Receiver statics of converted waves without stack: test with real data

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ABSTRACT

A commonly used method for estimating the receiver statics correction for converted wave (PS-wave) uses a Common Receiver Stack (CRS), which requires stacked data and a stacking velocity model (V_C). A new method that does not require V_C has been proposed. It obtains the differential receiver statics δR between two Common Receiver Gathers (CRG) automatically by crosscorrelations. This report presents a test of this new method on real data. The method requires of editing of outliers to obtain δR. A meaningful receiver statics correction is obtained, which improves the stack section, and generates better data for velocity analysis.

INTRODUCTION

The PS-wave receiver statics correction is challenging, and is a demanding step in processing. A method that uses Common Receiver Stacks (CRS) has shown successful applications in the industry (Harrison, 1992; Cary and Eaton, 1993). However it requires a velocity model for stacking PS-reflections (V_C), and a reflection to be flattened, which are not always easily obtained.

A method for converted wave receiver statics correction without stacking reflections was proposed in a previous report (Guevara and Margrave, 2014). This method is based on the surface consistent equation, which has been very useful for statics correction of P-waves (Schneider, 1971; Taner et al., 1974). It is basically the same principle of the method that uses Common Receiver Stacks (CRS), namely that all the traces of a Common Receiver Gather (CRG) have the same receiver statics correction, which can be obtained by using the surface consistent approximation, after separating this effect from the other meaningful effects. However while the CRS method obtains the statics correction from stacking the traces, in the new method the delay between adjacent receivers corresponding to the statics is obtained by crosscorrelation of analogous pairs of traces, each one of a CRG.

A previous report (Guevara and Margrave, 2014) presents the principles of the method illustrated with synthetic data. In this report a test of this new method using real data is presented and analyzed.

METHOD

The principle of the method is illustrated in Figure 1. Two adjacent receivers, identified as G_1 and G_2, have a surface consistent delay caused by the near-surface layer (a difference in thickness in this case). This delay is identified as the *receiver statics*. However any event is affected by other components of the arrival time, namely the source statics, the normal

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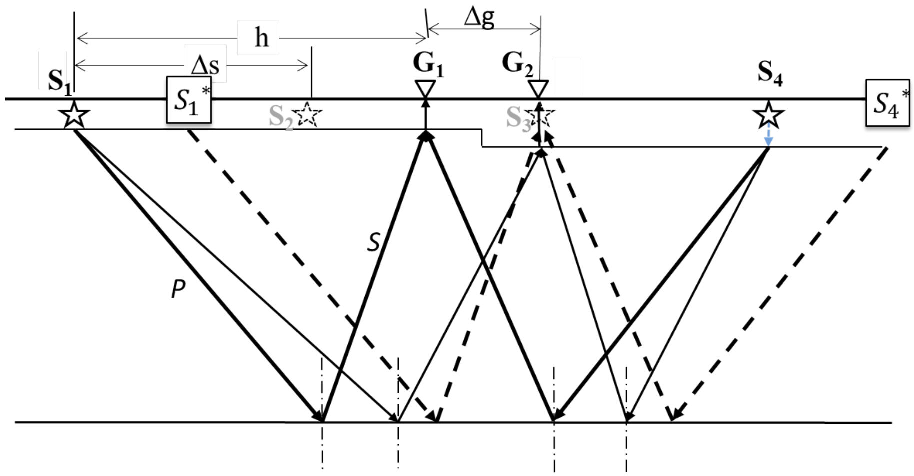

FIG. 1. Ray sketch of traces affected by receiver statics, that shows the PS events used for crosscorrelation in the receiver statics algorithm. The traces of a CRG have the same R_i delay. The time delay between traces corresponds to the differential source and receiver time delays in the NS-LVL, plus the offset and geological time delays. Each trace of a CRG is crosscorrelated with the trace of the adjacent CRG corresponding to the same offset to obtain R_i.

incidence arrival time, related to the geological structure, and the moveout delay time, caused by the offset (Schneider, 1971). It would be possible to find a *differential delay time* δ between two traces generated by the same source (let's say S_1) and detected by G_1 and G_2, which includes the receiver statics. The surface consistent equation applied to the differential delay time between the two adjacent CRGs is:

$$\delta t_{ijk} = \delta R_i + \delta S_j + \delta G_k + \delta M_k \tag{1}$$

where R_i= receiver statics at the i_{th} receiver position. S_j= source statics at j_{th} source position. G_k= time shift caused by the geology for the kth reflection. M_k= Move Out delay corresponding to the k_{th} reflection gather.

The surface consistent equation can be simplified if traces of the same source are related. Thus, the source statics S_j, obtained previously from the P-wave processing, can be applied; it is possible to assume that the delay caused by the geology G_k is negligible, since adjacent receivers are close together; it would be possible to assume that the delay caused by the offset *h* (Move-Out or MO), M_k, is negligible, since the offset difference is only Δg, the distance between receivers, however it is not the case, as shown by Guevara and Margrave (2014). To overcome this issue, a new trace with the same offset is obtained using interpolation of traces, or equivalently generating a virtual source, S_1^* in Figure 1. After that, the missing delay corresponds only to the differential receiver statics δR between the two adjacent receivers.

Since all the traces of two adjacent CRGs are affected by the same differential receiver statics delay, it is possible to calculate the delay for any pair of corresponding traces, as illustrated in Figure 1 by the traces generated at source S_4.

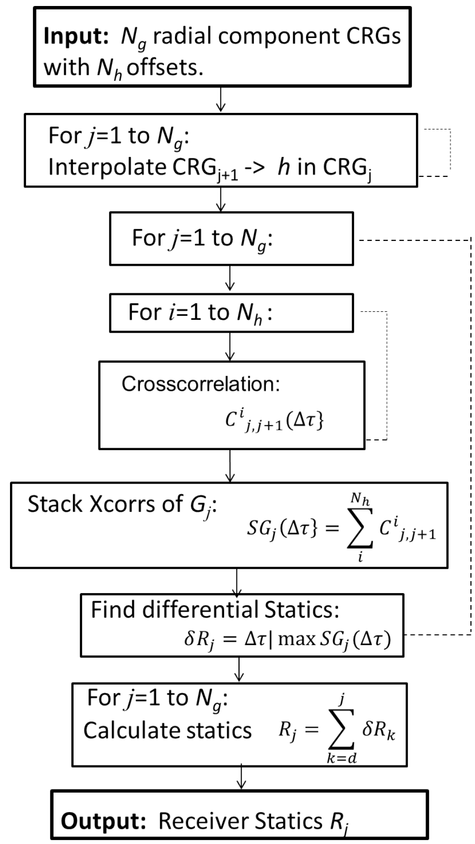

FIG. 2. Flow diagram of the method for PS-wave receiver statics correction.

The delay between two traces is obtained by crosscorrelation, according to the equation:

$$C_i(\Delta\tau) = \sum_{n=1}^{N_t} \frac{D_i(t_n, h_m) D_{i+1}(t_n + \Delta\tau, h_m)}{\sqrt{\sum_t D_i(t_n, h_m)^2 \sum_t D_{i+1}(t_n, h_m)^2}} \tag{2}$$

where D_i and D_{i+1} are corresponding traces of adjacent CRGs, N_t is the number of time samples, and $\Delta\tau$ corresponds to the time shift between the two traces. The denominator makes a normalized result, since the maximum possible value is 1 for the case when both traces are identical (Li, 1997). Thus a crosscorrelation function C_i is obtained as a function of $\Delta\tau$ for each couple of traces i and $i+1$.

The cross-correlations corresponding to a CRG pair can be added, since all of them should have the same δR,

$$SG_i(\Delta\tau) = \sum_{h=1}^{N_h} C_{i,h} \tag{3}$$

where h corresponds to an offset, and N_h is the number of traces to crosscorrelate. Hence the maximum of the function SG_i corresponds to δR_i.

Finally, the statics correction with respect to a datum d of a surface location i is the summation of all the differential statics corrections between the datum and the surface location i:

$$R_i = \sum_{j=d}^{i} \delta R_j \tag{4}$$

The receiver statics correction method is summarized in the flow diagram of Figure 2. For each couple of CRGs it can be applied in both directions, left to right and right to left. In both directions the delay should be the same, however with the opposite sign.

APPLICATION TO REAL DATA

The method was tested on the experimental 2D 3C seismic survey acquired at Spring Coulee 2008,Alberta, Canada, by the CREWES project with the support of sponsor companies. Details have been published in CREWES Research Reports and at technical meetings (e.g Lu and Hall, 2008; Al-Dulaijan and Stewart, 2010). The seismic data selected for testing the method are from a 6500 m long seismic line, composed of 652 3C sensors separated 10 m from each other, and with 192 energy sources separated nominally at 30 m.

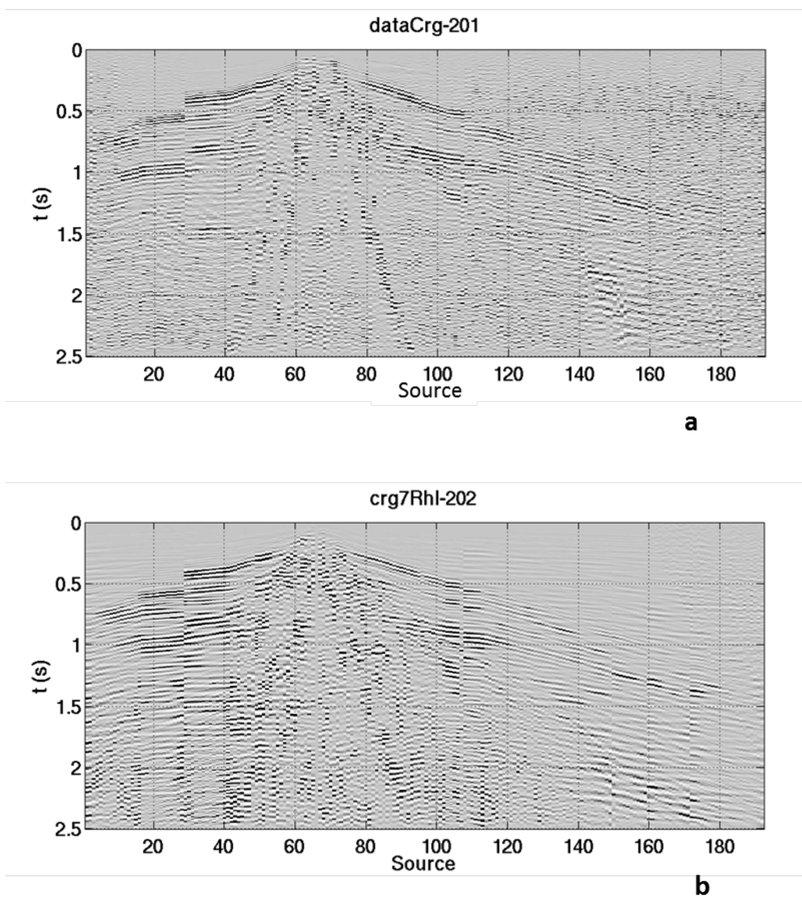

FIG. 3. Data corresponding to the crosscorrelation of CRG 201 from left to right hand side. (a) CRG 201 (b) CRG 202 interpolated, such that the offsets are the same that in the case of CRG 201.

Receiver statics calculation

First the seismic traces are organized by CRGs and interpolated. As an example Figure 3 shows two CRGs corresponding to the crosscorrelation left to right. Figure 3(a) corresponds to the CRG 201 and Figure 3(b) corresponds to the CRG 202 interpolated to obtain the offsets of CRG 201.

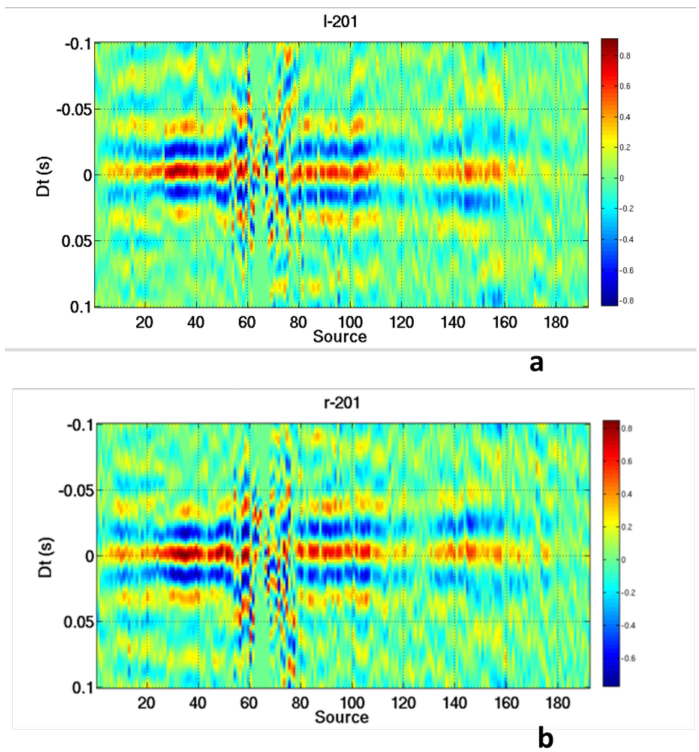

FIG. 4. Crosscorrelation of the traces in CRG 201 (a) Left to right direction. (b) Right to left direction. Notice the opposite polarity between these two directions.

Figure 4 shows the resulting crosscorrelations of the traces between CRGs 201 and 202, left to right in (a) and right to left in (b). Notice that they have a consistent delay however with opposite sign, as expected. Additionally we can identify a bias of about -2 ms, which can be attributed to the interpolation method. Notice that there are picks with a value about 0.8, which is an indication of good quality.

Figure 5 shows the result of the crosscorrelations in direction left to right for the CRGs adjacent to CRG 201, to illustrate the receiver statics variation, since all of them have a different prevailing delay. It is also illustrated in Figure 6(a), the stacks of the crosscorrelations in CRGs 200, 201 and 202 (shown in Figures 4(a) and 5).

Figure 6(b) shows the crosscorrelation stacks for all the CRGs, with the approximated location of the previously mentioned (Figure 6(a)) shown by an arrow. Figure 7 shows the values of the maximum picks in Figure 6(b). Notice that some of them have a low value, therefore they can be considered unreliable.

Figure 8 shows the picking of the largest amplitude of the crosscorrelation stacks for the

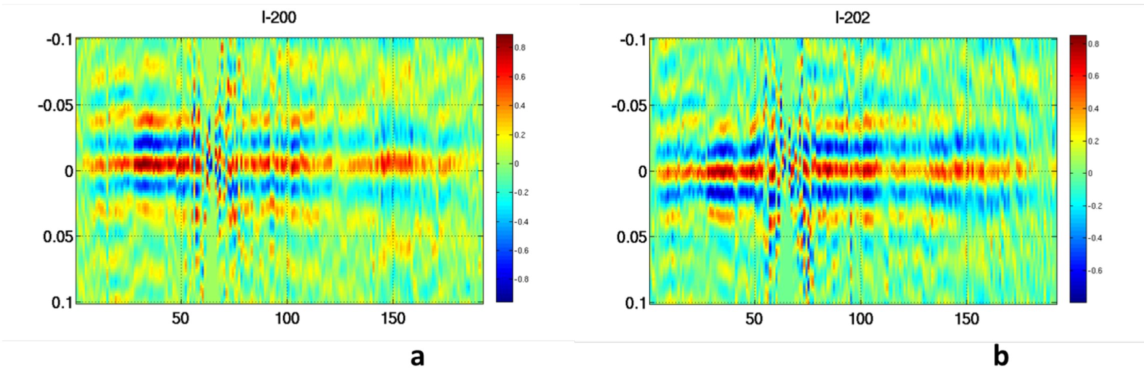

FIG. 5. Crosscorrelations results of the traces in CRG adjacents to CRG 201, in the direction left to right. (a) CRG 200, (b) CRG 202. Comparing with Figure 4(a) and **??**(a) notice a suble delay.

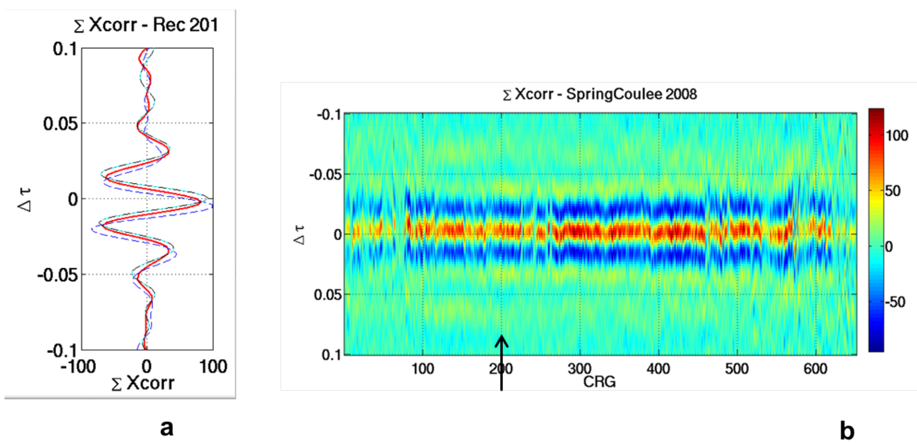

FIG. 6. Crosscorrelation stacks in the direction left to right for all receivers. (a) Individual stacks for CRGs 200 (blue dashed line), 201 (solid red) and 202 (black dash dotted). (b) Stacks for each one of the CRGs; the location of the selected in Figure (a) is shown by an arrow.

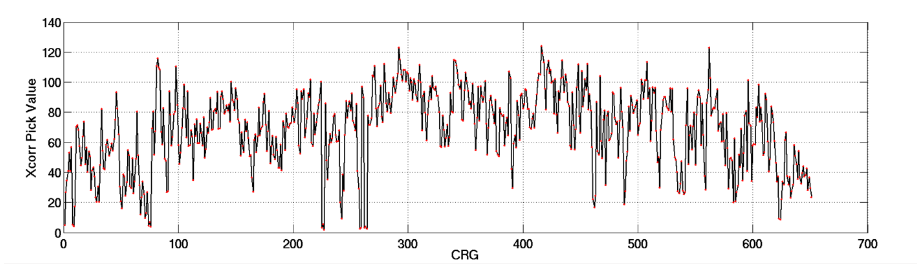

FIG. 7. Maximum picks on the crosscorrelations, obtained from the crosscorrelation stacks (Figure 6). The maximum possible value is 192, and low values correspond to lack of reliable data.

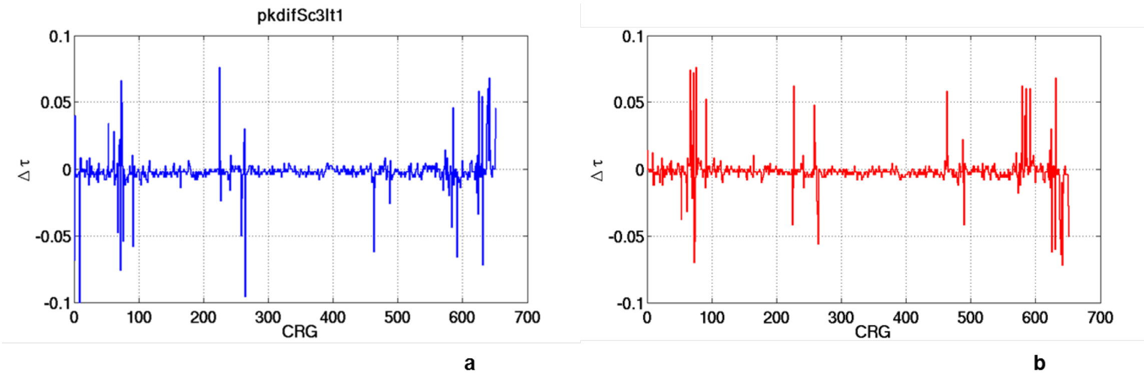

FIG. 8. Time delay for maximum picks on the crosscorrelations for both directions, obtained from the crosscorrelation stacks. (a) Left to right. (b) Right to left. Notice that Figure 8(a) is close to the inverse in $\Delta\tau$ of Figure 8(b) however with a bias of about -2 ms, and that there are a number of outliers, (values higher than 0.02 s).

analysis in the left to right direction (Figure 8(a)) and in the right to left direction (Figure 8(b)). Notice that they are alike with opposite sign, as expected, and both have a bias of about -2 ms. There are also a number of outliers, with values larger than 20 ms. Notice that these outliers coincide to some degree with the low values in Figure 7.

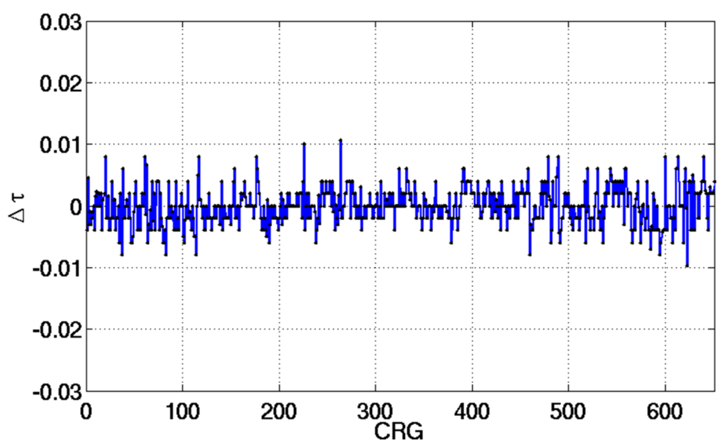

FIG. 9. Differential receiver statics after bias correction and edition of outliers. For the bias correction the results of Figure 8 are substracted and divided by two.

Editing of the outliers in Figure 8 was carried out. After that, a subtraction between these maximum picks allows us to edit the 2 ms bias. As a result the differential receiver statics δR for all the CRGs is obtained, and are shown in Figure 9. The receiver statics are obtained from the integration of the differential statics, namely the summation with respect to a datum.

The resulting receiver statics corrections are shown in Figure 10, labeled *New*, compared with the result of the CRS method (labeled *CRS*). They have been shifted to allow the comparison. Notice that both follow the same trend, however with marked differences in specific values.

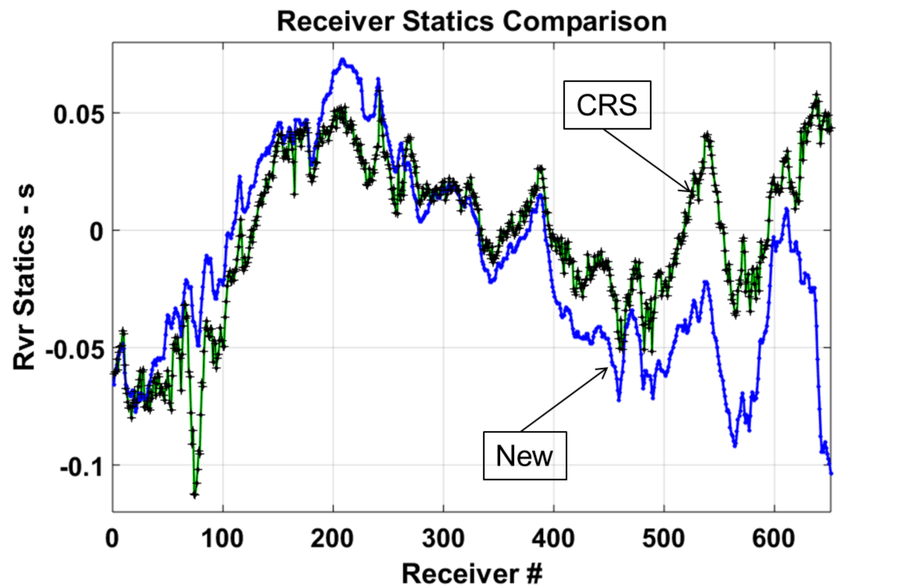

FIG. 10. Comparison of receiver statics delays using the CRS method and the new method.

Real data processing

Basic processing included noise filtering to attenuate ground-roll and other coherent events, and spikes (random high amplitude noise) editing. The source statics obtained from the PP-wave processing were applied. A stack using ruslts frm the new method result is compared to a stack with elevation statics alone.

Converted wave stack was created using asymptotic binning assuming a V_P/V_S ratio γ=1.9. The converted wave stacking velocity V_C is preliminary, and is obtained from the PP-stacking velocity V_P (from the P-wave processing) according to the approximate equation

$$V_C = \sqrt{\frac{V_P^2}{\gamma}} \tag{5}$$

Statics application

Figure 11 shows the effect of the statics correction calculated with the CRG method on the stacked section (Figure 11(b)) compared with a section stacked with elevation statics applied to the receiver (Figure 11(a)), which correct the data for a flat datum. Notice that there is more continuity on the events of Figure 11(b), which implies that a meaningful receiver statics outcome was obtained.

Figure 12 shows a stacked section following the same processing but applying the final CRS receiver statics of Figure 10. Notice that the resulting section shows a rather remarkable consistency, which supports the quality of this CRS solution.

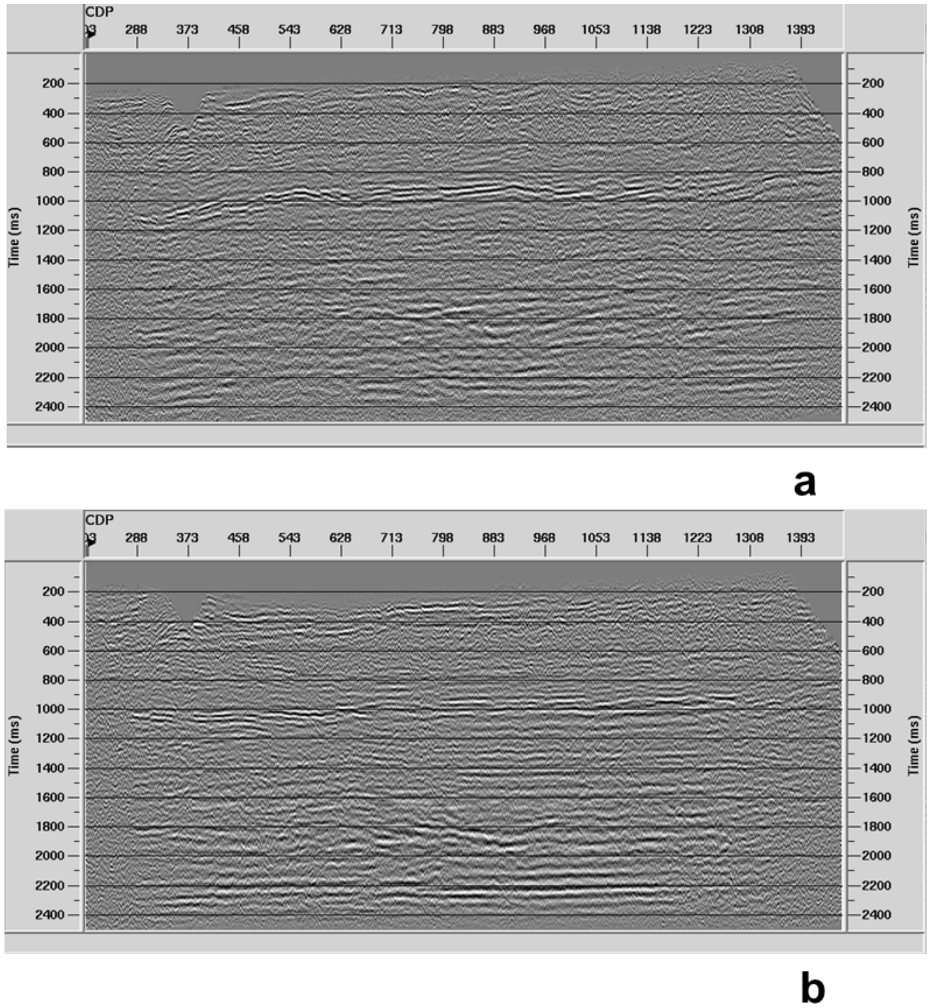

FIG. 11. Effect of the statics correction in stack sections. (a) Stack section using elevation statics. (b) Stack section using the receiver statics result. Notice the better continuity in (b).

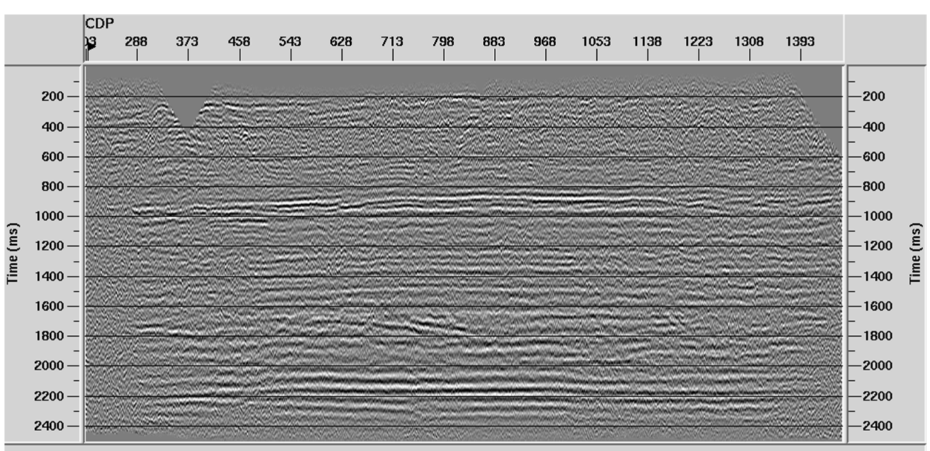

FIG. 12. Stack section using the receiver statics obtained with the CRS method.

Effect on the velocity analysis

Figure 13 show typical displays of the velocity analysis without (Figure 13(a)) and with (Figure (13(b)) the CRG statics correction. The semblances (left hand side panels) shows better continuity and stronger picks in (b), which allows easier picking of stacking velocities, and which illustrates a potential benefit of the new statics correction method.

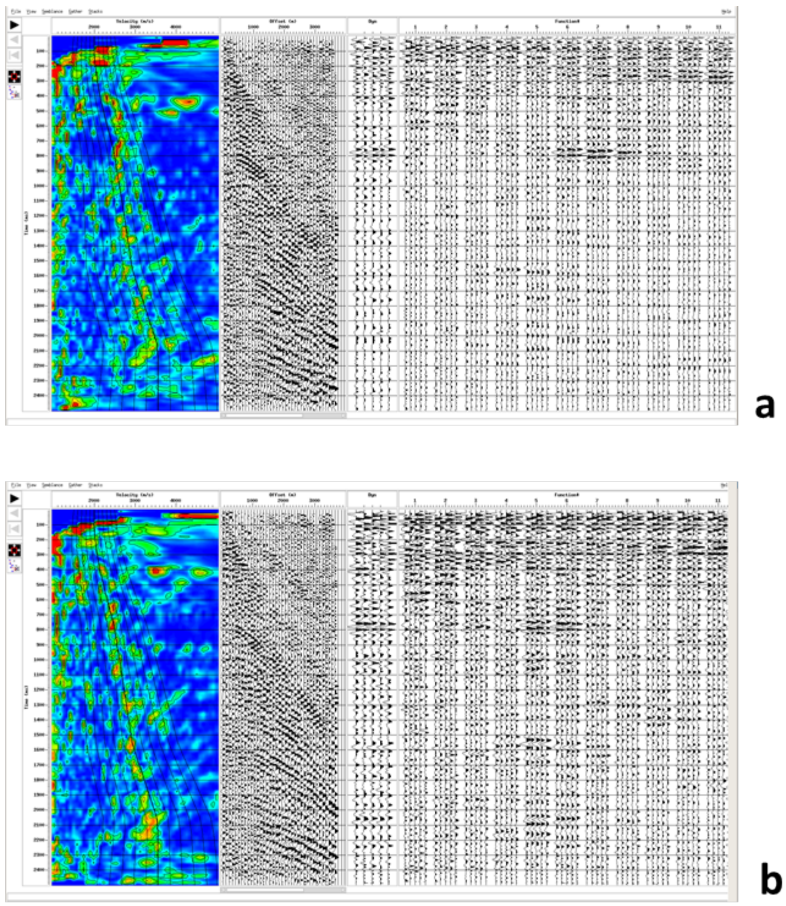

FIG. 13. Comparison of the receiver statics effect on Velocity analysis of a CDP. (a) Without the receiver statics correction. (b) With the receiver statics correction: the events are easier to follow.

CONCLUSIONS

- We have been presented a test on real data of a converted wave receiver statics correction method based on Common Receiver Gathers (CRG).
- The receiver statics is obtained from the crosscorrelation of corresponding pairs of traces of adjacent CRGs.
- The maximum picking of the crosscorrelation stacks shows outliers, which can be related to low quality CRGs. It is required to edit them to obtain the differential statics δR.
- There is more continuity of the events on a stacked section after application of the

new CRG method, compared to a section stacked with elevation statics alone. This implies that a meaningful receiver statics outcome was obtained.

- On the velocity analysis, the semblance shows better continuity and stronger picks with the CRG method, which allows easier picking of stacking velocities. This illustrates a potential benefit of the new statics correction method.
- The stacked section using the CRG method result was compared to a section with final receiver statics correction using the CRS method. The stacked section using CRS appears more continuous.
- The new method does not require stacking velocity V_C, or a horizon to flatten, which are required by the CRS method.
- The new method is automatic, so it is less laborious than other methods.

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