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Repeatability of 3-D ocean bottom cable seismic surveys

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Abstract

The repeatability of seismic data acquisition and processing has become an important question in determining the role of conventional land, marine, and transition zone systems in seismic monitoring of reservoirs. In this paper we examine a case study involving two repeated 3-D seismic surveys acquired using an ocean bottom cable (OBC) system. Although not originally acquired as part of a monitoring project, the survey design and preplanned source and receiver patterns were identical over a significant area. We found, not surprisingly, that since the two had some differences in acquisition and processing, "off-the-shelf" final migrated data volumes showed significant differences. However, by careful reprocessing of the prestack data with a sequence designed to maximize repeatability of the signal, the differences were reduced dramatically. The level of repeatability required for a given monitoring project depends on the specifics of the reservoir and the monitoring goals; however, in this case, repeatability achieved between the two data volumes indicates that OBC data would likely be suitable for analysis of reservoir fluid movement.

INTRODUCTION

There has been a resurgence of interest lately in using repeated seismic surveys as a reservoir description and production monitoring tool. Although studies of repeated seismic surveys for mapping steam fronts go back more than 10 years, recent advances have extended time lapse or 4-D seismic to map gas-oil and oil-water contacts with significant economic benefit (Greaves and Fulp, 1987; Pullin et al., 1987; Dunlop et al., 1991; Johnstad et al., 1995). Recent studies, e.g., Watts, 1995, have made fortunate use of legacy 3-D data not originally acquired for a 4-D study and found that the varying quality of the different vintages of 3-D data was a factor limiting the resolution of their studies. As a result, the question arises how best to carry out the data acquisition and processing for a 4-D seismic program so that the data are repeatable to the extent that differences are attributable to movement of the reservoir fluids rather than acquisition and processing.

In this paper we present a case study of the repeatability of the OBC system based on two co-located 3-D surveys acquired and processed independently. First we compare off-the-shelf 3-D migrated data volumes. Then, beginning with migration, we back up in the processing sequence until we arrive at analogous flows for the two surveys. We found that in this case it was essential to reprocess the data from the prestack stage to account for known differences to achieve the best results.

ACQUISITION

OBC systems utilize cables that are deployed on the ocean bottom with attached receivers; in this case, both hydrohone and geophone sensors were located at each station. The cables are attached to a dynamically positioned recordng unit while a shooting boat traverses the planned shot locations. OBC is an attractive alternative for repeat seismic surveys for several reasons. Receiver positions are fixed for a number of shots and can be located with accuracy; moreover, as the shooting vessel is unencumbered with recording equipment, it is highly maneuverable and can thus position the source locations independently from the receivers.

The two OBC surveys were carried out with a separation of four months. The survey area contained no known hydrocarbon production or other mechanism for changing the seismic response. The survey plan was identical for the two surveys, but for a variety of reasons, such as varying currents and wind, the receiver positions were not identical between the two surveys. One of the main advantages of the OBC method is the ability to handle changes in planned versus actual receiver positions with changes in shot positions to achieve uniform coverage. Even though we found slight differences in the source and receiver positions, the final fold, offset, and azimuth distributions were very similar. The same recording instruments were used for the two surveys with one significant difference: while one survey employed a 3 Hz instrument low cut filter, the other used an 8 Hz filter. As we shall see, dealing with such seemingly minor differences in the initial stages of processing is key to insuring repeatability.

OFF-THE-SHELF 4-D

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PRESTACK REPROCESSING

Two main factors were first considered in the prestack reprocessing: velocity and statics. Surprisingly, we found that stacking with the same velocities and static treatment yielded only incrementally improved results (not shown) which led us to review the entire processing sequence. We first applied a shaping filter to equalize the instrument responses and bandpass filtered the data. Next we computed offset-consistent amplitude factors: for each common-offset gather, single time-varying scale functions were derived to balance the traces prior to further processing. Afterwards, identical processing sequences were applied to the data through stack. A single matching filter was derived as in the previous examples. Figure 4 shows the resulting differences after RNA and amplitude balancing as described above. The differences are now small compared to the original data in Figure 1.

CONCLUSIONS

At first glance, the use of powerful processing steps such as RNA and matching filters may cause concern. However, RNA removes only noise that is spatially random and, as used here, is common practice. Matching filters can be a concern if allowed to vary significantly or if they are influenced by the reservoir zone. In any case, such measures are likely to be necessary in 4-D processing. In our studies, the effects of noise play a major role in observed differences. In particular, adaptive processes are influenced by noise and should be avoided until the noise has been addressed.

We have shown in this particular example that the OBC system produced data with a high degree of repeatability provided the data are processed from the prestack stage with repeatability as a goal. We also found it essential to account for known differences such as instrument responses and noise characteristics at the prestack stage. Perhaps the best argument that conventional seismic systems are useful for 4-D is the growing body of literature that indicates successful use of legacy data acquired with varying acquisition systems and designs.

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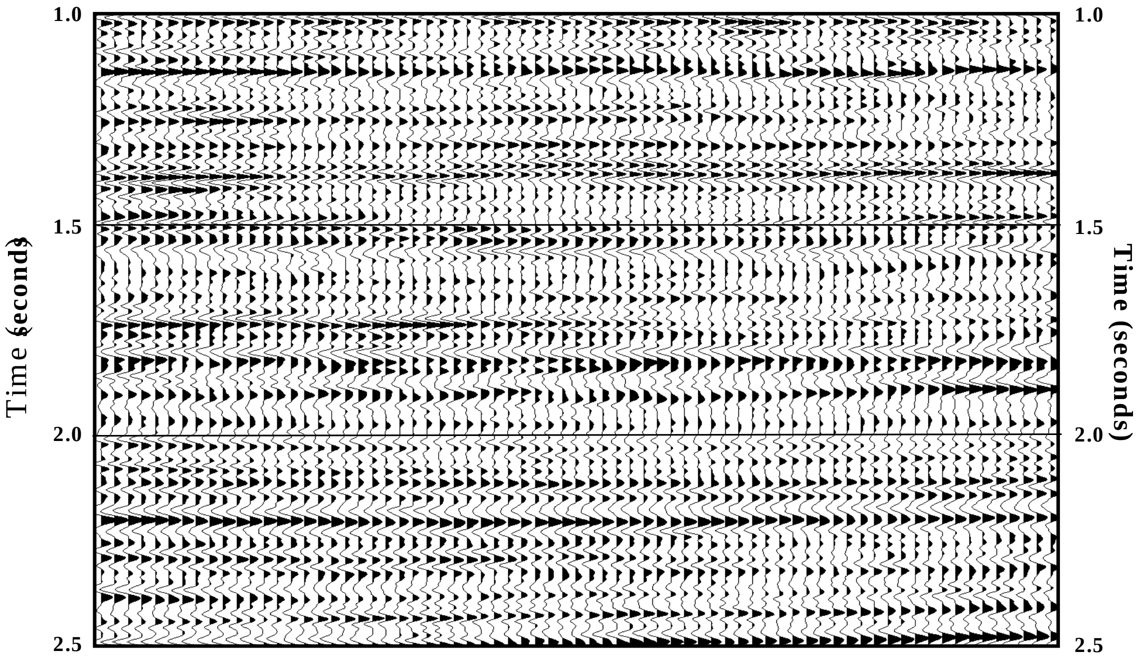

Figure 1. Survey “A” migration with RNA and time scale applied.

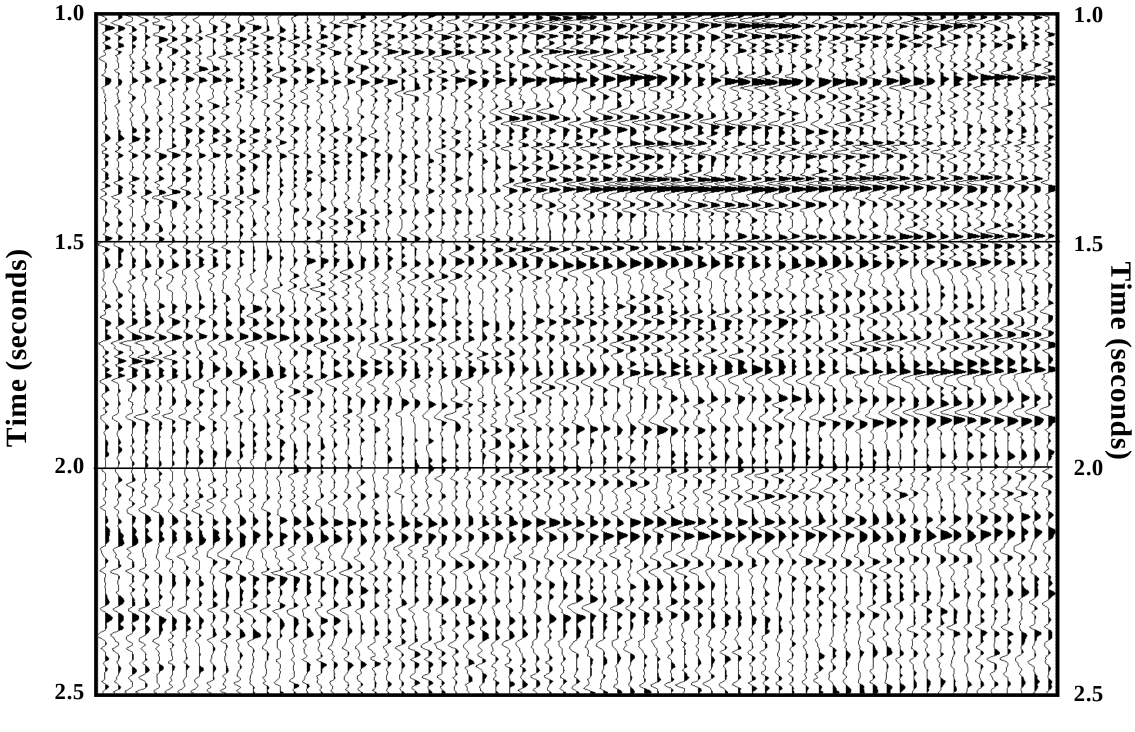

Figure 2. Survey “A” minus Survey “B” (migrated with RNA and time scale applied).

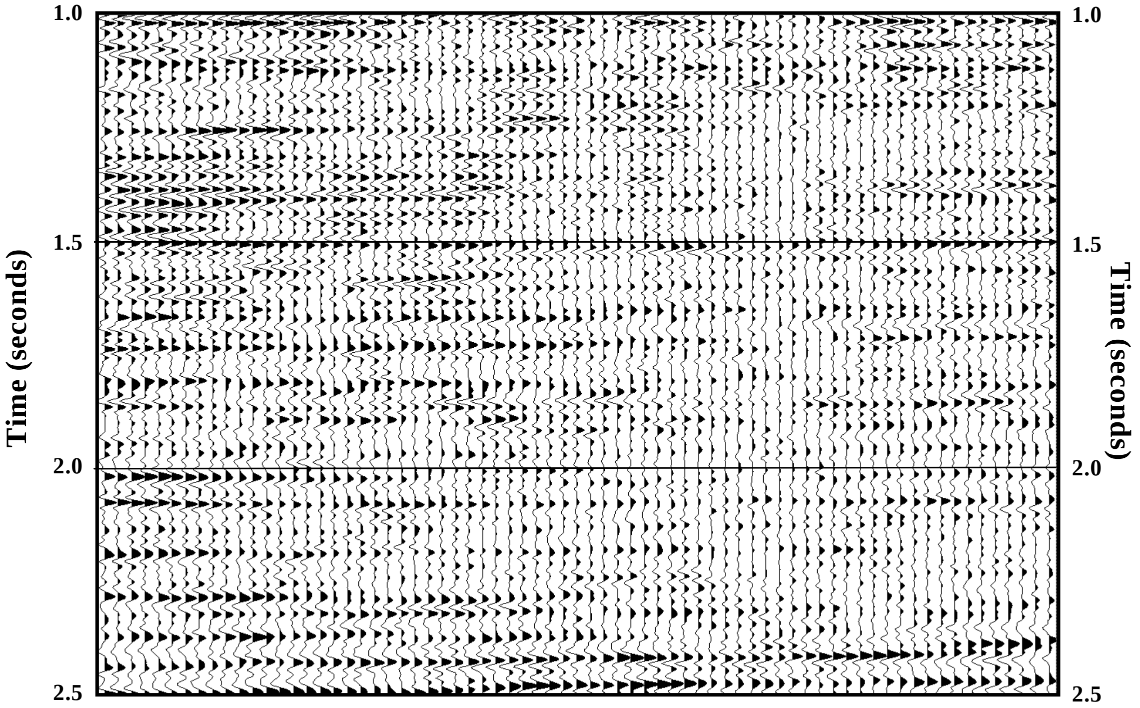

Figure 3. Survey “A” minus Survey “B” (migrated with RNA and time scale applied). Single trace shaping filter applied to Survey “B”.

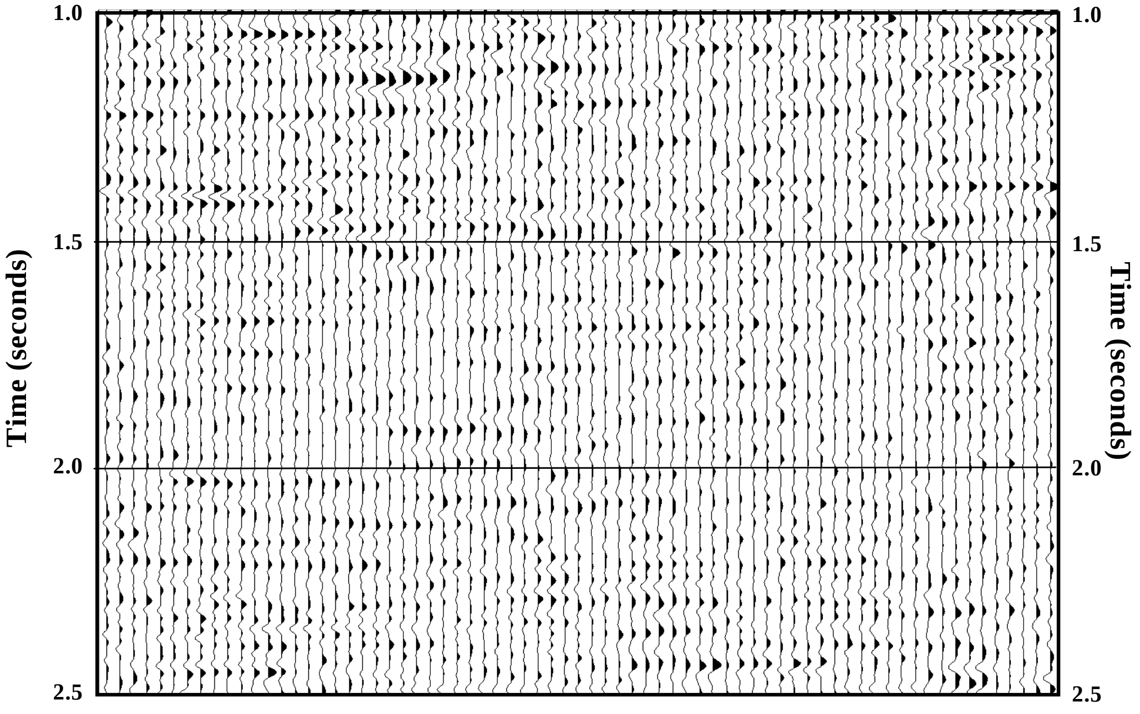

Figure 4. Survey “A” minus Survey “B” (stack of reprocessed data).