Huygens' High Definition Pstm
Patented Technology From Tsunami Development

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Introduction

Interpreters of seismic datasets are always looking for greater resolution and higher frequencies. It often happens that they zoom into the data further than the dataset can accommodate. When they do this, they wind up looking at either a fragment of a seismic wavelet, or some very coarse, pixilated view of the geology. It seems interpreters want as much resolution as the dataset will allow.

We now have the ability to provide greater resolution, higher frequency images from the same input datasets. This will provide far more information to interpreters and geologists particularly in those areas of interest where productive wells may be drilled.

Using patented technology developed by N.S. Neidell & Associates we can increase the frequency content and the resolution of the migrated seismic dataset dramatically. Tsunami Development is the exclusive provider of commercial software based on this technology.

Holographic Imaging

What Dr. Neidell discovered is that there is far more information contained within the seismic dataset than we currently reveal in a standard migration. This information has been hidden from us because we have been imaging based on sampling theory, rather than creating a more holistic image of the subsurface geology. A corollary to Huygens' principal states that the information contained within a recorded seismic wavefield does not depend simply on the wavefield sampling and source properties, but on the information contained within the wavefield(4). The geologic features we are trying to image are not samples and frequencies, but real structures that have form and substance. As such we can approach the problem more like creating a hologram, rather than like migrating a set of traces and samples.

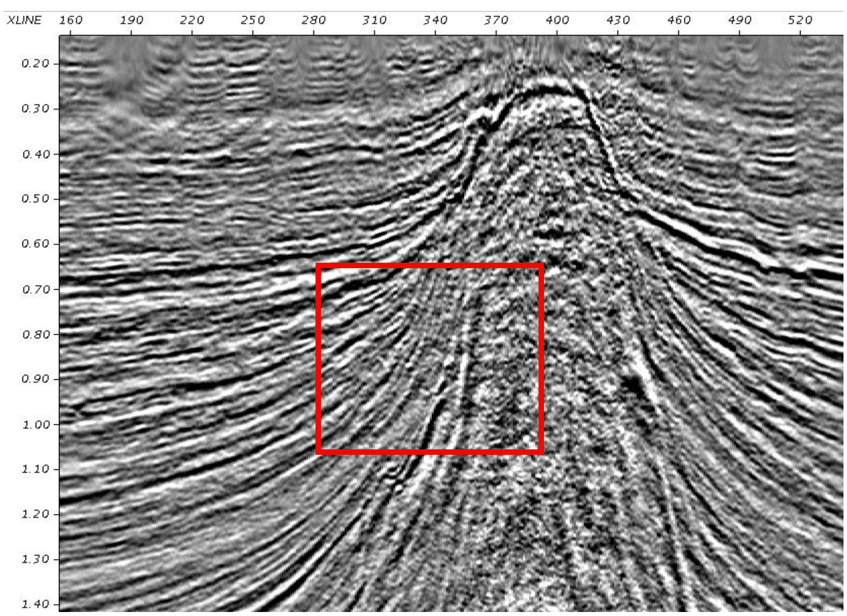
To explain this process we paraphrase Enders Robinson(5). Seismic migration transforms the input seismic dataset into the migrated seismic dataset. The migration starts with the recorded wavefield, that is the wavefield incident upon a measuring array placed upon the surface of the earth. This is the input seismic dataset. The migration algorithm reconstructs the wavefield (the subsurface geology) by using various approximations to the wave equation. The wavefield is then imaged to produce a migrated seismic dataset. It is important to distinguish between the wavefield reconstruction step, and the imaging step. The wavefield reconstruction step is the approximation of the subsurface geology, over an area of interest. The imaging step is the sampling of this reconstructed wavefield and the creation of the output seismic dataset.

We need to think of the reconstructed wavefield not as traces of seismic samples in computer memory, but as a hologram of a solid object (the subsurface geology), a continuous surface, described in computer memory by an approximation to the wave equation. In the imaging step we then sample this hologram at an increment fine enough to reveal the detail of the subsurface geology.

The accuracy of the wavefield reconstruction depends on the accuracy of the algorithm, and the signal to noise ratio of the data. The resolution and frequency content of the output seismic dataset depends on the accuracy of the wavefield reconstruction and the output sampling increment of the wavefield. The feasible resolution of the subsurface geology is not simply a function of the sampling of the input seismic dataset. So just like a hologram, the detail revealed in the image depends on the detail depicted in the object (the subsurface geology) and the sampling of the output image.

By making a series of modifications to the Tsunami Kirchhoff Pstm we can accurately reconstruct the wavefield, and therefore the subsurface geology, as a hologram. We can then image this hologram at a sampling increment necessary to reveal the detail within the reconstructed subsurface geology. The available detail depends on the physical structure, and the depositional nature of the geology. Assuming the input data has a good signal to noise ratio, the resolution and frequency content of the migrated seismic dataset will be far greater than if the data were imaged at the sampling increment of the input seismic dataset. . The necessary modifications to the Kirchhoff Pstm are proprietary and are based on the patented technology of N.S Neidell & Associates.

Example Results



In Figure 1 we have an image of a salt dome. The area of interest is the area described by the square box, which is the left side of the salt flank.

Figures 2 and 3 show a comparison of the zoomed in area of the salt flank displayed as seismic wavelets. It is obvious that Figure 3 has higher frequency content and more detail. The traditional image is output at a 4ms sample rate, and at a 110ft x 110ft spatial sampling. The High Definition image is output at a 1ms sample rate, and at a 27.5ft x 27.5ft spatial sampling. From the wiggle trace display it is a bit difficult to appreciate the differences we see.

Figure 1

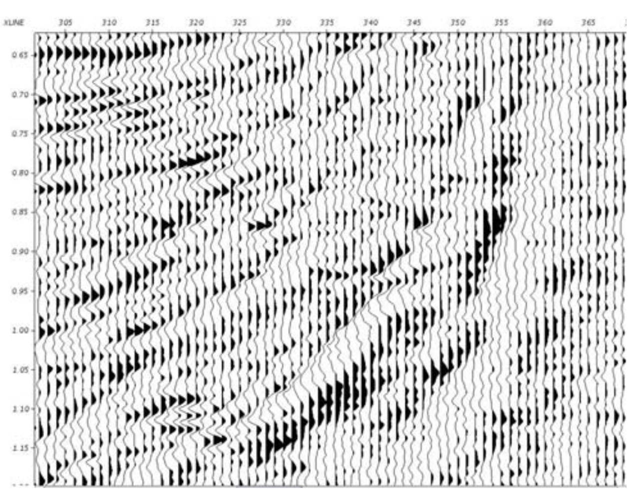


Figure 2

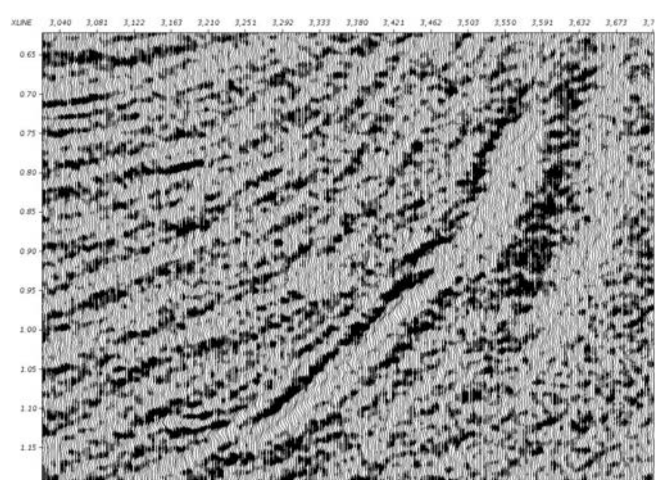


Figure 3

If we look at Figures 4 and 5, we see this same zoomed in area displayed as variable density display. In this comparison we see more clearly what is happening. The image in Figure 4 has been zoomed in to the point that we are seeing a very blurry and pixilated image. We see a blurry image of the salt flank and the intersecting sediments. The image in Figure 5 shows a much clearer, more complete image of the salt flank and the intersecting sediments. Figures 3 and 5 are displays from a much more informative dataset for the geologist and interpreter.

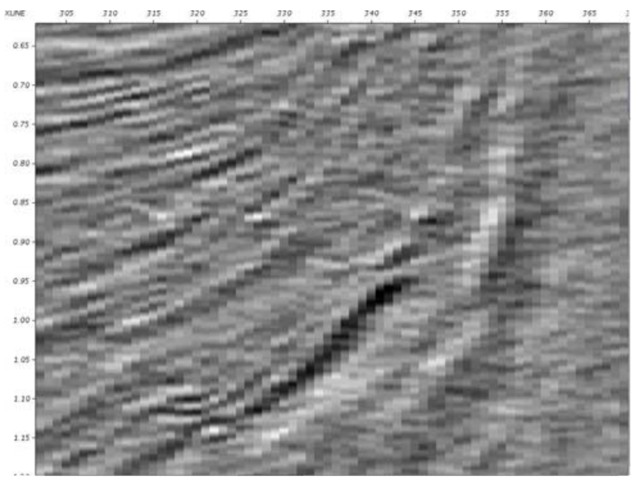


Figure 4

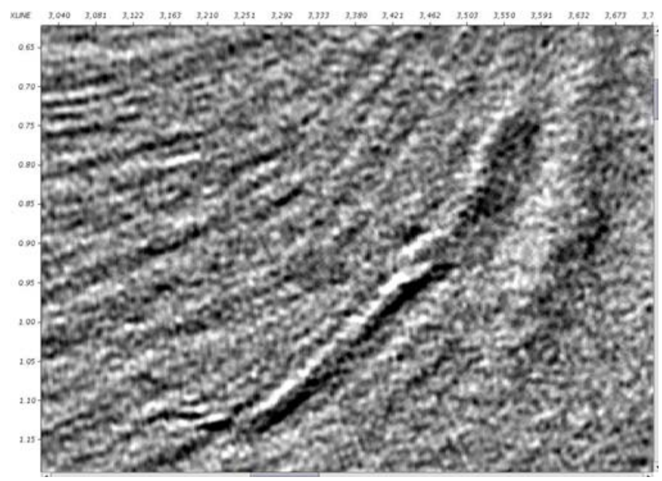


Figure 5

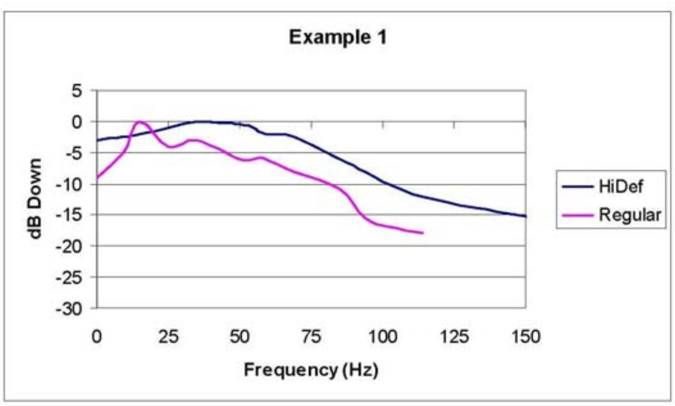
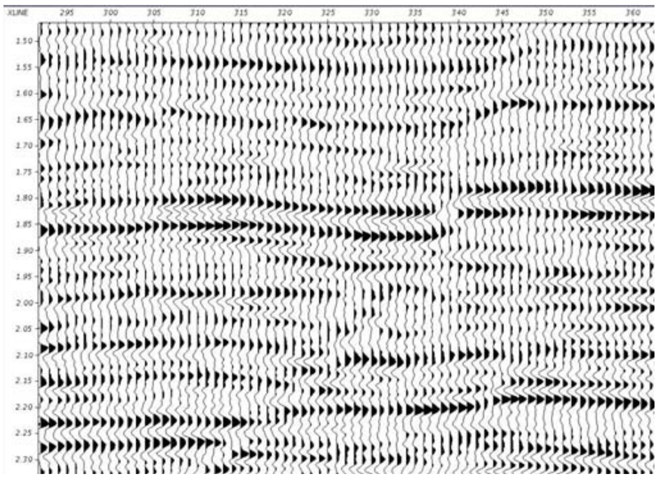


Figure 6

Figure 6 shows a comparison of the frequency spectrum of the salt dome results. The HiDef result has greater frequency content at both the high end and the low end. This confirms that there is much more information in the HiDef result. The frequency content of the HiDef image extends higher than in the standard image.

Figures 7 through 10 show another comparison. This example shows a result imaging a fault structure. Figure 7 is the standard result shown in wiggle trace, and Figure 8 is the HiDef result shown in wiggle trace. The standard result is shown at a 4ms sample rate with 110ft x 110ft spatial sampling, and the HiDef result is at 1ms sampling with 27.5 x 27.5 spatial sampling.



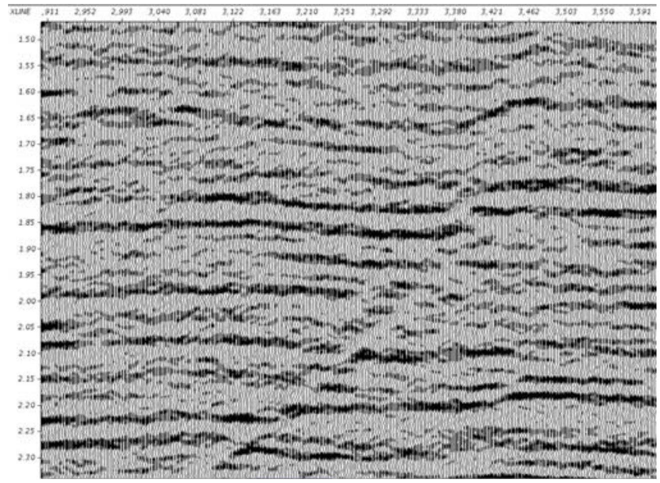
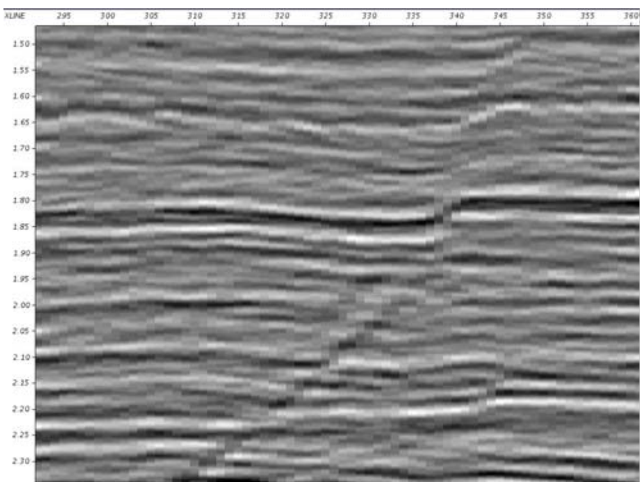


Figure 7 **Figure 8**

Figures 9 and 10 are variable density displays of the same area. As before, the image in Figure 9 shows a very blurry pixilated image, while the display in Figure 10 shows much more detail. Figure 11 shows the comparison of the frequency spectrums.



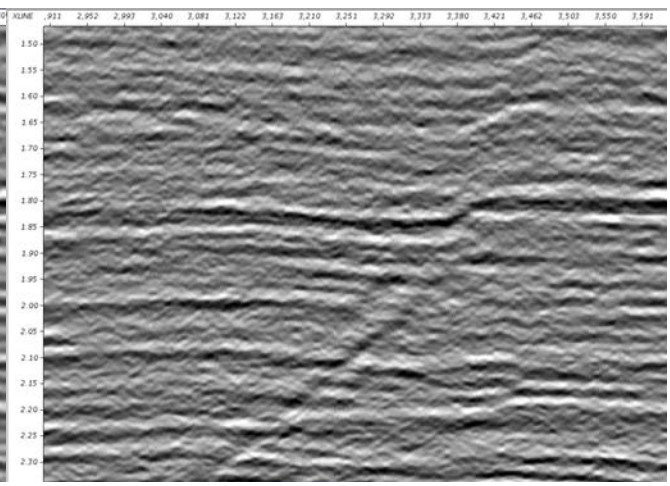


Figure 9 **Figure 10**

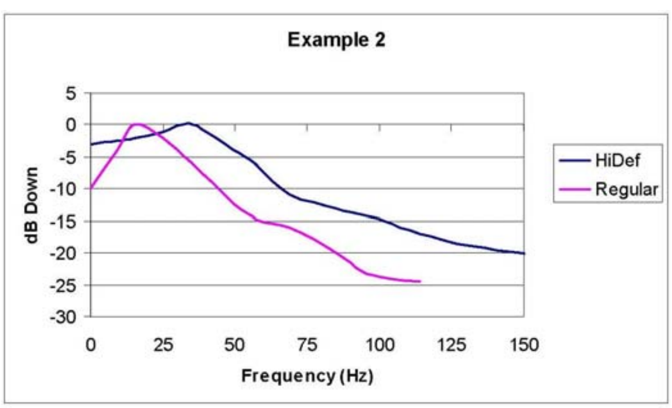


Figure 11

Resolution Limits and Computational Costs

The sampling increments in this article were chosen at a 4:1 ratio because these were sufficient to demonstrate the power of the technology. With a standard PDF viewer you can magnify the images to see the full resolution within the examples. The Tsunami HiDef Pstm gives the user complete control of the output sampling increments in the migrated data set. Finer sampling increments may reveal even greater detail and higher frequencies. The resolution limit depends on the geologic structure being imaged, the depositional nature of the geology, the accuracy of the algorithm and the signal to noise ratio of the input seismic dataset. To produce the best possible image, the Tsunami HiDef Pstm increases the accuracy of the algorithm as the sampling increment is decreased.

Because we are producing a migrated seismic data set sampled at a denser increment, there is a greater computational cost to producing the output seismic dataset. The incremental cost depends on the output sampling increment, but it can be high if very high-resolution images are desired. For this reason the Tsunami HiDef Pstm allows the user to output target areas, in both space and time. For example, the user could choose to output the High Definition image from two seconds to four seconds, and over an area of fifty inlines by fifty crosslines. This is completely under the control of the user.

The High Definition Pstm is available from Tsunami Development. Tsunami Development provides the necessary license for the use of the patent owned by N.S Neidell & Associates.

Future Developments

In the next months Tsunami Development will produce more products based on the High Definition technology including a High Definition PSDM.

References

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(2) *NEIDELL, NORMAN S., N. S. Neidell & Associates, Houston, Texas*. Perceptions in seismic imaging Part 2: Reflective and diffractive contributions to seismic imaging. *Pg. 1121. THE LEADING EDGE , AUGUST 1997*

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Reference articles may be found on the Tsunami Development website:
http://www.tsunamidevelopment.com/support_articles.php