

The new SYNTH/LOGSEC modelling facility

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ABSTRACT

LOGSEC is an interactive GUI program used to create stratigraphic cross-sections tied to wells, and to propagate well logs through those cross-sections. SYNTH generates a single full-offset shot gather including P-P and P-S data from a single well log. We are integrating the functionality within SYNTH into LOGSEC to allow the generation of full-offset P-P and P-S synthetic gathers through the entire cross-section in order to simulate a 2-D seismic survey across the section. The resulting data is available to MATLAB directly or to other processing packages via SEG-Y formatted files.

INTRODUCTION

LOGSEC

LOGSEC is a CREWES software package originally developed by Gary Margrave in 1994. Subsequently it has been modified and upgraded numerous times. In addition to the improvement of the newly integrated SYNTH functionality, work is currently under way to stabilize the code and to improve compatibility with current releases of MATLAB.

LOGSEC was introduced by Foltinek et al. (1997). It is designed to view and manipulate geologic cross-sections with well information. A small number of wells are imported into a cross-section. Horizons are either included in the well data or added using the LOGSEC graphical user interface (GUI). These horizons are used as control points to guide an interpolative algorithm that will “fill in” the area between the well logs and generate synthetic logs in-between that smoothly match from one log to the next. LOGSEC can be used to generate a synthetic section using a single zero-offset synthetic trace generated at each log location.

SYNTH

The SYNTH algorithm uses full Zoeppritz equations with raytraced incident angles to model offset-dependent reflectivity effects. SYNTH requires P-wave logs, and can optionally use S-wave and density logs. If density logs are unavailable, an approximation is generated using Gardner’s relation. S-wave logs can be estimated using a constant V_P/V_S relation. SYNTH accepts an arbitrary user input wavelet, and returns full-offset P-P and P-S synthetic seismogram gathers to the user either as MATLAB data, or as SEG-Y files. A detailed discussion of the original SYNTH algorithm is provided by Margrave and Foltinek (1995), with improvements and upgrades outlined by Larsen et al. (1997).

LOGSEC and SYNTH

It seemed natural to combine the abilities of both software products. This version of LOGSEC demonstrates the ability to take a LOGSEC-generated interpolated geologic cross-

section and generate full-offset P-P and P-S gathers and stacks in both time and depth. The resulting data is available either as MATLAB variables suitable for direct manipulation, or as SEG-Y data files for use with traditional software geophysical processing packages.

DEMONSTRATION OF LOGSEC

Real log data

To begin, a new cross-section is created, and the wells are loaded in with appropriate horizon information. Horizons are edited as required. See Figure 1 for a sample cross-section containing real P-wave logs with picked horizons.

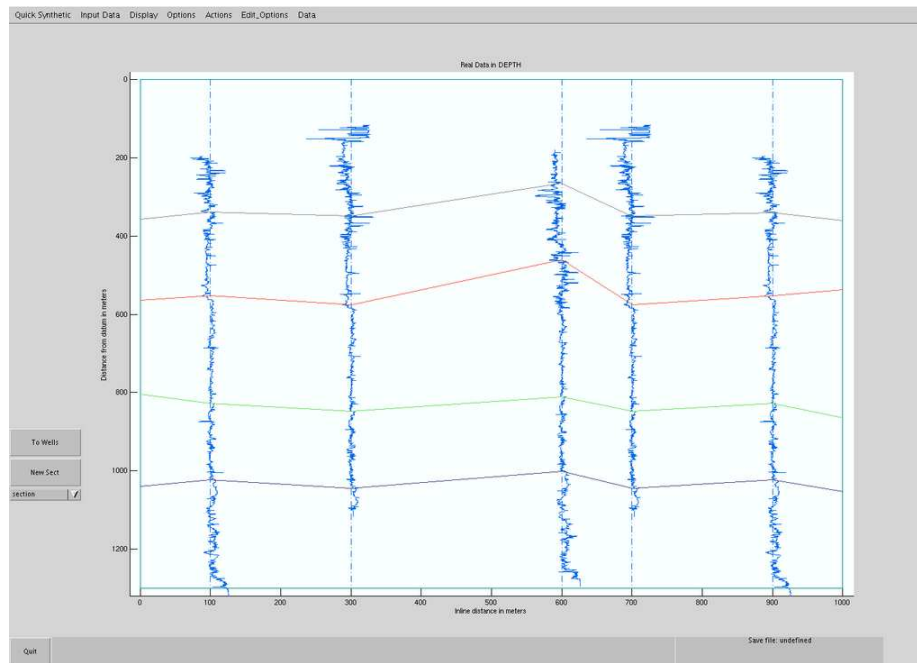


FIG. 1. Creation of a new cross-section.

Once the section has been created, the logs are interpolated, as in Figure 2. A new interpolation section is created for each log type (P-wave, S-wave, density) to be used for the synthetic seismogram generation. P-wave logs are required while density and shear sonic logs are optional.

Next, wavelets for the P-P and P-S data are chosen (See Figure 3). Wavelets are typically generated using the CREWES software package WAVELETED.

Once the wavelets have been chosen, the synthetic seismic section may be generated. The SYNTH algorithm is applied to the log sections trace by trace. The resulting data is displayed in a previewing window that allows inspection of each generated gather along with an example stack. Data may be displayed in both time (Figure 4) and depth (Figure 5). This display was designed primarily to give the user a quick look at the data that was generated. Once a suitable synthetic section has been generated, it is expected that most users

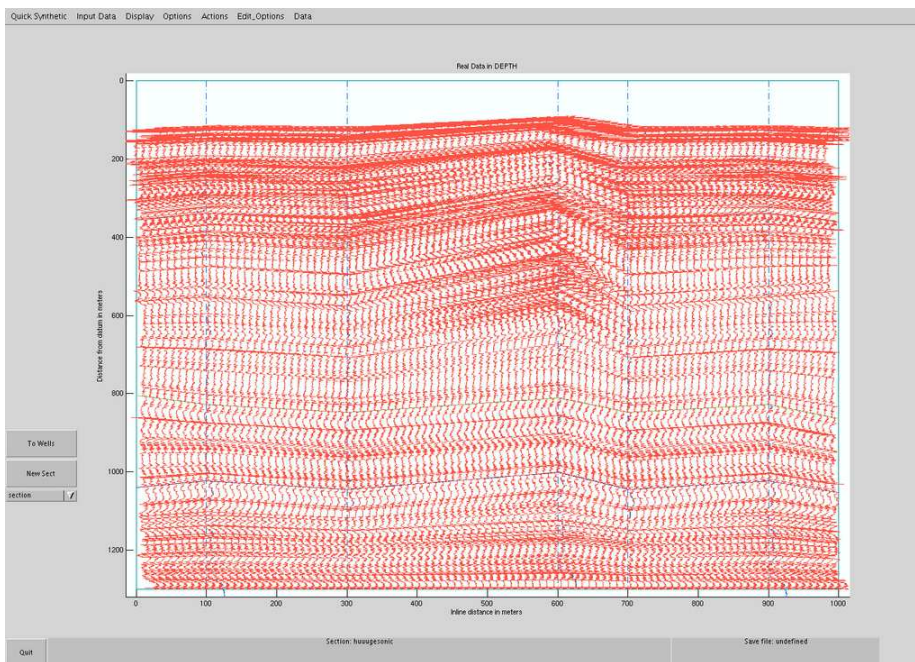


FIG. 2. Interpolation of logs.

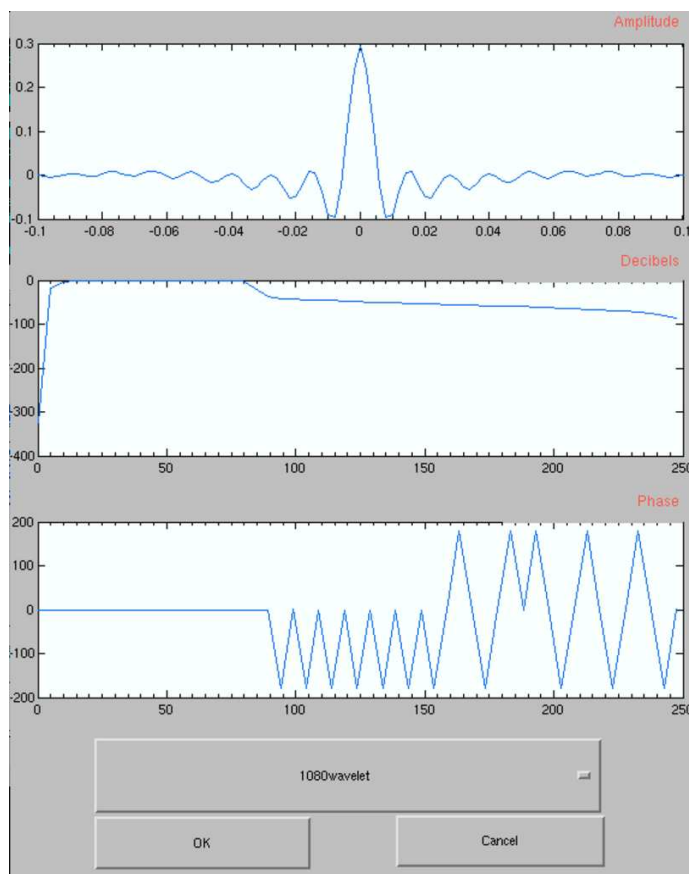


FIG. 3. Choosing wavelets.

will export the data via SEG-Y to their favourite software packages for further processing as required.

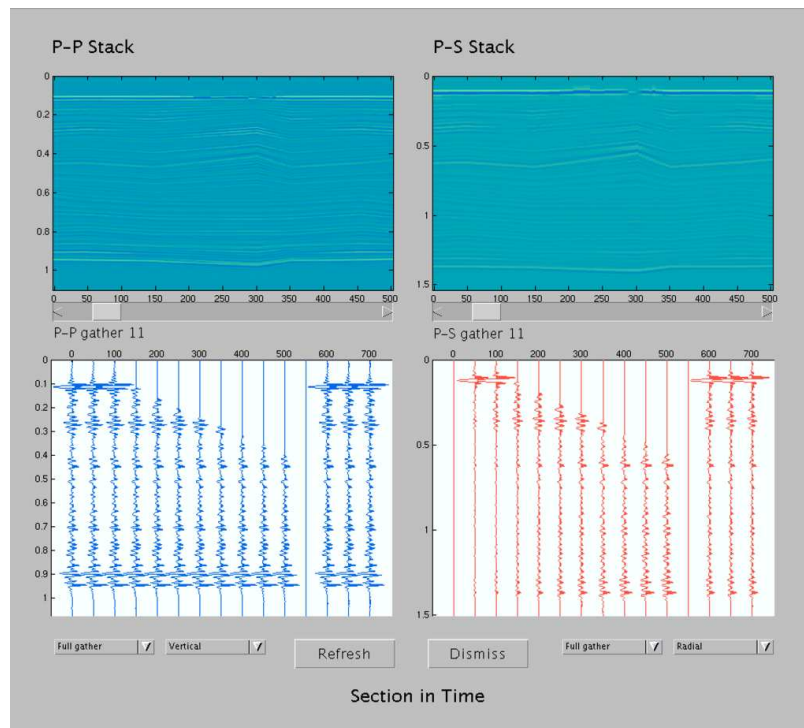


FIG. 4. Synthetic seismic data in time.

Model log data

Of course, cross-sections may be built with model well logs instead of real well logs. Model logs can be generated with the CREWES well-log editing tool LOGEDIT. For example, a simple three-layer model cross-section may be constructed and well logs propagated, as shown in Figure 6. The model logs yield the synthetic seismic data seen in Figure 7. Notice the difference between the P-P and P-S stacks in Figure 7. The P-P stack remains strong throughout the entire section, but the P-S stack dims in the centre. In Figure 8, the S-wave log section can be seen. The S-wave velocity slows dramatically in the centre of the section. Careful investigation of the P-P data, including gathers, will also reveal subtle differences between the left side and the centre of the model.

FUTURE WORK

LOGSEC development continues. Work is currently underway to improve LOGSEC as a general cross-section and synthetic seismic data generation tool. We are refining the SYNTH integration code. Additionally, we are about to begin further development of the SYNTH engine that drives the seismic modelling. It is hoped that future releases of LOGSEC and SYNTH will offer more realistic attenuation support including models of both apparent and intrinsic attenuation.

As of October 2004, the new LOGSEC software with SYNTH functionality is very new

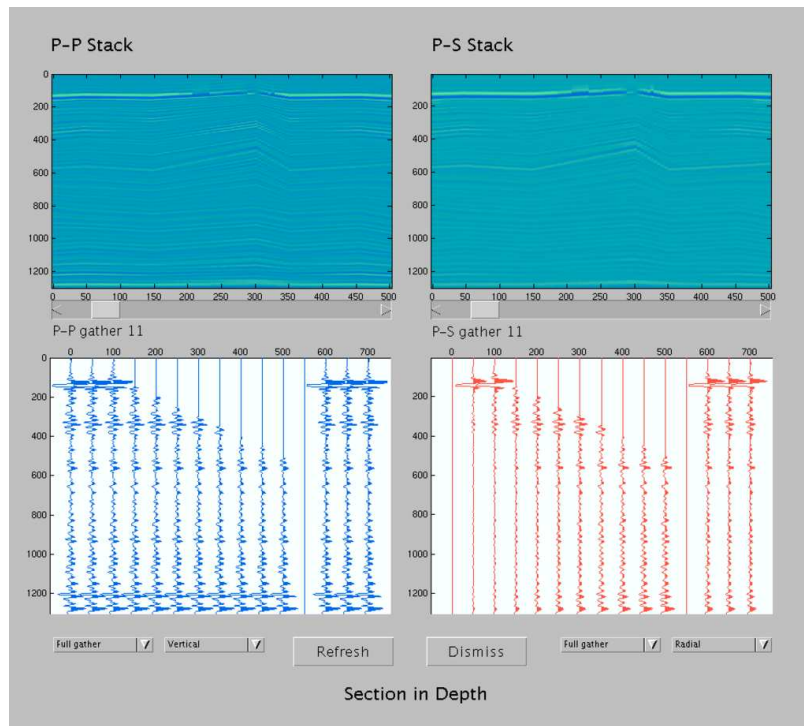


FIG. 5. Synthetic seismic data in depth.

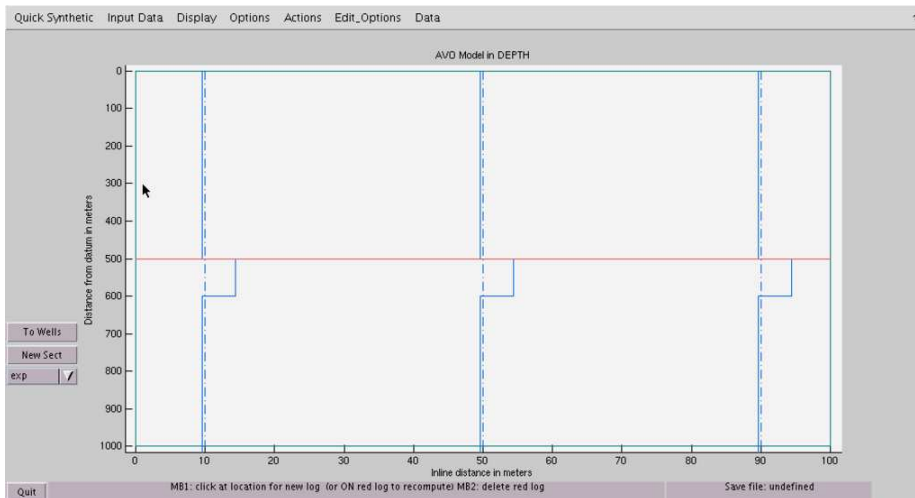


FIG. 6. Model cross-section with P-wave logs

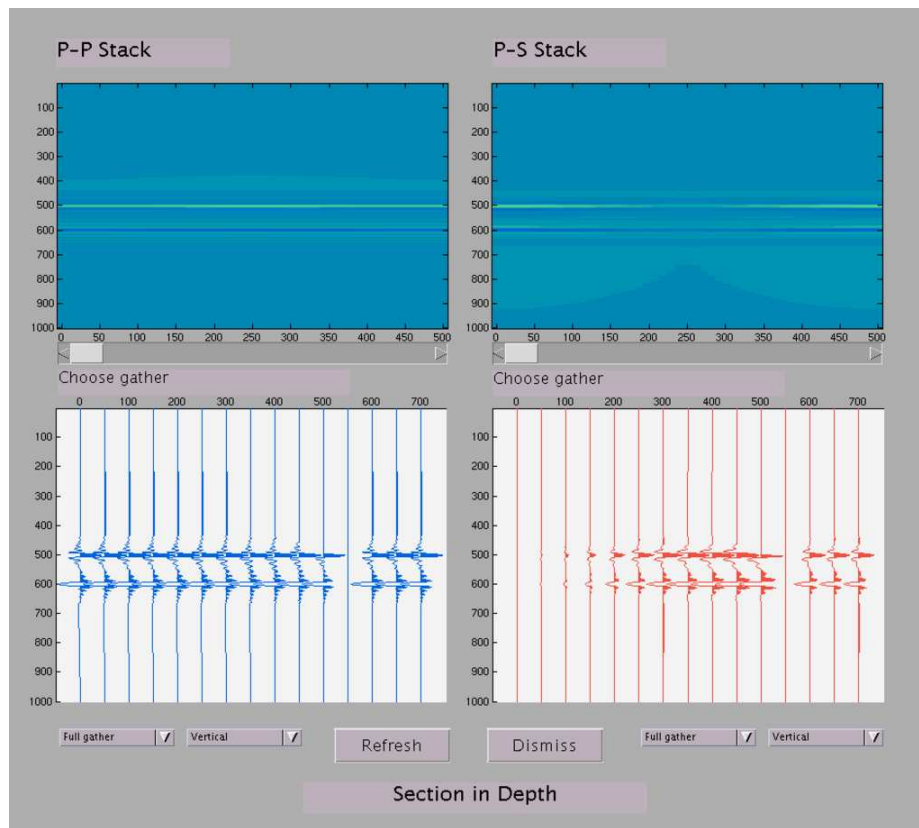


FIG. 7. Model synthetic seismic data in depth.

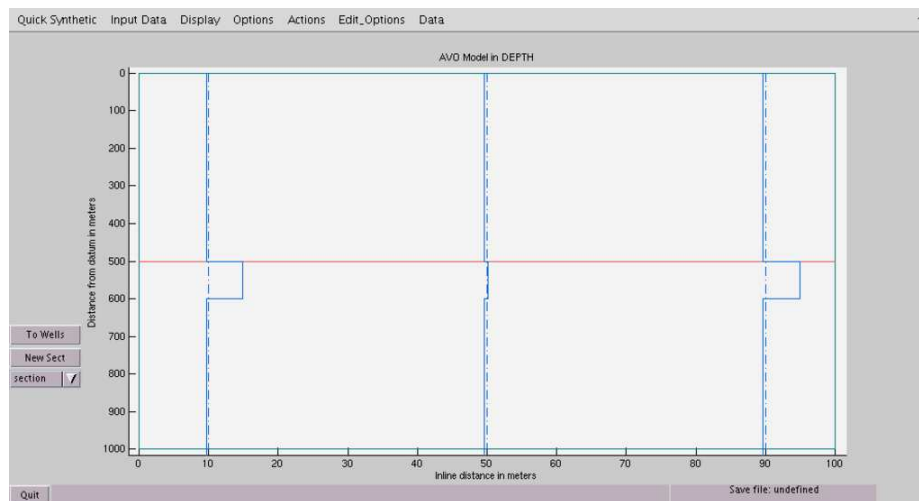


FIG. 8. Model cross section with S-wave logs.

and highly experimental. Currently, heavy development is in progress, working towards maturing and stabilizing the code. We encourage any users of the software to contact us directly with reports of bugs in the software or with suggestions for improvement.

REFERENCES

Foltinek, D. S., Margrave, G. F., Larsen, J. A., and Bland, H. C., 1997, CREWES Software Release: CREWES Research Report, 9.

Larsen, J. A., Margrave, G. F., and Foltinek, D. S., 1997, New developments in the SYNTH algorithm: CREWES Research Report, 9.

Margrave, G. F., 1997, LOGSEC Users Guide, CREWES Software Release: CREWES Research Report, 9.

Margrave, G. F., and Foltinek, D. S., 1995, Synthetic P-P and P-SV cross-sections: CREWES Research Report, 7.

APPENDIX – QUICK START GUIDE TO SYNTHETIC SECTIONS WITH LOGSEC

Start MATLAB, and run LOGSEC to generate a new cross-section:

```
>> logsec('new')
```

Supply the information required by the dialogue (Figure 9) to specify the cross-section dimensions.

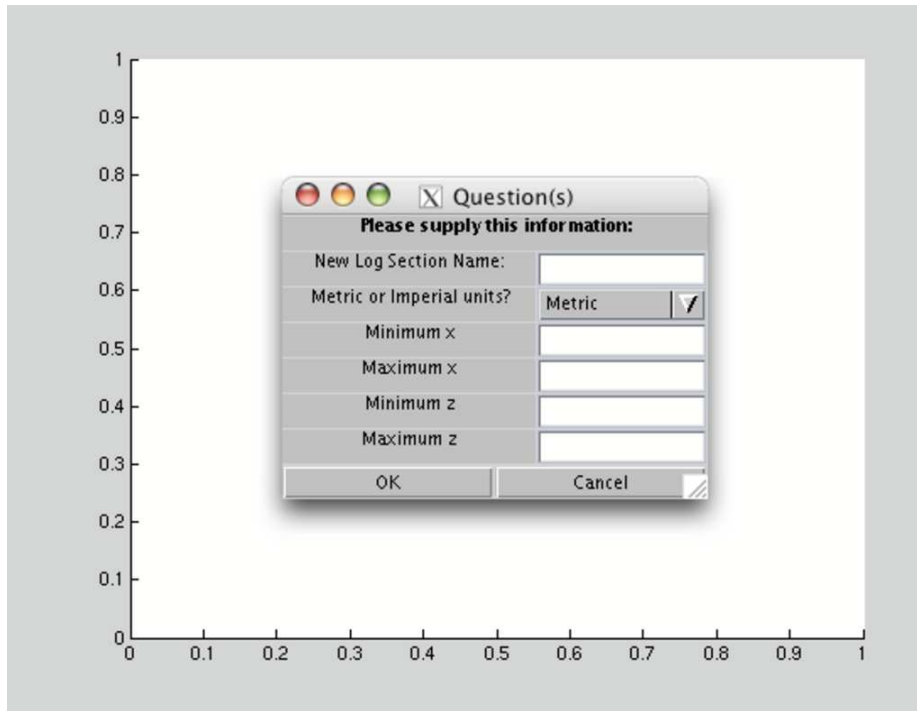


FIG. 9. Starting LOGSEC.

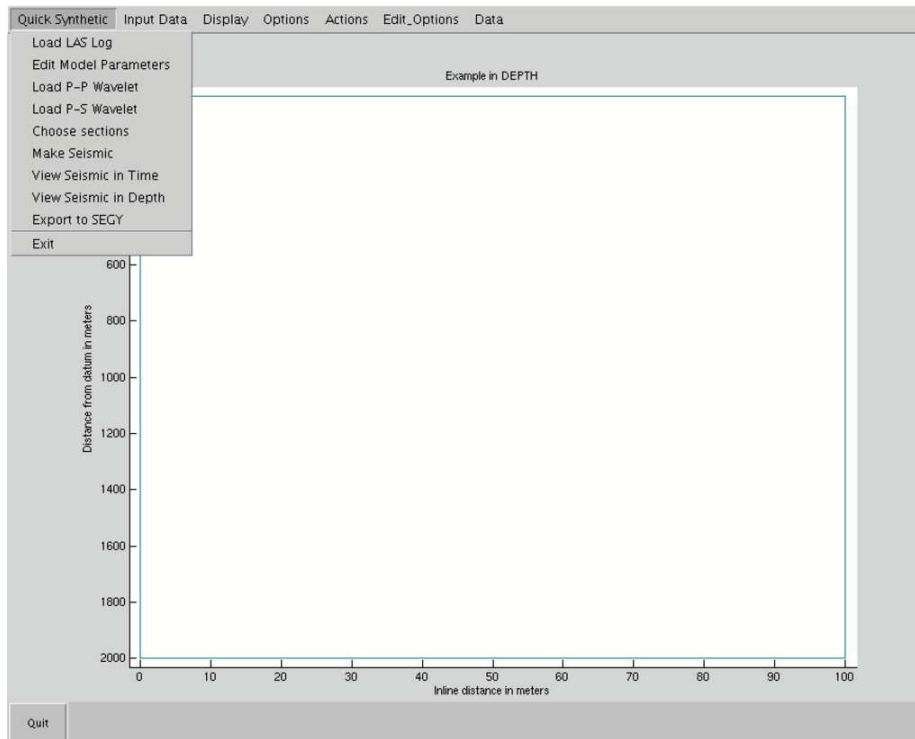


FIG. 10. Quick Synthetic menu.

The “Quick Synthetic” menu (Figure 10) contains several operations that were unavailable in previous version of LOGSEC. In the new “Quick Synthetic” menu, use the “Load LAS Log” item to load several LAS-formatted well logs. Each must contain at least a P-wave sonic log. Optionally, S-wave sonic and density logs can be used.

Ideally well logs with existing horizons within the LAS file should be used. It is possible to include or modify horizons in the cross-section within LOGSEC. See Margrave (1997) for a complete discussion of the LOGSEC utility, including the editing of horizons.

Once the sets of logs have been imported, the appropriate traces must be selected and displayed. From the main menubar, choose “Data”, then “Logs” (Figure 11). A list of all of the imported log names appears. Each name contains a list of the logs included within a particular set. Choose the same type of log (density, P-wave sonic, or S-wave sonic) for all logs.

Following the selection of well log type, synthetic log sections must be generated. In the main menubar, select “Propagate Logs” (Figure 12) from the “Actions” menu. On the left side of the interface, three new GUI elements will appear. Choose the pop-up menu with “exp” and select “section” (Figure 13). A dialogue will appear (Figure 14). Choose a name for the new section that indicates the type (eg “psonic”). Use only alphanumeric characters in this name. Choose minimum and maximum x coordinates to specify the dimensions of the new interpolated cross-section. Note that the minimum and maximum coordinates must be *within* the section. If the overall section geometry has an inline distance from zero to one hundred metres, the x coordinates for the interpolated log section have a minimum of one and a maximum of ninety-nine. Also choose the increment interval for the interpolation algorithm. This interval must be an integer. “Geom from other section” may be left blank.

Upon successful selection of section parameters, the interpolated well logs will be calculated and displayed. Watch the MATLAB command window for a progress report. Minimally, an interpolated P-wave sonic section must be generated. To generate another section for S-wave and/or density logs, simply select the appropriate density log from the “Logs” element of the “Data” menubar item for all log sets (Figure 11)

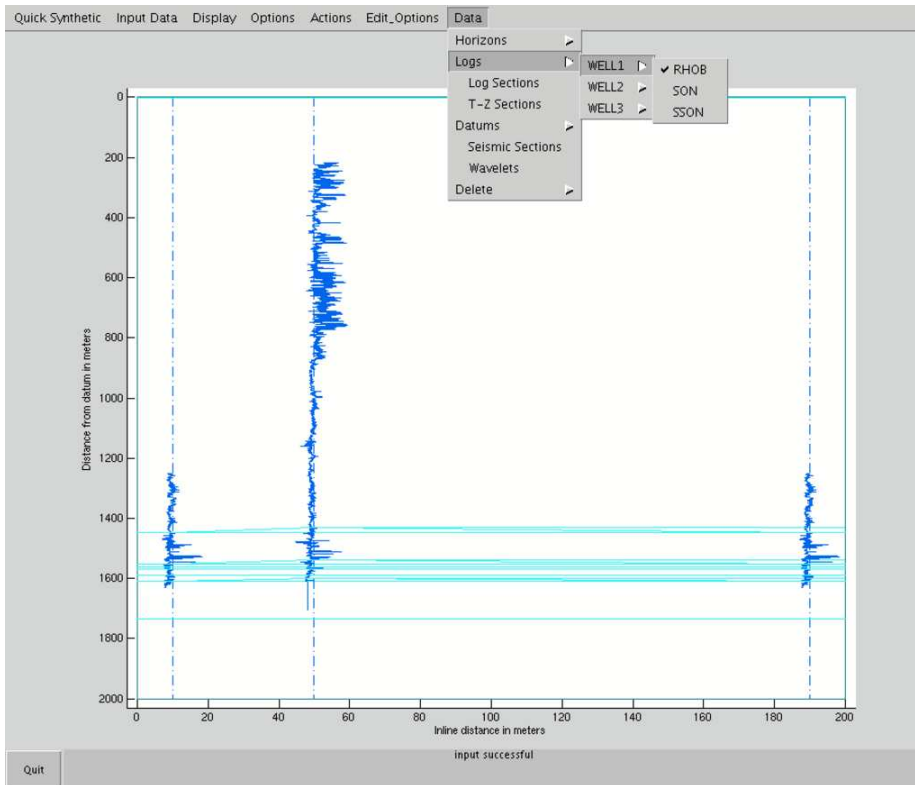


FIG. 11. Selection of log types.

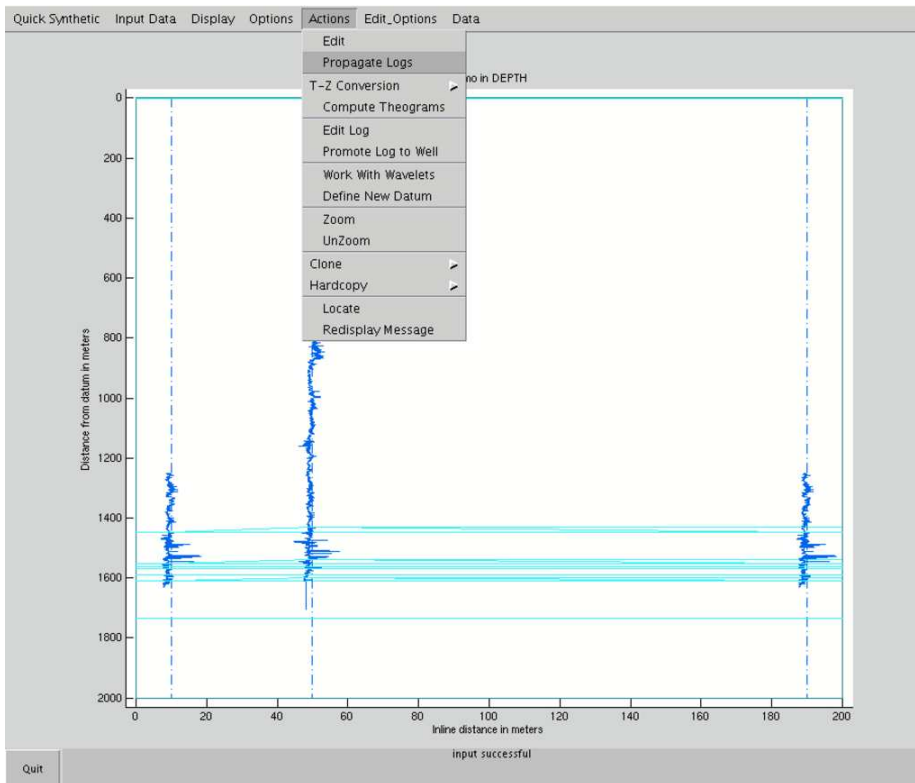


FIG. 12. Propagation of logs

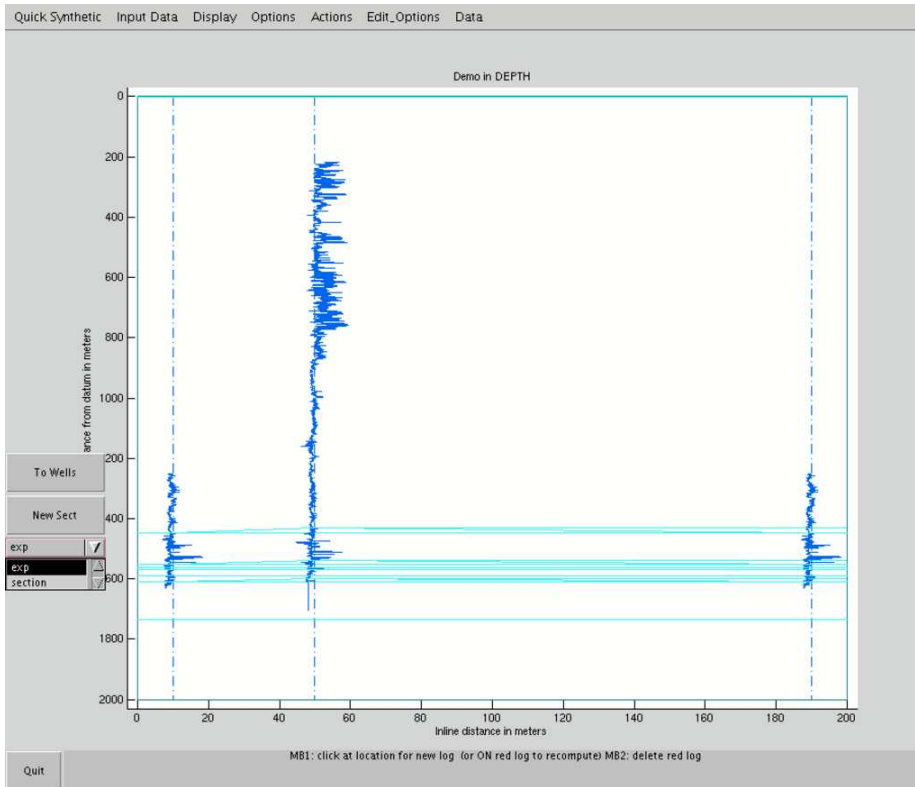


FIG. 13. Selection of “section” propagation

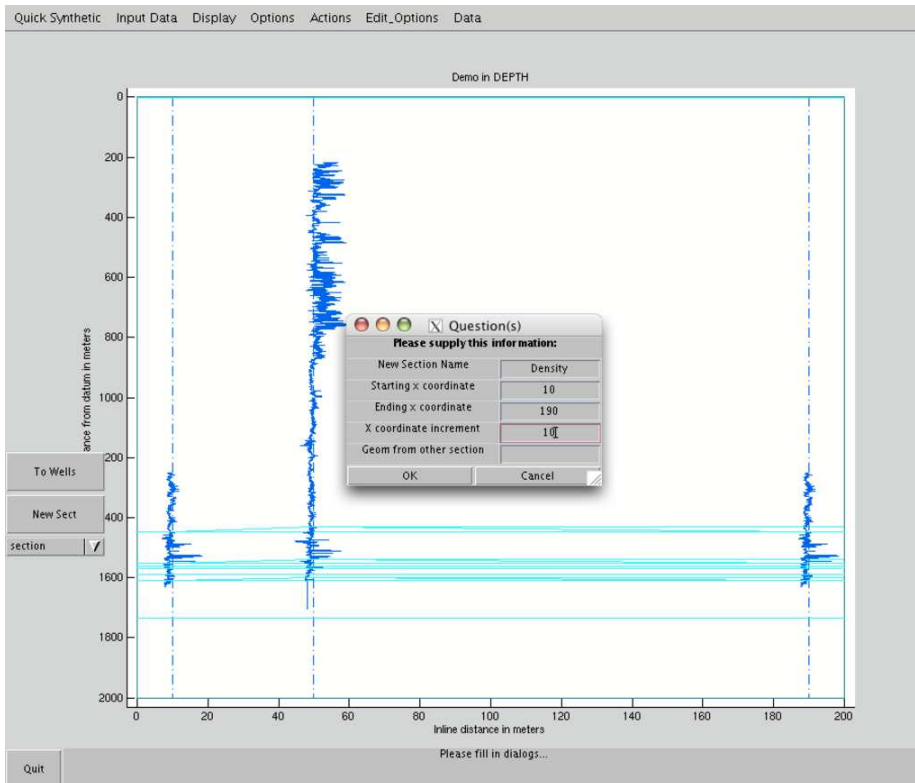


FIG. 14. Section creation dialogue

The figure shows two windows from the SYNTH/LOGSEC modelling facility. The left window, titled 'Number of receivers per shot?', contains the following parameters:

- Number of receivers per shot? (input field): 11
- Receiver spacing? (m) (input field): 100
- Near offset? (m) (input field): 0
- Shot depth? (m) (input field): 0
- Receiver depth? (m) (input field): 0
- Recording length? (s) (input field): 2

The right window contains the following parameters:

- Surface V_P (input field): 2000
- Surface V_S (input field): 1000
- Surface Density (input field): 2000
- Default Section V_P/V_S (input field): 2
- Simple Q value? (input field): Inf
- Model transmission losses? (dropdown menu): No
- Model spherical divergence? (dropdown menu): No
- Gardner scalar? (input field): 310
- Gardner exponent? (input field): 0.25
- Phase rotation? (degrees) (input field): 0
- Max offset/depth ratio? (input field): 1

Both windows have 'OK' and 'Cancel' buttons at the bottom.

FIG. 15. Synthetic seismic parameter selection

imported. When the new log type is displayed for each well, select the “New Sect” button on the left of the GUI. A prompt will appear to confirm and save the interpolated data that was generated. Select “Yes” and then “Ok” to continue. For the next section, ensure that the geometry of the new section has exactly the same size and shape as the previously-generated P-wave sonic section.

Repeat this procedure for the remaining logs (if all three log types are used). When all log sections have been generated, select the “Propagate Logs” item from the “Actions” menu (Figure 12) once again. This will deselect the propagation mode of the program, and the GUI elements on the left hand side should disappear.

Next, select “Edit Model Parameters” from the “Quick Synthetic” menu (Figure 15) to observe the parameters of the synthetic seismic program. Two windows will appear, one after the other. If you are satisfied with the first set of parameters, click “Ok” and inspect the second set. The parameters are set to generally useful defaults for most surveys, so this step is optional. If you wish to estimate the S-wave sonic and/or density log sections, you may set the V_P/V_S and Gardner’s rule parameters in the second.

After this, a wavelet must be chosen from a file containing suitable MATLAB-formatted wavelets. To choose a wavelet for convolution with the P-P reflectivity series, choose “Quick Synthetic” and select “Load P-P Wavelet”. This dialogue (Figure 16) allows the user to select the appropriate (stationary) wavelet to use for all P-P data. Wavelets are generally created with the CREWES software package WAVELETED. In a similar fashion, “Load P-S Wavelet” must also be selected to choose the wavelet for convolution with the P-S reflectivity series.

Finally, the appropriate sections must be chosen with the “Choose Sections” button in the “Quick Synthetic” menu (Figure 17). For each of the log types, choose the section that was generated from the pop-up menus. A P-wave sonic section must be selected. If you do not want to use a section for S-wave sonic and density, select “NONE” and one will be estimated using the V_P/V_S relation and Gardner’s rule. Otherwise, choose the interpolated sections that were previously generated.

Now the software is prepared for synthetic seismic data generation. Choose “Make Seismic” and watch the MATLAB command window for progress updates. Upon completion, time and depth windows will automatically display (see Figures 4 and 5). These windows may be dismissed without loss of data.

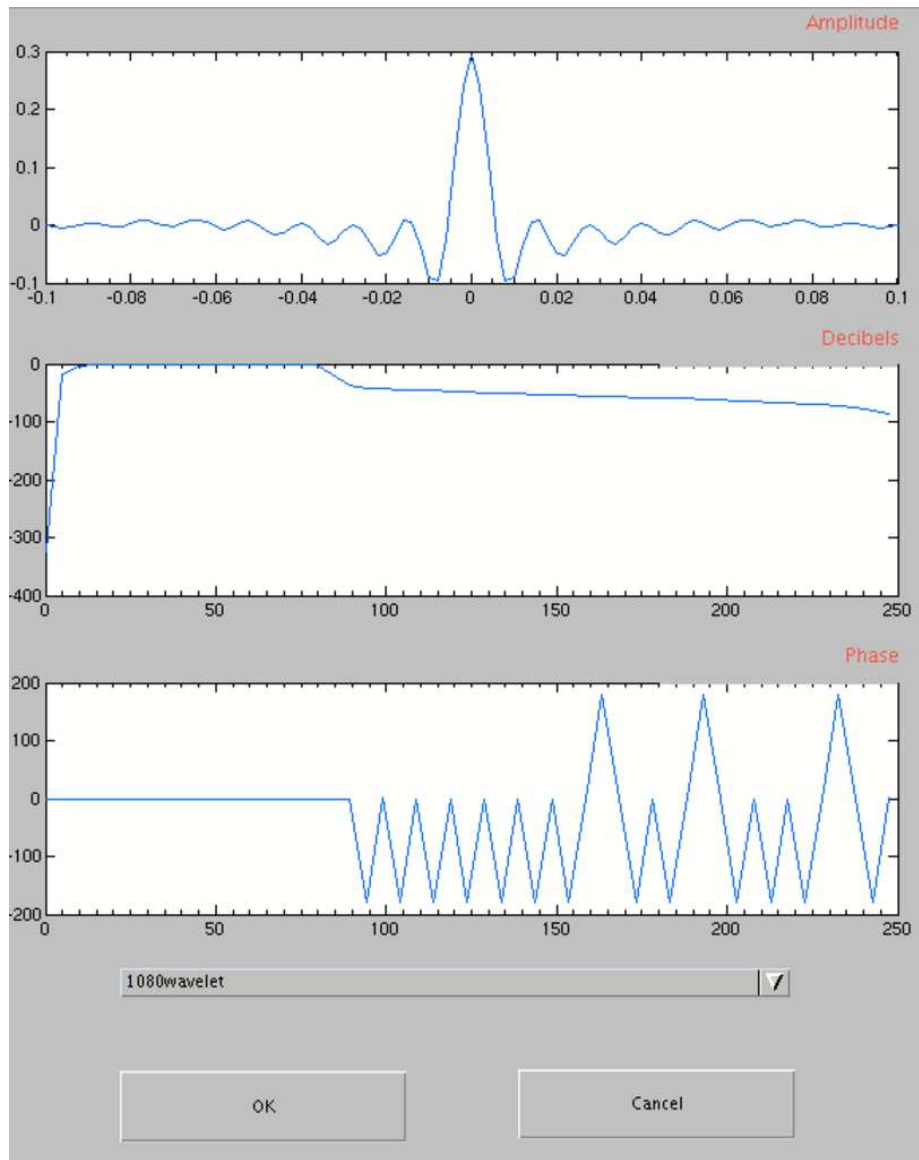


FIG. 16. Choosing a wavelet

Sonic log section sonic

Shear log section NONE

Density log section NONE

Choose the sections that are generated for sonic, shear, and density logs. If you do not have a section for a type of log, choose "NONE". You must choose at least a sonic section.

OK Cancel

FIG. 17. Choosing log sections

P-P Data

Vertical Gathers DemoModel/PPVerticalGathers.segy Choose..

Radial Gathers Choose..

Hydrophone Gathers Choose..

Vertical Stack bFDemoModel/PPVerticalStack.segy Choose..

Radial Stack Choose..

Hydrophone Stack Choose..

P-S Data

Vertical Gathers Choose..

Radial Gathers fFDemoModel/PSRadialGathers.segy Choose..

Hydrophone Gathers Choose..

Vertical Stack Choose..

Radial Stack Choose..

Hydrophone Stack Choose..

Export Data Cancel

FIG. 18. Exporting synthetic data to SEG-Y

When a successful synthetic section has been produced, this data may be exported to SEG-Y for further processing or investigation with traditional software tools (Figure 18). Right-clicking on the data within the time and depth windows will also allow export of data to SEG-Y. Some or all of the various stacks and gathers may be exported to SEG-Y. Stacks and gathers may also be exported to a MATLAB saved data file by right-clicking on the data within the time and depth windows.

The generated SEG-Y files contain EBCDIC headers and little-endian data.