Polarity Preserving Chirp Sub-bottom Profiler

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Goals

The goal of the project is to develop an acoustic imaging system to investigate the shallow subsurface of the seafloor in areas with gaseous sediments.

BACKGROUND

Chirp sub-bottom profilers use a high frequency sweep signal to produce high-resolution images of the seabed subsurface. The images produced by the chirp sub-bottom profiler are seismic profiles displaying reflections from the subsurface discontinuities due to changes in the physical properties of the sediments. When this project began none of commercially available chirp systems preserved the polarity of the reflections (positive versus negative). It is important to retain the polarity of the signal because it can be used to discriminate changes of the acoustic impedance of the sediments and then calculate the physical properties of the sediments on the seafloor.

Density is one property that can have a significant effect on the strength of the signal recorded at the receiver. If there is a strong density difference between two sediment layers, then there will be a strong reflector in the data. Furthermore, density differences are to be expected due to compaction of buried sediments with depth and\or significant differences in the lithology (sand versus clay, soft sediments versus hard rocks etc.). The presence of gas in the subsurface can decrease the density and produce a strong reflector as well. Fortunately, we can begin to distinguish between these two situations because the preserved polarity of the signal provides us insight into the direction of the density change (either increasing or decreasing). The capability to map the presence of gas in the shallow sediments is very important in many areas of ocean geological investigation, such us: natural and man-made hydrocarbon seeping, seafloor stability, geo-hazard assessment, benthic habitat mapping.

To achieve our goal we developed a set of specifications for a system that would preserve the polarity of the signal and challenged industry to produce an instrument that could meet our needs. Several industry leaders vied for the option but only Geo Acoustics, Ltd. provided convincing information that their system would indeed preserve the polarity.

AUV INTEGRATION

MMRI maintains a close working relationship with the Undersea Vehicle Technology Center at the University of Southern Mississippi and their survey class Autonomous Underwater Vehicle (AUV) Eagle Ray was identified as a suitable test bed for the new system (Fig 1). Mounting the hardware in the vehicle was relatively straight forward but integrating the system operations with the AUV mission software proved more challenging. Even though Geo Acoustics has years of experience with ship mounted and tow-body systems, this was the first unit for AUV application they had produced. AUV engineers Max Woolsey and Roy Jarnagin worked closely with Geo Acoustic engineers to work through the bugs in the software.

Figure 1. The Eagle Ray Autonomous Underwater Vehicle has a large payload capacity making it a suitable test bed for the development of new sensors and instruments.

SYSTEM SPECIFICATIONS

- 2000m depth rating
- Raw and match filter data recorded
- 40 to 50 m penetration
- 1.5 to 16 kHz frequency sweep
- 100kHz sample rate
- 24bit dynamic range
- Configured to operate from different platforms (AUVs)

FIRST SEA TRIAL: R/V PELICAN TO EWING BANKS 873 JULY 2011

The first sea trial of the new system was at a suspected gas expulsion feature in Ewing Banks 873, Gulf of Mexico. High-resolution bathymetric mapping, using multibeam sonar, with the AUV discovered mud volcanoes and pock marks on the seafloor (Fig 2). Four transects of the area were made with the new chirp system to evaluate its function with and without the multibeam sonar running. The polarity-preserving chirp sub-bottom profiler adds the third dimension to the bathymetric map and clearly shows the structure of the gas expulsion features below the seafloor (Fig 3). These early results are somewhat limited by the many noise bands over-printing the image. The noise bands are from the AUV operator’s numerous inquiries of system status during the maiden voyage and should not be an issue on future cruises. Now that the system has been

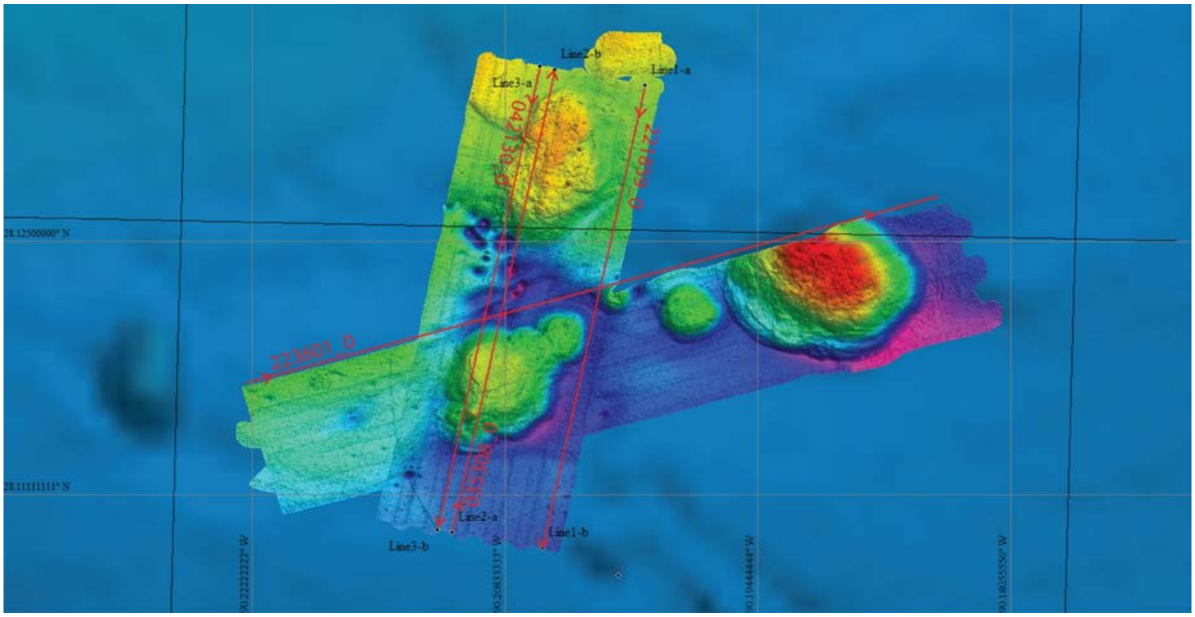

Figure 2. High-resolution bathymetric image of Ewing Banks 873, Gulf of Mexico, acquired by the Eagle Ray AUV. Note the mud volcanoes (red to orange areas) and the pock marks (dark blue to magenta circular areas) gas expulsion features on the sea floor.

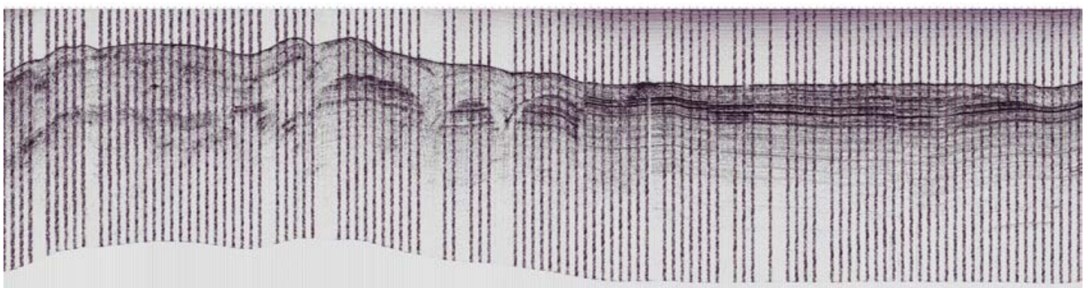

Figure 3. Sub-bottom profile through gas expulsion feature in Ewing Banks 873, Gulf of Mexico, acquired with the Polarity Preserving Chip Sub-bottom Profiler.

proven on the AUV, interrogations can be limited to the end of track lines and the noise bands will be minimized.

Future Work and Continued Development

With this new system, we can now obtain high-resolution sub-bottom profiles that are co-registered with the bathymetry. We also have the preservation of the polarity which is one of the basic tools used to begin to estimate the physical properties of the sediments. The system also allows us full access to the raw data so we can start to develop new processing techniques. One of the first tasks is to define the anti-aliasing filter inherent in the system and to obtain a calibrated source signature. With this information, we will be able to improve the resolution and achieve greater accuracy in interpreting the acoustic response of sub-bottom sediments.

Surveys using chirp sub-bottom profilers are common today because they are a proven tool for mapping faults and fractures in the subsurface. Our new system expands the usefulness of chirp surveys with an evaluation of the potential for natural gas accumulation and migration along these fracture zones. The presence of gas in fracture systems is significant because it affects the stability of the seafloor and can help promote the formation of gas hydrates. We plan to conduct a comparison study of two different fault and fracture patterns in the Gulf of Mexico: the well-known radial fracture above the salt dome in Mississippi Canyon 118 with a suspected polygonal fracture pattern on a massive slump block in Mississippi Canyon 798.

Collaborators

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