

An investigation of the Radon transform to attenuate noise after migration

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ABSTRACT

The Radon transform is a useful tool that is used in industry to reduce the presence of multiples in seismic data. The three main drawbacks of the Radon transform are: smearing, data loss and creating a non-unique solution from unique input data. The Jumping Pound data set was processed in VISTA, and a Radon transform was added to the processing flow. Three different migration algorithms were used to process the data: finite difference migration (15 degrees and 45-65 degrees), and Kirchhoff migration; and the Radon transform was added to each migration method. The Kirchhoff migration with or without the Radon transform shows the best resolution of horizontal and dipping events.

INTRODUCTION

There are three unique types of Radon transforms that have been defined to reduce multiples in seismic data; the slant stack (τ -p), the hyperbolic and the parabolic Radon transforms (Cao, 2006). The τ -p Radon transform reduces multiples based on their periodicity (Cao, 2006). Both the hyperbolic and parabolic Radon transforms reduce multiples based on the moveout difference between primaries and multiples (Cao, 2006). Although there are many advantages of the Radon transform, there are three major drawbacks, which are outlined below.

The purpose of this research was to gain familiarity with the VISTA processing software and the Radon transform function within VISTA. The Jumping Pound data from Gary Margrave's Geophysics 557/657 Seismic Processing course was used to go through the processing steps. I followed the processing steps that Joanna Cooper and Saul Guevara outlined as teaching assistants for the Seismic Processing course. The default VISTA Radon transform function was used to illustrate the effects of the Radon transform on the seismic section.

USE AND DRAWBACKS OF THE RADON TRANSFORM

VISTA processing has a default 2D Radon transform that, when combined with the other processing tools (such as NMO, velocity analysis, etc.), can be used as a valuable method to reduce multiples in seismic data.

When a CMP gather is transformed into the Radon domain, near offsets generally have the same amount of energy and are transferred to the Radon panel multiple times, which causes smearing (Cao, 2005). Cao (2005) outlined that the second major problem facing the Radon transform is the data loss. This loss is due to the fact that a Radon transform is not an orthogonal algorithm, so with every step of the process data loss occurs.

Cary (1998) illustrated that when you begin with one input section and transform it in different ways (he used four different methods), then complete the inverse process on these four results, you transform it back to the original input. Starting with the input data, the results after the four different forward transforms are completely unique from one another (Cary, 1998). When the inverse transforms are completed, the original input data is re-created, therefore a non-unique input set can create a unique solution when the forward transform is completed (Cary, 1998).

BACKGROUND OF VISTA PROCESSING

VISTA is a seismic processing tool developed by Geophysical Exploration and Development Corporation (GEDCO), which is based out of Calgary, Alberta. For the purpose of my research, I used VISTA to create data flows to process the CREWES Jumping Pound data (used in Gary Margrave's Winter 2007 Seismic Processing course).

METHODS

An overview of the steps that were used to process the Jumping Pound data are outlined in the following four VISTA flows. In the first flow, the raw shots were imported into VISTA, an Automatic Gain Correlation (AGC) with length of 400ms was completed, and FK filter was designed and applied, spiking deconvolution was applied and the result was then output. The second flow used the output from the first flow as input, and applied AGC of 400ms, spiking deconvolution, normal moveout, mean amplitude scaling, and CMP stacking. The third flow used the result from flow number two and added a static shift.

The fourth flow I created used the results from flow number three and produced three different outputs, using different migration techniques, and adding a Radon transform. I used a 15 degree finite difference migration, a 45-65 degree finite difference migration and a Kirchhoff migration along with the Radon transform function in VISTA (using the default parameters at first, to see if the results would tell me anything, and to get a baseline, before I started changing parameters).

RESULTS

The images below in figures 1, 2 and 3 are the respective finite difference migration (15 degree and 45-65 degree) solutions and the Kirchhoff migration solution without the Radon transform function on the top and with the default Radon transform added to the flow and illustrated on the bottom of each figure.

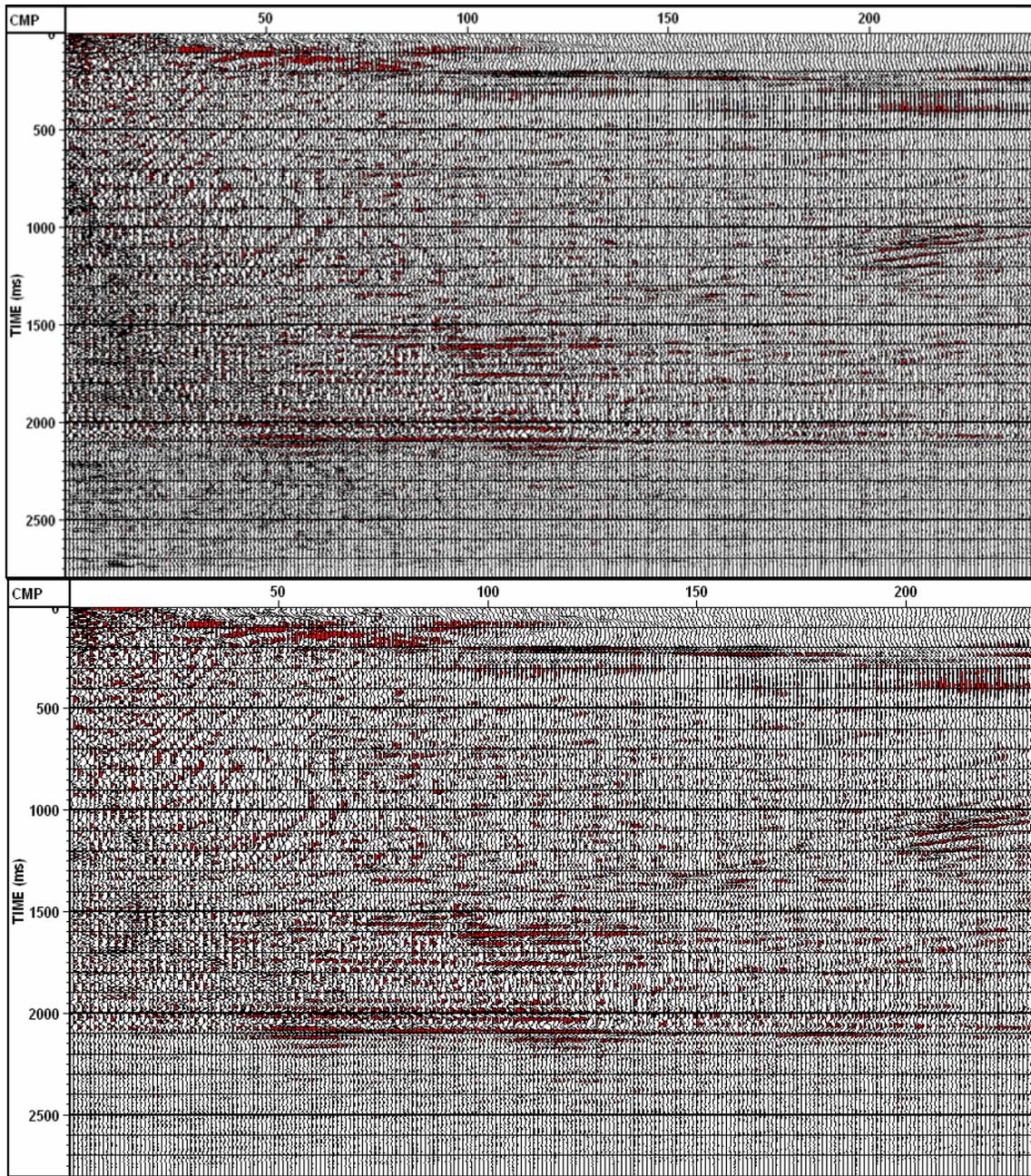


FIG. 1. Finite difference migration (15 degrees) without the Radon transform function (top) and with the Radon transform function (bottom).

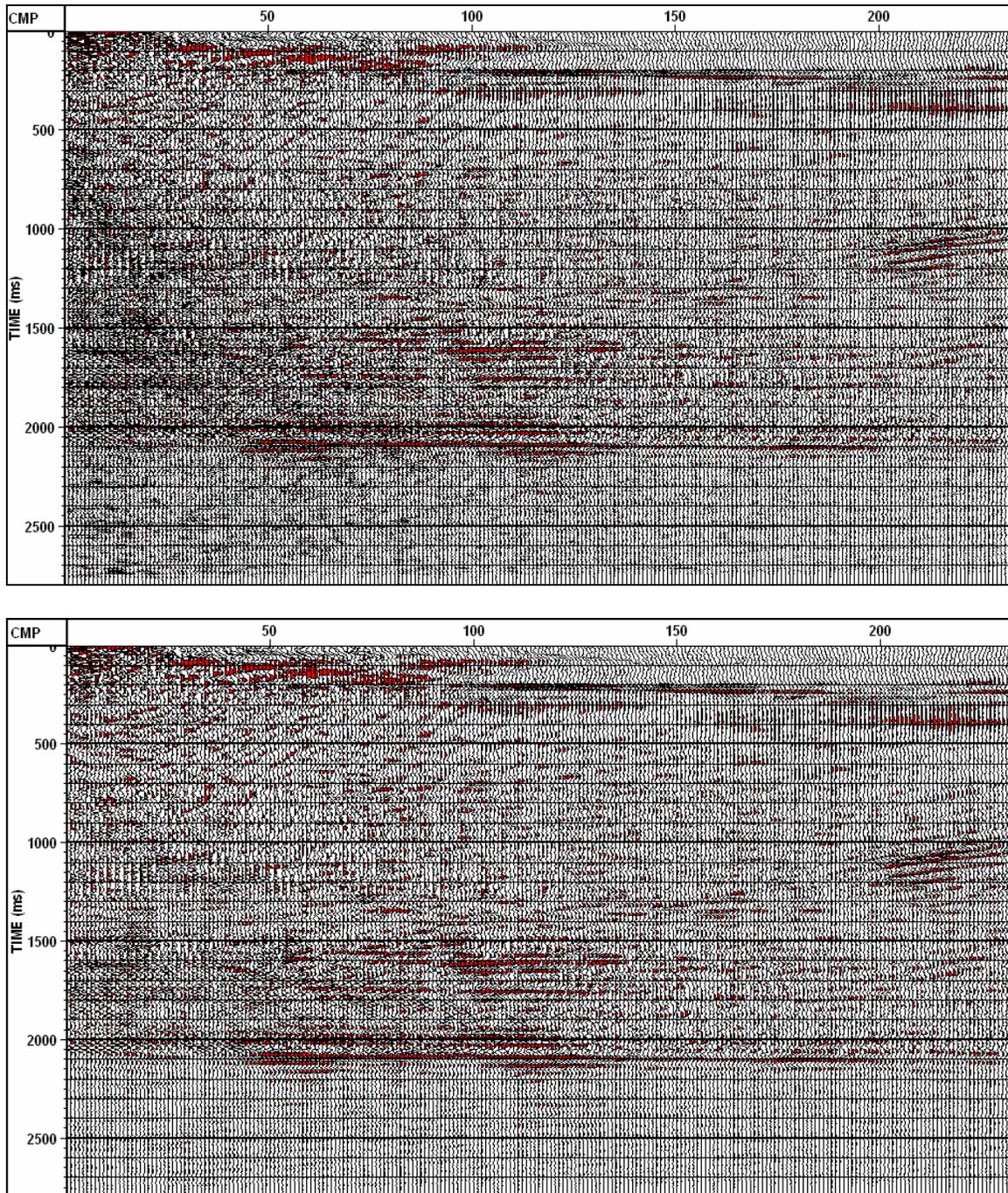


FIG. 2. Finite difference migration (45-65 degrees) without the Radon transform function (top) and with the Radon transform function (bottom).

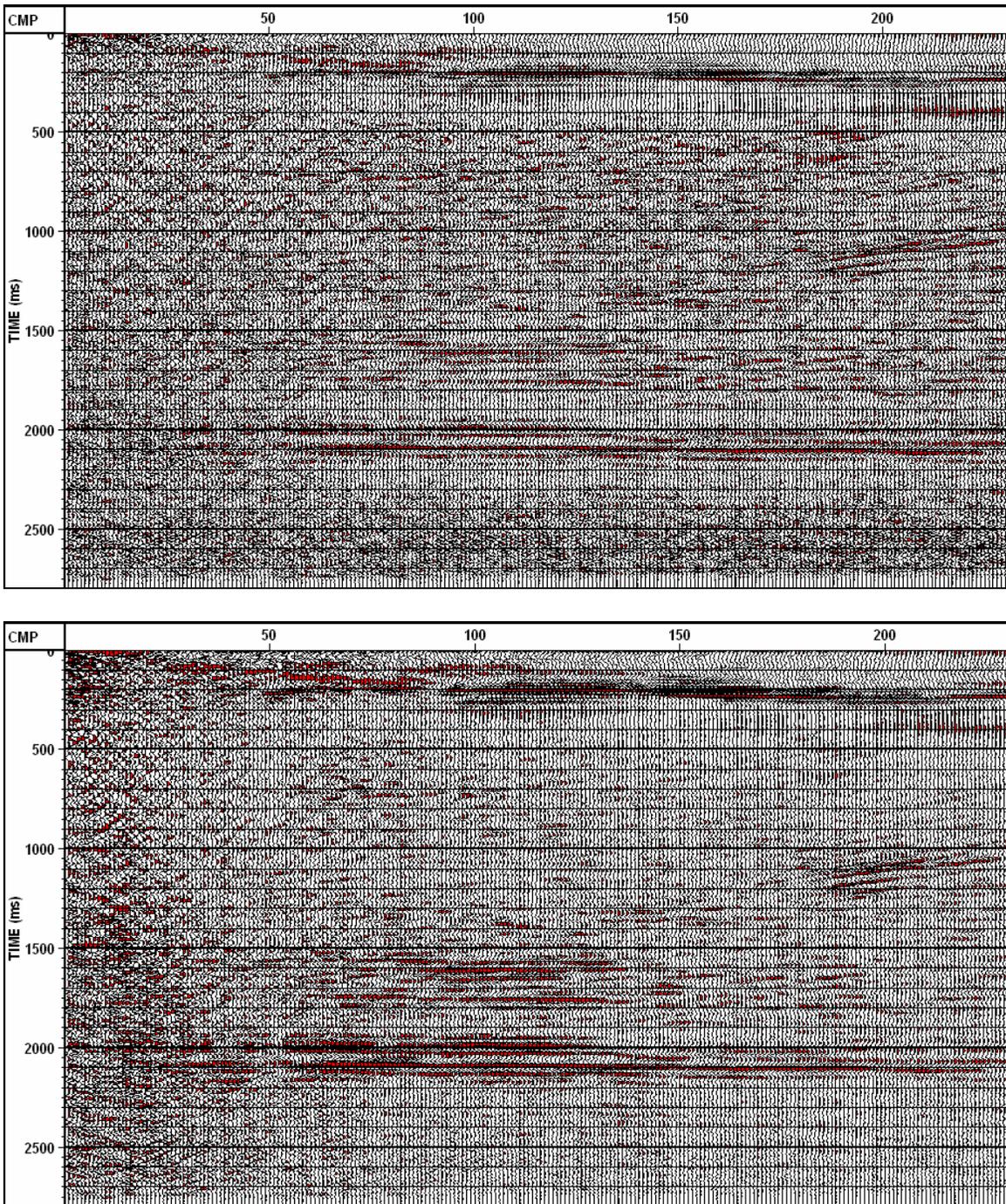


FIG. 3. Kirchhoff migration without the Radon transform applied (top) and with the Radon transform applied (bottom).

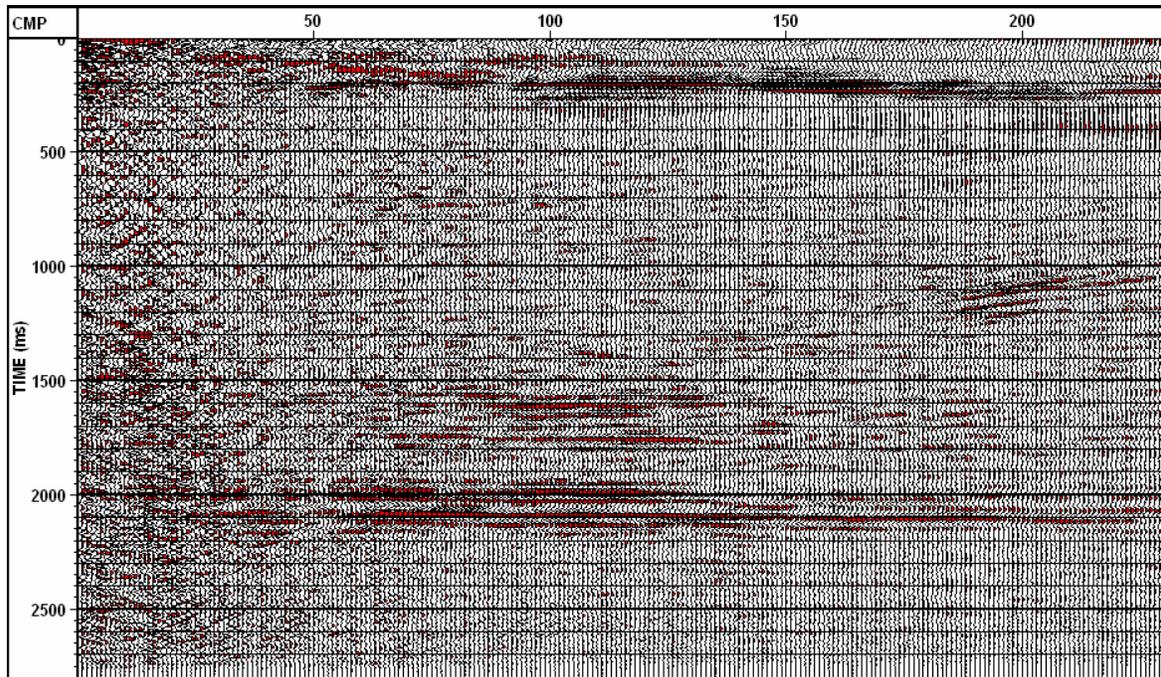


FIG. 4. Kirchhoff migration with the Radon transform interpolator set at 1 (instead of 0 in the default setting).

DISCUSSION

It is clear from the above images that the three different methods of migrating the Jumping Pound data produce similar results. For the purpose of familiarizing myself with VISTA and the Radon transform function in VISTA, I decided to use the default Radon transform parameters (for figures 1 through 3) and in figure 4 I changed the interpolating operator from zero to one, to see if my results would be impacted or enhanced.

It is clear that in the case of the Jumping Pound data, the Radon transform does not have much of an impact attenuating multiples. This is due to the fact that the data was originally used for the Geophysics 557/657 course as a processing exercise and multiple attenuation was not one of the main goals. As you can see in the above figures, performing the Radon transform on the data does give a slight enhancement of the picture, especially in the vicinity of the horizontal event towards the bottom of the image and the dipping events on the right of the image.

It was only for the purpose of learning how to process data and trying different processing options that I chose the finite difference migration at the two different angles and the Kirchhoff migration. From these images (the left sides of figures 1, 2 and 3), I would choose the Kirchhoff migration (figure 3) as the best migrated result. In this image, the horizontal and dipping events are more clearly visible, and there is less distortion in the rest of the migrated area (although along the edges, we see more distortion). This choice holds true through the Radon transformed step (the right sides of figures 1, 2 and 3) as the horizontal events become more dominant and there is a decrease in multiples in the center area of the screen.

Since this is just a very brief look at the Radon transform in VISTA, more work will need to be done on a different data set that contains more multiples. As mentioned above, this project was just to allow me to gain a greater amount of comfort and familiarity with processing in VISTA; having a geological background, I am just recently starting to process seismic data.

CONCLUSIONS

The Radon transform has a few very serious drawbacks: smearing due to near-offsets being transferred to the Radon panel, data loss as multiple transforms are processed (Cao, 2005) and inverse results being produced by non-unique starting points (Cary, 1998).

With respect to processing the Jumping Pound data set, I gained familiarity with many processing techniques such as AGC, F-K filtering, deconvolution, normal moveout, statics, and velocity picking. I used three different migration methods to examine the differences, advantages and fallbacks, finding that in this case, the Kirchhoff migration gave the best result. I added the Radon transform function to the processing flow of each of the three migrations and found that there is improved resolution in the areas around the horizontal and dipping events and that there are some edge effects that need further investigation.

As mentioned above, this was an elementary study to familiarize myself with VISTA, and more in-depth research is needed with a different data set.

ACKNOWLEDGEMENTS

The authors wish to thank the sponsors and staff of the CREWES consortium for financial support and technical assistance.

REFERENCES

- Cao, Z., 2006, Analysis and application of the Radon transform: University of Calgary, Department of Geology and Geophysics, Graduate Thesis.
- Cao, Z. and Bancroft, J., 2005, Radon Transforms and multiple attenuation of White Rose data: CREWES Research Report, **17**.
- Cao, Z., 2004, Radon Transforms and multiple attenuation of White Rose data: CREWES PowerPoint Presentation.
- Cao, Z. and Bancroft, J., 2004, Multiple attenuation by semblance weighted Radon Transform: CREWES Research Report, **16**.
- Cary, P., 1998, The simplest discrete Radon transform: 1998 SEG Expanded Abstracts
- Margrave, G., Cooper, J., Guevara, S., 2007, Geophysics 557/657 Course and Laboratory Notes.