Accurate imaging through integration of subsurface illumination and optimal data acquisition

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Summary

In this abstract some examples will illustrate the importance of analyzing illuminating beams for accurate imaging and locating important target zones in the subsurface. The analysis of illuminating beams through subsurface models provides insight to optimally acquire all necessary seismic data with the objective to image more accurately the subsurface structures. By studying illuminating beams through the earth's subsurface models, it is possible to locate shadow zones in the subsurface to verify why certain imaging algorithms would fail in imaging specific areas. On the other hand, illumination analysis of wave propagation through the earth's subsurface plays a very important role, in more accurate imaging and thus locating important target prospects and optimizing the success of exploration wells.

Introduction

Illuminating beams provide a unique, integrated and cascaded tool for additional insight and interpretation of target prospects, optimal data acquisition design and seismic data processing. For ultimate success of exploration wells, the quality and accuracy of seismic images is crucial and this is being calculated from weighted energy distributions along areas that are dominantly contributing to potential oil and gas reservoirs. As part of the 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. The examples shown in this abstract, illustrate the major contribution of illumination in understanding and interpretation of seismic data imaging.

Subsurface Illumination

Subsurface illumination helps to optimally acquire the necessary seismic data to image important structures in the subsurface, and therefore reduces the risks of dry exploration wells. Illuminating beams visualized through initial velocity subsurface models, introduced by (Alá'i and Berkhout, 1996), are very important in understanding the wave propagation inside the earth's subsurface. 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 following, some illustrations will outline the appearance of illuminating beams. In Figure 1a, a 2-D slice from a layered model has been selected and with a series of snapshots, the propagation of waves from a point source is shown. Because the subsurface structures above the point source are not very complex, the *shape* of the wave front in the various snapshots does not shows major changes. Figure 1b shows the illuminating beam for the subsurface model and source point in depth. As can be observed, a lot of energy within a lateral range is arriving at the surface.

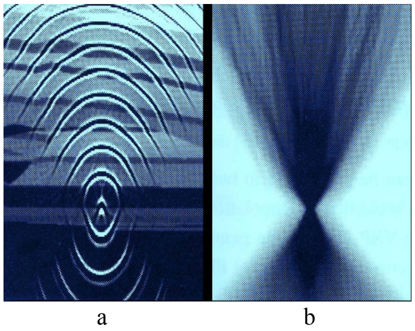


Figure 1: a) Series of snapshots of propagating waves from a point source and b) illuminating beam.

In the situation that the subsurface model is more complex e.g. the SEG/EAGE salt model (Aminzadeh et al., 1995, 1996), the following illustration will show the effect of the salt body to the illuminating beam and its appearance and complexity. Figure 2 shows an illuminating beam from a point source in depth (see arrow for location of the point source).

Figure 2: Illuminating beam for a point source in depth.

From this figure, it can be clearly observed that the amount of energy arriving at the surface is focused to two distinct lateral locations at the surface.

In this example, a point source was chosen in the subsurface and the illuminating beam was calculated for the waves propagating from the depth to the surface. This example was chosen to provide insight to the importance of data acquisition for subsalt imaging : e.g. if point sources would have been selected at the surface (including the two specific locations at the surface of Figure 2), then those point sources would optimally contribute to the imaging of the subsurface point (shown by arrow in Figure 2); this is the reciprocal situation of exchanging sources and receivers.

In the previous example, a point source was chosen in depth, and an illuminating beam was calculated, and the result was observed at the acquisition surface. This directly outlines 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.
To achieve higher success rates in finding potential reservoirs, many complex technologies and algorithms are being developed in the oil and gas industry and optimized for better imaging of subsurface structures in the earth's subsurface. However, often it appears that specific necessary data never was recorded during the "data acquisition" phase and no available migration or imaging algorithm will produce the accurate image at desired target areas. The acquisition of seismic data must be designed in such a way that propagating wave fields illuminate specific target zones beneath the complex overburden. Initial subsurface velocity model estimates are necessary to determine subsurface illumination and ray paths of maximum energy and their analysis and integration with improved migrations produces local target images in shortest possible times.

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.

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 the remaining part of this abstract, 3 dimensional illuminating beams have been used to study and analyze the subsurface (Alai et al., 2007) and accurately image and locate target zones with optimally acquired seismic data.
These 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 SEG/EAGE salt model, (Aminzadeh et al., 1995, 1996) has been used in these examples. 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.

Figure 3 shows some intermediate results of vertical cross sections of illuminating beam analysis with sources at the surface. Note that the model has been integrated with the illuminating beams for optimal insight and interpretation. In the following example, a point source has been selected deep in the model and illumination from that source within a salt model has been calculated (Thorbecke, 1997). Figure 4 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 5 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.

Thus far, some examples have been shown for single point sources. In the last example, one sail line has been selected over the subset salt model, and illuminating beams have been calculated for a series of sources along a sail line. Figure 6a shows the addition of illuminating beams for a number of shots along a sail line. 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 6b shows the result for slices along the y-direction. Figure 6c shows the depth slices of model illumination at the target depth level. The display shows the illumination of the propagation of P-waves through the salt. Note the "shadow zones" and areas of poor illuminations.

Conclusions

Illuminating beams are very important in understanding the wave propagation inside the earth's subsurface. 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. The integration of subsurface illumination and optimal data acquisition provides accurate imaging and increases the success rate of oil and gas exploration.

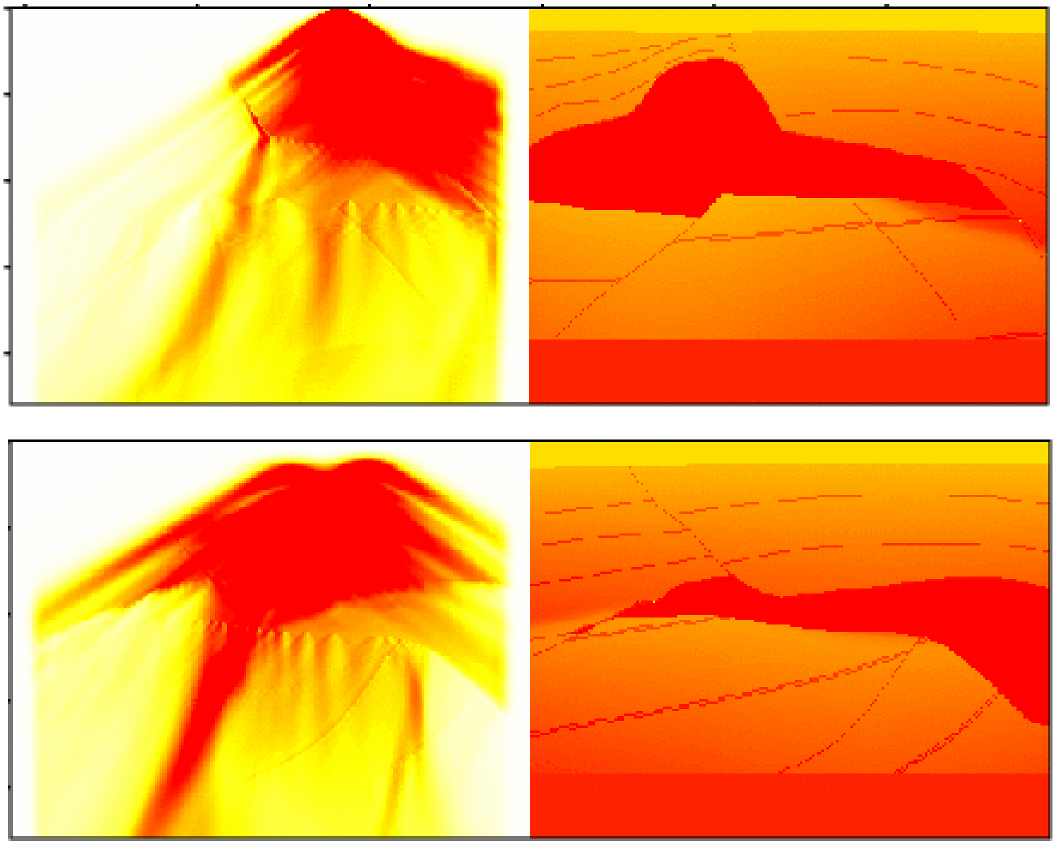


Figure 3: Intermediate results of vertical cross sections of illuminating beam analysis. Note the integration with the subsurface model for better interpretation.

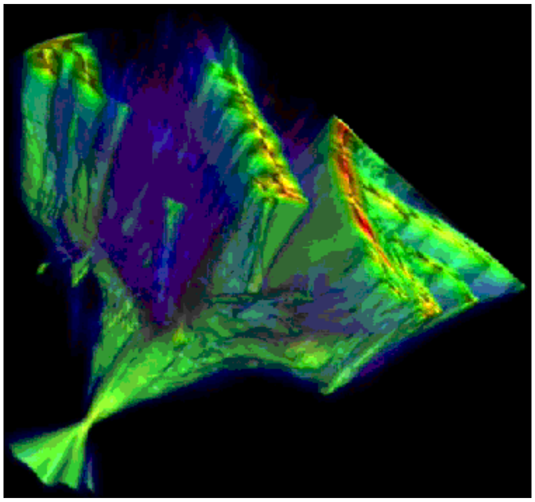


Figure 4: An illuminating beam based on a point source in depth.

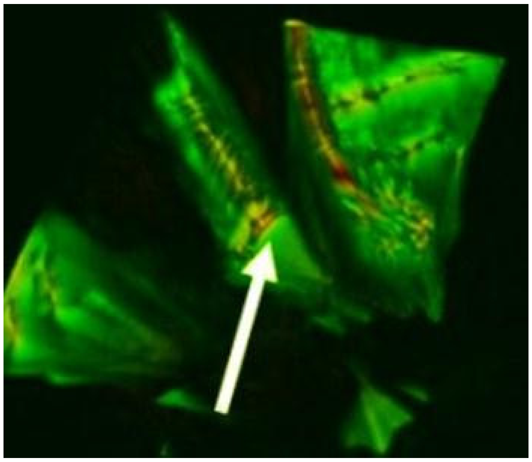
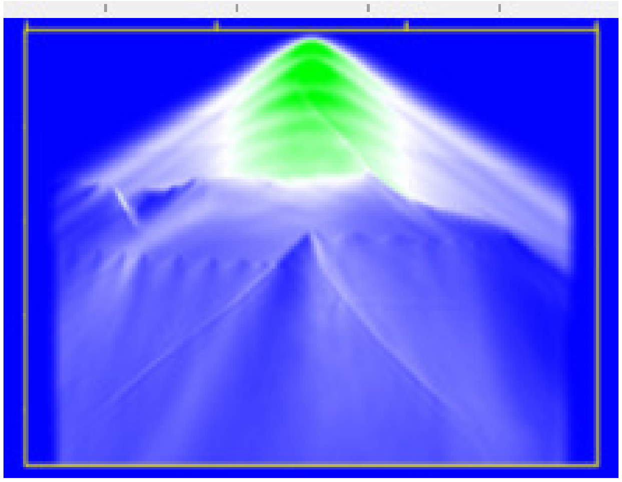
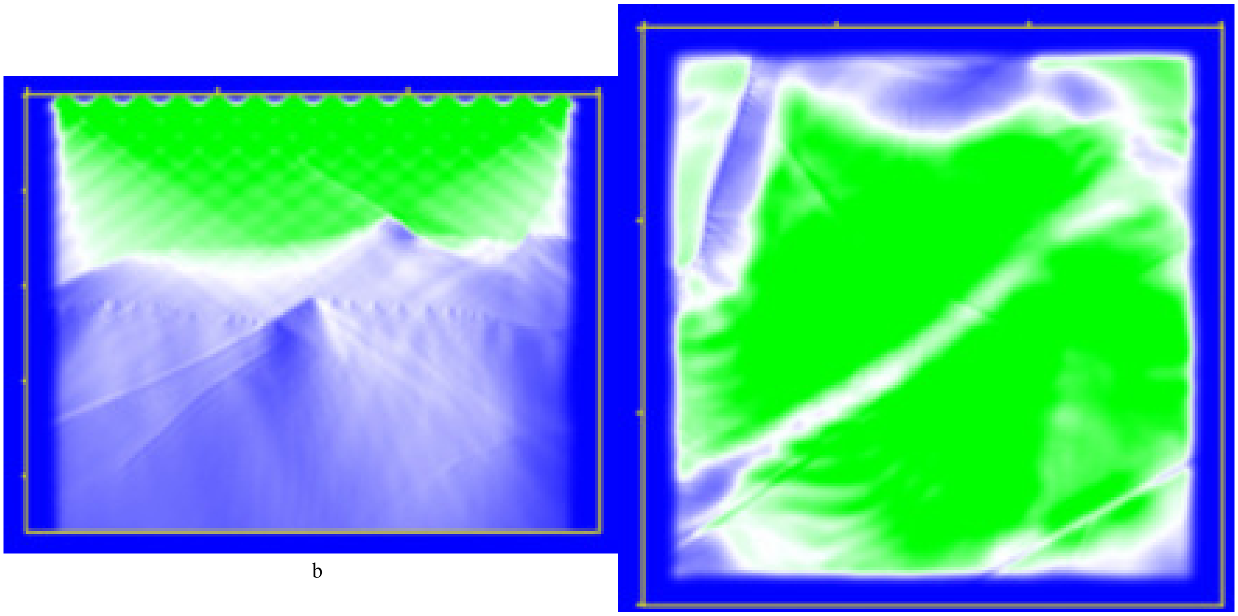


Figure 5: Horizon at acquisition level.



a

Figure 6: The illumination of a sail line (series of sources) has been simulated. a) Shows a slice along the x-direction where P-waves have traveled through the salt body.



b

c

Figure 6: b) Illustrates slices along the y-direction. c) Depth slice of the model illumination at the target depth level. Note the "shadow zones" and areas of poor illumination because of the complexity of the SEG/EAGE salt model.

EDITED REFERENCES

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