The effect of the near surface on internal multiples: a test of 1.5D prediction on synthetic examples

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OVERVIEW

- Internal multiples occur in seismic data when incident energy reflects downwards within a geological layer, and are recorded at the surface as a unique reflection event.
- These multiples must travel at least twice through a low velocity, unconsolidated near surface, possibly having different properties at each raypath location.
- Various geological models are tested, in which at least one internal multiple is produced from a deeper low velocity layer.
- Internal multiples (IMs) are compared for different complexities of near surfaces, and a 1.5D internal multiple prediction algorithm is tested on the produced seismic data.
- For simple models, the 1.5D prediction is accurate, but for a laterally heterogeneous near surface, the 1.5D prediction is insufficient to correctly predict the multiples.

GOALS

- Observe the effect of lateral near surface changes on internal multiples in shot records.
- Test 1.5D IM prediction on these shot records.
- Find where 1.5D prediction fails when using data acquired over a complex near surface.

MODEL 1

- Reference model for this study
- Laterally homogeneous, horizontally layered near surface, with gradient velocities.

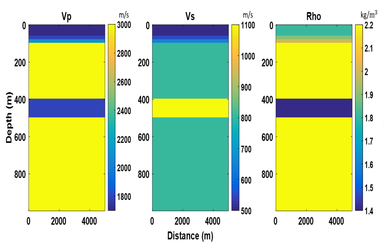

FIG. 1. Velocity model 1, with simple symmetric geometry.

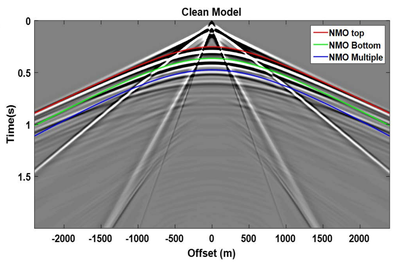

FIG. 2. Shot record of Model 1 with NMO curves overlain of reflections from the IMG, and the first IM.

- The raw shot record (FIG. 2) is tau-p transformed to filter direct arrivals, refractions, and slower linear events. Then a mute is applied above the first primary reflection to remove remaining tau-p artifacts.
- This is necessary because otherwise these events will be interpreted as reflection events by the IM prediction.

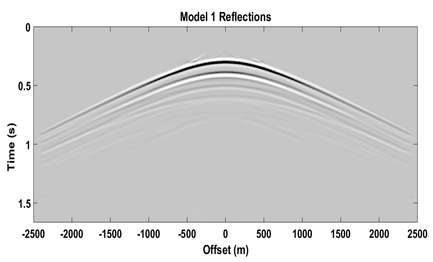

FIG. 3. Model 1 shot record, reflections and IMs only

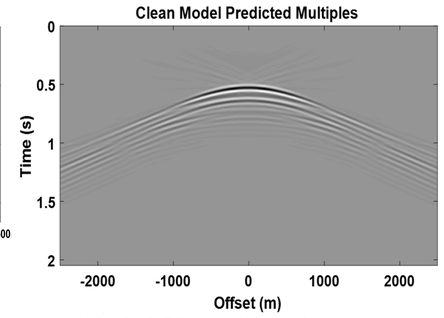

FIG. 4. 1.5D predicted internal multiples

The internal multiples are correctly predicted by the 1.5D prediction. This is the expected result for this model, due to its symmetry about the source location (1.5D medium).

MODEL 2

- Vertical near surface discontinuity in a single layer.
- Source located on the discontinuity.

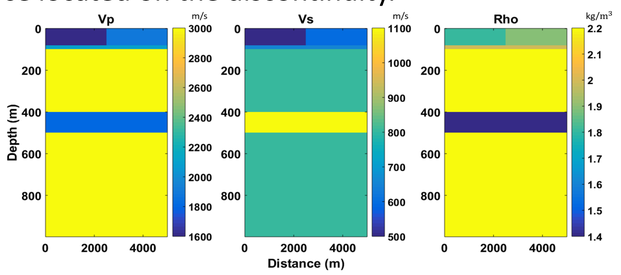

FIG. 5. Model 2, with a vertical discontinuity in the centre of the model.

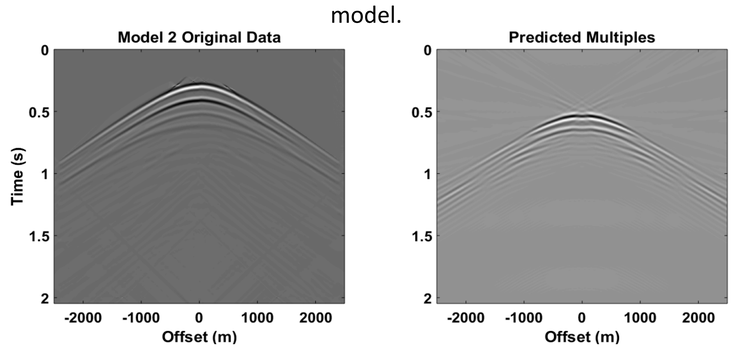

FIG. 6. Left (a): Filtered data for Model 2. Right (b): 1.5D predicted IMs from FIG. 6a.

- There are IM travel time differences on opposite sides of the source in FIG. 6a which are not correctly predicted in 6b.
- IM removal using this 1.5D prediction would not be effective.

MODEL 3

- Vertical near surface discontinuity through 3 layers with velocity variations.
- Source located on the discontinuity.
- IM and predicted IM mismatch increases with offset. (FIG. 8, 9)
- Left shot prediction is symmetric(FIG. 9b), and includes travel time shift present on only positive offset data (FIG. 9a)

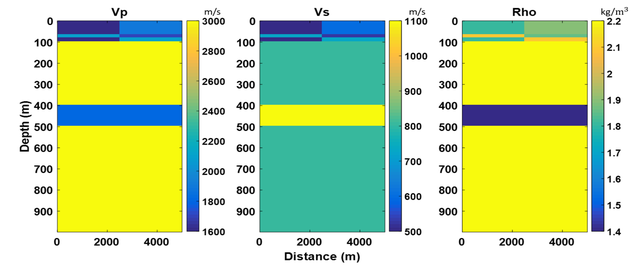

FIG. 7. Model 3, with a vertical discontinuity in the centre of the model, through 3 layers.

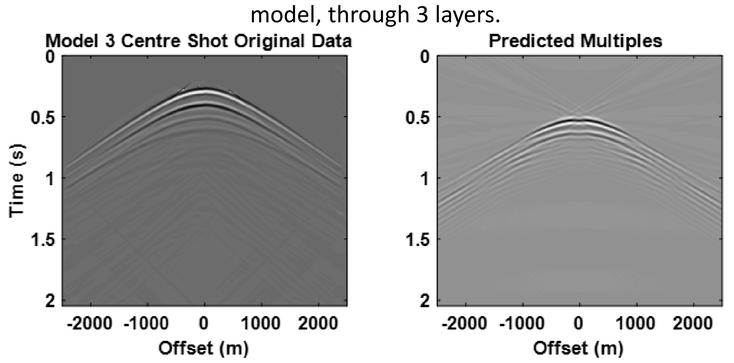

FIG. 8. Left (a): Filtered data for Model 3, centre shot. Right (b): 1.5D predicted IMs from FIG. 8a.

Source located at x=2200m, 300m left of discontinuity.

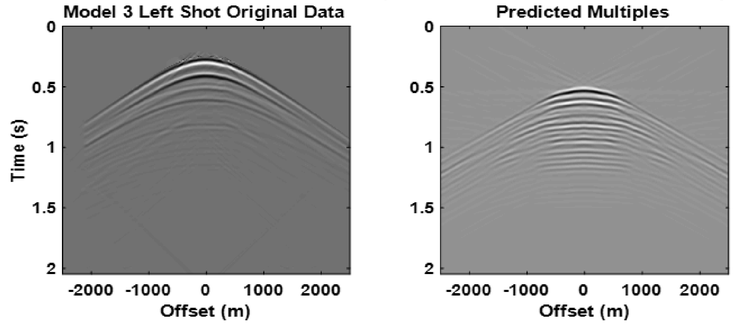

FIG. 9. Left (a): Filtered data for Model 3, shot at 2200m. Right (b): 1.5D predicted IMs from FIG. 8a.

SUMMARY

- Asymmetry of IM arrival times in modelled data are not accurately predicted by 1.5D IM prediction.
- Removal of predicted IMs from modelled data would result in partial multiple removal.
- The near surface has a substantial enough effect on IMs to necessitate a 2D IM prediction and removal in cases of a complex, laterally heterogeneous near surface.

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