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In Search for Optimal Seismic Data Acquisition through Illumination

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SUMMARY

In this paper a strategy is outlined to analyze illuminating beams for optimally locating target zones, and optimally acquiring all necessary seismic data. Illumination analysis of wave propagation through the earth s subsurface plays a very important role, in locating shadow zones and target prospects, to optimize the success of exploration wells. Using illuminating beams for optimal data acquisition design and data processing provides a unique integrated and cascaded tool for insight and interpretation of target prospects. The quality and accuracy of seismic images is being calculated from weighted energy distributions along areas that are dominantly contributing to potential oil and gas reservoirs. During illumination analysis, migration parameters are being determined to locate target images in shortest time. The a priori integration of seismic data acquisition design and optimal imaging of target zones minimizes the overall expenses for seismic data acquisition, data processing, and high costs of exploration wells.

Introduction

Illuminating beams, introduced by (Alá'i and Berkhout, 1996), are very important in understanding the wave propagation inside the earth's subsurface. In this abstract, 3 dimensional illuminating beams have been used to study and analyze the subsurface (Alai et al., 2007) and optimally locate/image target zones with optimally acquired seismic data. The illumination of the subsurface is a crucial analysis tool to accurately locate migrated images and study the overall detailed interpretation of the earth's subsurface (Alá'i, 1997). In the oil and gas industry, many complex technologies and algorithms are being developed for better imaging of subsurface structures in the earth's subsurface. However, often it appears that specific necessary data has not been recorded during the "data acquisition" phase and any available migration or imaging algorithm will never produce the accurate image at desired target areas. Therefore, apart from the technology improvements, it is important to focus on the necessary acquisition of seismic data. To avoid unnecessary processing of data, insight and understanding of the shadow zones in measured data is crucial. Initial subsurface velocity model estimates are necessary to determine subsurface illumination and raypaths of maximum energy and their analysis and integration with improved migrations produces local target images in shortest possible times.

Subsurface Illumination

Many onshore and offshore datasets recorded in North Africa suffer from good signal quality due to disturbances of the wave field caused by a complex near surface. Subsurface illumination helps to optimally acquire the necessary seismic data to image important structures in the subsurface, and therefore reduce the risks of dry exploration wells. In North Africa acquisition design is very important to illuminate target zones through the complex overburden.

The illumination analysis method uses illuminating beams to integrate data acquisition design followed by target-oriented imaging. In this way it will provide an accurate and controlled method for obtaining improved imaging of target structures in shortest possible time.

Examples

In this abstract, examples illustrate the importance of designing seismic data acquisition surveys, based on a given subsurface model, for optimal imaging and higher rate of success in finding potential reservoirs. The subsurface model used in this abstract is the salt model, issued from the joint SEG/EAGE 3-D Modeling Project (SEM) (Aminzadeh et al., 1995, 1996). This model has been chosen because its characteristics are well known, and it has already been used in many imaging studies. However, any subsurface model can be used to fine tune the resolution and accuracy of imaged target zones.

In the following example, an experiment is performed in which a point source is located at a depth of z=3820 m and illumination from that source within a salt model has been calculated (Thorbecke, 1997). Figure 1a shows an illuminating beam based on this point source in depth. From this illuminating energy migration parameters can be extracted, calculated and used to migrate the data and obtain an image at the target. Figure 1b shows a horizon at acquisition level. The differences in illumination energy at acquisition level are used to select which acquisition geometry will illuminate the target optimally (see the arrow in this figure) with a minimum acquisition effort.

Figure 2a shows the target point at depth z=3820m, and Figure 2b illustrates the response at the acquisition surface. This figure illustrates the illumination energy that has been recorded at the acquisition surface with various levels of amplitudes. From this result of illumination, three point sources were selected at the surface along the illuminated areas of Figure 2b with highest energy values. Figure 2c shows the location of the three point sources at the surface level z=0m. Three illuminating beams have been calculated separately from these 3 point sources at the surface, and all resulting beams of these 3 point sources have been added together. Figure 2d shows a depth slices at depth z=3820m from the added illuminating beams. From this figure, it can be noticed that specific aligned areas, including our chosen target point, are illuminated in the subsurface. Other areas, outside our chosen target area, are shadow zones for the optimally chosen source combinations at the surface.

Another experiment is performed to better understand the illumination areas through the salt model. Figure 3a illustrates the illuminating beam superimposed on a subset of the salt model (vertical section along the lateral y-direction) and Figure 3b shows the illuminating beam on a vertical section along the lateral x-direction. Figure 3c shows the depth slice at depth z=3820m in which the location of the point source can be observed. This example shows clearly that for that particular point source, some specific areas at the surface will be illuminated and carry energy to the points of interest (other areas are considered shadow zones). Acquisition in the shadow zones does not capture energy from the subsurface point of interest.

These examples show the importance of data acquisition design for optimally illuminating and imaging target structures (target-based data acquisition). On the other hand, illuminating beams can assist in optimizing target-oriented migration (acquisition-based imaging). This will avoid unnecessary processing of data.

In the last example, one sail line has been selected over the subset salt model, and illuminating beams have been calculated for source distances of 400m along the sail line x=3000m. Figure 4 shows the addition of illuminating beams for a varying number of shots along a sail line in the y-direction at x=3000m. Note the shadow zones and changes in energy in the various displays. Strong wave conversions may occur at the interfaces of sediments and adjacent salt bodies. Figure 4b shows the result for slices along the y-direction. Figure 4c shows the depth slices of model illumination, with a source distance of 100m at depth level z=2780m. The display shows the illumination of the propagation of P-waves through the salt. Note the "shadow zones" and areas of poor illuminations.

Concluding remarks

Subsurface illumination studies are used to identify shadow zones in the data and facilitate the understanding of the limits in imaging. Subsurface illumination also indicates an optimal acquisition design given a specific area of interest. In this abstract it has been illustrated that based on a model, optimal seismic data can be acquired. On the other hand, with a given data acquisition, optimal migrations can be performed.

References

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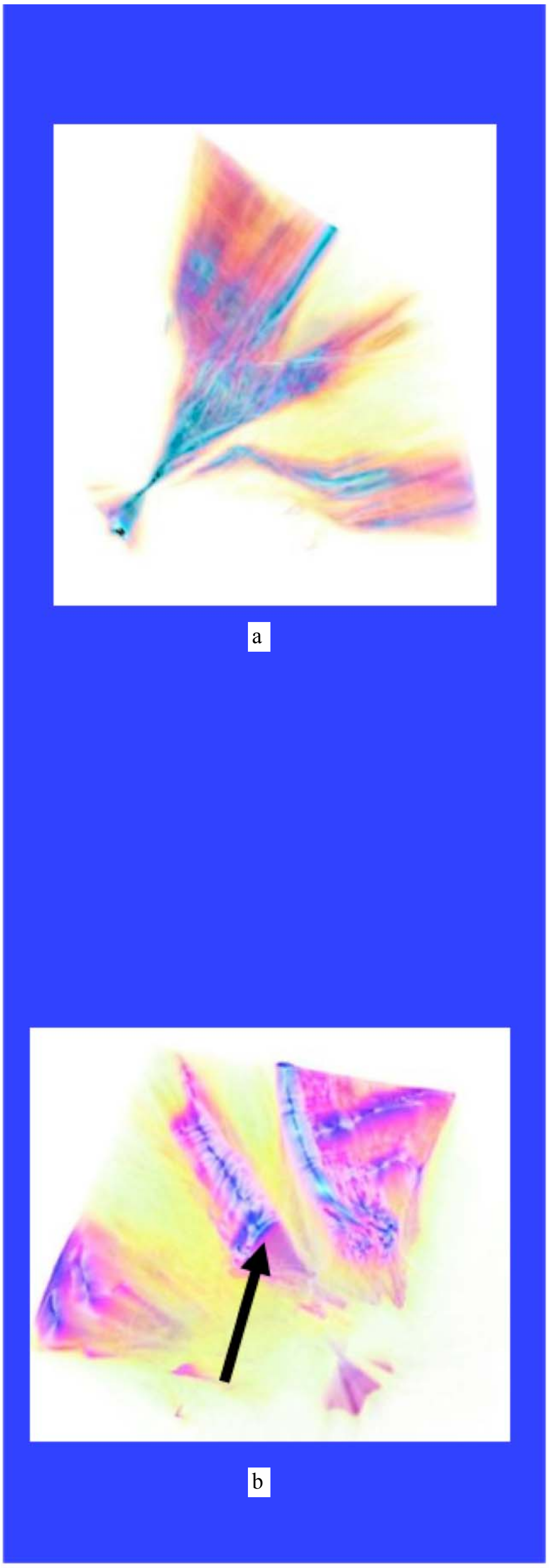


Figure 1: a) A 3D illuminating beam based on a point source located at a depth of z=3820m. b) Horizon at target level in which the target has been imaged optimally (indicated with an arrow). It should be noticed that the image has been obtained with minimum acquisition effort.

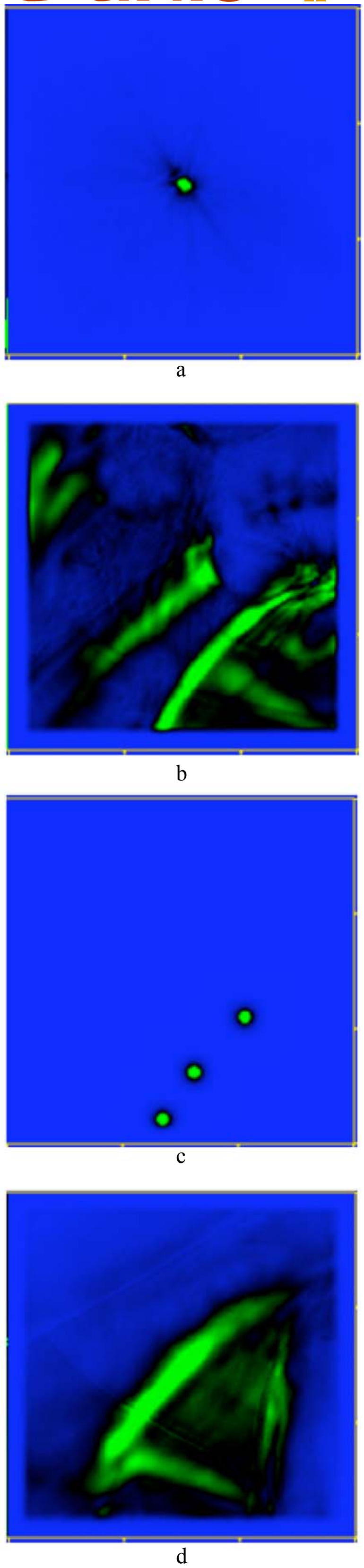
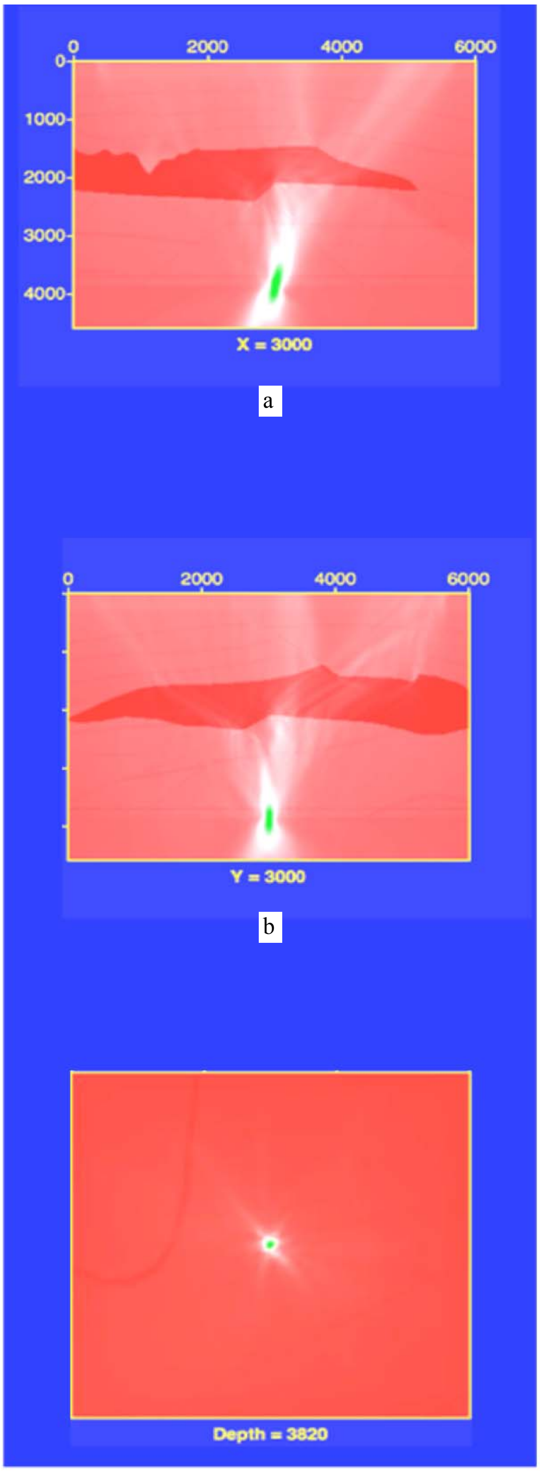


Figure 2: a) Point source at *depth* z=3820m, b) the determined energy at acquisition surface z=0m, c) three selected point sources at *surface* z=0m, and d) energy at depth slice z=3820m. Note the extended energy around the original target point at this depth.



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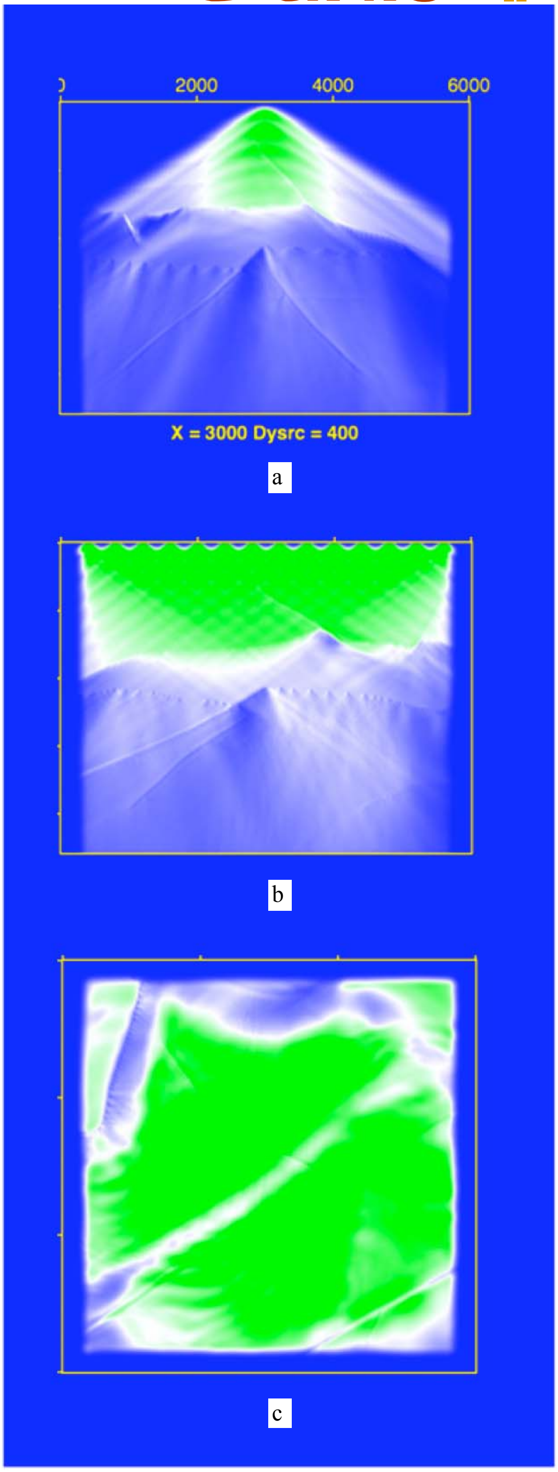

Figure 3: Illuminating beams superimposed on model, a) vertical section along y-direction, b) vertical section along x-direction and c) depth slice showing point source at depth z=3820m.

Figure 4: The illumination of a sail line in the y-direction at x=3000m has been simulated. The source distance is 400m: a) shows slice along the x-direction where P-waves have traveled through the salt body. b) illustrates slices along the y-direction. In c) depth slice of the model illumination at depth z=2780m is shown. Note the “shadow zones” and areas of poor illumination because of the complexity of the SEG/EAGE salt model.