Reflection seismic processing of the CCSS 2003 "high resolution" synthetic data set

C. Juhlin, J. Rodriguez and A. Tryggvason

Department of Earth Sciences, Uppsala University, Villavägen 16, SE-752 36, Uppsala, Sweden

Christopher.Juhlin@geo.uu.se

Approximately every three years the Commission for Controlled Source Seismology (CCSS) organizes a workshop where one or more data sets are processed and interpreted by various researchers using different methods. For 2003, two synthetic data sets were released prior to the workshop, a low resolution one along a 250 km long profile and a higher resolution one along a 45 km stretch of the model (175 km to 220 km). Both data sets were generated using a 2D viscoelastic code (Robertsson et al., 1994) and have receivers every 90 m. The low resolution synthetic data set has shot points about every 5 km and the higher resolution one shot points every 90 m. Shot point and receiver spacings of 90 m are close to those used in modern deep seismic reflection surveys (i.e., Cook et al., 1999). This prompted us to try to process the "high resolution" synthetic data set using using a commercial reflection seismic processing package. In this study we use only the vertical component of the synthetic "high resolution" survey for the reflection seismic processing.

Inspection of the shot gathers indicate the wavefield is dominated by scattering with few reflections from continuous interfaces. Some wide-angle reflections appear to be present in the shot gathers. The synthetic shot gathers have a similar appearance to real data acquired on Iceland (Figure 1). Note that the frequency content of the synthetic data is considerably lower than that of the real data from Iceland, therefore, the axes of the real data have been stretched to allow for a better comparison. The synthetic shot gathers may be divided into steep- and wide-angle components. The steep-angle component is that part of the shot gather containing data arriving after the strong surface wave, while the wide-angle component is that part arriving before the strong surface wave. A stack of the steep-angle component shows the upper 5 s to contain most of the scattering elements, corresponding to the base of the model at 15 km depth. Numerous processing schemes were attempted in order to extract continuous reflections from the steep angle component including radon filtering, but all failed. There does not appear to be any laterally continuous interfaces with sharp enough velocity contrasts present in the model that can be imaged at steep angles.

The presence of apparent wide-angle reflections in the synthetic shot gathers suggest that these events can be used to extract some information about the model. Constructive stacking of wide-angle reflections requires that the velocity field be well known. First arrival times from the low resolution synthetic data have been used to estimate a preliminary velocity field (Figure 2) to be used for the NMO correction prior to stacking. This field was calculated using the method described in Benz et al. (1996) and Tryggvason et al. (2002). Velocity analysis on the wide-angle reflections, as well as stacking tests at different percentages of the tomographic velocity field, indicate that a more coherent stack is obtained if the tomographic velocity field is scaled by 95% prior to NMO.

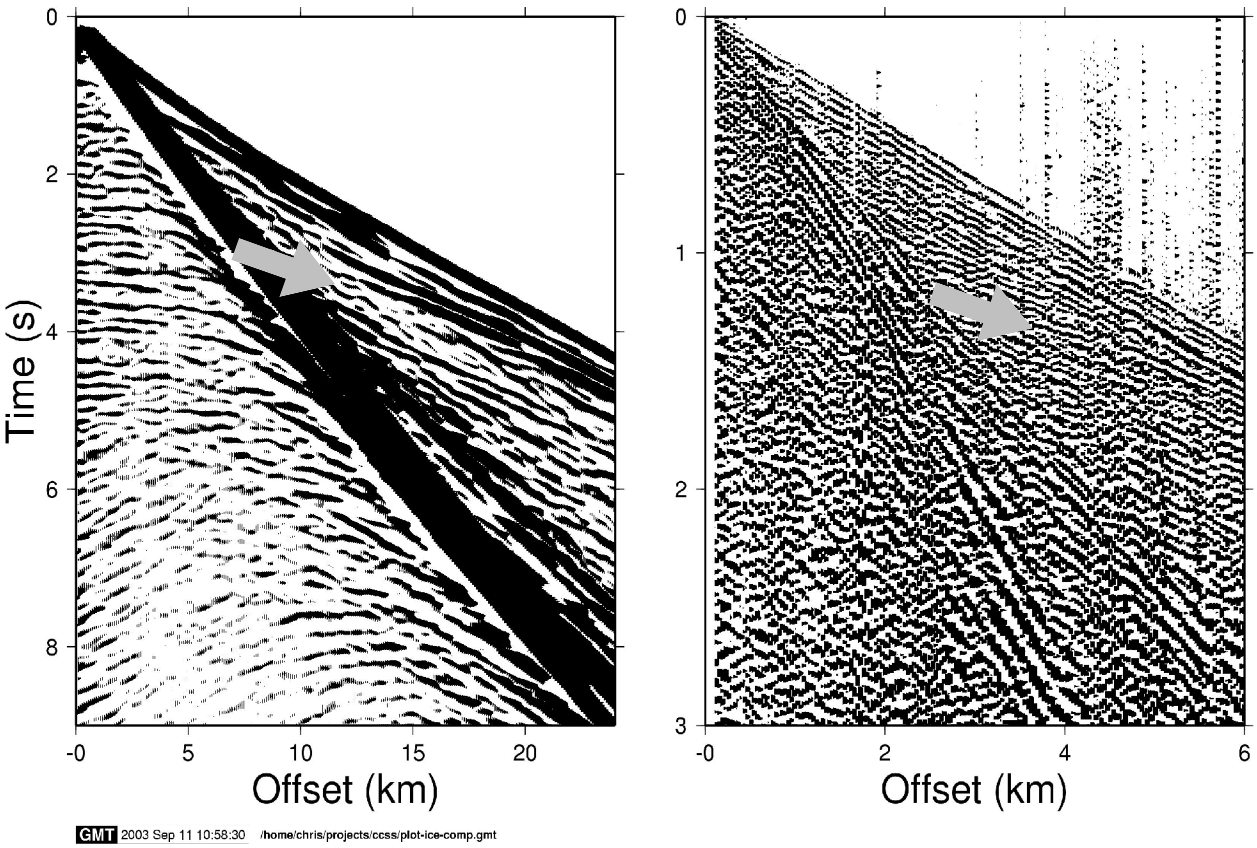

Figure 1. Comparison of a synthetic shot gather at SP 180.4 km with a real shot gather (SP 43) from Iceland (Juhojuntti et al., 2003). Wide-angle reflections (arrows) appear to be present in both data sets.

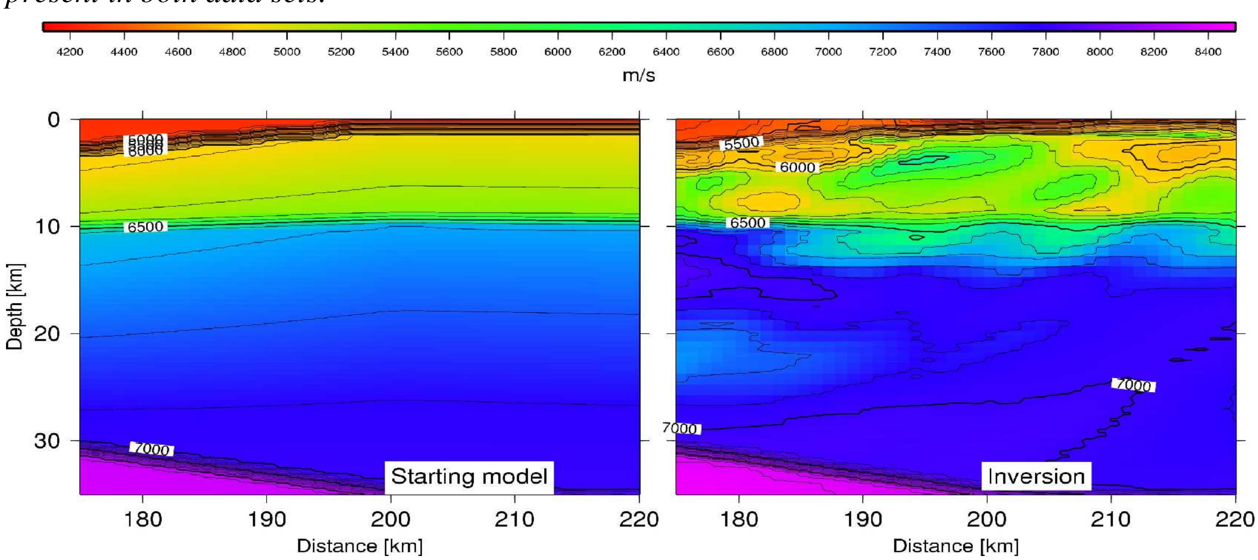

Figure 2. Staring velocity field and one of the inversions used for reflection seismic processing of the "high resolution" synthetic data. A velocity field was obtained along the entire 250 km long model, however, only that portion which overlaps with the reflection seismic processed sections is shown here.

Clear reflections from depths of 5-12 km are observed on the stacked and migrated sections (Figure3). The geometry of the lowermost reflections on the right half of the section, at about 11 km, appears to follow that of the 6500 m/s contour, suggesting that these reflections are generated from a sharp increase in the velocity gradient near this contour, possibly associated with a low velocity zone above. Overlying reflections are from within a zone of relatively constant velocity. Either the tomographic inversion has preformed poorly in this zone or there are sharp gradients that are below the resolution limit of the tomography. Alternatively, the reflections may be artefacts from the processing.

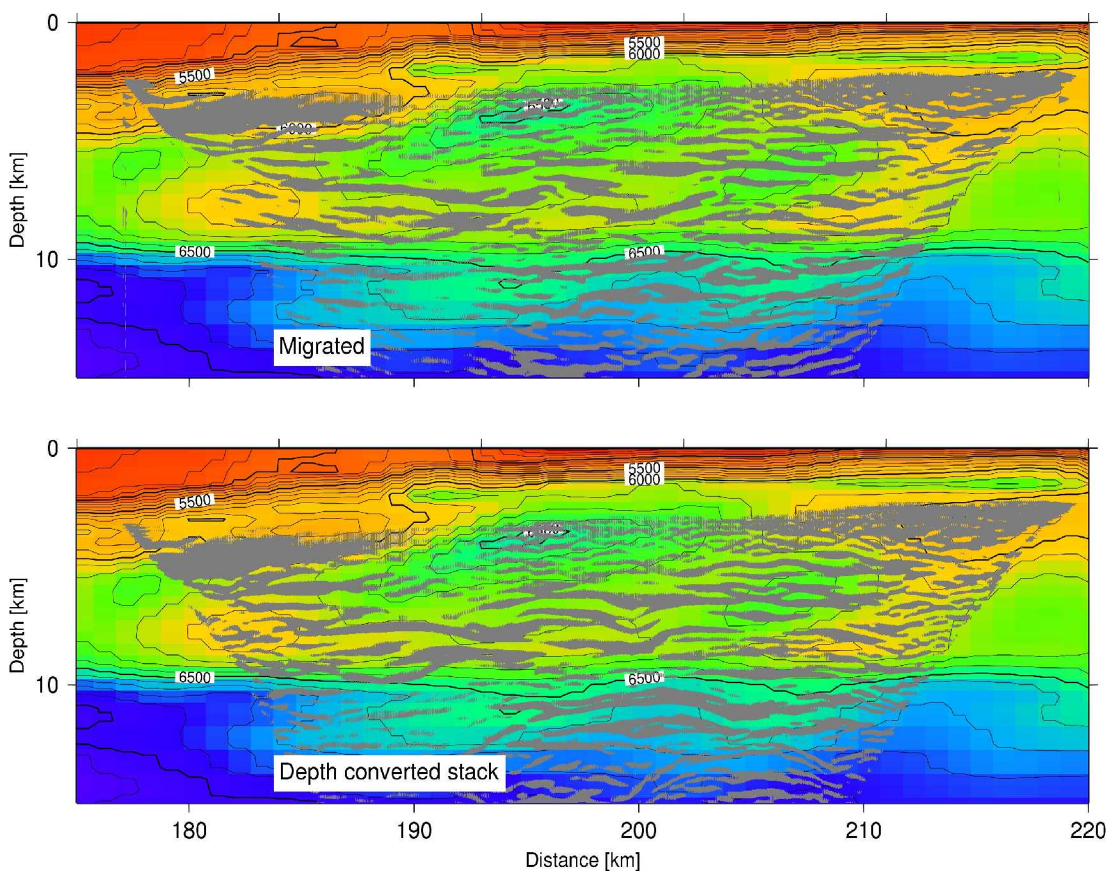

Figure 3. Wide-angle stacked time section (bottom) and time migrated section (top). Both sections were depth converted using the velocity field in Figure 2.

Pre-stack migration was attempted using the same velocity field (Figure 2) as for the wide-angle stacking. The commercial pre-stack time migration program performs rather poorly (Figure 4). Although the image may look reasonable, varying the velocity field gives essentially the same image, which is not reasonable. An in-house pre-stack depth migration program performs better (Figure 4). Here, the resulting image is highly dependent upon the velocity field used. However, even on the in-house section, there is a discrepancy between the spatial position of strong velocity gradients and continuous reflections, suggesting that the velocity model used is not optimal, or that the straight ray approximation in the in-house program is not always valid.

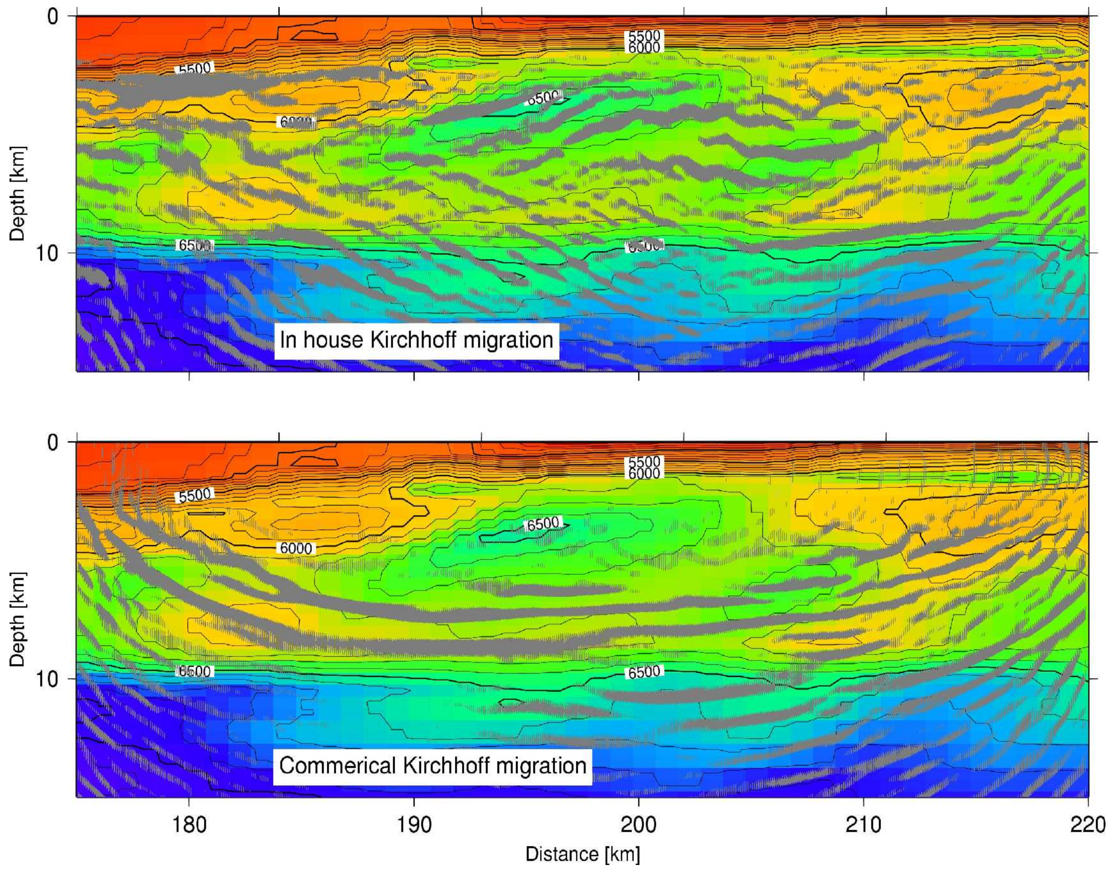

Figure 4. Commercial pre-stack Kirchhoff migrated section (bottom) of the wide-angle component and an in-house pre-stack Kirchhoff depth migrated section (top). Both sections were migrated with the velocity field in Figure 2.

Benz, H. M., Chouet, B. A., Dawson, P. B., Lahr, J. C., Page, R. A., and Hole, J. A., 1996, Three-dimensional P- and S-wave velocity structure of Redoubt Volcano, Alaska: J. Geophys. Res., **101**, 8111-8128.

Cook, F. A. , van der Velden, A. J. and Hall, K. W., 1999. Frozen subduction in Canada's Northwest Territories: Lithoprobe deep lithospheric reflection profiling of the western Canadian shield: Tectonics, **18**, 1-24.

Juhojuntti, N., Juhlin, C., Kjartansson, E., Bjarnasson, I. Th., Grönvold, K. and Tryggvason, A., 2003. Crustal reflectivity imaging and shallow crustal velocity tomography in SW Iceland: submitted to Geophys. J. Int.

Robertsson, J. O. A., Blanch, J. O. and Symes, W. W., 1994. Viscoelastic finite-difference modeling: Geophysics, **59**, 1444-1456.

Tryggvason, A., Rögnvaldsson, S. Th., and Flovenz, Ó. G., 2002, Three-dimensional imaging of the P- and S-wave velocity structure and earthquake locations beneath Southwest Iceland: Geophys. J. Int., **151**, 848-866.