

Iterative velocity model building for 3-D depth migration by integrating GOCAD and AVS

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ABSTRACT

We have developed a procedure for building a 3-D velocity model starting from a 2-D geological model in order to image 3-D poststack data. The 3-D model was built using GOCAD, and it was iteratively refined by interpreting the result of 3-D poststack depth migrations using AVS. At the beginning of the iterative process, when only few reflectors are detectable in the migrated cube, we interpret only one surface. From the deformations measured on the selected reflector we compute a displacement field for every point in the model. The application of the displacement field to the GOCAD model used for migration leads to an improved model. The migration of the data with this improved model shows better focusing of some reflectors and allows a more complete interpretation of the structure.

INTRODUCTION

One of the most crucial problems in imaging 3-D seismic data is the determination of the velocity model. With the ever increasing speed of parallel supercomputers new options for defining and refining the velocity model are becoming possible. These new options take advantage of the speed of these super computers to integrate time consuming operations such as migration, into an interactive and iterative processing flow (Wyatt et al., 1992; Jones, 1993). Sheppard and O'Brien (1993) took advantage of these new options by creating a 3-D velocity model by performing depth migration, interpreting the resulting image, and refining the geologic model. In addition, improved visualization software has made 3-D model building, viewing, and manipulating an easier task. Della Malva and Williams (1992) used GOCAD to combine a series of 2-D velocity models into a 3-D model. We blended elements of both of these methods in an attempt to obtain a good 3-D velocity model for 3-D poststack migration. We started with a 2-D geologic model, along with the prestack and poststack 3-D data sets in which initially very few reflectors were identifiable. We migrated the data with 2.5-D model created in GOCAD. We then viewed the 3-D cube using AVS and picked a series of surfaces on various slices of the cube parallel to the direction of the initial 2-D geologic model. From this series of surfaces we created a 2-D displacement net for the cube. Choosing a single surface and then extrapolating its changes in depth to the entire geologic model does not accurately

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describe geologic sedimentation and the time variant nature of the stress field accompanying it. The methodology is not a bad first approximation, and proved effective in improving the migrated image and the accompanying geologic model.

BUILDING THE 3-D GEOLOGIC MODEL

The first challenge was to convert the 2-D AIMS geologic model into a 3-D GOCAD model.

AIMS model

AIMS creates its model by constructing a series of surfaces defined by numerous line segments. These line segments are defined in an ASCII file by a pair of coordinates representing the beginning and end of the line segment. In addition to the coordinates, each line contains the number of the corresponding surface. The surfaces are chosen so that only one velocity is represented below them and that velocity is defined in a horizon call. An example of a portion of an AIMS 2-D model file is presented below:

```
HORI      40,                , 4600.0
BEG       40,   2310.374,   1108.975
END       40,   2331.748,   1058.843
BEG       40,   2331.748,   1058.843
END       40,   2355.868,   1000.688
BEG       40,   2355.868,   1000.688
END       40,   2378.594,   956.565
BEG       40,   2378.594,   956.565
END       40,   2499.702,   889.891
```

3-D Model in GOCAD

As described in Berlioux (?) a GOCAD 3-D model is defined by a series of surfaces files and a partition file. Each surface file is divided into two parts. The first part contains a series of points (vertices in the GOCAD nomenclature) upon which the surface lies. The second section is devoted to constructing a series of triangles from the defined points in order to give the surface continuity in two-dimensions. Figure 1 illustrates a simple model constructed from the surface file defined below:

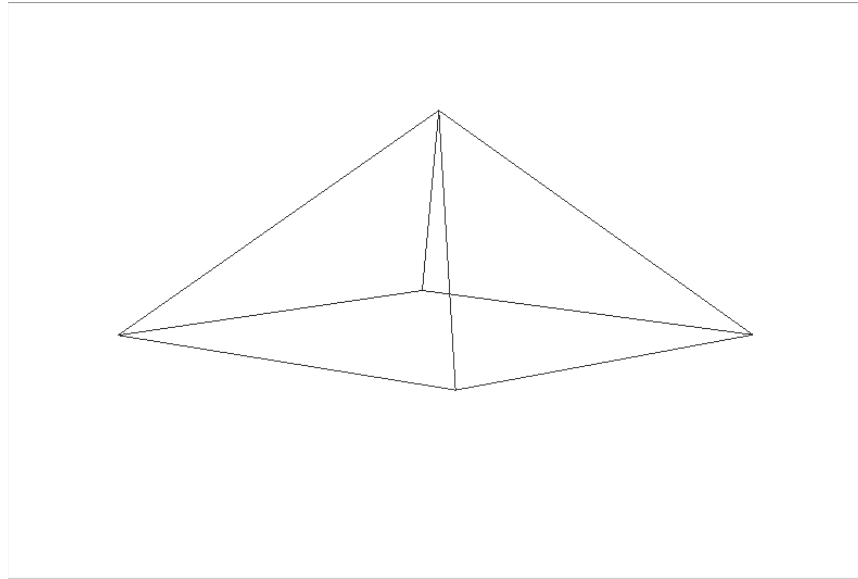


Figure 1: A simple GOCAD model. `bob-gocad1` [NR]

```

VRTX 1 0.00    0.00    0.00
VRTX 2 2.00    0.00    0.00
VRTX 3 2.00    2.00    0.00
VRTX 4 0.00    2.00    0.00
VRTX 5 1.00    1.00    1.00
TRGL 1 2 5
TRGL 2 3 5
TRGL 3 4 5
TRGL 4 1 5

```

The partition file defines a series of domains bounded by the various surfaces. The domains can then be assigned properties such as velocity or density.

The Conversion

Rather than converting the AIMS file manually into a series of GOCAD files it was decided to develop a procedure that would accomplish this task automatically. The conversion program was written in standard SEP-like format to better allow it to be integrated into future processing flows. The input is simply the AIMS file, parameters defining the extension in the cross-line direction, and an option to create a free surface. The output is a series of *.ts* files (GOCAD extension for a surface file) corresponding to the surfaces described by AIMS.

Once the initial AIMS file has been run through the conversion routine it is a relatively simple matter to create the GOCAD model. Figure 2 represents the GOCAD model corresponding to the input AIMS geologic model. In order to run the CM-5 migration program it is necessary to convert the GOCAD model to SEP format. Figure 3 represents a 2-D slice of the resulting velocity model using the program described in Berlioux(1993).

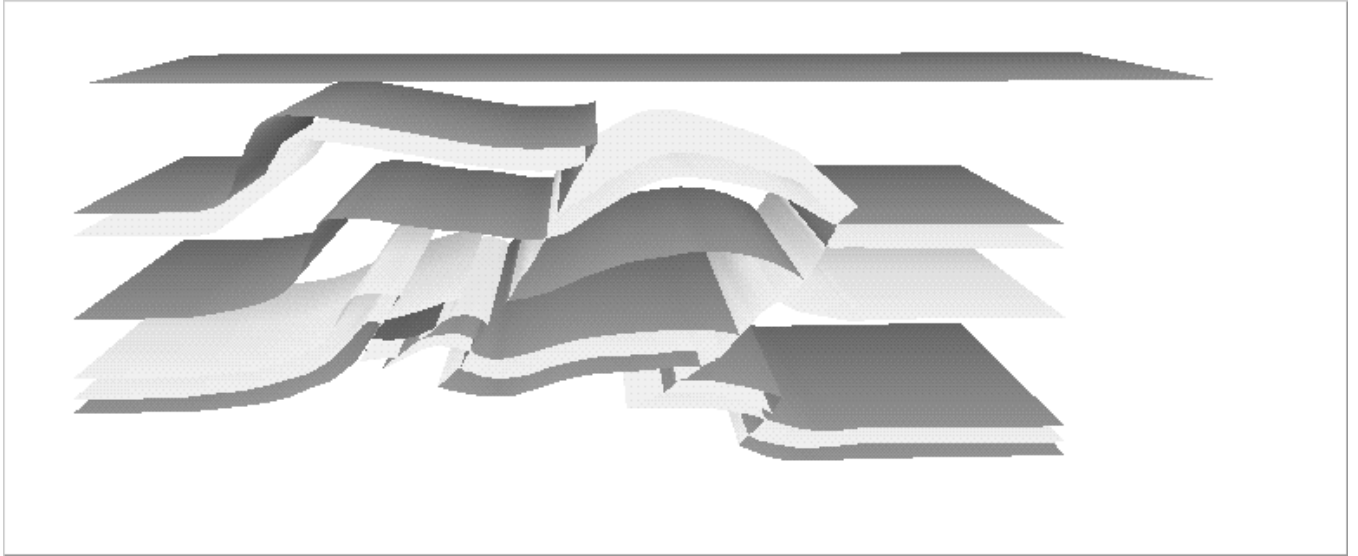


Figure 2: GOCAD model corresponding to input AIMS model. `bob-gocad2` [NR]



Figure 3: Gridding output based on initial AIMS model.

REFINING THE GEOLOGIC MODEL

Once the initial geologic model had been built, the task was to better describe the 3-D nature of the area. The velocity model was used as input to a depth migration program on the CM-5 developed at SEP (Biondi and Palacharla, 1993). The resulting cube was then viewed using AVS.

AVS picker

Dave Nichols has created an AVS network, and written a module for that network which enables the user to pick a polyline on a 2-D image and write that polyline in a GOCAD *pline* format. In order to create the displacement field, we chose a 2-D slice of the data cube parallel to the geologic model (see Figure 4), then chose a surface that was possible to identify on all/most of the 2-D images. We picked the surface on the image and saved it in a file corresponding to the slice number. Part of the recorded pline file for Figure 4 can be seen below:

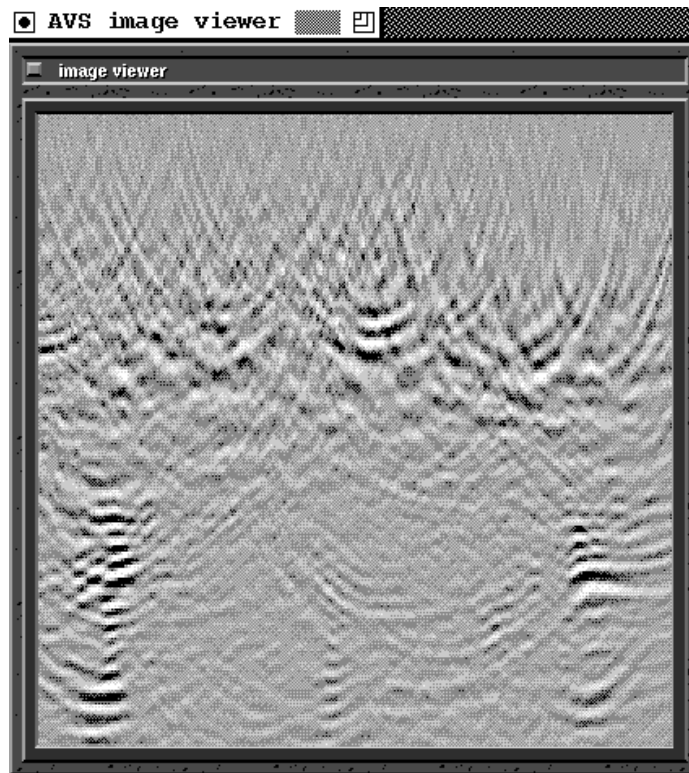


Figure 4: Slice 324 of 3-D migrated cube. `bob-avs3241` [NR]

```

VRTX 1 32.000000 58.000000 0.000000
VRTX 2 42.000000 54.000000 0.000000
VRTX 3 44.000000 53.000000 0.000000
VRTX 4 48.000000 55.000000 0.000000

```

```

VRTX 5 51.000000 58.000000 0.000000
VRTX 6 56.000000 60.000000 0.000000
VRTX 7 59.000000 63.000000 0.000000
VRTX 8 62.000000 65.000000 0.000000
VRTX 9 65.000000 68.000000 0.000000
VRTX 10 67.000000 70.000000 0.000000
VRTX 11 70.000000 72.000000 0.000000
.
.
.
SEG 1 2
SEG 2 3
SEG 3 4
SEG 4 5
SEG 5 6
SEG 6 7
SEG 7 8
SEG 8 9
SEG 9 10
SEG 10 11
.
.
.

```

We then attempted to pick the same pline on another in-line slice in order to approximately quantify the changes in depth along the cross-line direction of the geologic model. Figure 5 shows a second slice in the in-line direction, note the change in the surface approximately 80% of the way down the image in comparison to the same surface on Figure 4.

Creating GOCAD model from series of plines

Creating the 3-D GOCAD model from the series of 2-D plines was a two-step process. The first step was to create a 2-D displacement field. The displacement field was created by: first, reading in the series of vertices making up the various plines, then resampling in the in-line direction using linear interpolation between the points, and finally, subtracting the resampled values from a baseline corresponding to the original 2-D geologic model. The corresponding displacement net is specified by a user defined density parameter in the in-line direction and by the number of slices of the 3-D cube in which plines were chosen in the cross-line direction. It was not necessary to resample in the cross-line direction due to the combination of GOCAD and the gridding program doing the same linear interpolation as the program performs in the in-line direction. Once the 2-D displacement net has been created, Figure 6, the net is used to construct the same series, and in virtually the same manner, the *.ts* files constructed in the original 2.5-D GOCAD model. Figure 7 represents the GOCAD model derived from the displacement field shown in Figure 6.

Even though the initial data quality was poor, and the re-migrated image far from ideal (Figure 8), the image does appear to be improved compared to the corresponding slice migrated with the initial 2.5-D velocity model, Figure 4. The improvement is especially noticeable in the middle of the image where an anticline has become better focused.

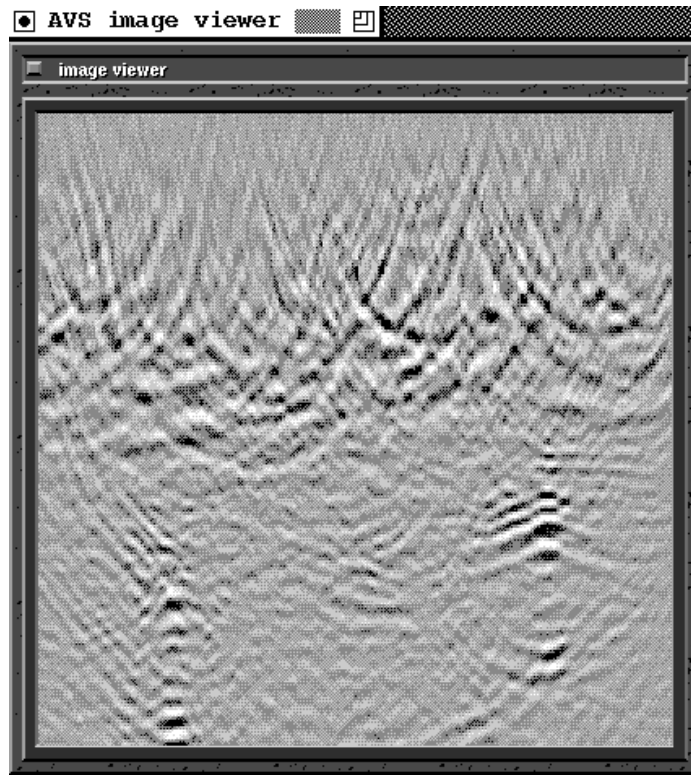


Figure 5: Slice 220 of 3-D migrated cube. `bob-avs220` [NR]



Figure 6: 2-D displacement net.

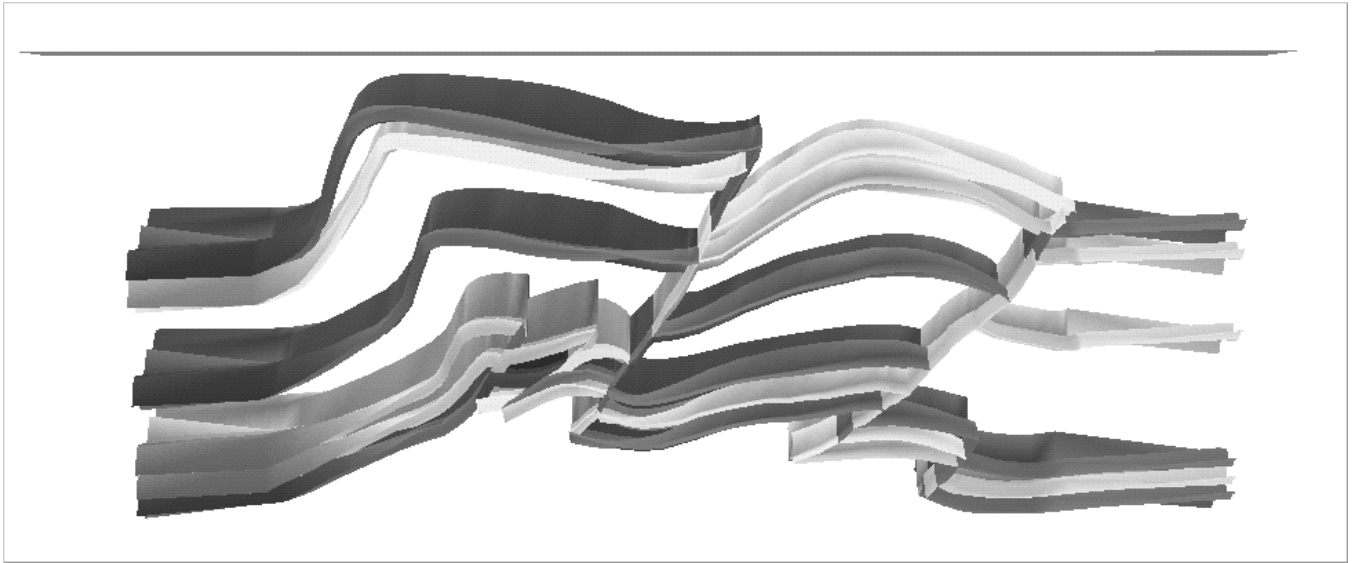


Figure 7: GOCAD model constructed from initial displacement field calculations.
`bob-gocad4` [NR]

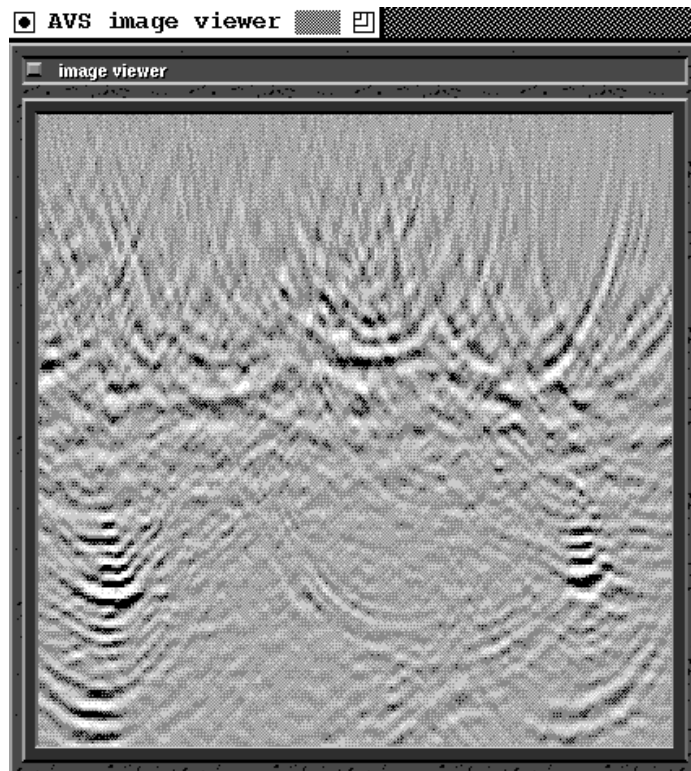


Figure 8: Slice 324 of migrated cube with 3-D velocity model. `bob-avs3242` [NR]

CONCLUSIONS

By creating a 2-D displacement net and applying it to the geologic model, the 3-D poststack migration image did show some improvement. The velocity model could be further improved by re-choosing the surface on the series of 2-D slices. The improved quality of the velocity function should enable a more consistent and improved picking, further enhancing the quality of the 3-D model. Further, once the surfaces become more apparent in the migrated image, extending the displacement field into the third dimension by picking two or more surfaces might help improve the results and better approximate the true nature of sedimentation variation with time. In addition velocity inside the model could be better defined by intergrating geophysical data derived from such source as velocity analysis.

ACKNOWLEDGEMENTS

We would like to thank Husky Oil for providing the dataset, and in particular Fred Kierulf with Husky Oil, for his enthusiastic support. At SEP, we are indebted with Arnaud Berlioux for the numerous hours spent explaining GOCAD and his gridding program, and Dave Nichols for explaining some of the intricacies of AVS and his network.

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