Computing pseudo-crosswell data by using seismic interferometry with sources on the surface

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Abstract

Seismic interferometry is a method based on the use of cross correlation and stacking operations to redatum seismic data. The special case of vertical seismic profile (VSP) in a crosswell configuration is the interest of this study. We present an approach using seismic interferometry to compute pseudo-crosswell information. This study shows an analysis of the aperture effect and fold distribution for direct waves, and full wavefield interferometry at four different maximum offsets. Results indicate that as the maximum offset increases the match between raytraced traveltimes and the interferometric receiver gathers improves. The interferometric fold distribution showed a similar result; as the maximum offset increases the fold is improved and reaches deeper parts of the model. This type of processing may help to generate data suitable for exploiting the benefits of the crosswell experiment without the risks involved in the acquisition.

Modelling parameters

Acquisition parameters used for the simulation

Number of shots	401
Spacing between shots	20m
Number of receivers	100
Spacing between receivers	10m
Spacing between wells	600m
Maximum offsets:	1000m, 2000m, 3000m, 4000m
Reflector depth	950m

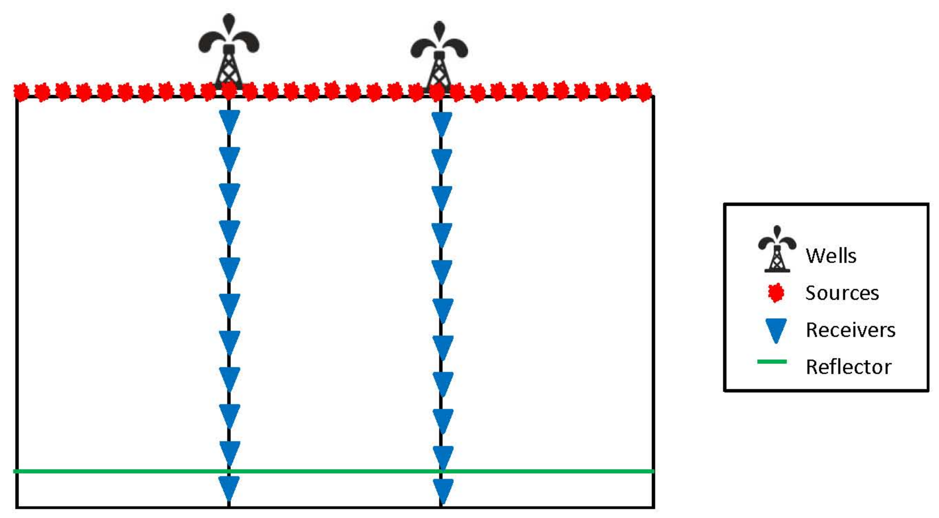

Fig. 1. Simulated acquisition configuration

Cross correlation

Seismic interferometric processing in a cross-well configuration

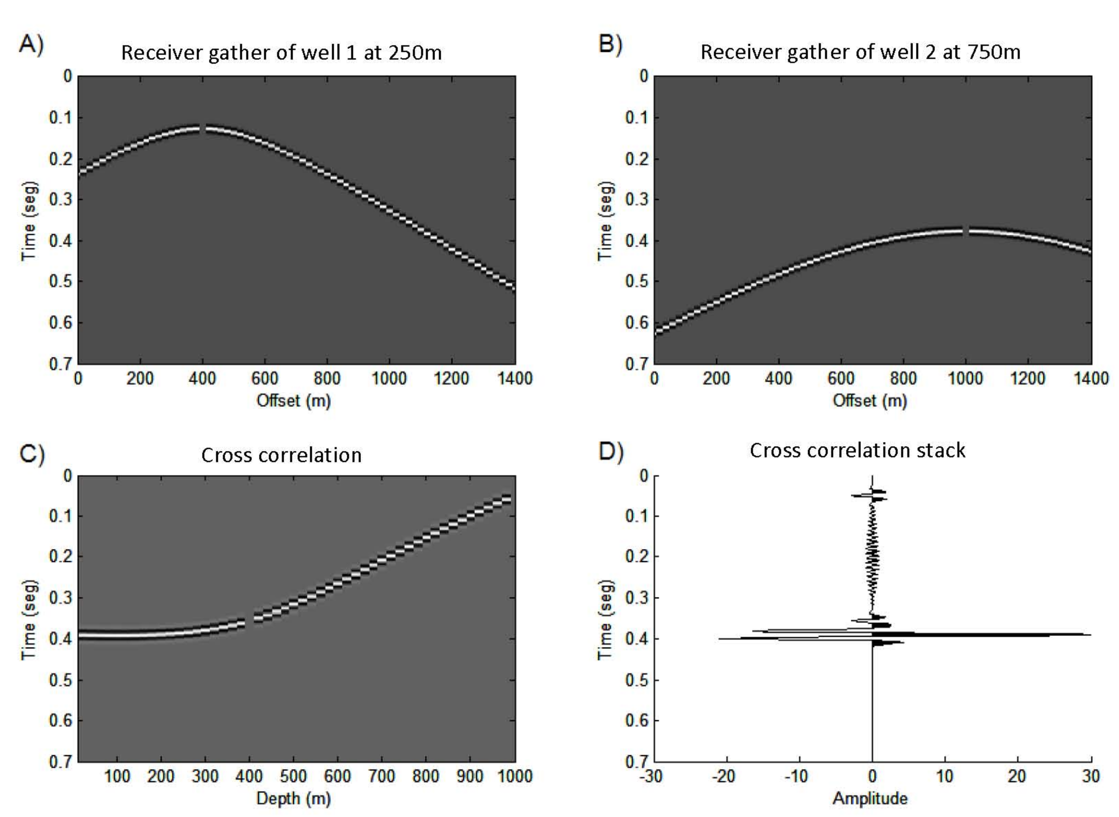

Fig. 2. Interferometric computation of a pseudo-crosswell trace. Two receiver gathers (A) and (B) at different depths from each well are cross correlated (C) and stacked (D). The result is a seismic trace with a shorter traveltime corresponding to the traveltime between both receivers.

Results

Aperture effect

Direct arrival interferometry

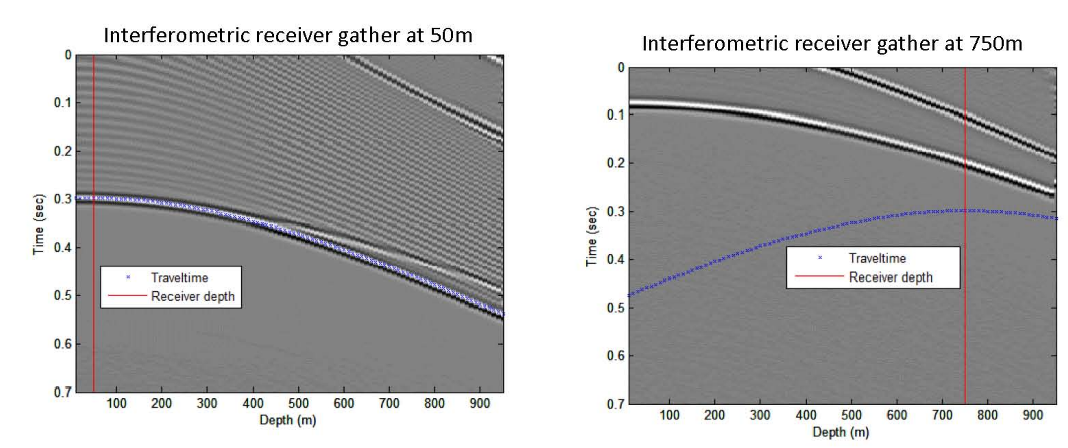

Fig. 3. Pseudo receiver gathers at depths of 50m and 750m for an offset of 1000m.

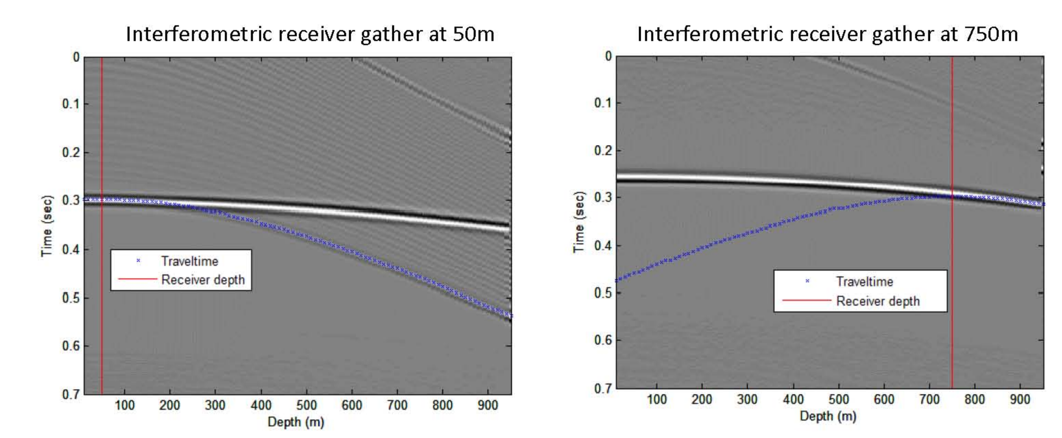

Fig. 4. Pseudo receiver gathers at depths of 50m and 750m for an offset of 4000m.

Full wavefield interferometry

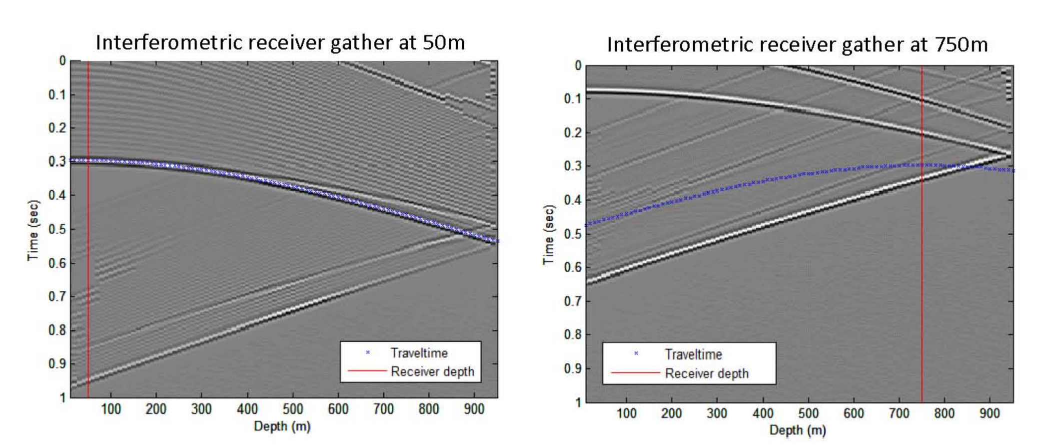

Fig. 5. Pseudo receiver gathers at depths of 50m and 750m for an offset of 1000m.

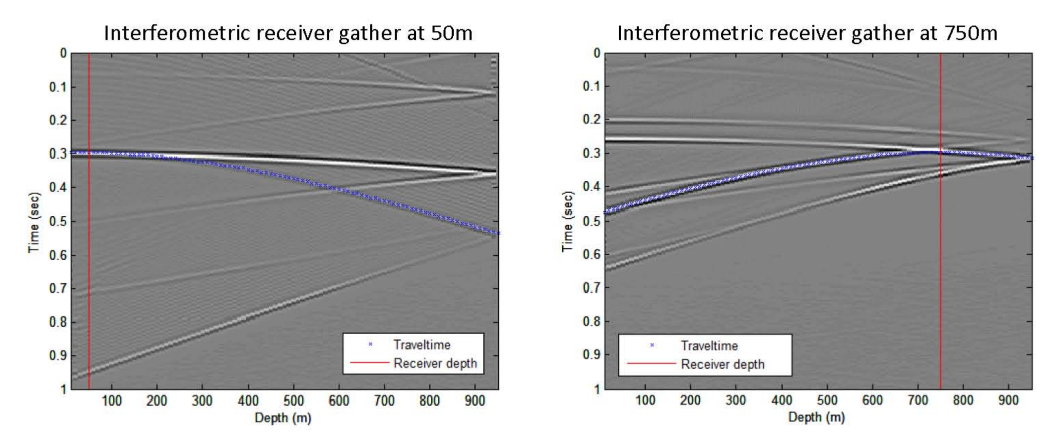

Fig. 6. Pseudo receiver gathers at depths of 50m and 750m for an offset of 4000m.

In both cases, as the maximum offset increases the relationship between the pseudo-traces and the raytraced travel times gets better for the deeper receivers.

The reflected upgoing waves are easily identified, they have a different moveout. They can also be identified by examining the depth where the downgoing and the upgoing waves converge, which should be at the reflector's depth (950m).

Results

Fold distribution

Interferometric fold maps

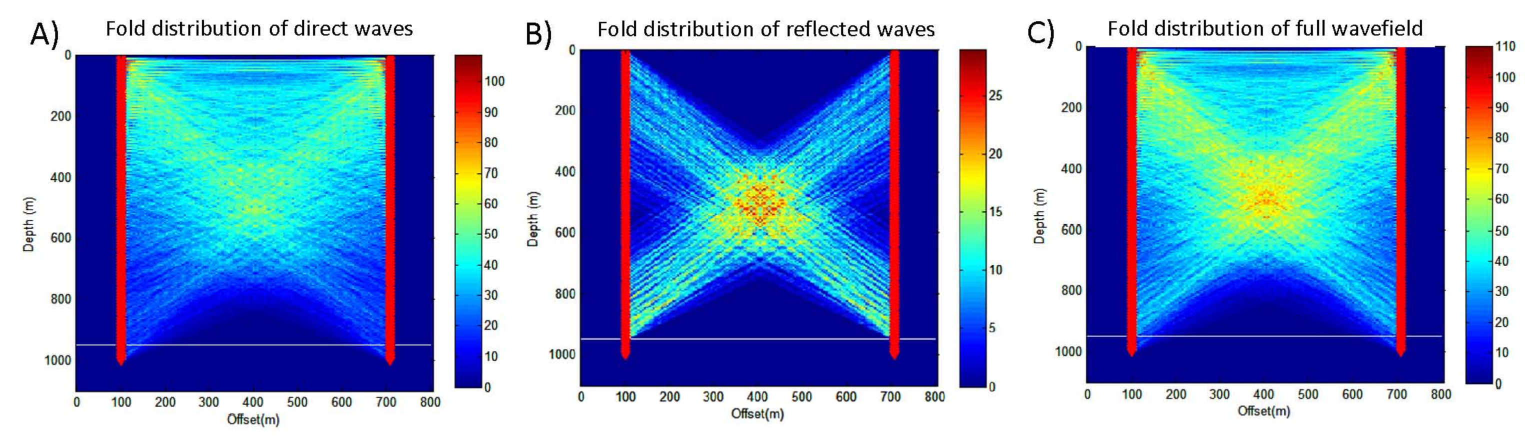

Fig. 7. Fold map for a maximum offset of 2000 m. (A) Direct arrivals, (B) Reflected waves and (C) full wavefield.

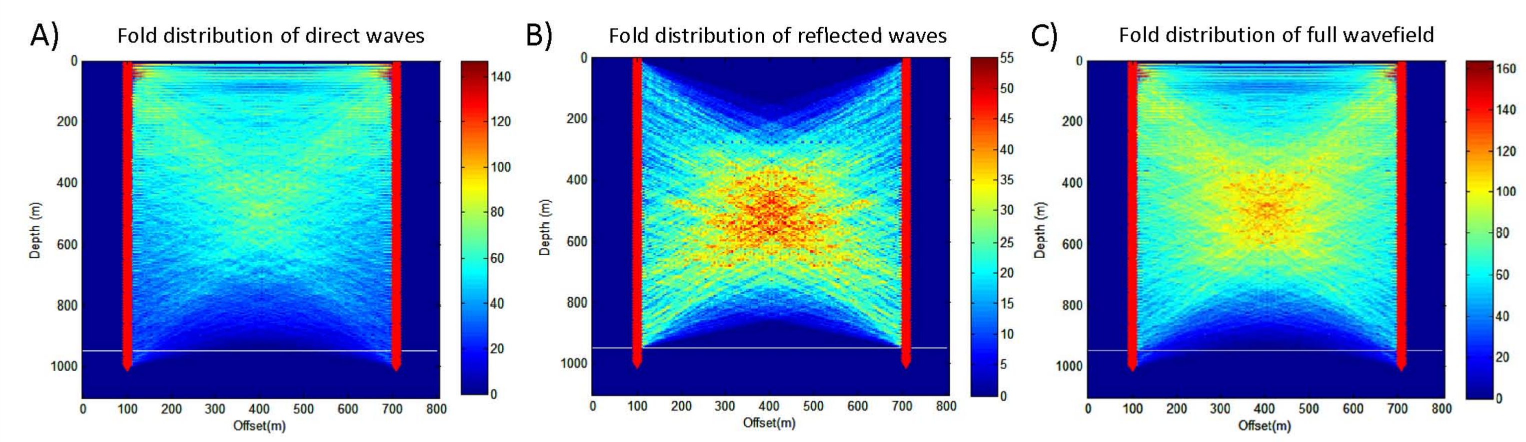

Fig. 8. Fold map for a maximum offset of 4000 m. (A) Direct arrivals, (B) Reflected waves and (C) full wavefield.

Fold comparison

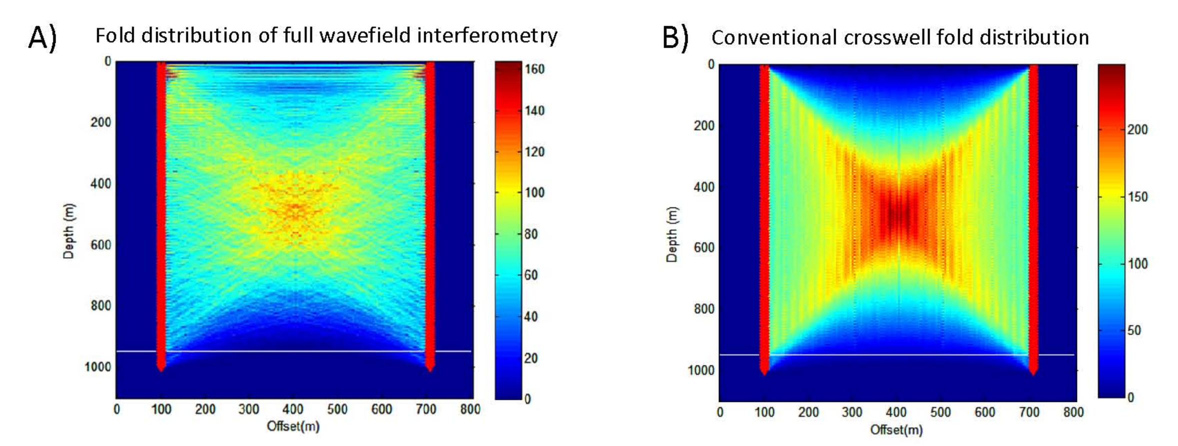

Fig. 9. A) Fold map for full wavefield interferometry at a maximum offset of 4000m and B) conventional crosswell fold map for direct arrivals.

The conventional crosswell fold (Fig. 9B) exceeds by far the maximum fold of the best interferometric fold outcome (Fig. 9A). However, the interferometric result displays a well distributed fold along the model. This is an important requirement for seismic tomography studies.

Conclusions

Seismic interferometry is a method of cross-correlating traces recorded at different locations to retrieve subsurface information. This study has shown an approach where the use of seismic interferometry can be helpful to reconstruct crosswell information that was not available with the conventional methods. The analysis of the aperture effect showed that as the maximum offset increases, the relationship between the timing of the pseudo-traces and the raytraced travel times improves. We also noted that this agreement is more complete when the full wavefield is used in the in the processing. The fold distribution has a similar result, by increasing the maximum offset we were able to reach the deepest part of the model. Although the conventional crosswell fold yields superior results than the interferometric crosswell fold, the latter one may be good enough for performing a tomographic inversion.

Future work

These achievements provide an opportunity to attempt towards further use of seismic tomography for computing a velocity model between the two wells. Also, we think the use of converted waves events will be of important interest. Including these procedures, we may be able to compute both P- and S-wave velocity models using tomographic methods.