Issues in processing seismic data from complex areas

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Abstract

A seismic line from Colombia, acquired in an area of large topographical variations, high velocity rocks at the surface and lateral near-surface velocity changes presented problems in data processing because standard data processing techniques did not address these issues adequately. We applied various standard processing techniques to attenuate noise and enhance the signal. Reflectors were imaged in different locations on post-stack time migrated sections depending on which algorithm was used for the migration. Pre-stack depth migration produced a more interpretable section than time processing even though the velocity model was hard to determine because of the inconsistent quality of the seismic data and lack of well data.

Seismic data processing

A seismic line was acquired in southern Colombia with the purpose of imaging underneath an overthrust layer of high-velocity Mesozoic granodiorites which were believed to overlie complexly structured sedimentary rocks. The near-surface high velocity rocks, variable topography and lateral velocity changes each caused problems for seismic data acquisition and processing as they gave rise to seismic signal attenuation, noise contamination and distortions of arrival times. The issues of imaging below a high velocity thrust layer are similar to those of imaging beneath basalt and have not yet been satisfactorily resolved for seismic methods (Ziolkowski et al., 2001).

The survey comprised 139 shots spaced nominally at 72 m. The split-spread receiver configuration had 240 channels at a 36 m station interval, giving a nominal CDP fold of 60. The nearest offset was 18 m and farthest 4302 m. The data were quite noisy and suffered from statics problems caused in part by the high velocity, absorbent rocks at the surface and the severe changes in elevation of 1300 to 2300 m. Figure 1a shows a typical shot gather. High amplitude, low velocity surface wave noise dominates the near offsets while back-scattered surface waves degrade reflections. On the left side of the shot gather we see severe statics, which were not removed by elevation statics alone. The data were processed as well as possible to attenuate the noise, enhance coherency, resolve the statics problems and determine velocity models for stack and migration.

We derived refraction statics through Hampson and Russell's GLI3D program, even though this surface-consistent technique is best suited for low velocity near-surfaces rather than the high velocities encountered here. Abma (2001) proposes the use of an iterative inversion technique to calculate surface-consistent statics that are function of both time and offset when near-surface velocities are high. The final velocity model obtained through tomographic analysis showed high velocities in the subsurface on the western part of the line and lower velocities in the east, which is consistent with the surface geology. Despite the theoretical limitations of this GLI method, the refraction statics obtained from this solution removed the static inconsistencies observed in the first breaks of Figure 1a and helped to enhance some reflections (see Figure 1b). We also applied residual statics later in the flow.

To address the problem of noise, we applied several signal enhancement techniques. Surface wave noise attenuation targeted a velocity of 900 m/s at low frequencies then predictive deconvolution followed by a bandpass filter attenuated multiples and removed low frequency noise (Figure 1b). We also experimented with other filtering techniques, including radial (Henley, 1999) and coherency filters. Velocity analysis on these data was not easy for, despite all the filtering, there did not seem to be many coherent events. As the initial stack was rather unsatisfactory, we applied an *f-x* filter in the offset domain to attenuate further some dipping events that were assumed to be noise. After refinements of the stacking velocities, the final stack (Figure 2) was formed then this section was post-stack time migrated using two alternative algorithms, finite difference (Figure 3) and Kirchhoff (Figure 4). Both migrated sections suffer from migration artifacts because of the low signal to noise ratio but show surprising differences in reflector locations and character, even though the migrations were based upon the same velocity model.

Because of the difficulty of interpreting these different post-stack time migrated sections with any confidence, the data were imported into GX's Sirius program for pre-stack depth migration analysis. This program works on the hypothesis that reflections on common reflection point (CRP) gathers will be flattened in depth if the correct velocity is chosen. However, it is hard to determine the imaging velocities in areas of poor data. This method also fails to account for near-surface velocity variations (Tieman, 1995). A tomographic approach using turning rays may be preferable (Al-Rufaii et al., 2001). We found that, in places, the velocities that flattened the CRP gathers were unreasonably high and in other places we were unable to make any picks at all. In the absence of picks we interpolated from the areas of better quality data. The final depth section and interval velocity model are shown in Figure 5. This depth section is easier to interpret than the post-stack time migrated section. However, we cannot have a great deal of confidence that the interval velocity section represents the true velocity structure of the subsurface because of the limited amount of good data and consequent lack of good focussing picks. There was no well data available to provide constraints on the velocity model.

Summary

The data were not easy to process by conventional methods because of the attenuation of signal in the high velocity near-surface layer, the variable topography, lateral velocity variations and the large amount of noise in the data. The large receiver group interval caused some surface wave energy to be aliased. A longer receiver spread night enable better imaging beneath the high velocity near-surface layers. Pre-stack depth migration produced a better image than time processing. The final velocity model was not easy

to determine and may well not be correct but we were not able to obtain a better model. Despite the issues with velocity models, it appears that the depth processing has produced a more interpretable image than the time processing. In the future it might be beneficial to employ numerical modelling to address the question of field parameters such as receiver group interval to solve aliasing issues and receiver spread length for obtaining turning rays. Development of more advanced data processing techniques would help to resolve some of the special problems associated with the processing of seismic data acquired in complex areas.

References

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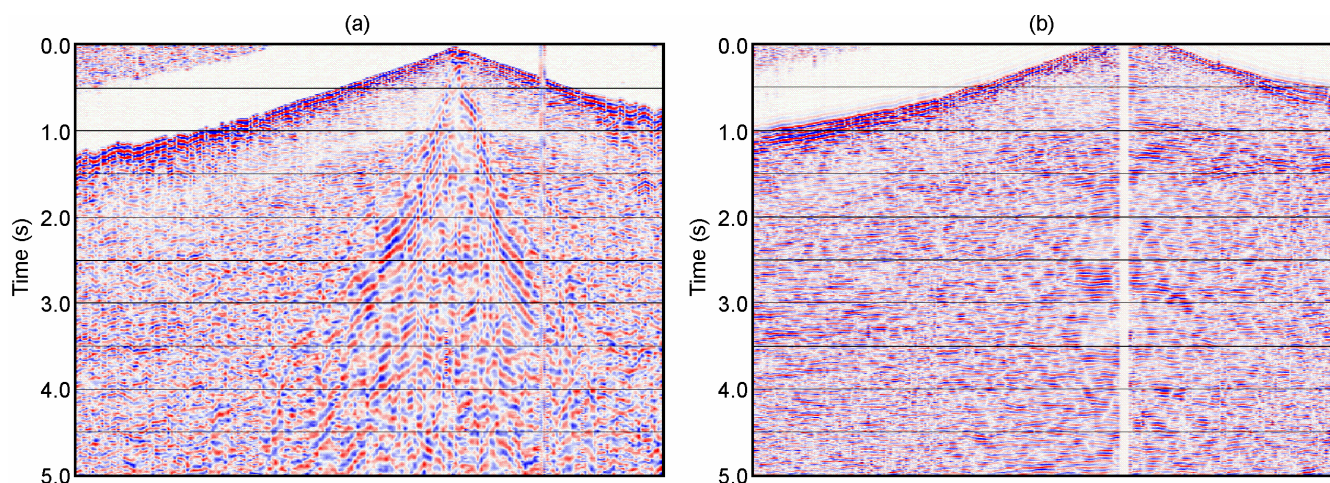
Figure 1. (a) A typical shot gather which shows statics problems, especially at the left end, low-frequency noise trains and a lack of coherent reflectors. (b) The same gather with pre-stack processing applied. AGC has been applied to the shots for display.
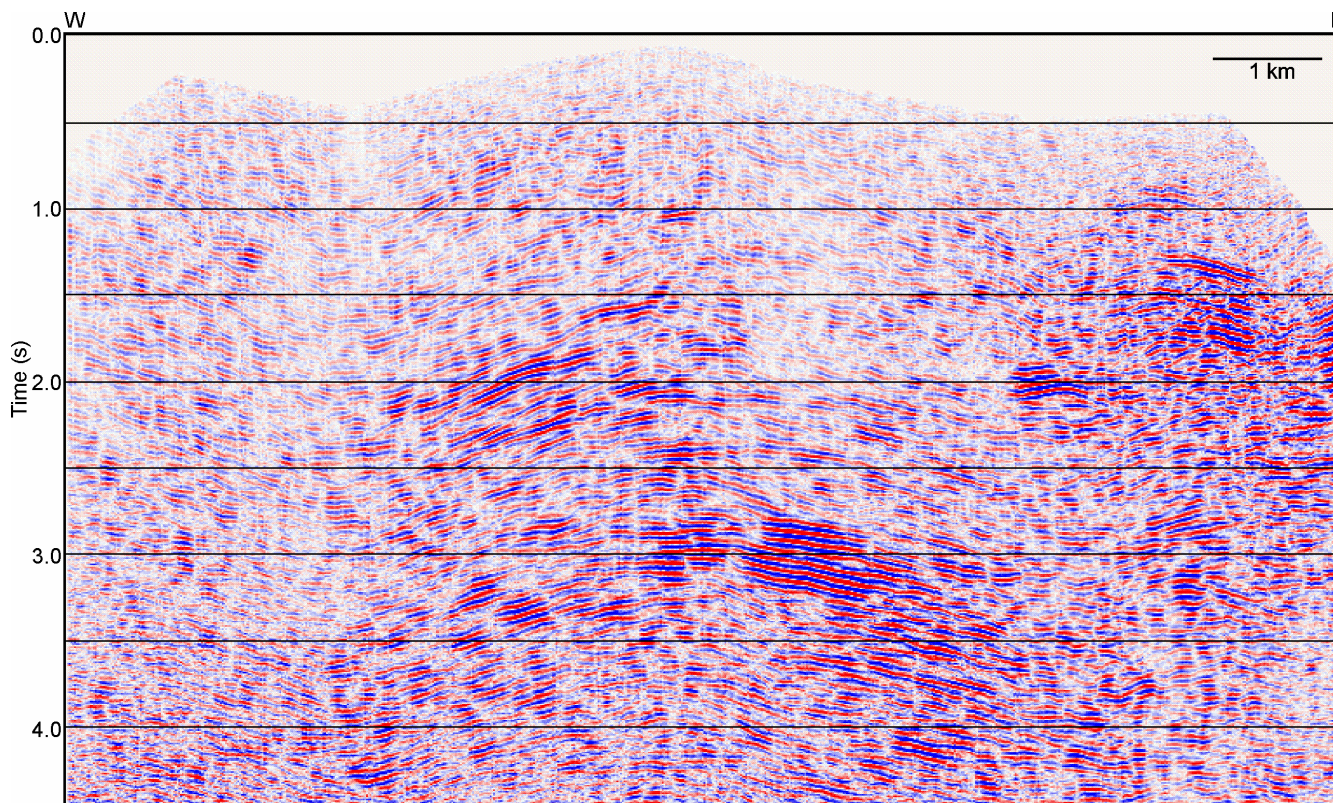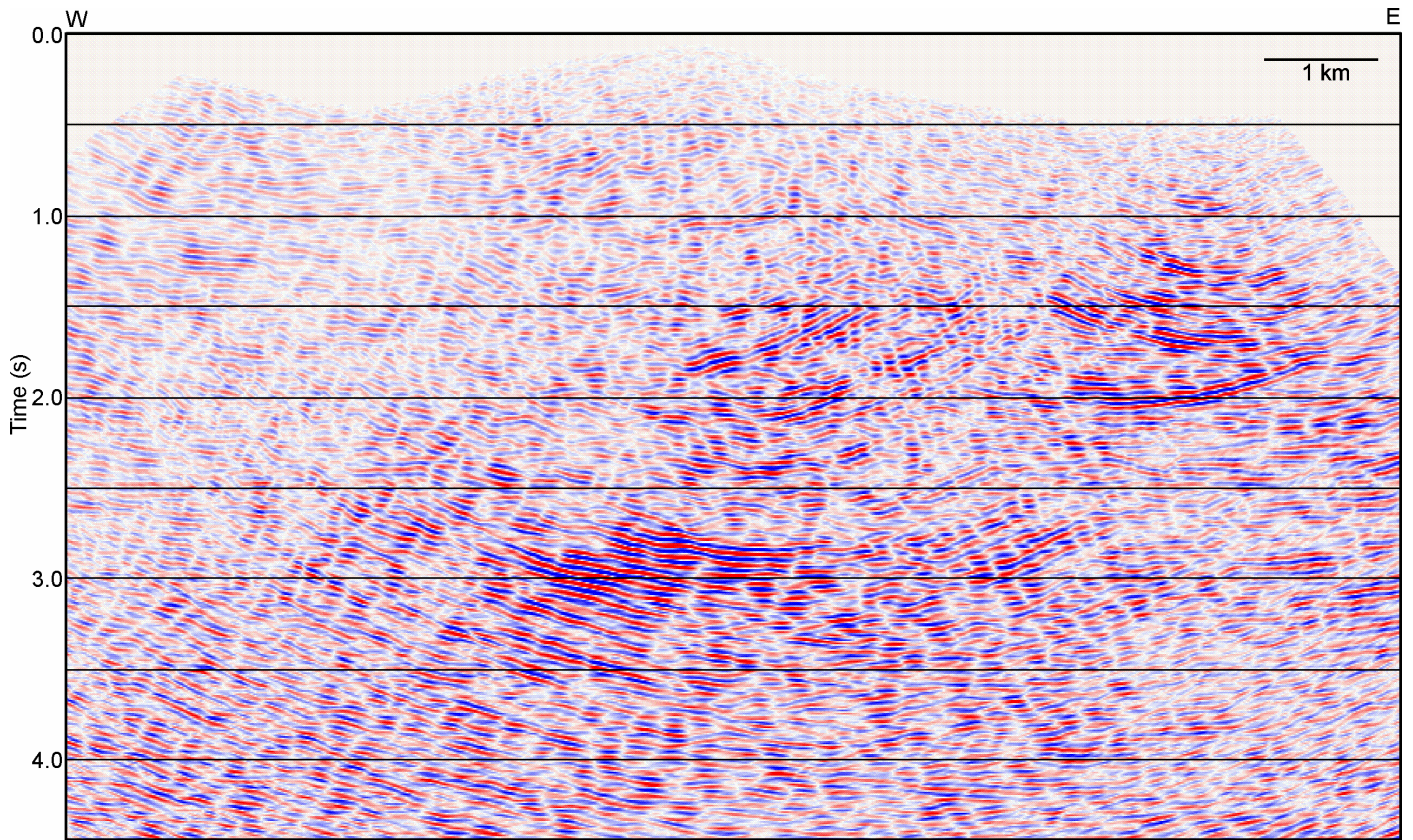

Figure 2. Stacked time section.

Figure 3. Section post-time migrated with a finite difference algorithm.
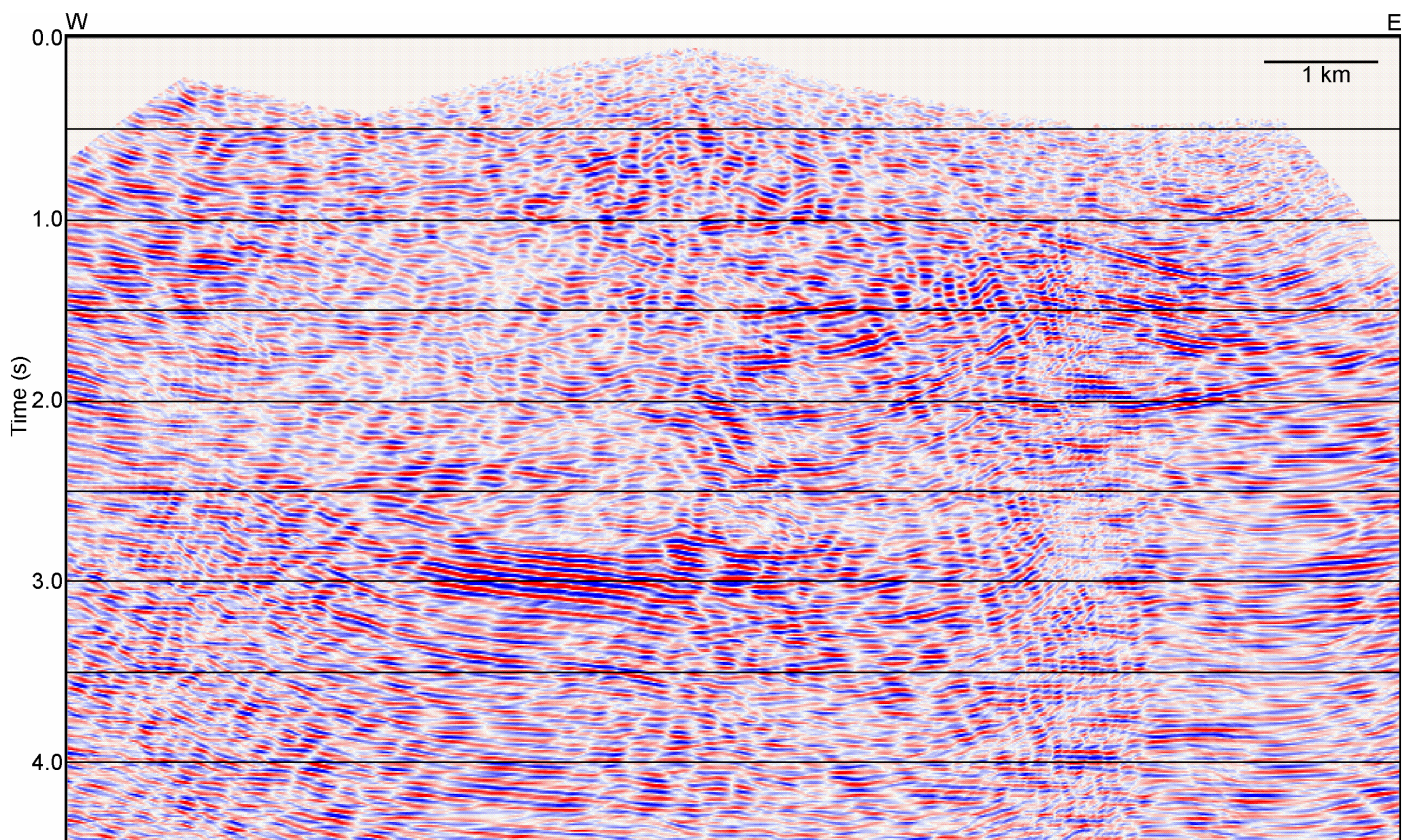

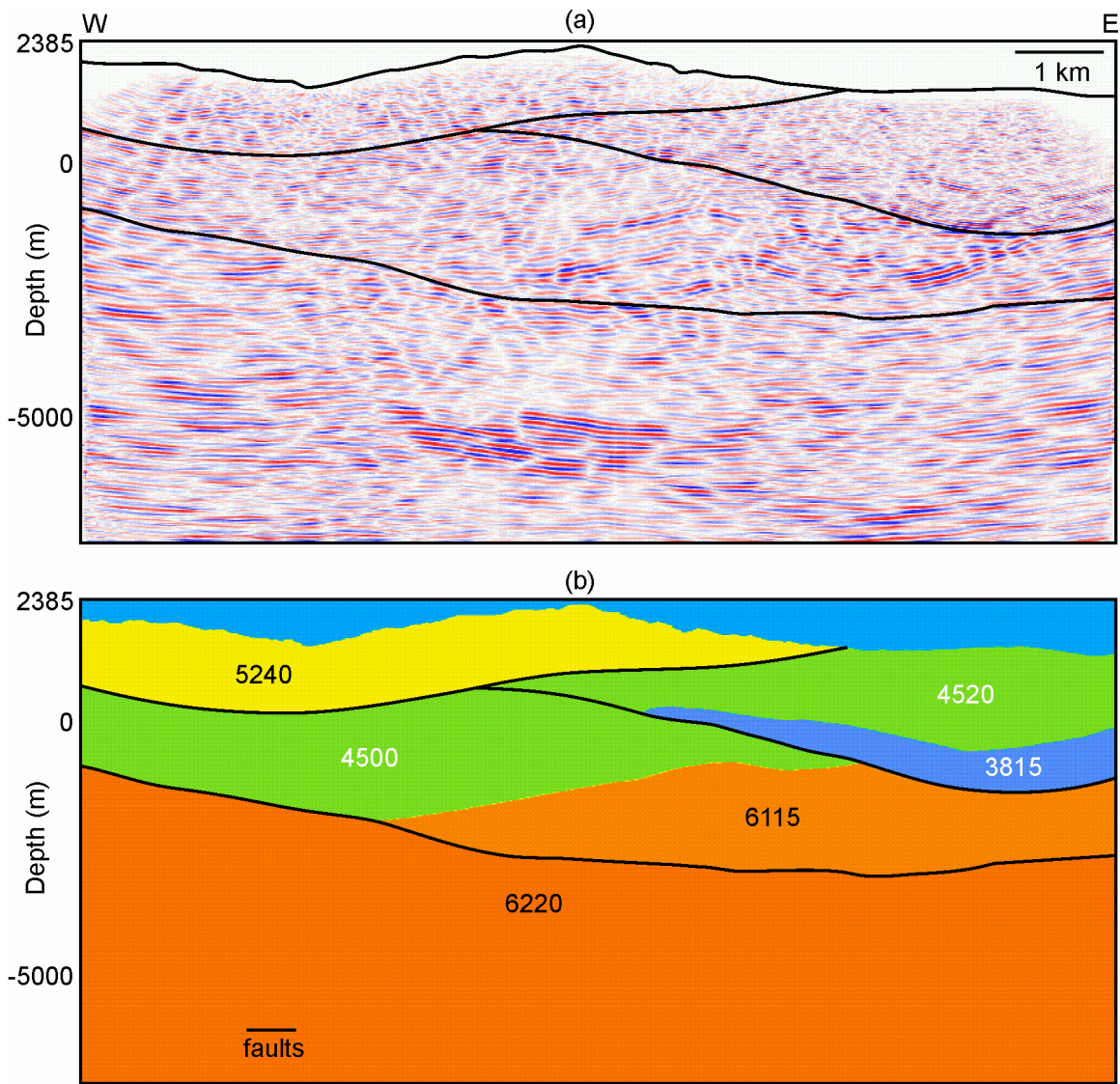Figure 4. Section post-time migrated with a Kirchhoff algorithm.

Figure 5. Pre-stack depth migrated section (a) and the final interval velocity model (b).