Marchenko-based isolation of the seismic response of a target-zone

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Introduction

It is well-known that internal multiples are more sensitive to time-lapse changes in a reservoir than primaries, since they probe the reservoir several times. Hence, if we would be able to identify reservoir-related internal multiples in the baseline and monitor reflection responses at the surface, we could very accurately resolve time-lapse changes in a reservoir. In reality, however, these multiples are weak and very difficult to discern from the primaries and multiples of the over- and underburden. Recently, we developed a methodology to isolate the response of a reservoir layer from the full reflection response (van IJsseldijk and Wapenaar, 2023). This opens the possibility to monitor minute time-lapse changes in a reservoir from its primary and internal multiple reflections.

Methodology

Figure 1 schematically shows a target zone, consisting of a reservoir layer (light-blue), embedded between two reflecting interfaces. Figure 1(a) shows that if the primaries of these interfaces (the blue rays) are cross-correlated, the result is a primary reflection of the lower interface, observed at the upper interface (the red ray). Similarly, Figure 1(b) shows the correlation of a primary of the upper interface with a multiple (the blue rays), resulting in a multiple between the two interfaces, observed at the upper interface (the red ray). The multiple in Figure 1(b) has traversed the reservoir layer four times (twice downward and twice upward), whereas the primary in Figure 1(a) passed this layer only twice (once downward and once upward). Hence, the multiple in Figure 1(b) is twice as sensitive for time-lapse changes in the reservoir as the primary in Figure 1(a). Higher order multiples can be obtained by cross-correlation in a similar way, yielding even higher sensitivity to time-lapse changes.

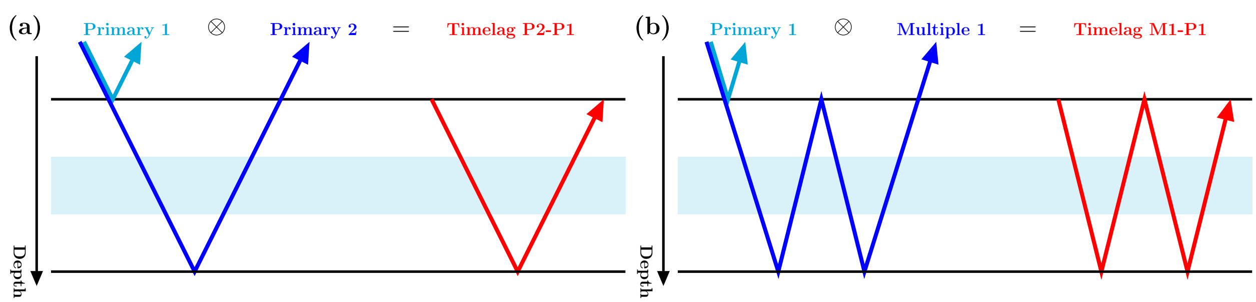

Figure 1. A target zone bounded by two reflecting interfaces (for explanations, see text).

In reality, a target zone is embedded between a complex over- and underburden. Hence, the reflections of the target zone are embedded between reflections of the over- and underburden. Moreover, multiple reflections occurring in the overburden may interfere with the target zone response and multiples occurring in the target zone may in turn interfere with the response of the underburden. This makes it very difficult in practice to identify the events, indicated in blue in Figures 1(a) and (b), in the reflection response at the acquisition surface. To address this issue, we developed a procedure, based on the Marchenko method, which suppresses the responses of the over- and underburden from the total reflection response (van IJsseldijk and Wapenaar, 2023). This leads to an isolated response of the target zone (primaries and internal multiples), free from interference with the responses of the over- and underburden. The only input that is needed (apart from the reflection data) is an approximate indication of the two-way traveltimes to the top and bottom of the chosen target zone. Cross-correlations of the primary of the upper interface with the primary of the lower interface and with the multiples yields the primaries and multiples of the target zone, observed at the upper interface. In case of time-lapse data, this target-zone isolation process is carried out for the baseline and monitor surveys. For further details we refer to the aforementioned paper.

Application to Troll-field data

We apply the methodology to a time-lapse marine dataset of the Troll field in Norway. Figure 2(a) shows a zero-offset gather of the baseline survey. The red and green lines indicate the primaries from the top and bottom of the target zone. The arrows indicate multiples from the overburden. The blue and orange lines indicate where the first and second order multiples of the target zone should be expected, but unfortunately the recording time was limited to 2 s, so no response is visible there. Figure 2(b) shows the situation after Marchenko-based isolation of the target zone for the baseline survey. The arrows indicate the suppressed multiples from the overburden. The predicted multiples of the target zone are now visible between the blue and orange lines. Figure 2(c) shows the difference before and after isolation of the target zone. Similar results are obtained for the monitor survey (not shown).

Next, for Figure 2(b) we correlate the second primary (green) and the two multiples (blue and orange) with the first primary (red) to retrieve the traveltimes of the primary and multiples of the target zone for the baseline survey. We do the same for the monitor survey. The time-lapse changes between the baseline and monitor traveltimes are shown in Figure 2(d) (primary 2 in blue, multiple 1 in orange and multiple 2 in green). The time-lapse changes for multiple 1 and 2 have been divided by 2 and 3, respectively, to compare them with the primary shift. Note that the match is very good, particularly between the red-shaded zones. Unfortunately the recording time was limited to 2s, which was too short to compare the predicted internal multiples with recorded internal multiples.

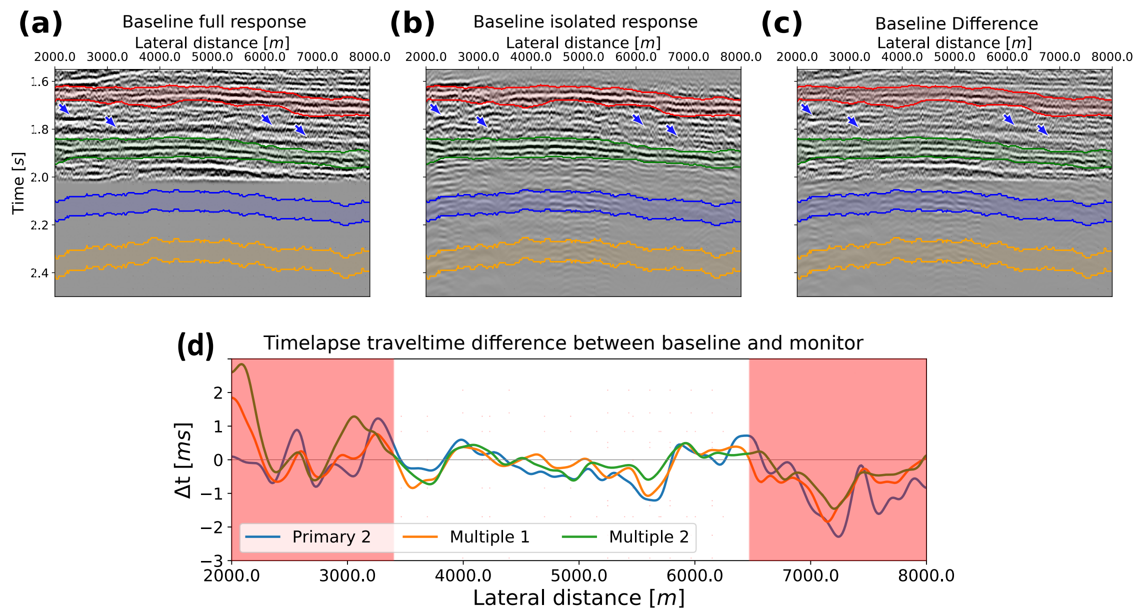

Figure 2. Results of target-zone isolation applied to Troll-field data (for explanations, see text).

Conclusions

We proposed a Marchenko-based method to isolate the response of a target zone from a seismic reflection response, with the aim to improve the determination of time-lapse changes in a target zone. We applied the method to Troll-field data and successfully predicted internal multiples of the target zone.

This method will ultimately aid our understanding of time-lapse changes in a reservoir caused by production or storage of resources in the subsurface.

Acknowledgement

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Reference

van IJsseldijk, J., and K. Wapenaar, 2023, Extracting small time-lapse traveltime changes in a reservoir using primaries and internal multiples after Marchenko-based target zone isolation: Geophysics, **88** (2), R135-R143.