

# Seismic Imaging of Converted Waves in the Presence of Significant Overburden: A Modelling Study

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## Summary

Overburden layers continue to be a problem for recording and analyzing information in seismic surveys. This study aims to examine the effects of overburden layers on seismic wave propagation and imaging. In the investigation, we look at the effect of low velocity, low density overburden on seismic imaging. To investigate this problem, a finite difference elastic wave modelling study was conducted to evaluate the effects of overburden layer when using 3-component surface or borehole receivers. The study compares the responses from a lenticular inclusion in a 2D background model with and without an overburden layer. The relatively slow P-wave and S-wave velocity of the overburden material impacts the travel time and the shape of the wave. As expected with borehole receivers, only the first few traces from shallow receivers are corrupted by highly dispersed surface waves. Deeper receivers from the borehole acquisition (Vertical Seismic Profiling-VSP) show clearer reflections from the sulfide lens than similar records from the surface receiver spread. The location of the shot also affects the seismic response depending on whether it originates inside the overburden or below.

## Introduction

The presence of an overburden layer can cause amplitude, frequency and phase fluctuations in seismic waves. For a seismic survey this can be a severe impediment to adequately resolve target structures. In a sedimentary basin, for example, inadequate corrections for the overburden effects results in poor control in the lateral scale lengths of sedimentary layers. In order to address the overburden problem, there is need to understand its impact on recorded seismic to identify potential methods for mitigation, such as suitable acquisition geometry or wave component analysis. Interfaces between overburden layers and bed rock are characterized by a sharp impedance contrast with low velocities atop higher velocities (clay overburden) or high over low velocities (Basalt overburden).

The first objective of this study is to analyze the effects of measuring seismic anomalies in the presence of a clay-like overburden layer at the surface. Additionally, the study aims to explore the use of both surface level receiver arrays and vertical seismic profiling arrays for seismic imaging in such an environment. Lastly, the possible applications of converted wave analysis are considered.

## Method

We used a 2D/3D finite difference viscoelastic code (Bohlen, 2002) to compute the seismic wave response from a 2D model consisting of a dipping sphalerite lens as target (Salisbury et al, 2003). Figure 1 and Table 1 show the 2D model and the input parameters for P-wave, S-wave and density models as well as a view of the structure of the overburden layer. The geometry of the surface and borehole receiver spreads is shown in Figure 3a. The seismic responses from different combinations of models and acquisition geometries were then evaluated.

Table 1: Model Parameters

Medium	P-wave velocity(m/s)	S-wave velocity (m/s)	Density (kg/m <sup>3</sup> )
Ore	5120	2490	4280
Background	6140	3550	2730
Overburden	2000	600	2000

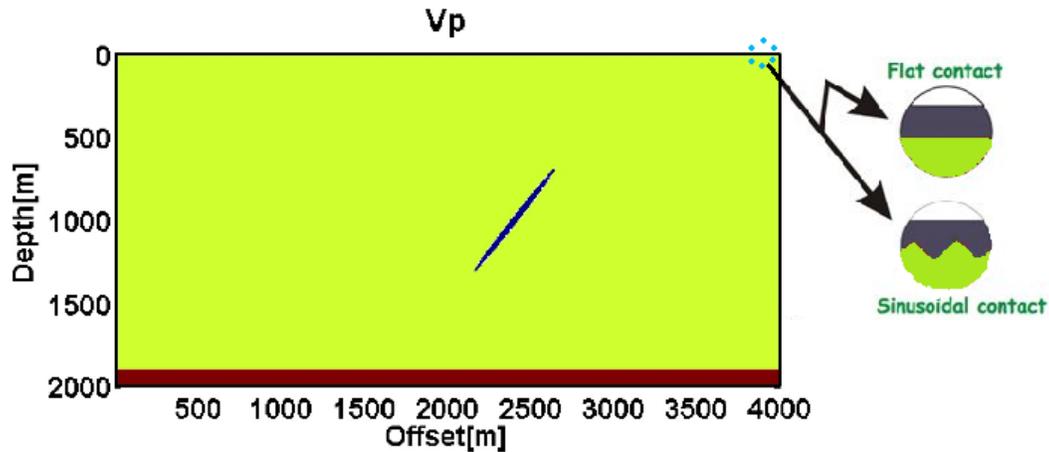


Figure 1: Petrophysical model characterizing the background host rock, the lens (high grade chalcopyrite), and the clay overburden. The layer at the base of the model is for quality control purposes. The high density difference between the host rock and the lens as well as between the overburden and the background rock causes the large impedance contrast. A zoom into the top clay layer highlights the thickness and roughness of the different clay-bedrock contacts used in this study.

## Examples

Synthetic results show that the overburden layer creates multiples strong enough to mask the diffractions from the dipping lens (Figures 2 and 3). Notice in Figure 2 that most of the diffractions and reflections from the orebody are in the dip direction.

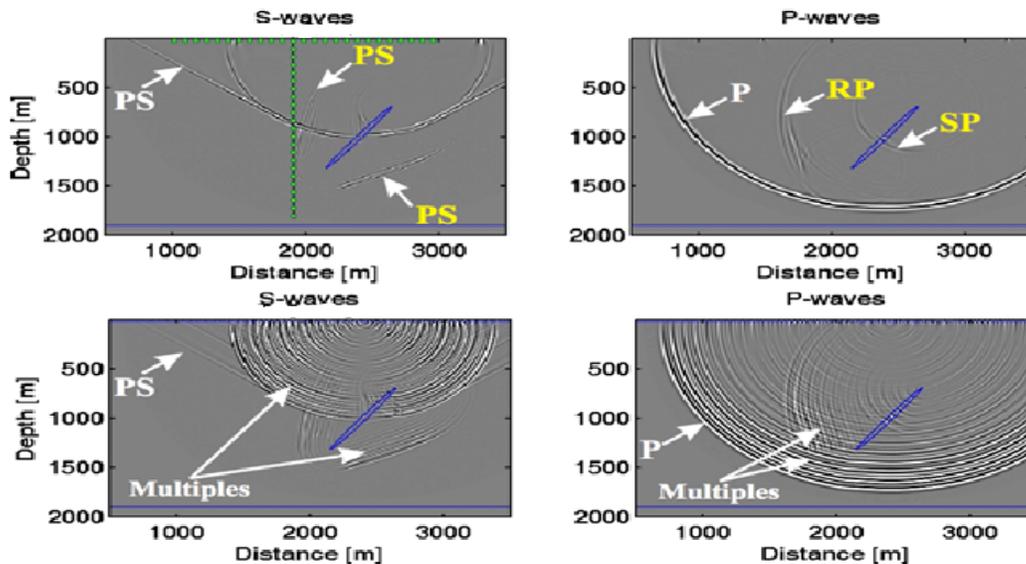


Figure 2: The top panel shows a snapshot of the P and S waves propagating in the model without overburden (Time=0.29s). Superimposed on the S-wave section is the surface and borehole acquisition geometries used in this study. The bottom panel shows both P and S waves for the case with clay overburden.

The reverberations within the clay layer cause energy to build up (constructive interference) with magnitudes larger than reflections from the lens. Masking of diffractions from the lens is more intense for the surface shot gather thus suggesting that the strategic VSP acquisition is more suitable for capturing the diffractions from the dipping lens (high diffraction amplitude from target). Only traces recorded by receivers within the overburden layer are severely affected by surface waves within the overburden layer. The shot depth equally affects the recorded seismic response. A shot located below the clay overburden mitigates the effects of multiples which undermine the detection of the target (Fig. 4, right panel). Note that the modelling results are based on an elastic case. The output may be different if intrinsic attenuation and other mechanisms affecting seismic amplitude are being considered.

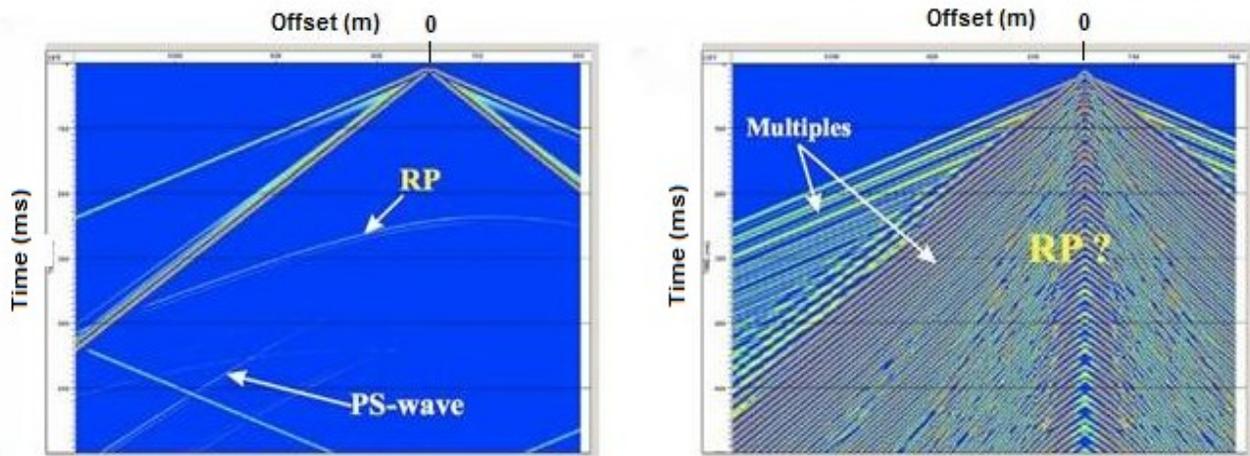


Figure 3: The vertical component shot gathers from the surface receiver spreads for the cases with and without overburden (shot depth=10m). The right panel shows the worst case scenario as any reflection from subsurface structure is masked by the multiples.

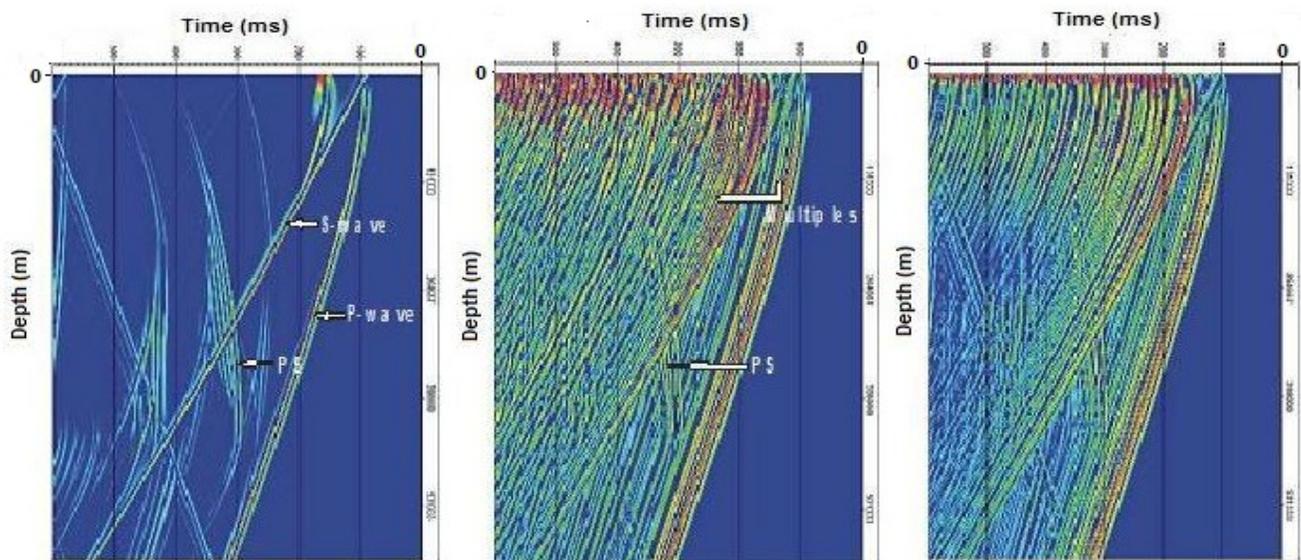


Figure 4: The left two panels are vertical component shot gathers from the borehole receivers (VSP geometry) with and without overburden. Notice how the amplitude from subsurface diffractions are greater than those from the surface receivers (shot depth=10m). The right panel shows the effect of shot depth (20m) whereby the amplitude strength of generated reverberations is reduced.

As shown in Figure 2 and 4, there is strong evidence for wave conversion processes. Thus far the focus of the study has been primarily on the P-wave response. However, the implications

for imaging with converted wave processing look promising. For example, in Figure 4 there is a strong PS response from the orebody at about 550ms. By isolating the PS responses, and perhaps the S-wave as well, imaging may be improved (Yilmaz, 2001).

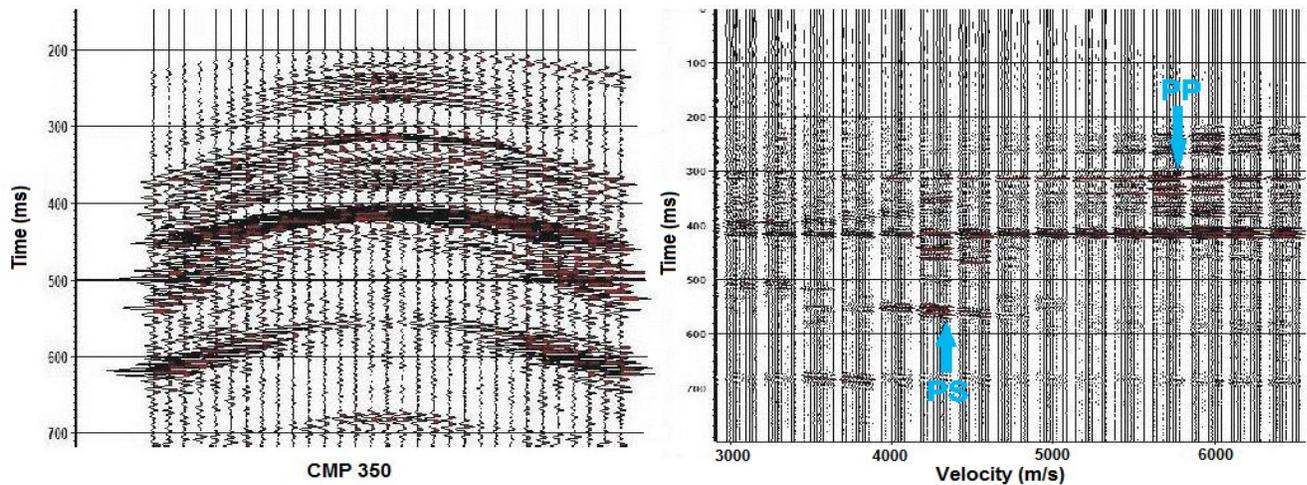


Figure 5: The left panel shows a CMP gather and the right panel shows the constant velocity stack. Both are from the vertical component using the model without overburden.

## Conclusions

Results from 2D forward modelling demonstrate that overburden layers can seriously undermine seismic imaging by masking target diffractions/reflections. In the presence of overburden layers, a suitable acquisition geometry to mitigate the effects from generated multiples is offset VSP geometry. This has the advantage of capturing most of the diffracted energy from the target as the overall source-receiver travel time is short, thus there is limited effect from other attenuation mechanisms like geometric spreading. Also, placing the shots at great depths above/beneath the overburden-bedrock contact/interface can minimize effects of multiples for both surface and VSP geometries. Although the present study does not consider other mechanisms affecting seismic amplitudes, the results can be very useful for characterizing the upper bound for overburden effects prior to seismic acquisition. Additionally, converted waves can be used to analyze results from surface receiver geometry. Accommodating such information in multicomponent seismic acquisition design and eventually in processing can be very useful for effective seismic imaging of subsurface target structures.

## Acknowledgements

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