Efficiency in multiple prediction, leveraging the CMP gather

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ABSTRACT

- The most successful method of internal multiple prediction is that based on the inverse scattering series.
- Typically when the data comes from structured geology, we must employ the more accurate, but costly 2D prediction algorithm.
- We show that by leveraging properties of the CMP gather, that we may extend the applicability of the more cost effective 1.5D algorithm, to the case of layers with moderate dip.

INTRODUCTION

- The presence of large amplitude internal multiples poses a significant problem to effective interpretation and processing of seismic.
- Internal multiple prediction based on the inverse scattering series searches the data for all triplets of events obeying a lower-higher-lower relationship. It then sums the traveltimes of the two lower events, and subtracts that of the higher event to predict the traveltime of all internal multiples in the data.
- The computational expense of the 2D algorithm, and limited accuracy of the 1.5D algorithm in the presence of structure is a roadblock to successful commercial application.
- We show that by leveraging the CMP gather, we may extend the applicability of the 1.5D algorithm to datasets from dipping reflectors.

2D versus 1.5D algorithms

When structure exists in the data, one source side horizontal slowness will in general lead to many receiver side horizontal slowness's. When this is the case we typically must revert to the 2D internal multiple prediction algorithm, in the planewave domain, this takes the form.

$$b_{3_{IM}}(p_g,p_s,\omega)=\frac{1}{(2\pi)^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-i\omega(\tau_{1_g}-\tau_{1_s})}dp_1 e^{-i\omega(\tau_{2_g}-\tau_{2_s})}dp_2\times\Psi$$

Where

$$\Psi(p_g,p_1,p_2,p_s|\epsilon)=\int_{-\infty}^{\infty} b_1(p_g,p_1,\tau)e^{i\omega\tau}d\tau\int_{-\infty}^{\tau-\epsilon} b_1(p_1,p_2,\tau')e^{-i\omega\tau'}d\tau' \times\int_{\tau'+\epsilon}^{\infty} b_1(p_2,p_s,\tau'')e^{i\omega\tau''}d\tau''$$

Equations (1) and (2) together represent the 2D prediction algorithm in the coupled planewave domain. If the geology lacks structure then $p_g=p_s$ and the algorithm reduces to the 1.5D one of equation (3).

$$b_{3_{IM}}(p_g,\tau)=\int_{-\infty}^{\infty} b_1(p_g,\tau)e^{i\omega\tau}d\tau\int_{-\infty}^{\tau-\epsilon} b_1(p_g,\tau')e^{-i\omega\tau'}d\tau' \times\int_{\tau'+\epsilon}^{\infty} b_1(p_g,\tau'')e^{i\omega\tau''}d\tau''$$

The1.5D algorithm is much less computationally expensive as the search integrals run only once for each frequency, and once for each output p_g. The 2D algorithm runs for every ω, for every p_1-p_2 pair, and then is repeated for every p_g-p_s pair.

Traveltimes in the CMP domain and the effect on IM prediction

The traveltime for a ray in dipping strata, for a fixed source or receiver at A can be shown to depend solely on the horizontal slowness at point B.

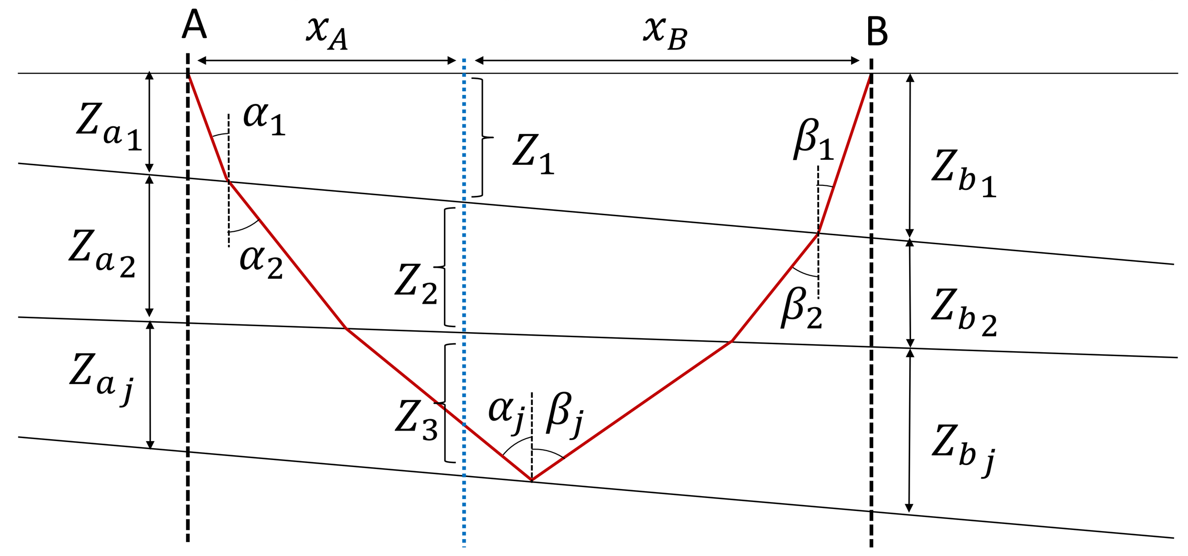

FIG 1. Schematic showing a single ray in dipping strata, and the geometric values required to derive an expression for the traveltime.

When both source and receiver are moving as in the CMP experiment, then the traveltime equation now depends on both the source and receiver side slowness,

$$T=p_A x_A+p_B x_B+\sum_j Z_j(q_{A_j}+q_{B_j})$$

In the CMP geometry when $x_A=x_B$ the traveltime becomes

$$T=x\bar{p}+\sum_j Z_j(q_{A_j}+q_{B_j})$$

This has profound consequences on the internal multiple prediction, by extending the applicability of the 1.5D algorithm since now $p_g\approx\bar{p}\approx p_s$.

Internal multiple prediction in the CMP domain

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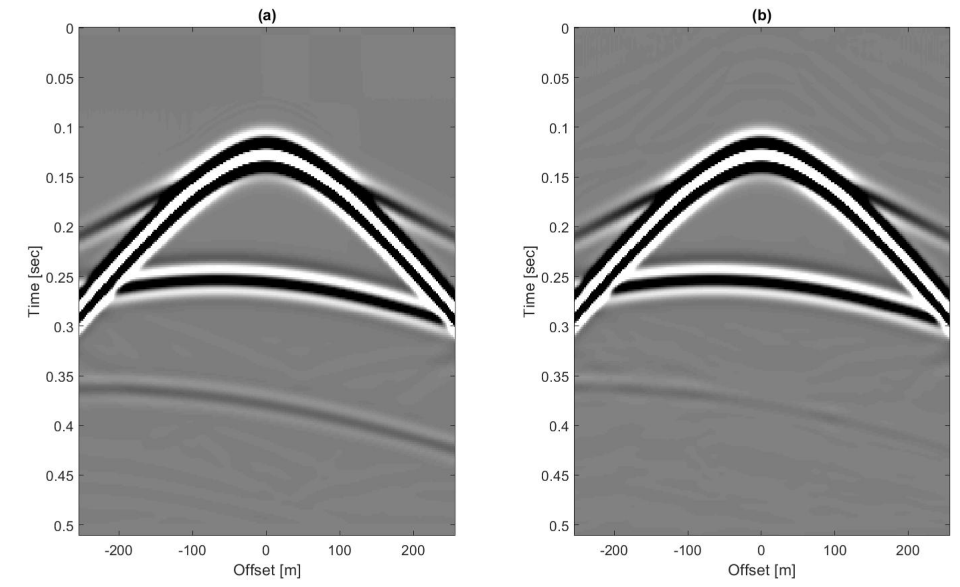

FIG 2. (a) Shot record from model with one reflector dipping at 10 degrees, (b) resulting 1.5D prediction.

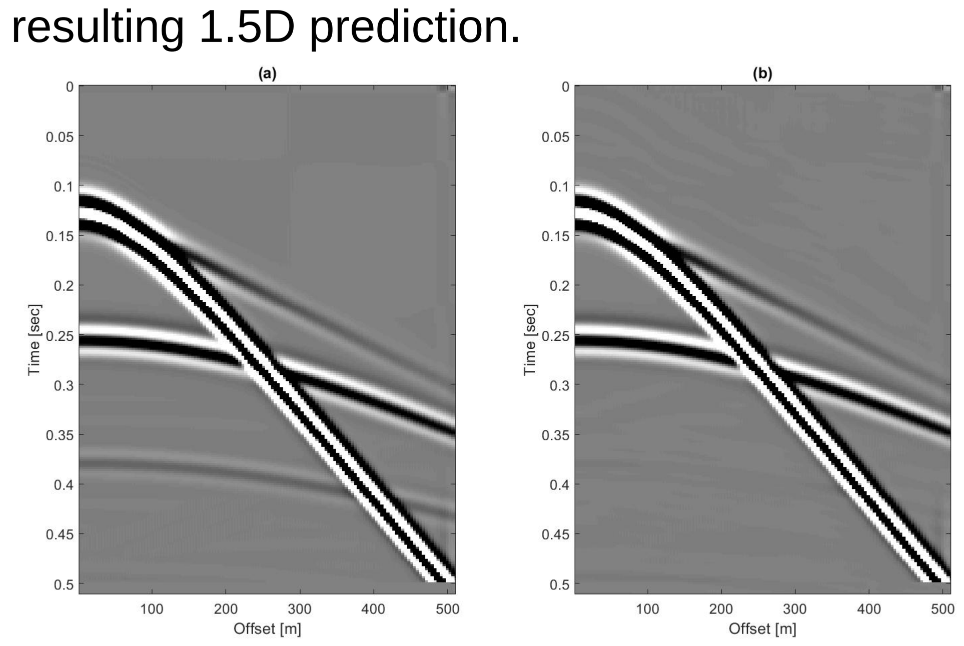

FIG 3. (a) CMP gather from model with one reflector dipping at 10 degrees, (b) resulting 1.5D prediction.

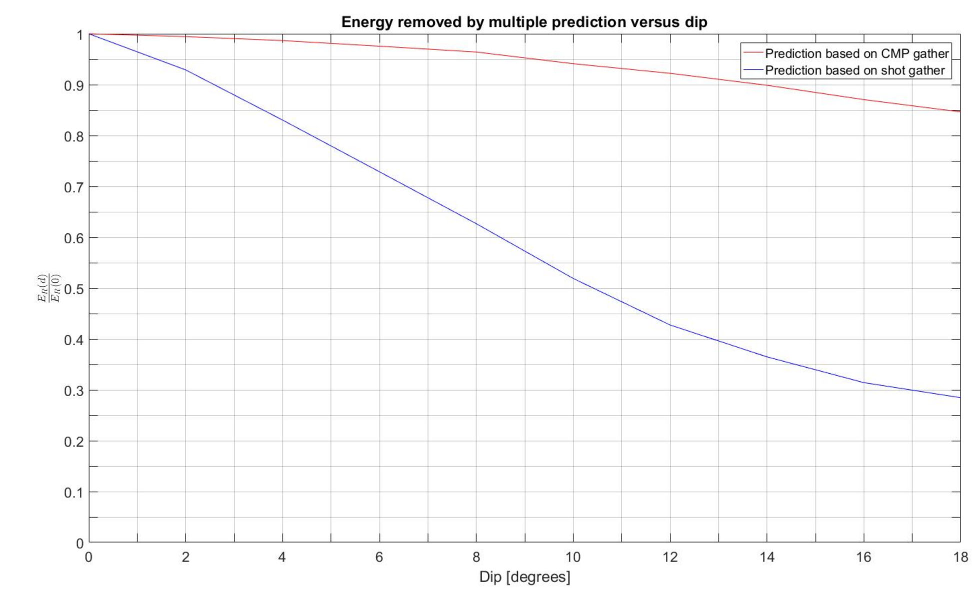

FIG 4. Energy removed by multiple prediction versus dip, relative to energy removed in the "perfect" zero dip case, for the CMP gather in red and shot record in blue.

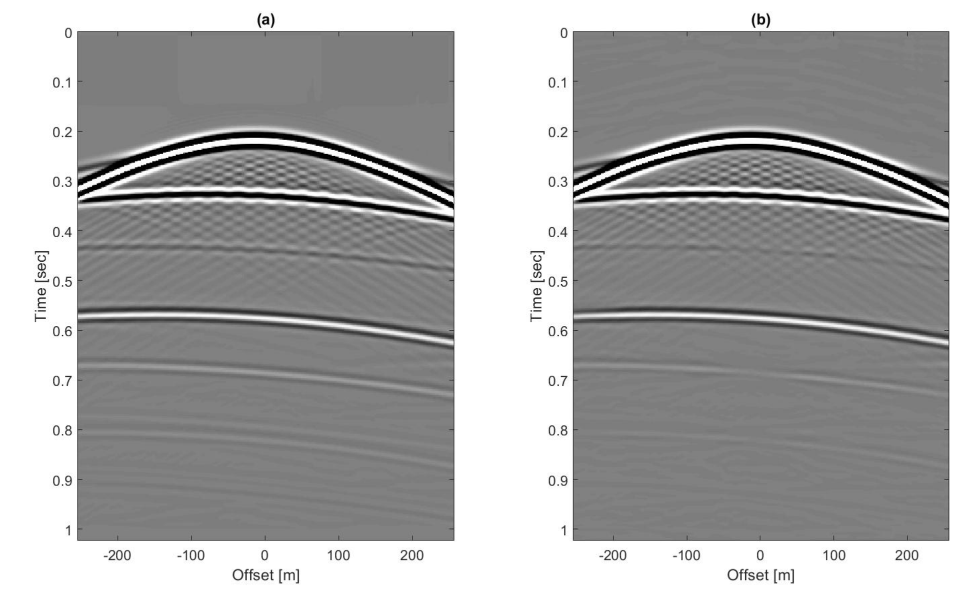

FIG 5. (a) Shot record from model with layers dipping at 2,4, and 6 degrees, (b) resulting 1.5D prediction, from model with multiple dipping layers.

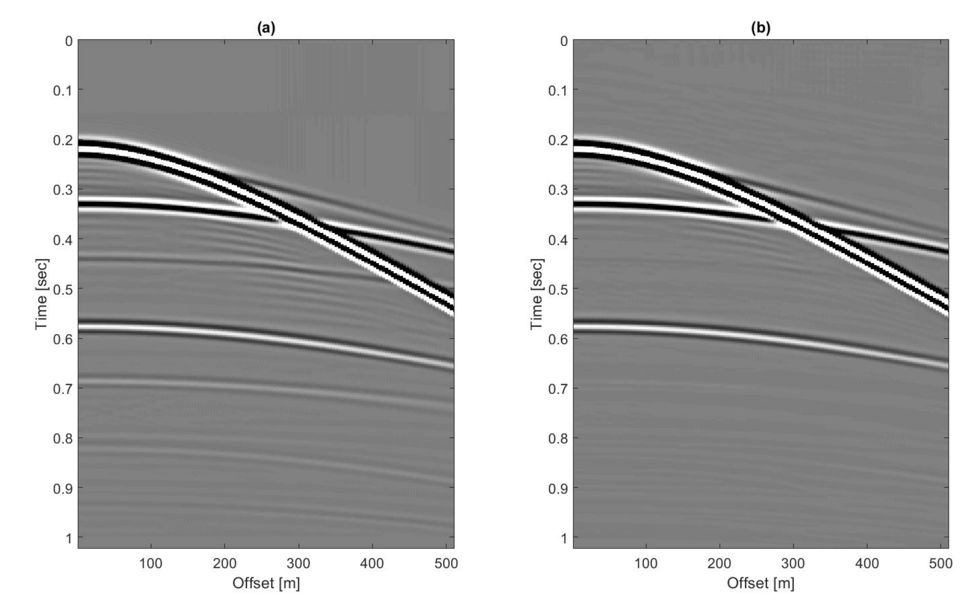

FIG 6. (a) CMP gather from model with layers dipping at 2,4, and 6 degrees, (b) resulting 1.5D prediction, from model with multiple dipping layers.

Conclusions

- Applying 1.5D predictions to shot records recorded from 2D geology is typically a fruitless endeavor
- Leveraging the inherent averaging of source side and receiver side slowness in CMP gathers extends the applicability of 1.5D algorithms
- We show that in the presence of dipping reflectors, the 1.5D algorithm maintains a high level of accuracy when applied to CMP gathers, improving efficiency in multiple prediction.

Acknowledgments

The authors thank CREWES and its sponsor companies for funding this work as well as NSERC through the grant CRDPJ 461179-13. We are grateful for the donation of the dataset used.

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