PROCESSING REFLECTION SEISMIC DATA WITH REFLEXW©

INTRODUCTION

Reflexw© is a software for processing and interpretation of refraction, reflection or transmission data from seismic or GPR surveys. It runs under *Windows™* and consists of 5 modules:

- ***2-D Data Analysis*** for data processing of 2D and 3D data using a 2D display approach
- ***CMP Velocity Analysis*** for velocity analysis of *CMP* or *Moveout data*
- ***3-D Data interpretation*** for 3D data display
- ***Modelling*** for modelling of seismic or electromagnetic waves using a finite difference approximation
- ***Traveltime Analysis 2-D*** for analysis and interpretation of first arrivals (refraction seismics)

RUNNING THE SOFTWARE

Run the software from the list of the installed programs or from the virtual desktop. The software asks you to create ("new project") or to select ("confirm project") a folder on the local disk or on the virtual machine where you have the write permission. If a new folder is created, the software will also create some subfolders where it will save the data:

ASCII
LINEDATA
MODEL
PROCDATA
ROHDATA
TRAVTIME

At the end of the lab session, you can save your work by copying the project folder and subfolders on a USB pendrive.

FK FILTER FOR GROUND-ROLL REMOVAL

Be sure to have the required data file: RRAW.SGY and copy this file using windows explorer into the ASCII subfolder.
Run the *2-D Data Analysis module* to import and display the data. The data format is SEGY, one of the standard formats internationally used to save and exchange seismic data. The format is shortly described in the following box.

File Header: it consists of 3200 bytes of text-header and 400 bytes of binary header and contains some info related with the whole file (e.g., time sampling, number of samples,..).
Trace Header: it consists of 240 bytes per trace and contains some info related with each single trace (e.g., source and receiver coordinates)

File headers		Seismic traces					
3200 bytes text header (EBCDIC)	400 bytes binary header	240 bytes trace header	seismic trace data	240 bytes trace header	seismic trace data	240 bytes trace header	seismic trace data

SEGY file structure

Open the Data Import window with the File/import command or with the Import icon .

Have a look at the parameters and options that can be selected.
In the *Fileheader-coordinates* box you are supposed to enter the geometrical info:

- *DistanceDimen.*: the measuring unit for distances (*mm,cm, m, in, ft, tracenr.*).
- *data type*: the type of survey (*const. offset, single shot, several shots,3-D const offset, timeslice*).
- *rec. start:* the coordinate of the first receiving station.
- *rec. end:* the coordinate of the last receiving station.
- *lat. Offset:* the lateral offset of the receiving spread.
- *shot pos:* the coordinate of the seismic source.
- *shot lat. offset*: the lateral offset of the source.
- *number:* an integer number between 0 and 99 that will be used to define the name of the output file when the automatic name option is selected.

The RRAW.SGY files is a Common Shot gather recorded with a 59 channels off-end spread. The group interval is about 12.3m and the first group is 33m far from the source while the last group is at 747m from the source. Based on that, enter the coordinates of the first and last receivers and the coordinates of the shot.

Within the *format specification* box you are supposed to enter:

- *input format:* the format of the data file (*SEGY, SEG2, SEG2-RADAR, RADAN, RADAN_ANALOG, pulseekko, MALA RD3, EMR, UTSI, INFRASENSE, IDS, BGREMR,TRS2000, ABEM, BISON-2, OYO8BIT,ASCII-1COLUM and ASCII-MATRIX*).
- *Output format:* the format of the output file (*new 16 bit integer, new 32 bit floating point, old 16 bit integer, old 32 bit floating point*). The suggested format for seismic data is *new 32 bit floating point.*
- *scaling:* if the dynamic range of the output format is lower than the input data dynamic range, it is necessary to rescale the data by a proper factor so that they can fit the output dynamic range.

Within the *ControlOptions* box you are supposed to select some options whose meaning is described in the software manual. For the specific case, select only the options *Control Format, Read Starttime, Read File Header, Ignore Scaler.*
In *filename specification* you can enter the name of the output file or you can select the *original name* option so that the input filename will be used to define the output filename.
Within the *Time and comment specification* box you can enter the time measuring unit and (for some input data format) the sampling interval, the number of samples per trace, the size of the file header and trace header (in bytes). It is also possible to enter a comment text that will be saved in the output fileheader.
For a comprehensive description of the *Conversion Mode* options the reader can refer to the software manual. In the specific case there is no need to select any conversion option.
Within the *update traceheader* window, select the *fileheader* option so that your source and receiver coordinates, as specified in the *fileheader coordinates* box, are saved into the file trace headers.
Once the Import parameters are set up, click on Convert to Reflex and select the file to be imported (RRAW.SGY).
A table containing the *traceheaders* will appear in a new small window.
After checking that the coordinates are consistent with the spread geometry, close the traceheader window and look at the seismic data display. Use the *options* command from the *plot* menu to open the plot option window and optimize the data display.
Select the *wigglemode* option to display the signal waveshape. Optimize the plotscale value so that you can see each trace with proper amplitude without overlapping between neighbouring traces. Test the *tracenormalize* option to normalize each trace separately and compare the display with what you see when the option is not active. Refer to the software manual or to the software *Help* for further options available in the *plot* option window.
The data are sampled with a sample interval of 8ms. As a result each wavelet is described by a few number of samples. Zoom on some event to observe the poor description of the signal resulting from the linear interpolation adopted by the display software. To improve the wavelet

imaging, resample the data at a high sampling frequency by running the *1D-Filter* command from the *Processing* menu and by selecting the *Resampling* option. Select frequency in the *Working range* box and set the new sampling interval to 1ms. Click on *Start* and compare the result with the original data by zooming on some event.

Deselect the zoom using the *1/1* icon and observe the whole data and the ground-roll affecting the data. Ground-roll is the fan of low frequency and low velocity noise that partially disturbs the hyperbolic reflections. The objective is to design a dip filter in the FK domain that can remove this noise while preserving the hyperbolic reflections.
Run the *FK filter* command from the *Processing* menu. Select the *fk-filter* option on the new window that will appear. Generate the FK spectrum by clicking on the corresponding button at the bottom of the window. Optimize the display of the FK spectrum working on the plot options (e.g., de-activate the *Tracenormalize* option if active, select the *Pointmode* display with a proper colorpalette and limit the amplitude range of the colorbar to positive numbers). Select the option *Manual input* and design the mask of the filter to remove the ground-roll. Apply the filter and if the result is not successful try again or apply a second filter on the first result to improve the final result. To evaluate the results, compare the data before and after the filter by splitting the display in two vertical windows. Discuss the results with the instructor.

TVF FILTER

Be sure to have the required data file: 257Snew.SGY and copy this file using windows explorer into the ASCII subfolder.
Run the *2-D Data Analysis module* to import and display the data. The file consists of a stack section. There is no need to enter the coordinates of receivers and shots. Within the *ControlOptions* box, select only the options *Control Format* and *Read File Header*. Within the *update traceheader* box, do not select any option.
Optimize the display of the data.
Generate a band-pass filter bank with narrow adjacent bands (e.g., 15Hz). You can use the *Bandpass-Butterworth* filter from the *Processing/1D-Filter* menu activating the *SequenceProc* option. In the *Sequence Processing* window, select the *SingleProcess* option so that each filter that you will add to the processing sequence will be applied to the original input data and not the result from the previous filter in the sequence. Add the narrow bandpass filters to the sequence. Add also a very large bandpass filter (e.g., from 10 to 80 Hz) to create a reference copy of the original data to be compared with the filtered results. Save the sequence in a file so that you can modify and apply again the sequence if you need to change some parameters. Click on the *StartCurrentLine* button so that the original data will be filtered with each filter defined in the sequence and the result will be saved in a new file distinguished by a progressive number within the PROCDATA subfolder.
Use the *File/Open1-4Line* command to open more than one file simultaneously, up to a maximum of 4. As an example, compare in three vertical windows (use the *HorSplit* option) the reference file filtered from 10 to 80 Hz and a couple of narrow filter results. Compare all the results from the narrow filters with the reference file. The objective is to define the optimal band of a Time Variant Filter. Take into account that the ReflexW software offers the opportunity to design a TVF filter by defining only the band at the minimum time and the band at the maximum time. At intermediate times the TVF filter band will be automatically calculated by interpolation between the bands at min and max times.
Once the analysis has been completed, open the TVF filter menu by using the *Processing/1D-Filter/FilterTimeDependent* function. Enter the filter parameters at min and max times according to the results of your bank filter experiment. Apply the TVF filter and compare the result with the original data. Discuss the final result with the instructor.

VELOCITY ANALYSIS

Be sure to have the required data file: SEISMIC1.00R and SEISMIC1.00T and copy these files using windows explorer into the PROCDATA subfolder.

Run the *2-D Data Analysis module* to open and display the data with the command *Open*. The data consists of 39 Common Shot gathers with a total of 975 traces. Each CS gather consists of 25 traces recorded with a symmetrical split spread. The geophone spacing is 2m. Single geophones rather than group of geophones were used due to the very short receiver interval. The central trace of each gather is the zero offset trace.
For a better visualization of the data, zoom on the horizontal axis to display only a few CS gathers at a time. The time range (from 0 to 150 ms) and the very short source-receiver distances indicate that these data are the result of a high resolution survey for investigation of very shallow targets.
Optimize the display parameters and scroll the CS gather along the seismic profile to have a first look and to check the data quality. Note the presence of refracted arrivals, hyperbolic reflections and lateral artifacts at the edge of the profile.
Use the command *File/EditFileHeader* or the corresponding icon to open the *FileHeader* window and select the *ShowTraceHeader* button to open the *TraceHeader* window. Look at the source, receiver and CMP coordinates of the first trace. Increase the trace number and look at how the coordinates are changing. You can note that the source interval is 2m, equal to the geophone interval. Thus, what is the expected theoretical fold, i.e., how many traces are expected in any CMP gather?
Select the *CMP* option on the 2D-DataAnalysis window to load the menu for CMP data processing.
Select the *CMP sorting* option, choosing the *Offset* parameter as *SecondAxis* and update the data display by clicking on the *Show* button. The data will be displayed with a new organization based on CMP gathers. Zoom on the horizontal axis to display only a few CMP gathers at a time and scroll the gathers along the profile. Note that the first and last gathers at the edge of the profile are not complete, i.e., they have a lower fold compared to the expected theoretical fold. When the fold is maximum, e.g., at the center of the profile, how many traces are in a CMP gather? Note also that CMP gathers are alternatively populated by odd and even offsets.
Overall, the CMP gathers are 103, but the gathers with nominal fold are less than 103. The velocity analysis is usually performed on a selection of CMP gathers distributed along the profile. Thus, you are expected to enter the number of the first gather that will be analyzed and the interval between the gathers that will be analyzed. The suggestion is to work only on CMP gathers with nominal fold. So, start with the first CMP gather with nominal fold and select an interval that will produce 4 or 5 velocity analysis with the last analysis on one of the last CMP gathers with nominal fold. The parameters to enter are: *1CMP*, *LastCMP* and *Increment*. Then, start the velocity analysis by clicking on the *VelocityAnalysis* button.
The software asks for the *TraceIncrement*, i.e., the offset increment in meters between the traces that belong to the same CMP gather. The default value proposed by the software is calculated on the nominal increment expected from a regular acquisition. Confirm this value.
A new window will appear showing the first CMP gather to be analyzed (right side of the window) and the initial velocity model, with a constant velocity set at 3000m/s (left side of the window).
Select the options *View/NMOCorrectedEnsemble* and *View/StackTrace* from the *View* menu to display the CMP gather after NMO corrections and the corresponding stack trace. These images are automatically updated while the velocity analysis is in progress, so that the operator has a real-time feedback on the expected result from the NMO corrections performed with the current velocity function. Select the options *Vrms* and *Reflection* because the analysis is applied to a reflection seismic survey and the resulting velocity function is a stack velocity, which is about equal to the Root Mean Square Velocity of the layered geological structure. Select the *Semblance* or the *Unnormalized Corr* button according to the preferred coherency operator. Enter the velocity range (min and max velocity) and the velocity interval (i.e., the increment between testing velocities). For each velocity the software will apply the NMO corrections and will calculate the coherency operator.
Select the preferred Colorpalette to display the velocity spectrum and click on the *start* button. If the result is not optimal, regenerate the velocity spectrum after optimizing the velocity range and the velocity interval parameters. Look at the velocity spectrum. Move the mouse on the velocity spectrum and observe the shape variations of the synthetic hyperbola overlapped on the CMP data. Before beginning the velocity analysis, regenerate the velocity spectrum with the same velocity range and interval but using the other operator (semblance versus correlation). Compare the velocity spectra produced by the two operators and discuss the differences with the instructor. Choose the operator that is preferable on these data and start with the velocity analysis.

Select the *Insert* option and use the mouse to generate a time-velocity function on the velocity spectrum by clicking on the points where coherency is high and synthetic hyperbolas fit the most important reflections. Note that after any click the software updates the NMO corrected data and the stack trace. It also updates the velocity functions on the left panel. The dashed function is the estimated stack velocity while the other function is the corresponding interval velocity function calculated according to DIX equation. To better display these functions, optimize the axis parameters, i.e., the min and max velocities and the label interval (*dv*), and then the min and max depth and the label interval (*DeltaDepth*). Update the display with the *Plot/Reset* command. If you are not satisfied with the results of the first analysis, it is possible to reset and repeat the velocity picking by clicking on the *Reset* button. Once you are satisfied with your picks, save the velocity function with the *Save* button. The software automatically suggests a name that is associated with the analyzed CMP gather.
Press the Next button to move to the analysis of the following CMP gather. The software will present the data of the new CMP gather overlapped by the hyperbolic reflections picked on the previous gather. On the left you see the corresponding velocity functions, the stack trace and the data after NMO corrections. If the current gather and the previous gather are very similar, the user can find convenient to adjust the previous picks to the new situation. For this analysis the suggestion is to remove the previous analysis with the *Reset* button and to run a new analysis by selecting the preferred operator (*Semblance* or *UnnormalizedCorr*). At the end of the new analysis, save the result with the *Save* button. Press *Next* and repeat the procedure for all the planned velocity analysis.
At the end of the velocity analysis, select the *2D-Model* option in order to generate a 2D model of the velocity distribution along the seismic line as a result of a process of lateral interpolation of the picked velocity functions. Enter the size of the model (min and max distance and min and max depth). Select the *CreateCorefile* option so that the picked velocity functions are saved in the *ASCII* subfolder in a file with *.COR* extension that will be used to generate the 2D velocity model. Enter a name for the raster file that will be saved with *.DAT* extension in the *ROHDATA* subfolder. Select the *Create* button and load all the files that contains the results of the CMP gather velocity analysis. Enter a name for the velocity model that will be obtained by interpolation. The model will be shown on the right with a color scale. If necessary, the model can be plotted again later by using the *2D-DataAnalysis* module to open the raster file saved with *.DAT* extension. The single velocity functions saved as ASCII files with extension *.COR* can be opened with Notepad or with any other editor.
Conclude the velocity analysis by leaving the *CMP-VelocityAnalysis* environment and return to the *2D-DataAnalysis* window.

NMO CORRECTIONS AND STACK

Select the *NMO-Stack* option and load the 2D velocity model produced by the previous velocity analysis. Check that the data are sorted by CMP gathers and select the whole range of CMP gathers with step 1 in order to apply the NMO corrections to all the CMP gathers.
Press the *Correct* button to apply the NMO corrections. Enter a name for the output file. A preview of the result will be shown on a new graphic window. Close the window, deselect the *CMP* option and load the data after NMO corrections with the *File/Open/ProcData* command. Zoom on the horizontal axis to display only a few CMP gathers at a time and scroll along the profile to check whether NMO corrections have successfully flattened the reflections. Look on top of each CMP gather to see what happened to the refracted arrivals. They are supposed to be highly stretched and they should be muted. However, since they are not overlapped with reflecting events, it is more convenient to apply a muting function directly on the stack section.
Press again the *CMP* button. Check that the sorting *CMP* option is active and select again the whole range of CMP gathers with step 1. Press the *Show* button to display the data. Check that the *NMO-stack* option is active. Press the *Stack* button to generate the stack section by summing all the seismic traces belonging to the same CMP gather. Enter a name for the file where to save the stack section. A new graphic window will show a preview of the stack section. Close the window, deselect the *CMP* function and load the stack section with the *File/Open/ProcData* command.
Observe the quality of the stack section. Observe the disturbing effects generated by the refracted events on the upper part of the section. Observe the presence of artifacts and reflectors that need migration. Discuss the result with the instructor.

BANDPASS FILTER AND MUTING

Apply a bandpass filter with the *Processing/1D-Filter* command to improve the stack section.
Delete the refracted events with a muting function (use the *Processing/StaticCorrection/Muting*). The command will open a Muting window where you have to select the *Muting* option and then the *MuteDataAboveMutingCurve*. Select the *Insert* option and use the mouse on the data window to define the Muting curve. Pay attention to remove only the refracted events without deleting important reflections.
Increase the *ProcessingLabel* and press the *Start* button to apply the Muting function. Compare the stack sections before and after muting.

MIGRATION

Open the migration menu with the *Processing/Migration* command. Test three different types of migration and compare the results:

a) Kirchhoff migration with constant velocity (look at the 2D velocity model saved at the conclusion of the velocity analysis and choose an approximate average velocity)
b) Kirchhoff migration with 2D velocity field
c) Finite-difference migration (for choosing the nominal frequency, look at the average spectrum of the data with *View\Profile Histograms* and approximately select the central frequency of the spectrum)

Compare the migrated sections with the unmigrated data. Discuss the results with the instructor and select the best migrated section.

FINAL FILTERS

Try a bandpass filter to improve the final image by removing the noise and the artifacts generated by migration.
Try a 2D filter to improve the general quality of the section and the continuity of the reflectors. As an example, open the 2D filter window with the *Processing/2D-Filter* command and try to optimize experimentally the parameters of a 2D moving average filter (*Average XY-Filter*).

DECONVOLUTION

Try a deconvolution in order to improve the resolution. *ReflexW* offers many deconvolution functions. Test the *SpectralWhitening* function from the *Processing/ComplexTraceAnalysis* menu. This is basically a zero-phase deconvolution. Apply the function and compare the results before and after deconvolution. Use the *View\Profile Histograms* function to compare the average spectrum before and after deconvolution. If deconvolution was successful, the spectrum is expected to be more homogeneous within the bandwidth selected for the *SpectralWhitening* application.

TIME-DEPTH CONVERSION

Apply depth conversion to the migrated and deconvolved section by using the *timedepth conversion* command from the *migration* menu. Use the 2D velocity model that was also used for migration. Discuss with the instructor the results before and after depth conversion.

MULTIPLE SUPPRESSION

Be sure to have the required data file: *ShortStack.00R* and *ShortStack.00T* and copy these files using windows explorer into the *PROCDATA* subfolder.
Run the *2-D Data Analysis* and load the data with the *Open* command. It is a short segment of a stack section produced with the data from the previous survey.
Watch the data and look for possible multiples. To detect periodical events and to estimate the period you can calculate the autocorrelation of the data with the *Processing/1D-Filter/Autocorrelation*

command.
Try to suppress the multiples with a gapped deconvolution. Use the *Processing/1D-Filter/Deconvolution/Shap.* command. Select the *predictive* option. Use a long autocorrelation window (e.g., from 0 to 130ms) and a 50ms filter length. Enter in the *Lag* dialog box the gap, i.e., the period of the multiples. Select the *MeanAuto* option so that all the data will be deconvolved with the same deconvolution operator. Run the function and repeat, if necessary, trying to optimize the gap in order to produce the most effective multiple suppression. Discuss the results with the instructor.