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Numerical and measured data from the 3D salt canopy physical modeling project

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SUMMARY

The evolution of salt structures in the Gulf of Mexico have been shown to provide a mechanism for the trapping of significant hydrocarbon reserves. Most of these structures have complex geometries relative to the surrounding sedimentary layers. This aspect in addition to high velocities within the salt tend to scatter and defocus seismic energy and make imaging of subsalt lithology extremely difficult.

An ongoing program , the SEG/EAEG modeling project (Aminzadeh et al., 1994a; Aminzadeh et al., 1994b; Aminzadeh et al., 1995), and a follow-up project funded as part of the Advanced Computational Technology Initiative (ACTI) (House et al., 1996) have sought to investigate problems with imaging beneath complex salt structures using numerical modeling and more recently, construction of a physical model patterned after the numerical subsalt model (Wiley and McKnight, 1996).

To date, no direct comparison of the numerical and physical aspects of these models has been attempted. We present the results of forward modeling a numerical realization of the 3D salt canopy physical model with the French Petroleum Institute (IFP) acoustic finite difference algorithm used in the numerical subsalt tests. We compare the results from the physical salt canopy model, the acoustic modeling of the physical/numerical model and the original numerical SEG/EAEG Salt Model. We will be testing the sensitivity of migration to the presence of converted shear waves and acquisition geometry.

INTRODUCTION

It has long been recognized that salt diapir activation in the Gulf of Mexico distorts and faults the overlying, hydrocarbon rich sediments creating significant traps and reservoirs. In some areas these reserves are trapped by the relatively impermeable salt itself and underlie the salt body. These regions below the salt body are extremely difficult to image owing to the rugose, three dimensionally contoured and high velocity nature of the salt which scatter and arbitrarily defocus and focus seismic energy penetrating the salt. As a result, full prestack depth migration of three dimensionally acquired data is necessary to image the weakly illuminated subsalt reflectors (Lee and House-Finch, 1994; Ratcliff et al., 1992).

A consortium of university, industry and U.S. national laboratory participants have been involved in a project to accurately model the salt and subsalt complex using a numerical model developed by the SEG research committee (Aminzadeh et al., 1994). The SEG/EAEG model is fully three dimensional but because of current modeling restrictions is defined only by a single density with variable velocity within the model layers. An acoustic finite difference code developed by IFP has been employed to model synthetic seismograms. Full prestack depth migration of this data set has begun.

Commensurate with the development of the numerical model, Marathon Oil Company and Louisiana Land and Exploration proposed construction of a physical model patterned after the SEG/EAEG model (Wiley and McKnight, 1995, 1996). This model was constructed at the University of Houston Allied Geophysical Laboratory and data were collected over this model as part of an ACTI-funded project. Many companies participated in the data collection phase. A "physical" data set was acquired from this model mimicking a conventional marine data set. This physical model can support converted shear waves and a variable density medium but does not reflect the velocity gradients present in the numerical model.

The next step in testing the accuracy of these models was to create an acoustic version of the physical model and use the same IFP algorithm used on the numerical model.

THE MODEL

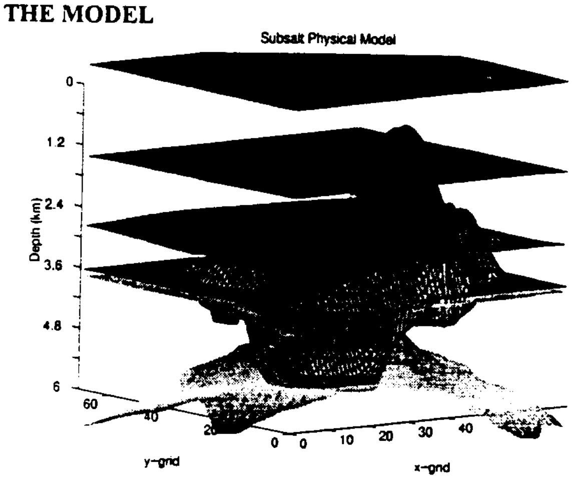

Figure 1. 3D perspective view of the physical model layers. Salt body shown as the mesh surface.

DISCLAIMER

Numerical and measured data from 3D salt

The design of the physical model was based on the based on the numerical model but material limitations forced the use of constant velocity layers in its construction. Seven materials. including water. silicone rubber. epoxy resin and machined Plexiglas for the complex salt structure were used (Figure 1).

Figure 1 was plotted from a digitized data set measure from the surface of each of the model layers as they were cast. The physical model dimensions were scaled to represent a 27.4 km X 27.4 km X 8.0 km block of the Earth's crust. To match the stability conditions at the frequencies used in the numerical salt model. the surfaces were interpolated to a 20m spaced grid. The physical dimensions of the regrided model were prohibitive for our current memory capabilities so the central 13.9 km X 13.9 km X 8.0 km of the physical model were retained and used in this study. A cross section along line 351 of the 3D salt canopy physical model is shown in Figure 2.

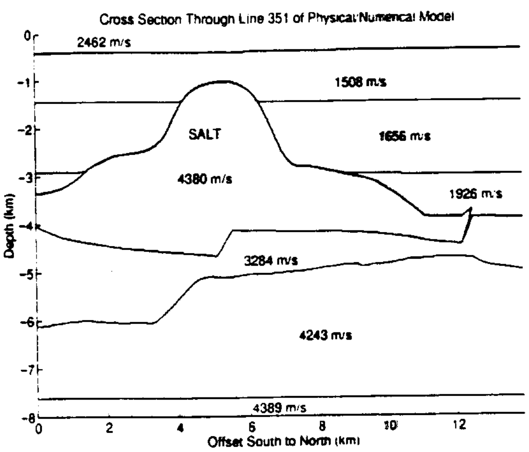

Figure 2. South - North cross section through salt canopy physical/numerical model at line 351

The portion of the physical model retained for this modeling contains the majority of the salt structure and is therefore still appropriate for measuring the imaging capabilities of subsalt reflectors. Figure 3 is a contour plot of the top of the salt complex and the position of the shot points along line 351 relative to the top of the salt complex.

Differences among the physical/numerical. the physical model and the numerical model are shown in Table 1.

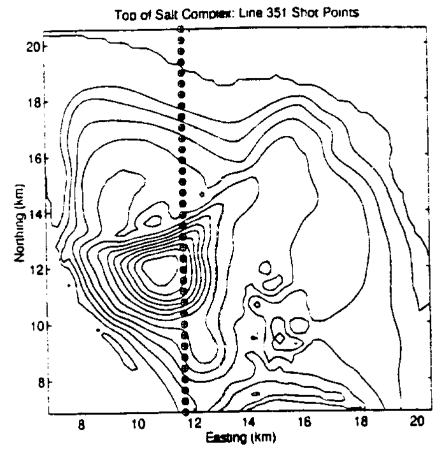

Figure 3. Contour map of the top of the salt complex with the position of line 351 indicated. Contour interval 250m. Axes distances are in relation to original 3D salt canopy physical model.

Table 1
Numerical Vs. Measured Data
Acquisition

	Physical/ Numerical	Physical	Numerical
Model Size	13.9 km	27.4 km	13.5 km
	13.9 km	27.4 km	13.5 km
	8.0 km	8.0 km	4.2 km
Density	fixed	variable	fixed
Gradient	no	no	yes
S-Wave	no	yes	no
Line 351			
# Shots	72	740	138
Shot dx	100 m	30 m	100 m
Rcvr dx	20 m	150 m	40 m
# Rcvr	311	32	65
Near Offset	0 m	600 m	160 m
Far Offset	6200 m	5250 m	2760 m
Total Receiver	22.392	23.680	8.971
Trace	**Data**		
Sample Interval	4 ms	7.2 ms	8 ms
# Samples	2000	2000	625

TESTING EXAMPLES

3D data from the physical/numerical model were acquired along a line matching one of the "Classic Data Sets" formed from the SEG/EAEG numerical model data set that is archived at Lawrence Livermore Laboratories. The line runs North-South and is offset from the East edge of the SEG/EAEG model by 11.700 m. This line compares with line 351 of the physical model. The structure beneath this line is shown in Figure 2.

The modeling was performed on a 32 node partition of the LANL Advanced Computing Laboratory Cray T3D MPP (massively parallel processor). The French Petroleum Institute serial code had originally been made parallel on the Thinking Machines CM5 and later converted to PVM (parallel virtual machine) on the T3D. Each shot run involved reading in a 6.2 km X 6.2 km X 8.0 km subcube of the model which was then shifted the same increment as the shot spacing for each run.

The velocity model was derived from the scaled velocity model used in the physical salt canopy model (Wiley and McKnight, 1995).

RESULTS

Each shot record required approximately 4 hours on the T3D. The physical/numerical data were collected in both marine and split spread survey acquisition geometry. Both the numerical and physical model data were collected in marine survey geometry. Figures 4, 5 and 6 show the near offset traces for a number of the shots in the three models.

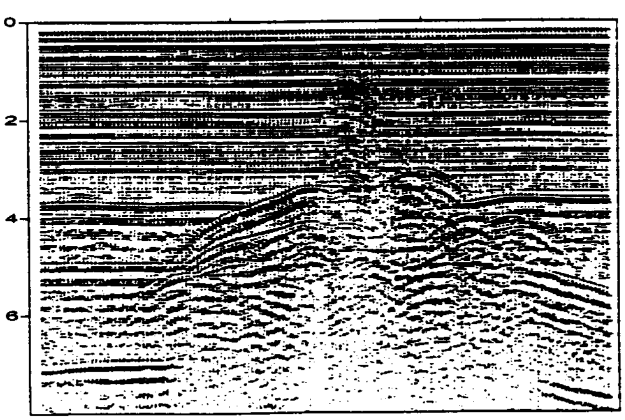

Figure 4. Near offset (600 m) section from the physical salt canopy model.

There are some differences in the strength of the deeper reflectors in the physical model. Both the numerical and the physical/numerical model show less complicated and acoustically transparent deeper structure. This may be due to the absence of converted shear wave energy.

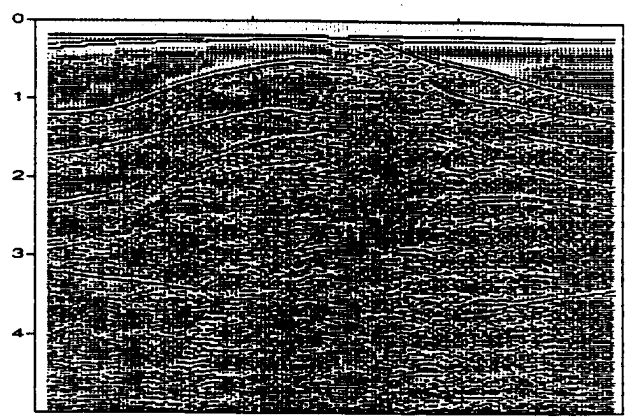

Figure 5. Near offset (160 m) section from the numerical salt canopy model. Notice the draping layers around the salt conopy.

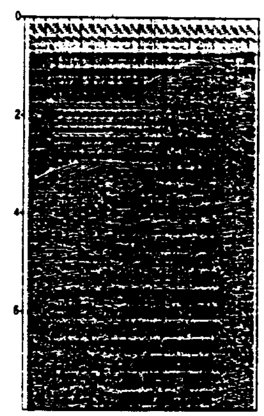

Figure 6 Near offset (160 - 600 m) traces around the flank of the salt canopy from the physical/numerical salt canopy model.

CONCLUSIONS

We have shown the results from modeling the 3D salt canopy physical model using the parallelized version of the IFP acoustic modeling code. It has been important to compare the shortcomings of acoustic models directly to the physical data. Although all these data sets are artificial, we can learn some of the influences of shear wave conversion, variable density and velocity gradients on migration of subsalt reflectors.

ACKNOWLEDGMENTS

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