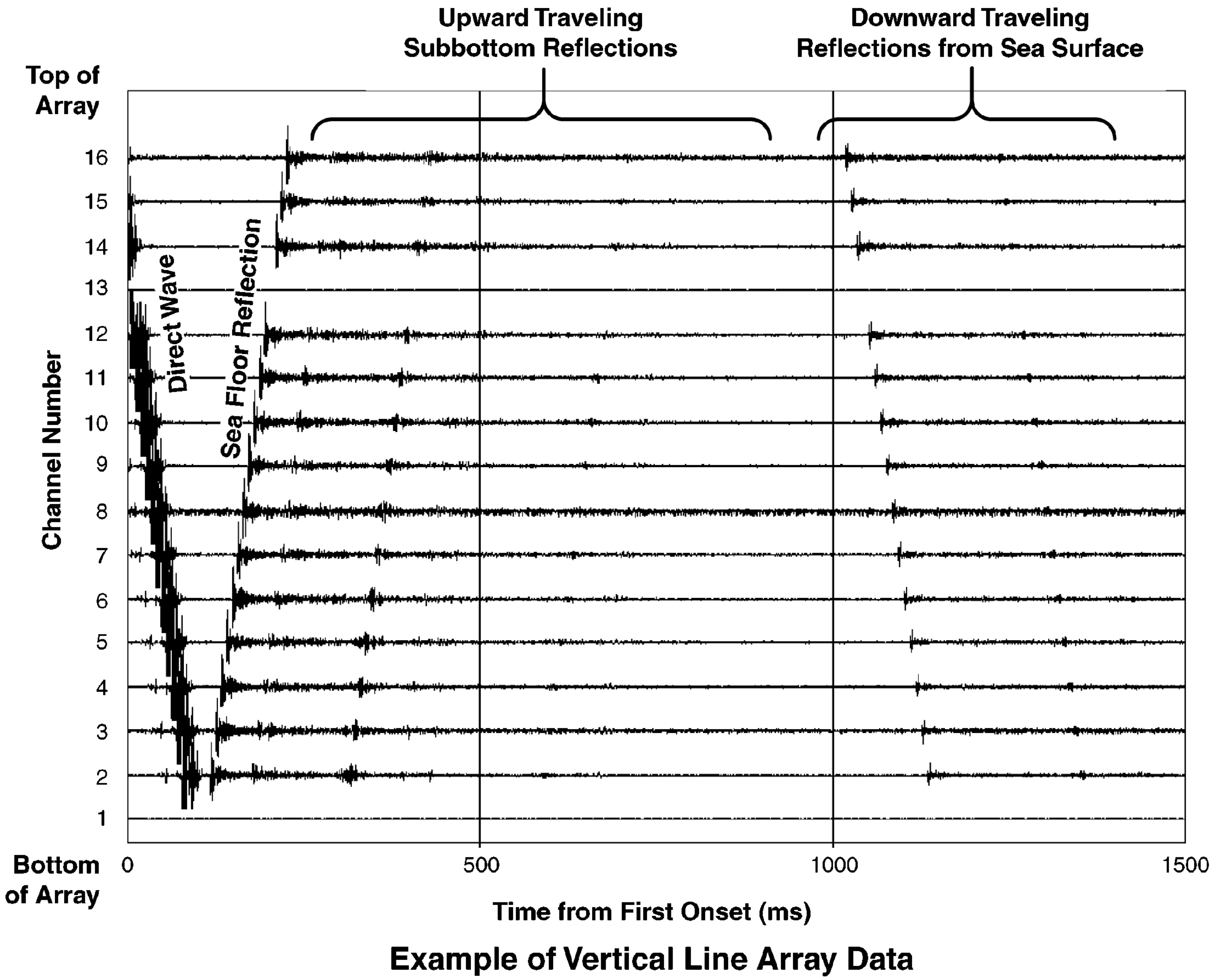

Fig. 2: Example of VLA Data from a Single Watergun Shot.