The effect of receiver statics on CCP stacks: An example from Spring Coulee, Alberta

J. Helen Isaac and Gary F. Margrave

ABSTRACT

A common method of estimating receiver statics for PS data is to pick a horizon on stacked receiver gathers and calculate the statics necessary to either flatten the horizon or smooth it. We investigated the effects of different smoothing operator lengths and the effects of using two horizons rather than just one. The differences in coherency and continuity of reflectors on the final CCP stacks of the radial component caused by the use of different smoothing operator lengths were surprising. The number of points in the smoothing operator that gave the best continuity also varied across the line. We chose the final smoothing operator length to be that which gave the best overall continuity of reflectors.

The method probably works best in areas of no structure, where flattening an event on receiver stacks does not harm true structure. In areas with a small amount of geologic structure, the amount of smoothing of the horizon picked on receiver stacks should be studied carefully before final receiver statics are selected. This method is not appropriate for areas with significant structure.

INTRODUCTION

Refraction statics for converted-wave data are determined separately for the shot component and the receiver component. The shot statics are derived from the processing of the PP data by standard refraction statics analysis using the first breaks. Estimation of the receiver statics, however, is challenging. The thickness of the low-velocity layer encountered by the upcoming shear waves is dependent on lithology and can differ a great deal from that encountered by the downgoing compressional wave, which depends on the depth of the water table (Tatham and McCormack, 1991).

Various methods have been proposed for the estimation of the receiver statics. Some of these involve picking the first breaks on the PS data (e.g., Lawton, 1989; Li, 2002; Cui et al, 2009) or analysing surface waves (Al Dulaijan and Stewart, 2010; Huang et al., 2010; Socco et al., 2010). CREWES personnel have also applied novel methods to the estimation of PS receiver statics (Chan, 1998; Henley and Daley, 2009; Henley, 2010). A common method is to stack receiver gathers and compute the statics necessary to flatten or smooth one or more picked horizons (Harrison, 1992; Cary and Eaton, 1993). This method can be effective in poor data areas with flat reflectors (Isaac, 1996). In this paper we investigate the effect on the final stacked CCP section of the amount of smoothing applied to the horizon(s) picked on the receiver stack.

DATA PROCESSING

We processed 3C data acquired at Spring Coulee in Southern Alberta (Figure 1) in 2008. The source was CCGVeritas vibroseis, which produced 192 sources at 30 m station intervals and the receivers were SM7 10 Hz geophones at 10 m station intervals. The processed line is just over 6 km long.

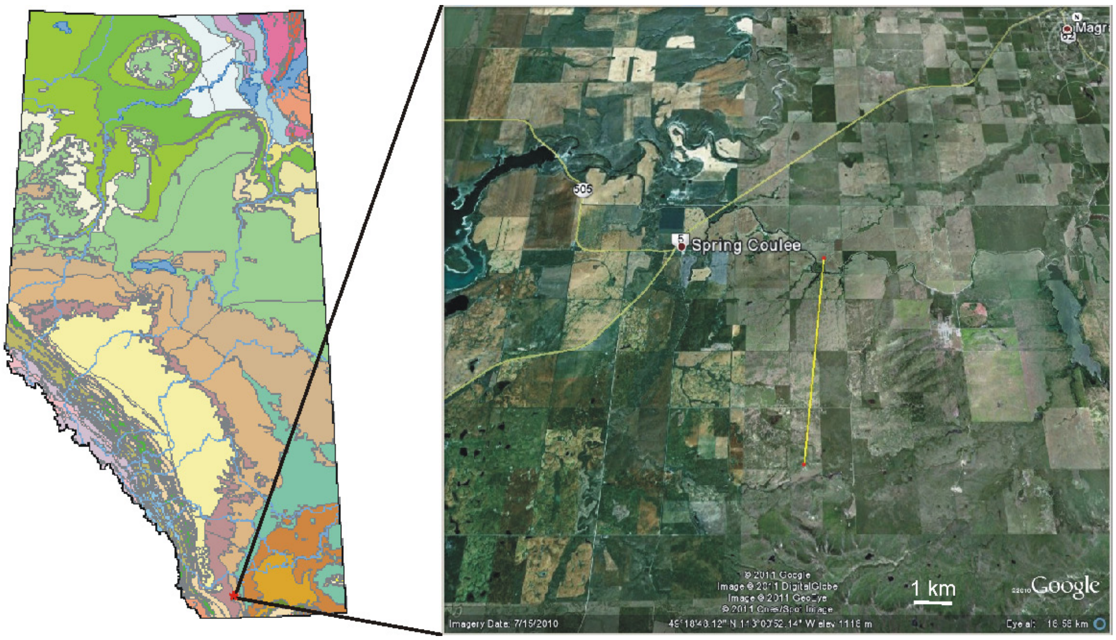

FIG. 1. The study area at Spring Coulee, Alberta.

We first processed the vertical component to obtain the shot static solution and to observe the structure of the subsurface. Standard processing techniques were applied, including surface noise wave attenuation phase-amplitude Q-compensation and Gabor deconvolution. The stacked and migrated sections for the vertical component are shown in Figure 2.

A similar processing stream was applied to the radial component of the 3C data. To estimate the receiver statics we created stacks of receiver gathers on which to pick one or more horizons. To apply NMO to these gathers we created a simple single velocity function based upon NMO observed on reflectors in the receiver gathers. A single simple velocity function produced a stacked receiver section with more continuous reflections than a spatially varying and more complex velocity function did. We applied elevation statics to the final datum to avoid introducing false structure by using the floating datum. The receiver stack with two horizons we picked is shown in Figure 3. There is clearly a tough receiver statics problem to be solved. We investigated the results on the stacked CCP section of picking either one horizon or two horizons and averaging the results, and of different smoothing filters.

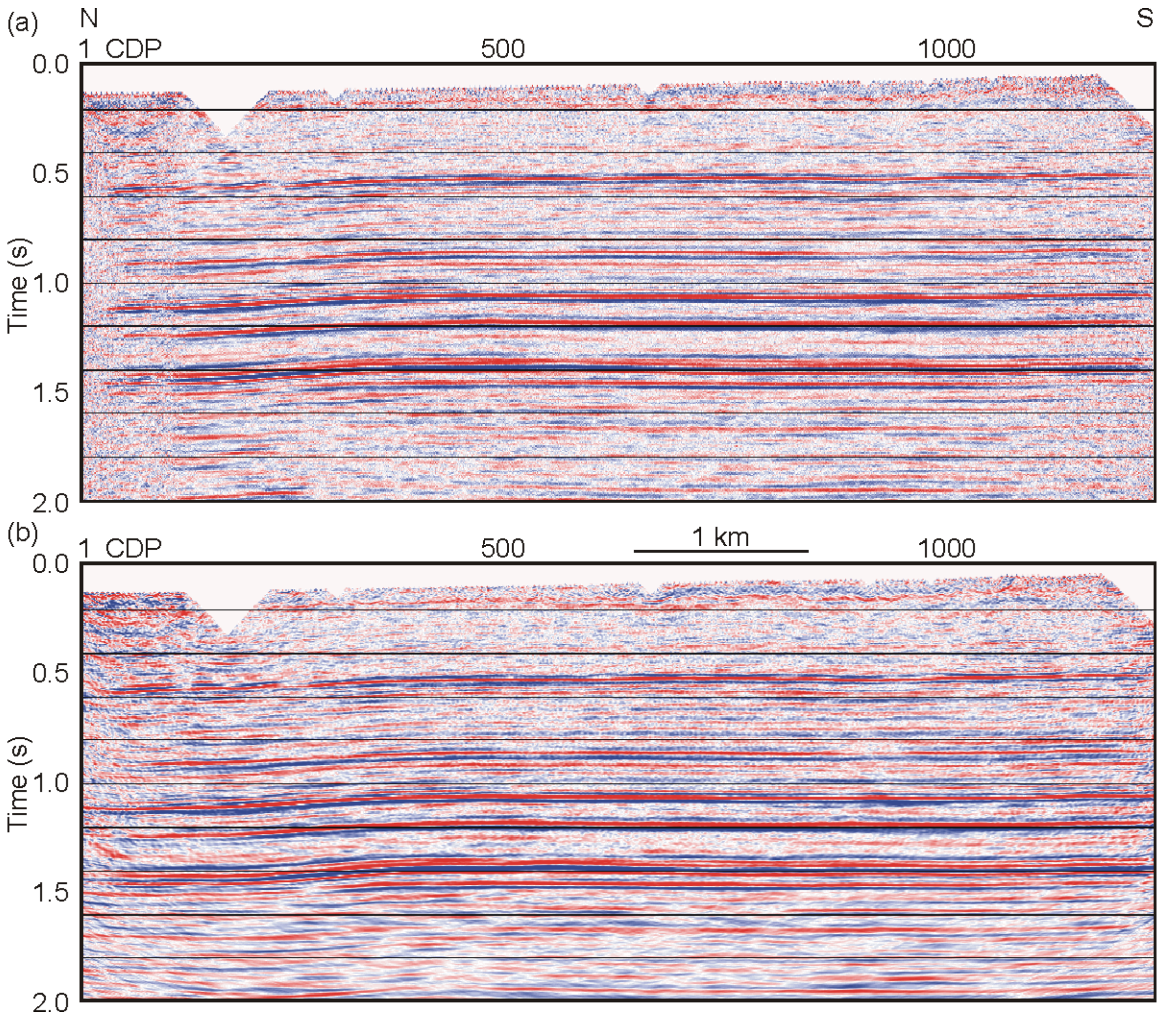

FIG. 2. Stacked (a) and post-stack migrated (b) sections for the vertical component.

The PS data were binned into CCP gathers using Vp/Vs of 2.01 and the data stacked with different receiver statics applied. These statics were obtained by calculating the difference between the shallower horizon picks near 0.9 s in Figure 3 and those picks smoothed with different lengths of smoother operator. Figure 4 shows three CCP stacks which had smoother lengths of (a) 201, (b) 301 and (c) 401 receiver stations. It is quite surprising how much difference the smoother length makes. A smoother length of 301 gives the best result over CCPs 500 to 1000 and a length of 401 gives the better result over CCPs 1 to 500. However, with a length of 401 we lose coherency between 500 and 1000 m. Figure 5 shows the CCP stacks with the same smoother lengths as in Figure 4 but averaged over the two picked horizons. As might be expected, when the lower horizon is included in the receiver statics analysis, the result is better continuity than when excluded, as in Figure 4.

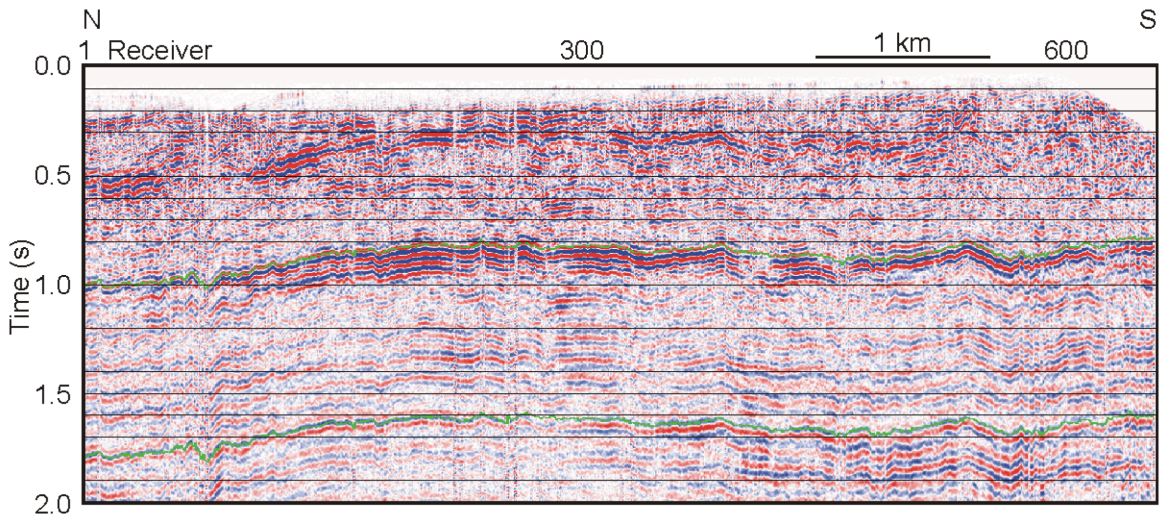

FIG. 3. The stacked receiver gathers. There is clearly a tough receiver statics problem to be resolved. The green lines are two horizons we picked.

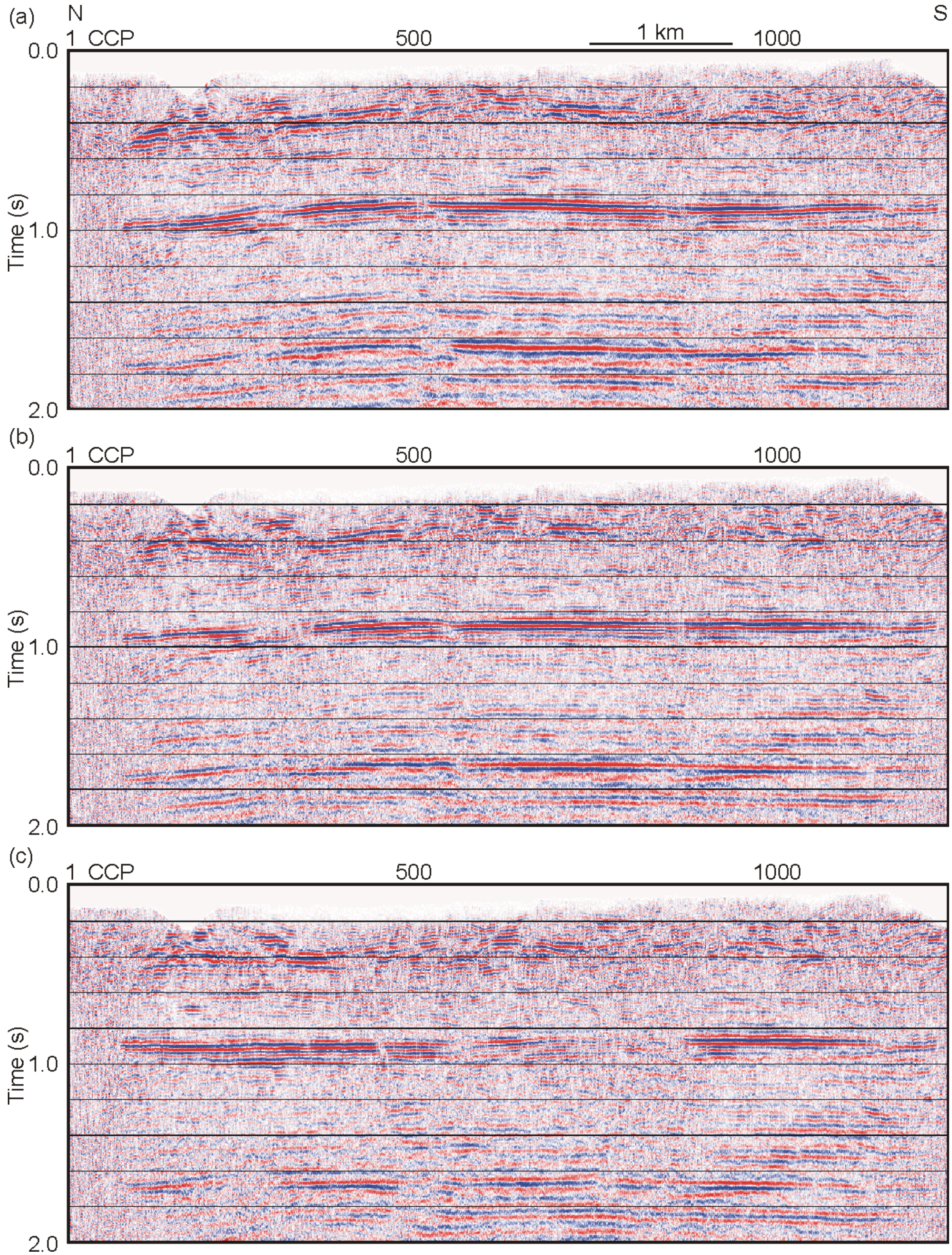

FIG. 4. Three receiver stacks with different statics calculated from the difference between the shallow picked horizon and a smoothed version of that horizon. The smoothing operator lengths were (a) 201, (b), 301 and (c) 401.

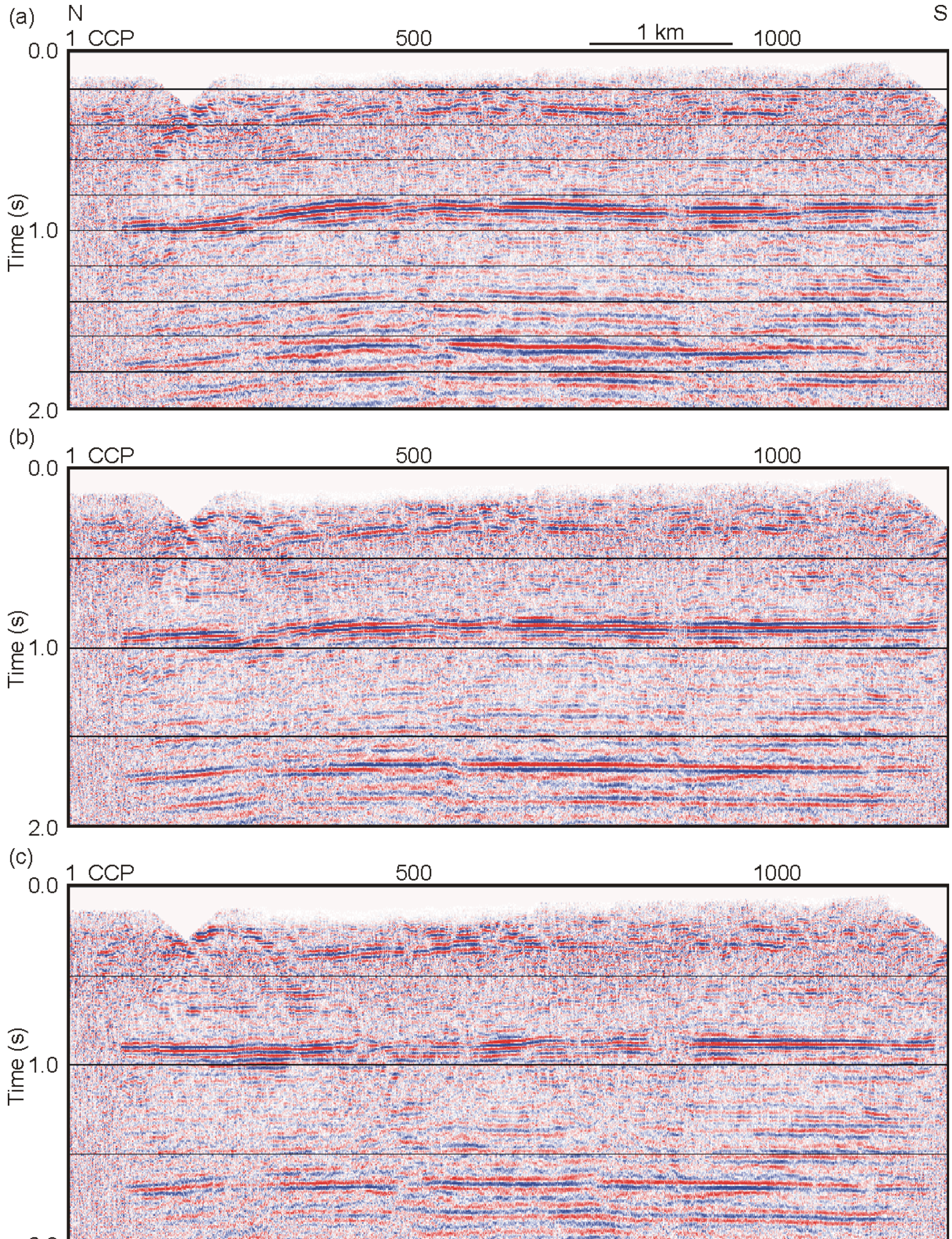

FIG. 5. Three receiver stacks with different statics calculated from the average of the differences between the two picked horizons and smoothed versions of those horizons. The smoothing operator lengths were (a) 201, (b), 301 and (c) 401.

In Figure 6 we smoothed the shallow horizon with a length of 501 (a) and with the picked event flattened completely (b). In Figure 6a the left part of the line from cdps 1 to 500 looks much improved but we are losing coherency over the right end of the line. The section in Figure 6b looks rather over-flattened. Clearly, different smoother lengths work best on different parts of the line. Thus we compromised by using a smoother length of 331 on both horizons and averaging the two statics estimations (Figure 7). This is probably the best CCP stacked radial component section.

The radial stacked section was migrated using a smoothed interval velocity function (Figure 8). Vertical and radial migrated sections are presented together in Figure 9, scaled so that corresponding reflectors line up. The polarity of the radial section was reversed to make the best character match.

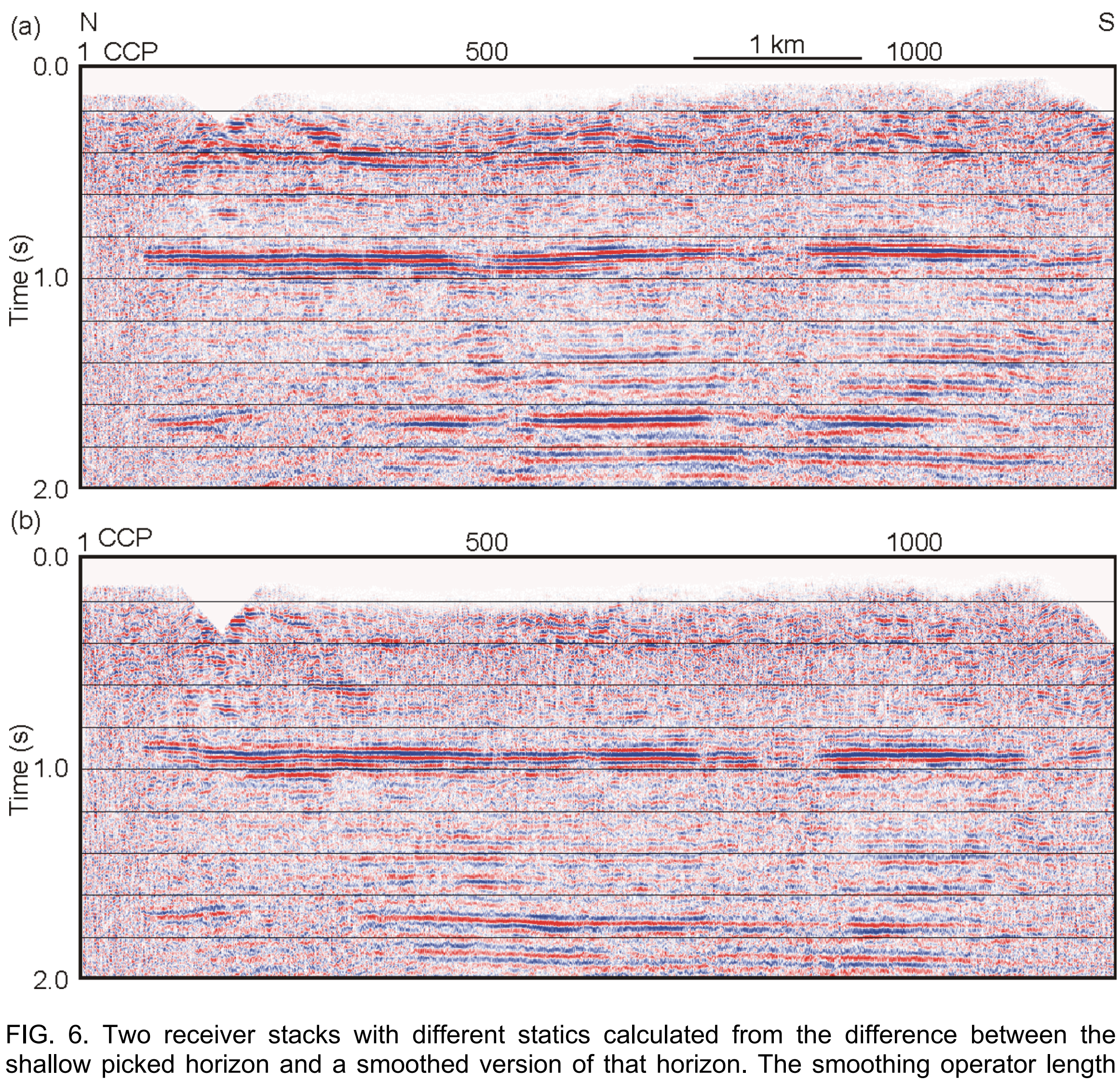

FIG. 6. Two receiver stacks with different statics calculated from the difference between the shallow picked horizon and a smoothed version of that horizon. The smoothing operator length for (a) was 501, while for (b) the horizon was flattened.

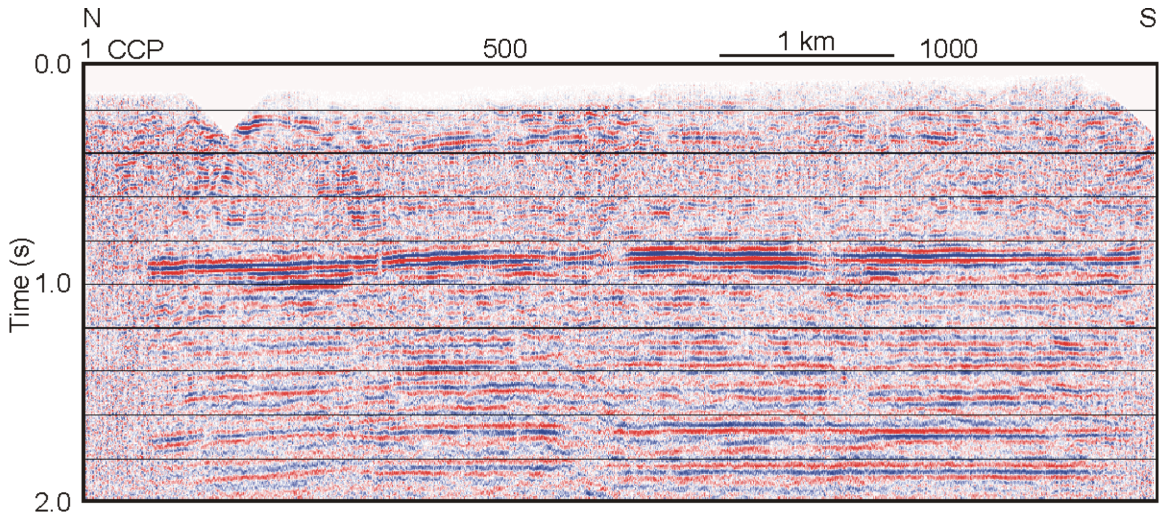

FIG. 7. The best CPP stack we could achieve. The receiver statics used both horizons with a smoothing length of 331.

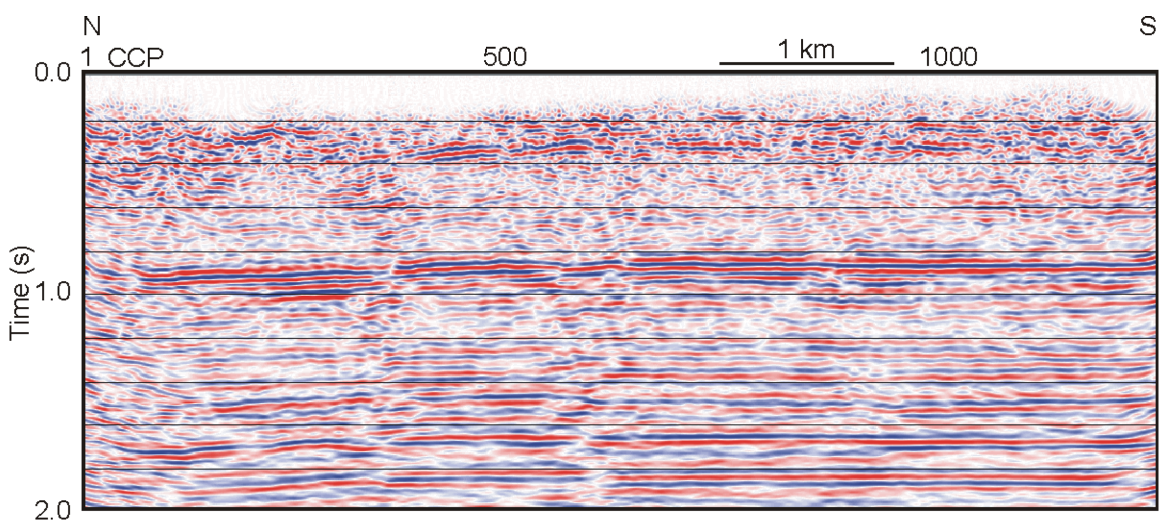

FIG. 8. The poststack migrated radial section.

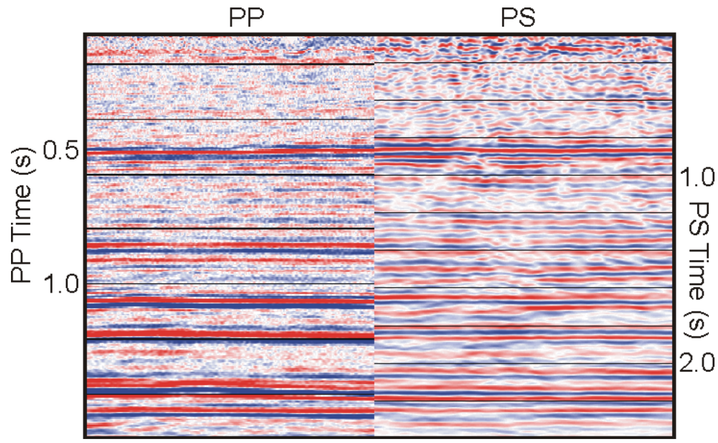

FIG. 9. Vertical (left) and radial (right) poststack migrated sections scaled to match reflectors. The polarity of the radial section was reversed to obtain a better character match to the vertical section.

SUMMARY

We investigated the estimation of radial component receiver statics using the method of picking a horizon (or two) and calculating the statics necessary to shift the data to a smoothed version of that horizon. The amount of lateral smoothing had a surprisingly strong effect on the final stacked CCP converted-wave section. We found our efforts became somewhat hit and miss as we tried different smoothing operator lengths and compared the results visually. We also compared results using one horizon versus the average of two horizons and found better continuity of both reflectors when using both horizons.

Stacking velocities were not addressed in this study and they also affect the continuity and coherency of reflectors on the CCP section. We used a single simple velocity function for NMO removal.

For future work, we would like to create a synthetic dataset with severe receiver statics problems and test various methods of statics estimation.

ACKNOWLEDGEMENTS

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