A Closer Look at Site-Survey Data

By Bob Van Nieuwenhuise, Manuel Perez & Mark Langer, Paradigm

Introduction

The acquisition of site survey data has always been a necessary precursor to stationing oil drilling platforms or vessels into a deep-water environment. Due to recent drilling concerns, these site surveys will likely be held to an even a higher standard than they have been in the past. The high frequency data sets illuminate features such as shallow gas condensates or gas deposits, shallow buried stream channels, recent mass movements, shallow diapir features and small shallow faults, just to name a few. Ideally, acquired site survey data need to be easily processed, integrated and viewed with normal low frequency seismic (8-125 Hz) data. By loading the complimentary data sets together, the site survey engineer or geophysicist will be able to make a more complete and accurate interpretation of the shallow subaqueous geologic section.

Sparker sources and the more modern chirp sources have become popular in the last ten years because of their ease of use and low cost (Duchesne, et. al, 2007). Site surveys can include multi-beam or side-scan sonar and magnetometer surveys as well. In the past, these data were interpreted in analog form to provide engineers the information they needed (Fish & Carr, 1990). Small volume gas-injected (GI) gun seismic surveys have also been recently used.

Although computers have tremendously improved the ability of the site survey engineer/geophysicist to interpret these data types in a digital display over the last 20 years, very rarely have these data been loaded into and integrated with modern 3D seismic data. By integrating these two unique datasets (high frequency: 22.5 KHz sparker and normal frequency: 8-125Hz 3D seismic data) into a 3D display system, one can realize a more complete interpretation of the shallow geology.

Deeply rooted shallow faults can pose a significant risk. Shallow faults interpreted in sparker data for example, often become unresolvable 60 m beneath the water bottom. If their “root” fault is not detected, the interpretation can suffer as the full extent of the faulting will not be realized. Integration enables one to tie the features observed in the shallow portions of the normal frequency 3D seismic data together with the shallow high frequency features seen in the sparker data.

Purpose

The seismic industry continues to develop innovative software tools to improve the usefulness of 2-D and 3D seismic data generally collected in the frequency range of 8-125 Hz. While these data are excellent for deep geological investigations, the low frequency data does not always provide the best resolution at the ocean bottom. With the recent concern for geological hazards in deep water environments, some software companies have been adapting their software to have the ability to process and display high frequency sparker seismic data. The processing software in this study is utilized to improve the S/N ratio of the mini-sparker data and the 3D visualizer and 2D seismic viewer are used to display those results. Public domain mini-sparker data, acquired in 2008 (USGS, 2008) off the California coast at Port Hueneme, California, were obtained from the USGS. The purpose of this paper is to present the results of reprocessing those data sets.

Geologic Setting

These data span the Hueneme Submarine Canyon through which the sediments from the lower Santa Clara River flow into the Santa Monica Basin. The data have been acquired to determine the tsunamigenic potential of the sediments at the mouth of the Hueneme Canyon because of the high relief features present in the seafloor. The Hueneme Canyon has near-vertical outcrops that are composed of young sedimentary sequences. This indicates that massive erosion occurred during the latest Holocene. Because the canyon’s side-walls are over-steepened and contain unconsolidated deposits that were rapidly accumulated, the potential to cause an earthquake-induced tsunami is considered to be rather high. As the canyon is near the highly populated Los Angeles metropolitan area, the risk due to local faulting needed to be fully assessed (Normark, et. al., 2007). This is the primary reason these data were acquired.

We reprocessed the data to better delineate on-lap and off-lap sequences and recent mass flows. We wish to show how these data can be re-processed to better delineate the geologic features present in the canyon area. It clearly is not the purpose of this paper to make any assessment of the tsunamigenic potential of the Hueneme Submarine Canyon.

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Data Acquisition and Initial Processing

The USGS acquired these data using a mini-sparker with a 500 joule high voltage electrical discharge that creates a seismic source with more power and lower frequency than a typical chirp system (21 KHz). Depending on the water depth, the source was fired at 1 to 4 times per second. At the survey speed of around 4 knots, data traces were created every 2 to ½ meters along the ship-track. These data were recorded every 62 µsec or 16 KHz using a 15 m long hydrophone streamer. The data we processed had variable record lengths ranging from 290 to 990 ms, depending on water depth. The sparker source was towed at roughly 2.5 meters beneath the water surface. This caused considerable bubble effects which translate into seismic noise which were muted out in our reprocessing sequence.

Differential GPS fixes were recorded in the SEG-Y trace headers in arc seconds. The data were digitally recorded in standard SEG-Y 32 point format using a Triton SBL system that merged the GPS and seismic data together. For this study, the data are positioned using relative locations only.

The data were collected either parallel or perpendicular to the coastline on a roughly 1.2 Km grid. The line locations acquired by the USGS are shown in Figure 1 in red and the lines reprocessed for this study are shown in Figure 2.

Data Enhancement

Fundamental data processing was performed on the mini-sparker data in order to achieve its inherent data resolution of about +/- 0.5 to 2 m. This need is apparent when one views the data before and after the reprocessing (Figure 3). The USGS typically processes the data using a 160-1200 Hz bandpass filter. The noise trains seen initially make the original data almost impossible to utilize (Figure 4).

The simple processing workflow we used to improve the S/N ratio is as follows:

1. DSIN - Data load
2. DBMUTE – Simple mute of the first arrivals of the water bottom.
3. FILTER – Band pass filter suppressing high bias seen as vertical line noise in the record. We used a tapered 32-64-1824-1856 Hz filter.

Figure 1. Study Location showing the Mini Sparker lines in red and enclosed within the green lines.

Figure 2. Actual Lines Tested.

Figure 3. The left panel shows the data before processing. Right panel shows the improvement in the S/N ratio from reprocessing. Time increment on both panels is 0.01 sec.
4. AGC – Automatic gain control with a varying 200-440 ms window, depending on data length.
5. RUNMIX – 1-7-1 weighted boxcar filter
6. FXDECON – FX domain Spectral Deconvolution using a 128 ms lag gap operator over the 32-1856 Hz range. This removed some ringing effects.
7. FKPOWER – FK sample power 1.1 over 200 ms to enhance the S/N ratio.
8. Final DBMUTE – Reinstate initial mute
9. DSOUT – Output the final data set.

Following application of this processing flow the inherent noise and chatter that typically is recorded with mini-sparker data has been considerably reduced (Figure 3). The time scale shown indicates a resolution of 1/5 of 0.01 sec TWT or +/- 0.002 sec TWT. At a velocity of 2000m/s, this equates to +/- 2m one-way distance, so we have satisfied the required resolution of +/- 2 m using this basic and rapid workflow. We can also conclude from the results seen in Figure 3 that these data have been acquired extremely well and will be useful in the hazard survey.

The noise train above the water bottom in Figure 3 is almost entirely due the sparker source’s bubble effect. This was removed by using a non-ramped mute at the water bottom. The data has a rich band of frequencies ranging between 32 - 1856 Hz. A de-spiking filter was also applied at 670 Hz to remove a prevalent noise train present in some of the lines.

Figure 4 shows that the re-processing successfully images geological layers and features well enough to clearly show several, otherwise hard to distinguish features. The rollover beds and the local gravity slump thrust fault toe are evident. Hence, as a result of reprocessing Line HC-12 using this workflow, a more useful display for the site engineers/geophysicists has been produced.

3D Visualization

The processed mini-sparker seismic lines were loaded into the 3D visualizer with a data sample rate of 62 µsec, rather than the typical 2 or 4 msec for 2D and 3D seismic data (Figure 6). Lines HC-12 and HC-14 are shown where Line HC-14 intersects Line HC-12 in the canyon where the previous slump features off the shelf can be observed on Line HC-12 in Figures 4 and 5. These two lines intersect within +/- .5 msec. These ties demonstrate how well the data were acquired.

A zoom on the intersection between line HC-12 and HC-14 reveals an old slump surface (Figure 7). This surface intersects with the water bottom multiple but is still interpretable.

This slump and toe thrust feature can be further observed by looking on the other side of line HC-14 (Figure 8). While the software allows for opacity, it becomes too confusing on a flat 2D picture so opacity is not used here. The slump toe is visible again on line HC-14 and a leading toe can be seen shooting up the opposite side of the canyon on line HC-12 over what appears to be a thrust surface.

Conclusions and Future Work

After performing a basic processing flow on these data and loading them into a 3D visualizer, we were able to easily view the 62 µsec data in a standard 3D seismic data package designed for typical 2-4 msec data. The added advantage of this is that both types of data sets
can be viewed together in 3D and hazard surveys can be effectively interpreted utilizing both types of seismic data. While multiples observed in these data do interfere in the interpretation, as long as the interpreter follows them closely he/she can see the primary signal brought out by the processing. It is our intent to further design filtering and/or muting methods that will enable us to remove these types of noise trains, which will further improve the data utility. One major problem in doing this with Chirp or mini-sparker data is that gathers with multiple offsets are not acquired; data are simply acquired one trace per record. Because of this, surface consistent methodology cannot be applied. Hence, the removal of multiples in these data will require creative processes to selectively remove them.

We demonstrated that 62 μsec data can be quickly and easily re-processed and imaged more clearly to define subtle and shallow geological features which can be hazardous to the placement of drilling rigs. These data can also be loaded into 3D Visualization tools with modern seismic reflection 1-2 msec data and co-rendered, thus revealing the full potential of this data integration.

References


