Considerations for Deepwater Seismic Imaging

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INTRODUCTION

Deepwater seismic imaging presents many challenges that are unique to deepwater environments, along with many familiar challenges that are emphasised by the presence of a long water column. In some cases, the depth of the water will make one or two of these challenges of paramount importance whereas, with a different water depth, the same challenges may be insignificant. It is important to have the tools to deal with all possible challenges to ensure that the image will not be compromised.

Some of the most significant problems include the time it takes seismic waves to travel through the water column, and how that traveltime may vary, as well as the strength of the waterbottom multiples. Also, in deepwater environments, it is common for the water depth to vary significantly and rapidly (e.g.: near a shelf edge) hence causing conventional time domain imaging to suffer. Further, for accurate imaging of deeper targets, it is commonly required to acquire longer offset recordings and hence the data is more susceptible to the effects of anisotropic wave propagation. All of these problems will be considered in more detail below.

WATER COLUMN STATICS

A deepwater 3D seismic survey can often take months to acquire. Within that time it is possible for water temperatures and salinities to change, especially when significant deep currents are possible. Even though the magnitude of the temperature and salinity changes may be considered small and may only lead to a water velocity variation of a few metres per second, the depth of the water column (potentially thousands of metres) can mean that these small changes lead to traveltime differences that will damage the seismic image. It is common to observe water column statics of up to six or ten milliseconds.

Estimating and removing water column statics is not a simple task. The data has to be carefully observed on a sail line by sail line basis while also taking into account acquisition time. When done correctly, this process leads to sail line dependent statics that remove the observable static “jitter”. It is imperative that this is removed before prestack migration, otherwise it will lead to migration artifacts.

WATER BOTTOM MULTIPLES

If the waterbottom is deep enough, we may be lucky to have the first-bounce of the waterbottom multiple appearing below the area of interest. In this case, multiple attenuation may be of little consequence, but care still needs to be taken to ensure that migration artifacts (“smiles”) caused by unattenuated multiples do no interfere with the interpretation in the area of interest.

If the water depth is such that the first waterbottom multiple falls directly in the zone of interest then the problem can be substantial. The first waterbottom bounce in a deep water environment can easily be more than 40 dB stronger than the underlying primaries. Very significant multiple attenuation is required otherwise interpretation of the primaries will be impossible. Generally, a cascaded sequence of multiple attenuative processes is applied to progressively attenuate more and more multiple energy. Typical processes applied include high-resolution Radon transforms, surface related multiple elimination (SRME), common offset volume prediction and subtraction (COWED) and residual multiple detection and suppression.

HYBRID KIRCHHOFF PRESTACK IMAGING

When exploring in deepwater environments, it is common for the water depth the vary significantly as well. Often exploration is conducted near the continental shelf edge, where there is naturally a sharp change in waterdepth, but there is also common shelf edge seafloor channel features that can cause extremely rapid waterdepth fluctuations. These waterdepth variations effectively lead to significant lateral velocity changes and cause conventional time domain prestack imaging to struggle to create a correct image.

Assuming that the velocity below the seafloor is relatively simple (in a lateral sense), conventional prestack time imaging can be extended to a “hybrid” technique. This technique handles the rapid changes in the waterbottom very accurately (like a prestack depth migration would), but treats the rest of the velocity just as a time migration would (that is, assumes lateral simplicity). Since the waterbottom undulations can cause the most significant distortion of the image, this “hybrid” approach can cause very dramatic improvements for relatively small effort. The application of the “hybrid” approach is not limited to seafloor undulations but can be applied to any undulating surface that is causing distortion of the prestack time migration image (e.g.: a top-of-salt surface).

LONGER OFFSET EFFECTS – ANISOTROPY

Longer offsets are regularly recorded in deep water environments. Reasons for this include multiple attenuation and achieving desired fold and angular coverage (for AVO analysis) at the target level. The combination of ray-bending at the deep waterbottom and longer offsets creates seismic raypaths traveling much more horizontally than normal. In the presence of anisotropy (eg; with a vertical axis of symmetry due to sedimentary layering) horizontally traveling seismic energy will travel faster than more vertically traveling energy. If this is not taken into account correctly, the resulting image is compromised in three ways;

1. inaccurate focusing of the events and hence inaccurate amplitudes
2. lateral positioning errors
3. depth prediction errors (seismic velocities are normally picked too fast if anisotropy is not taken into account)

For anisotropic prestack time migration, one extra parameter (in addition to the velocity) “eta” is required and can be found from observing far-offset moveout or by performing an “eta” scan. For anisotropic prestack depth migration, two extra parameters (in addition to the vertical velocity) “delta” and “epsilon” are required and it's preferable to have well velocities available for calibration. Correctly taking anisotropy into account can have a dramatic effect on image strength and resolution as well as the accurate positioning of fault plane reflectors and overall structural resolution. A further by-product are gathers that have actually been imaged flat (not flattened with arbitrary higher-order moveout) by the migration algorithm.

CONCLUSIONS

Processing of deepwater seismic data has a number of unique features. Some may actually make processing easier, for example, the absence of short period reverberations and the potential for the first waterbottom multiple to actually exist below the zone of interest. However, there are many other problems that add to the complexity. These include water variations that cause troublesome statics from line to line, very strong multiples when they do get in the way, image distortions due to undulating water depths and the increased likelihood of being affected by the anisotropic strata.

Today's state-of-the-art processing toolbox has a number of algorithms for addressing all of these issues, but care must be taken to correctly deal with each of these problems or some very poor images are possible.