1.5D internal multiple prediction on physical modeling data

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Outline

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Introduction

The problems with internal multiples:

- Events which can be misinterpreted as primaries;
- Events which can interfere with primaries;
- Events which can obscure the task of interpretation.

Two advantages of the inverse scattering series method:

- This method does not require any subsurface information.
- Internal multiples are predicted with accurate times and approximate amplitudes.

Motivation

- In many cases, internal multiples interfere with primaries, and removal of internal multiples without compromising primaries is very challenging.
- Reshef et al. (2003) pointed out that the prediction itself can be the final output, which is useful as an interpretation tool for identification only.
- Whether we decide to subtract internal multiples or not, the ability to identify them amongst primaries is still a technological necessity.

1.5D IM prediction algorithm

The formula for 1.5D internal multiple prediction (Weglein et al., 1997; 2003) is

$$PRED(k_g,\omega) = \int_{-\infty}^{\infty} dz e^{ik_z z} b_1\left(k_g,z\right) \int_{-\infty}^{z-\epsilon} dz' e^{-ik_z z'} b_1\left(k_g,z'\right)$$

Temporal frequency

$$\times \int_{z'+\epsilon}^{\infty} dz'' e^{ik_z z''} b_1(k_g,z'')$$

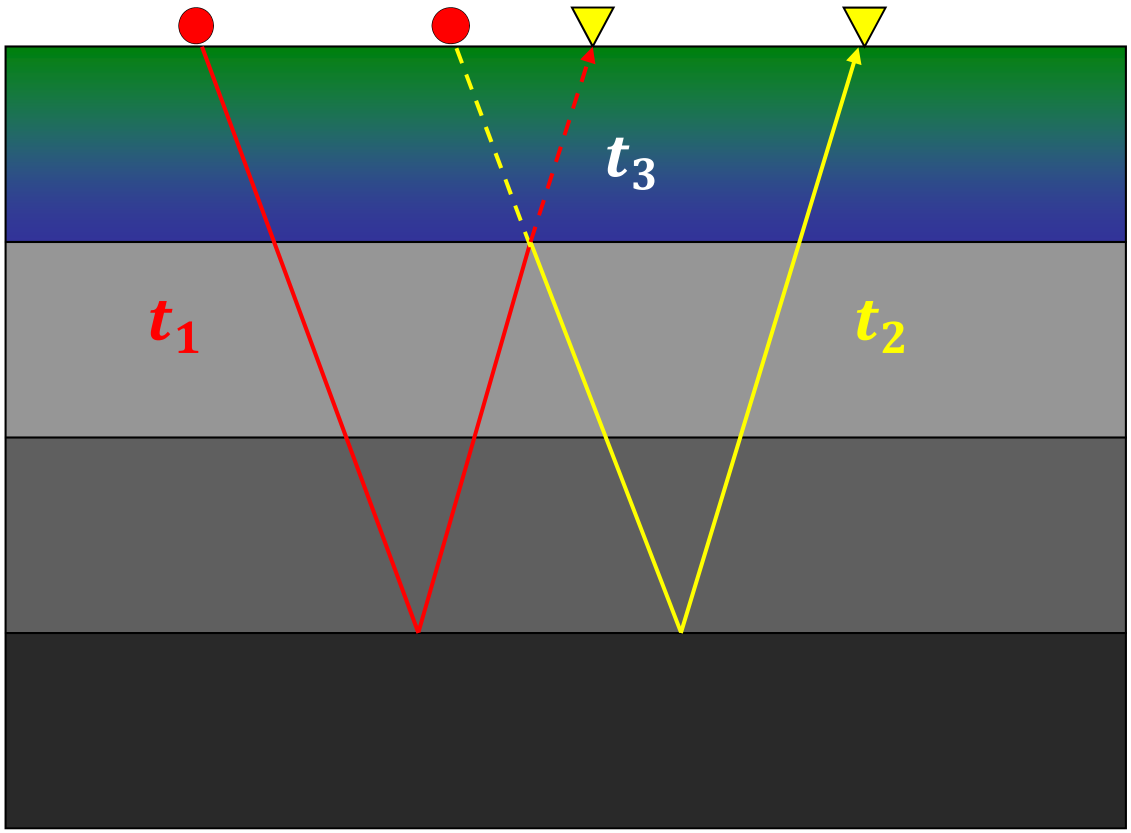
Lateral wavenumber

where $k_z = 2q_g$ and $q_g = \frac{\omega}{c_0}\sqrt{1-\frac{k_g^2 c_0^2}{\omega^2}}$.

Vertical wavenumber

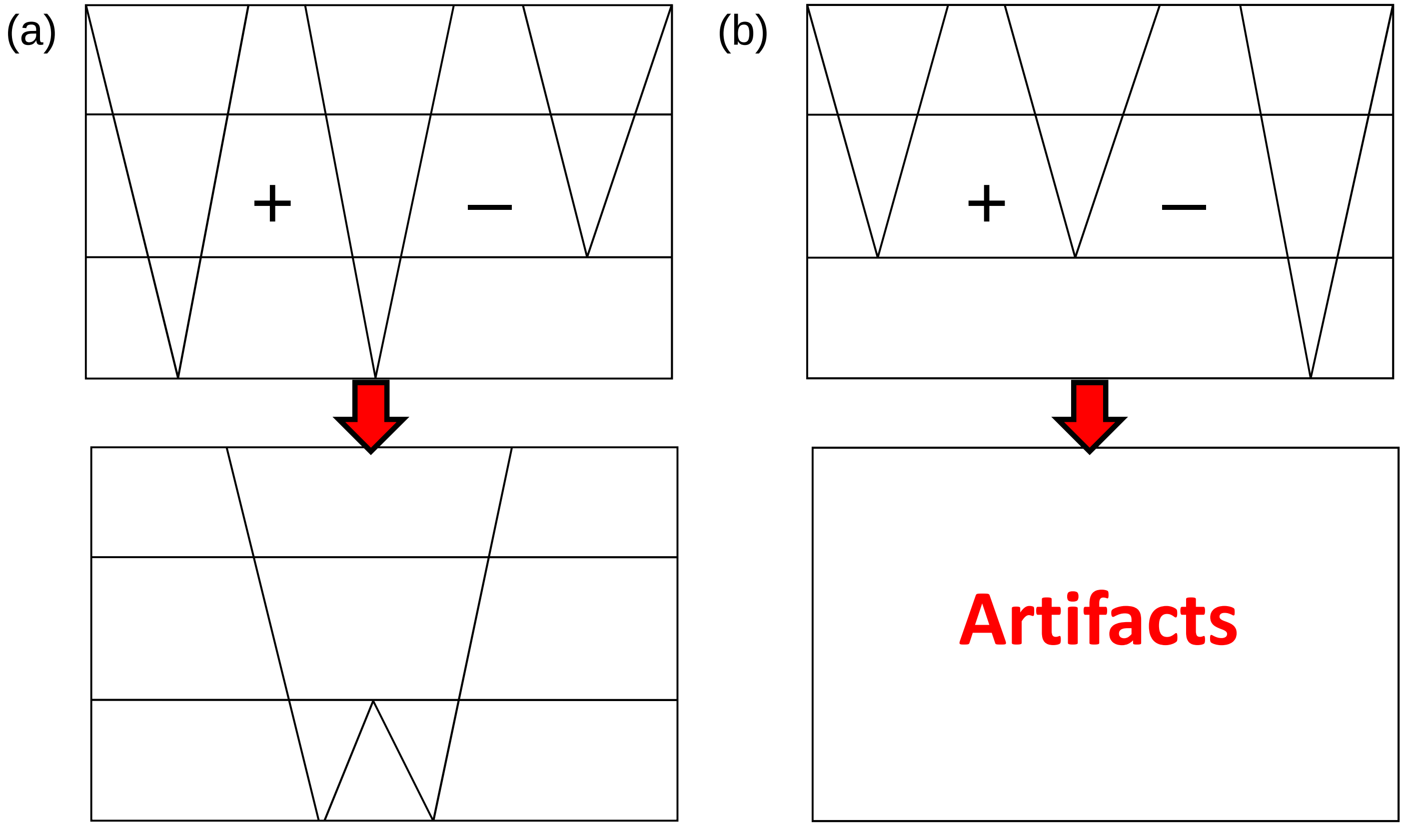
Reference velocity

Lower-higher-lower relationship



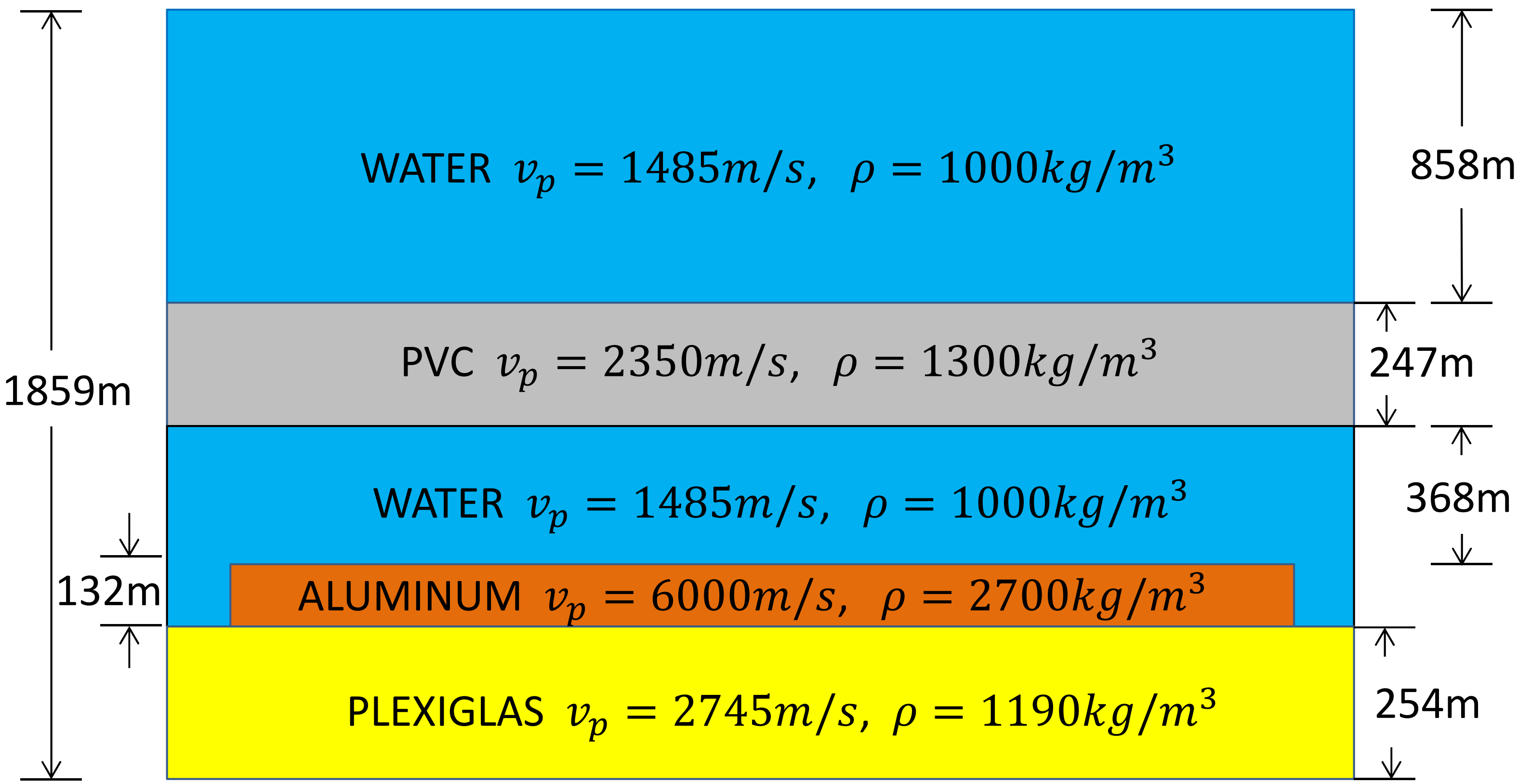
Construction of the travel time of an internal multiple.

Lower-higher-lower relationship



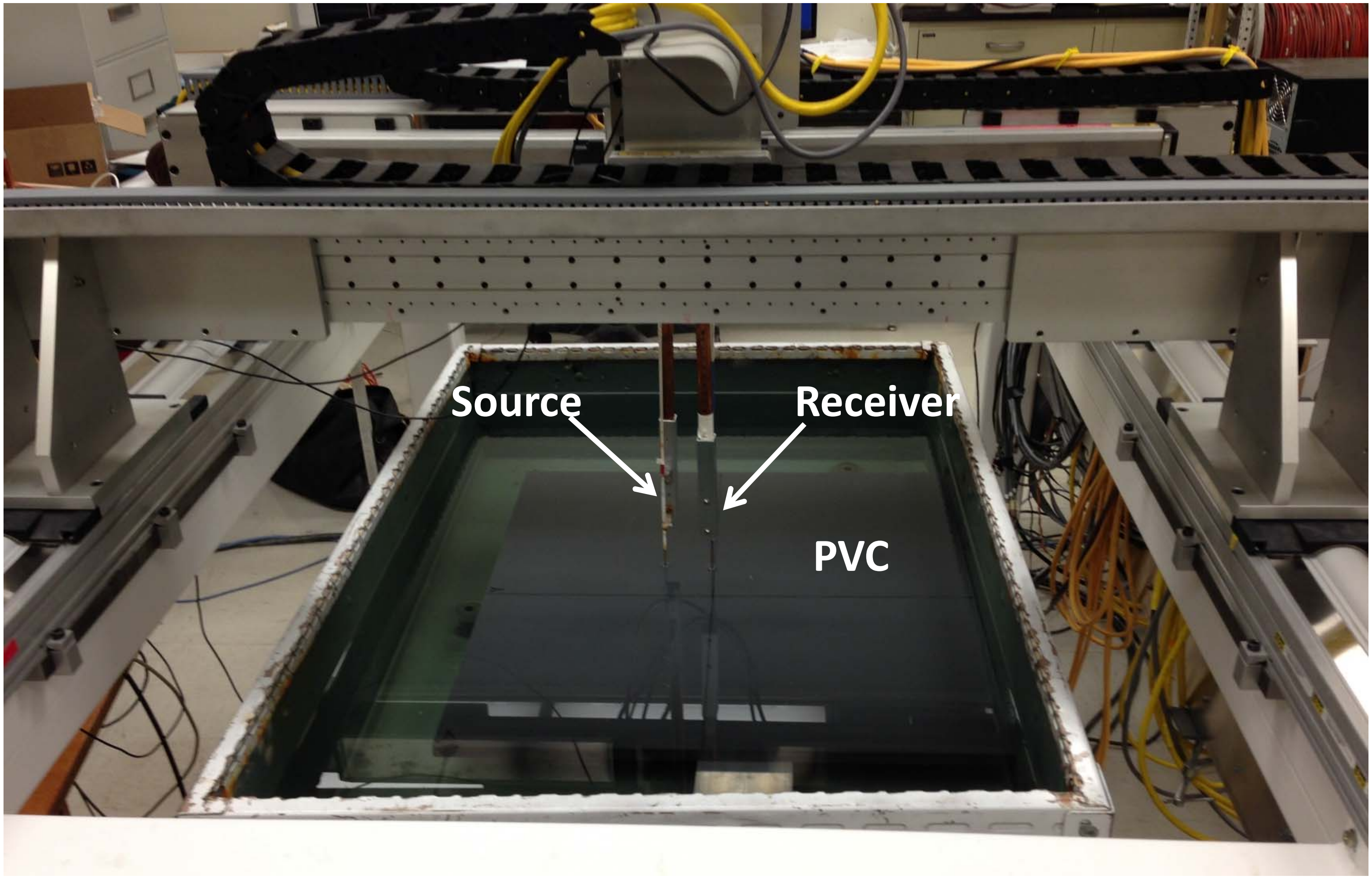
Two combinations of sums and differences.

Physical modeling experiment



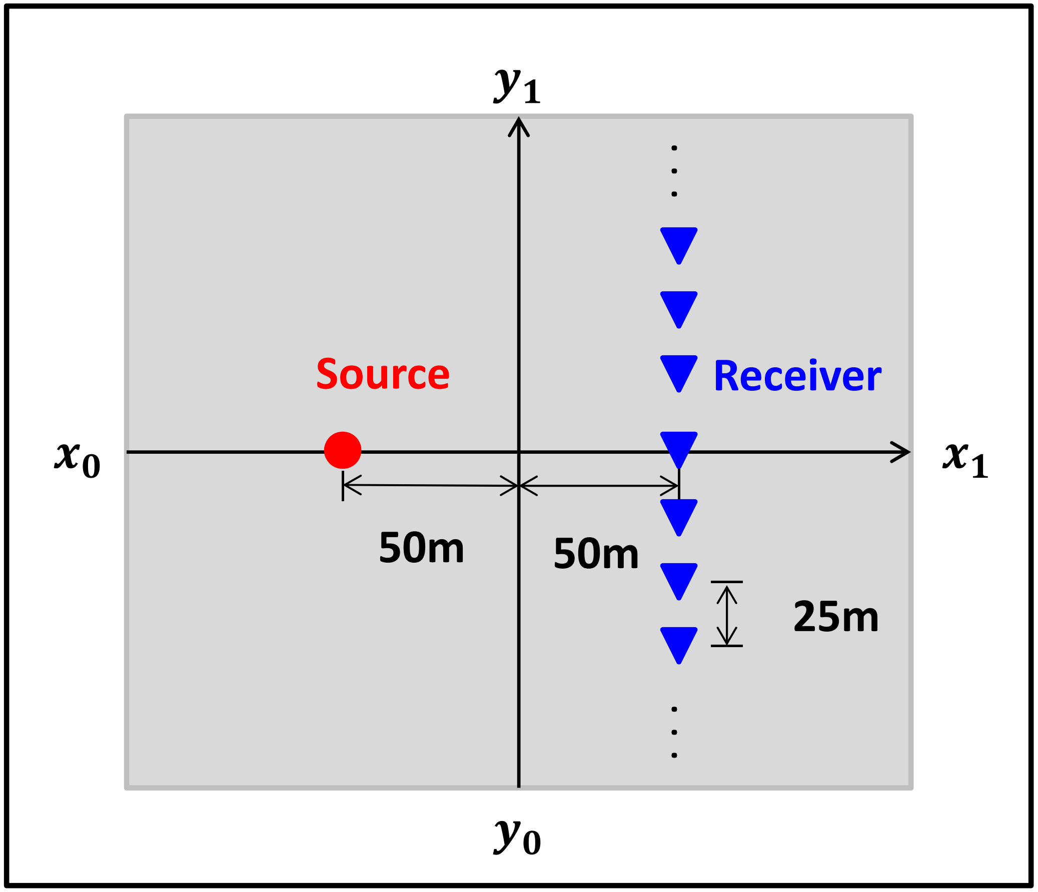
Schematic diagram of the physical modeling experiment. All lengths are in scaled units, the standard model scale factor is $1{:}10^4$.

Physical modeling experiment



The 3D positioning system.

Physical modeling experiment



- The source and receiver are 1.36mm-diameter piezoelectric pin transducers.
- The source and receiver are separated by 100m in the x direction.
- The source has been fixed.
- The receiver was moved from y_0 to y_1 direction in 25m increments.
- The sampling rate was 2ms.

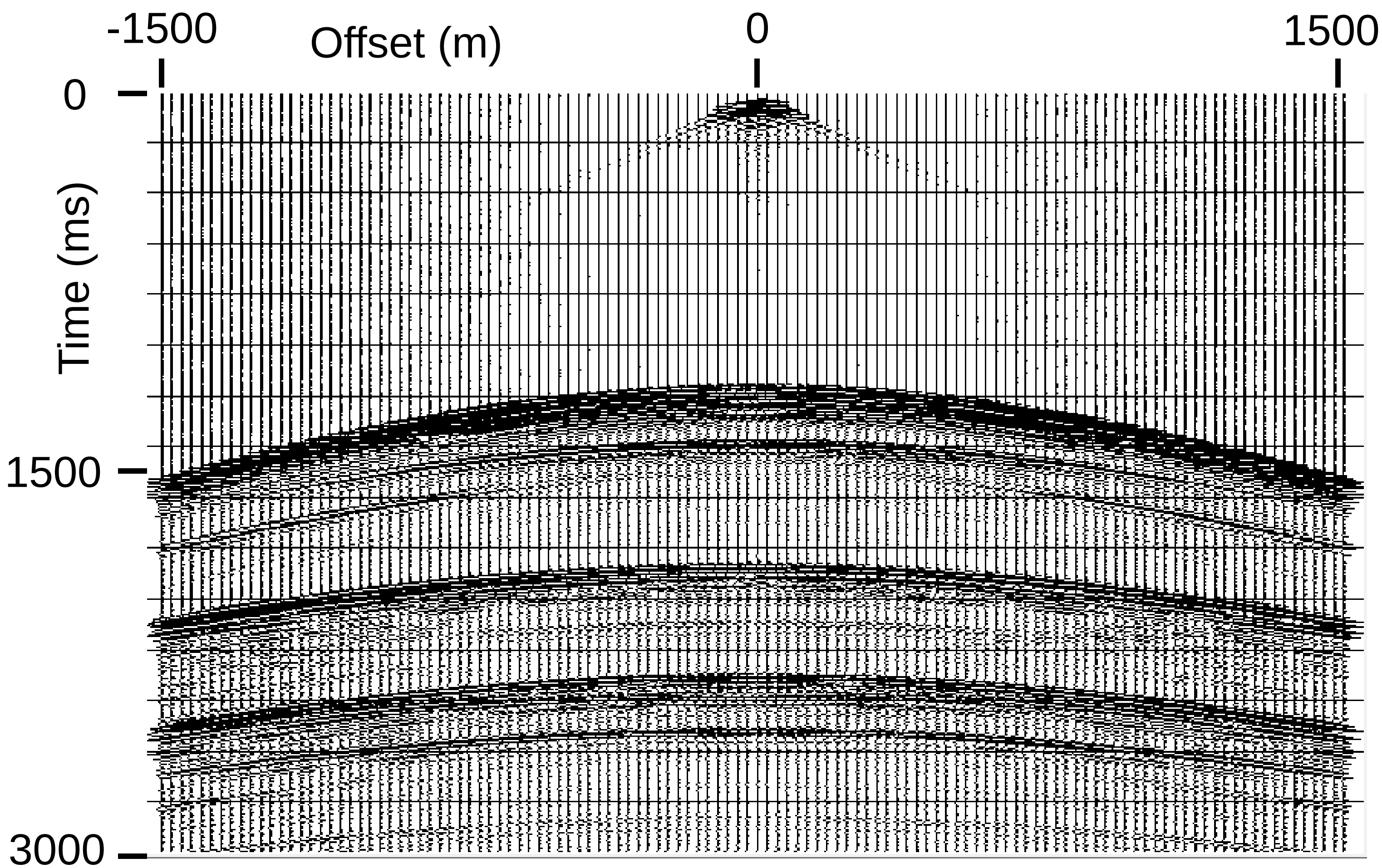
Plan view of the physical modeling data acquisition.

Seismic data processing

Table 1: A processing flow

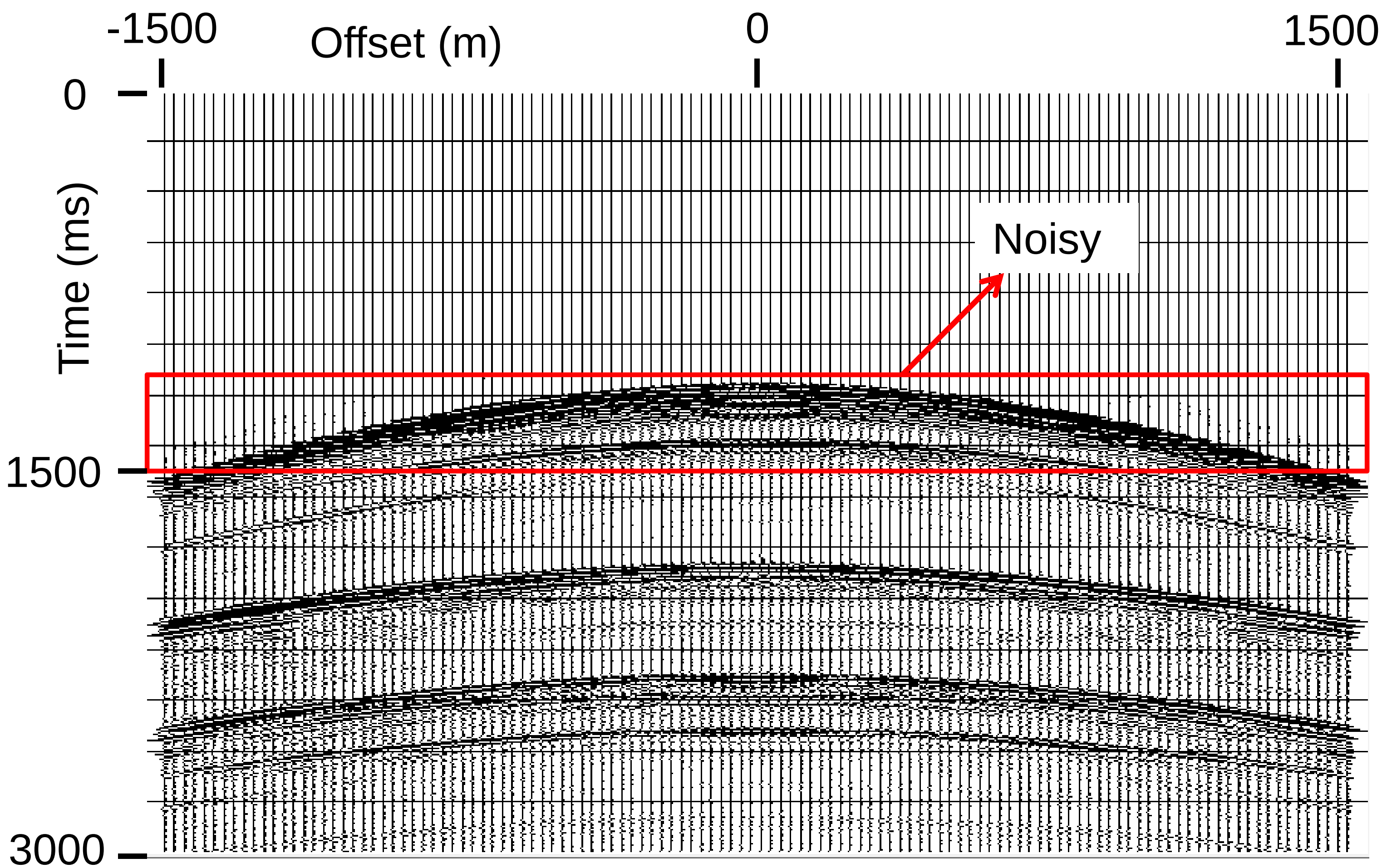
	PROCESSING FLOW
1	Trace Header Math
2	Top Mute
3	Spiking Deconvolution
4	Bandpass Filter

Seismic data processing



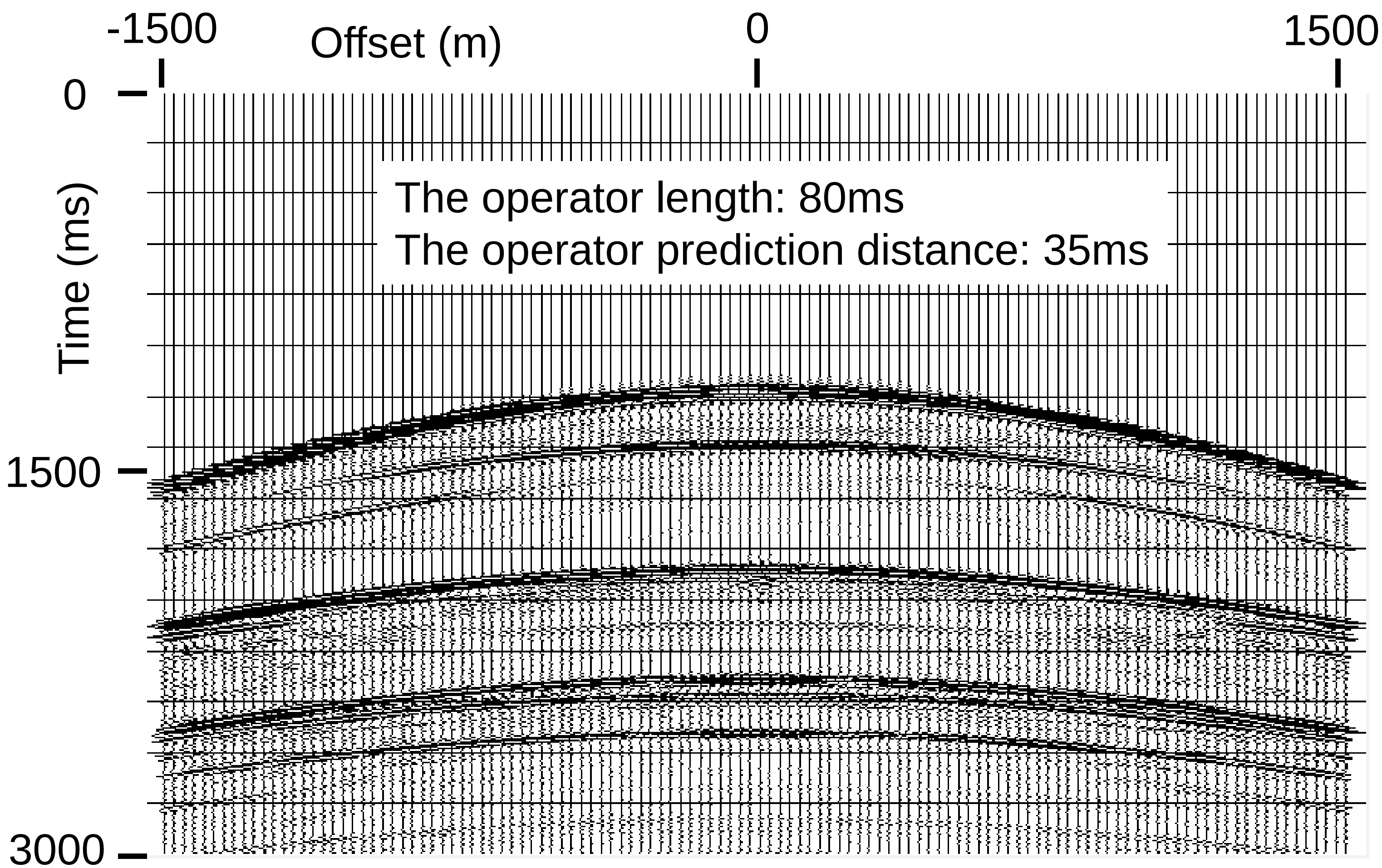
Raw data

Seismic data processing



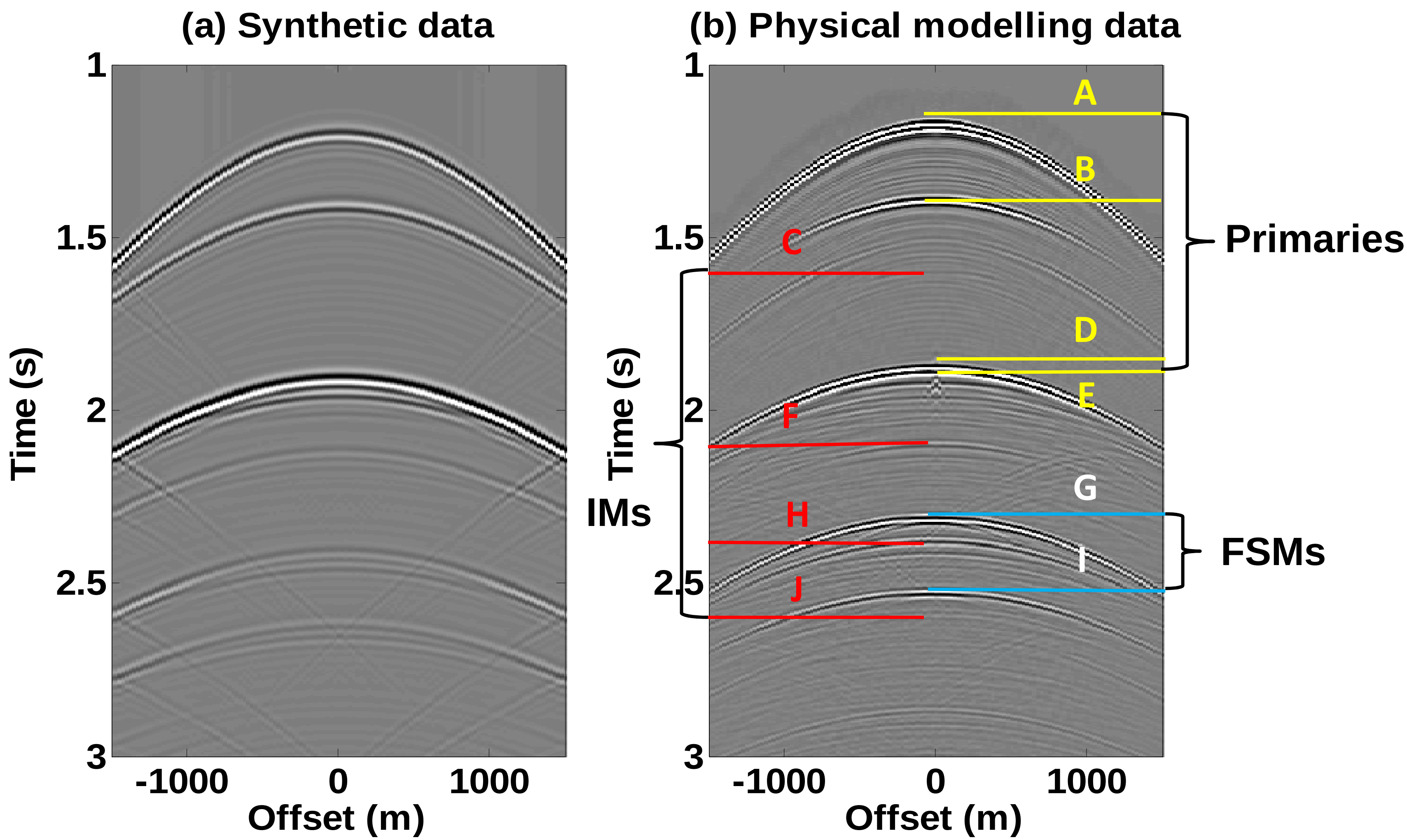
The data after applying Trace Mute.

Seismic data processing



The deconvolved data with a bandpass filter of 15-20-70-90Hz applied.

1.5D internal multiple prediction



Event identification by calculating two-way travel times.

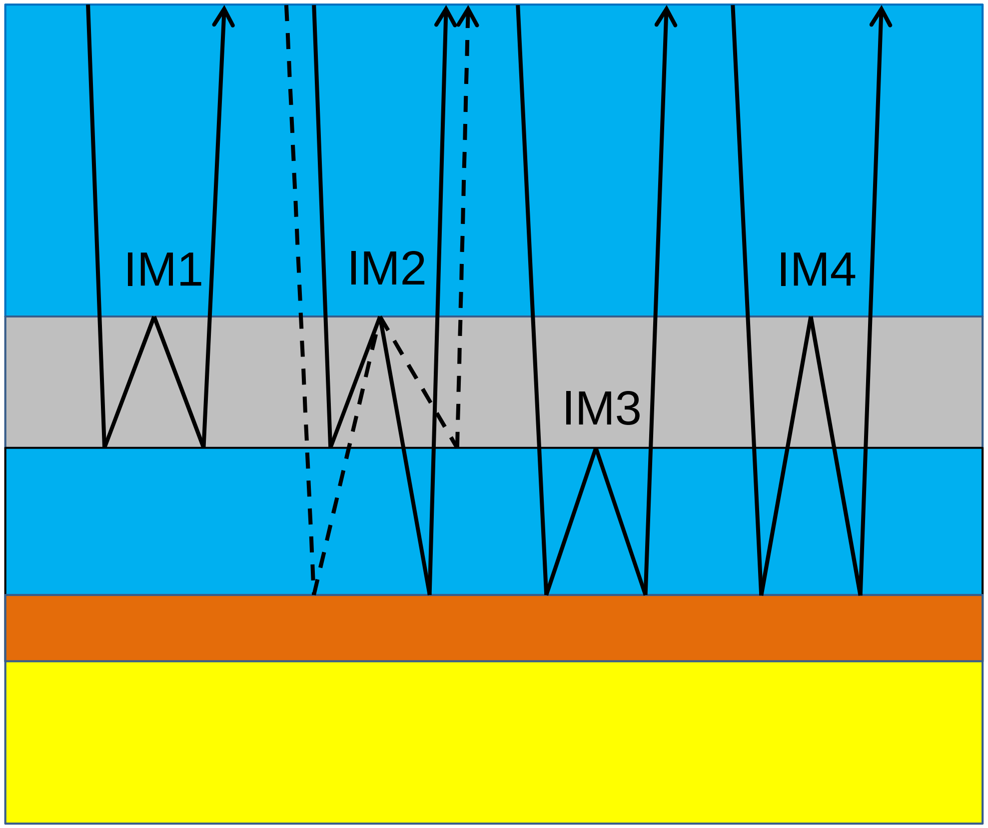
1.5D internal multiple prediction

Table 2: Summary of approximate travel times of the identified events

LABEL	EVENT	APPROXIMATE TRAVEL TIME
A	Top of PVC slab	1.155s
B	Bottom of PVC slab	1.365s
C	Internal multiple 1	1.575s
D	Top of aluminum slab	1.861s
E	Bottom of aluminum slab	1.905s
F	Internal multiple 2	2.071s
G	Free-surface multiple	2.310s
H	Internal multiple 3	2.357s
I	Free-surface multiple	2.520s
J	Internal multiple 4	2.567s

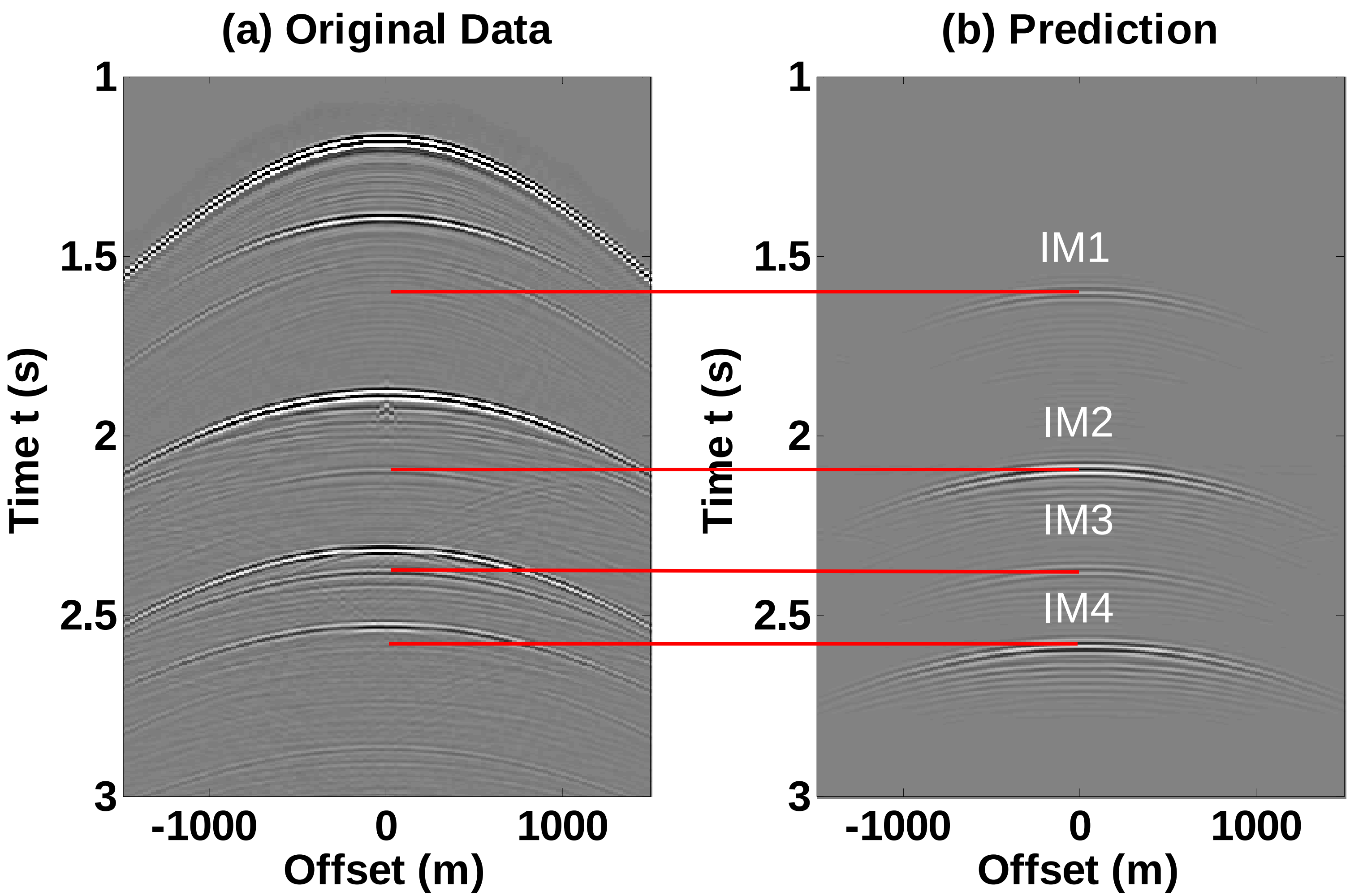
44ms

1.5D internal multiple prediction



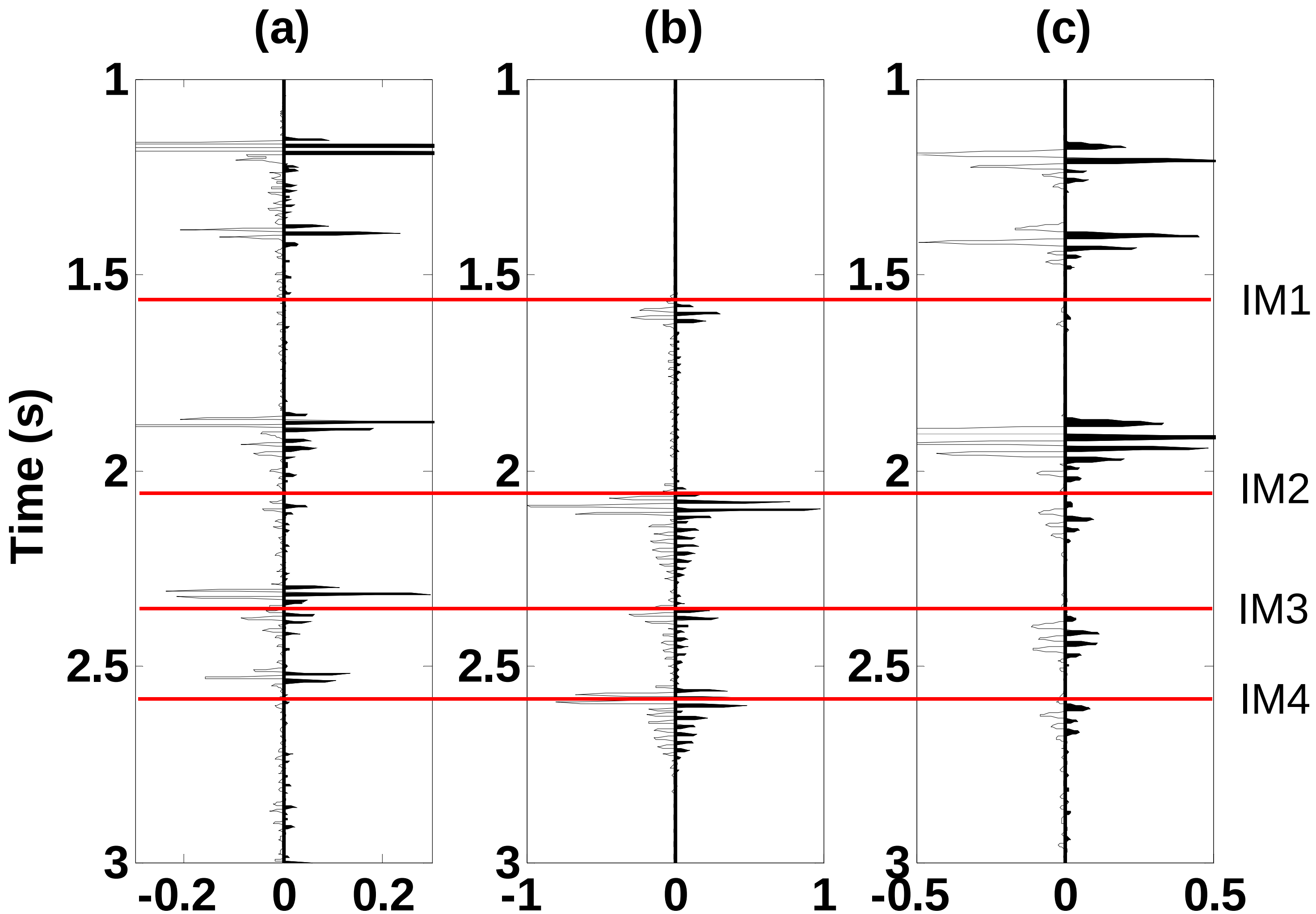
The ray paths of the four dominant internal multiples.

1.5D internal multiple prediction



Comparison of prediction output with input

1.5D internal multiple prediction



(a) Physical modeling trace; (b) prediction output; (c) synthetic data trace.

A discussion of the ϵ value

- Effects of various ϵ value have been described in Pan and Innanen (2014). Here we determine the optimal ϵ value to be 80 sample points.
- An important issue is raised by the notable absence in the prediction of internal multiples generated within the aluminum slab.
- The internal multiple prediction algorithm is designed assuming free-surface multiples have been removed. The presence of residual and/or unsuppressed FSMs will in principle affect internal multiple prediction; wherever possible they should be removed.

Analysis of the three parameters chosen

For $ii = kxB : kxE$
$F = kx(ii)^2 c_0^2./w.^2$ → Lateral wavenumber
$q_g = (w/c_0).*sqrt(1-F)$

For $jj = wB : wE$
$A1 = i*2*qg(jj)*z;$
$A2 = -i*2*qg(jj)*z;$ → Frequency
$I1 = b1(:,ii).*exp(A1);$
$I2 = b1(:,ii).*exp(A2);$

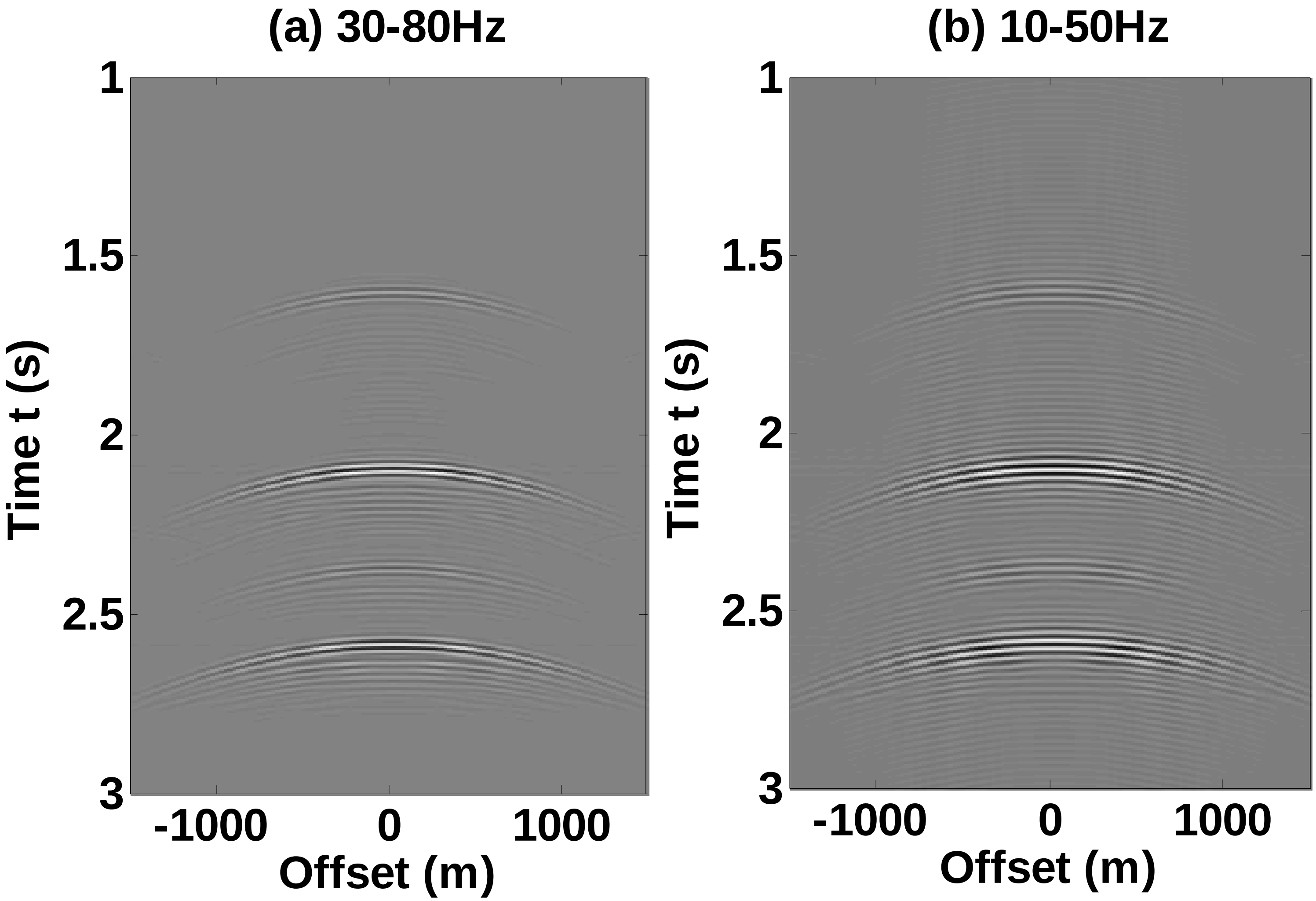
For $kk = zB : zE$
$S = sum(I1(kk+\epsilon : zE));$ → Pseudo depth
$P = P + I2(kk)*S^2;$
End

$P = P*dz;$
End

End

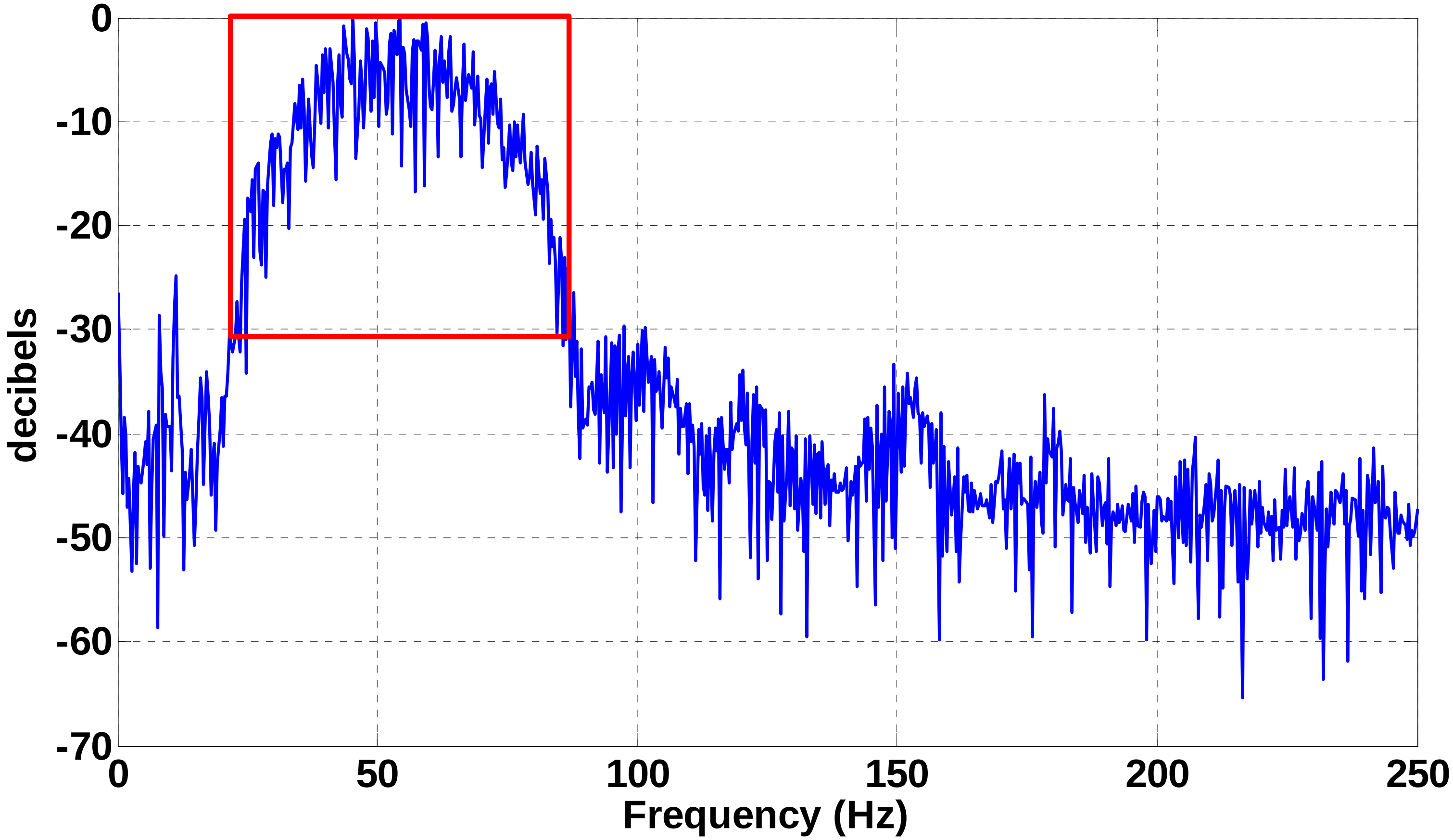
Prediction algorithm in the code (from Innanen, 2012).

Analysis of the three parameters chosen



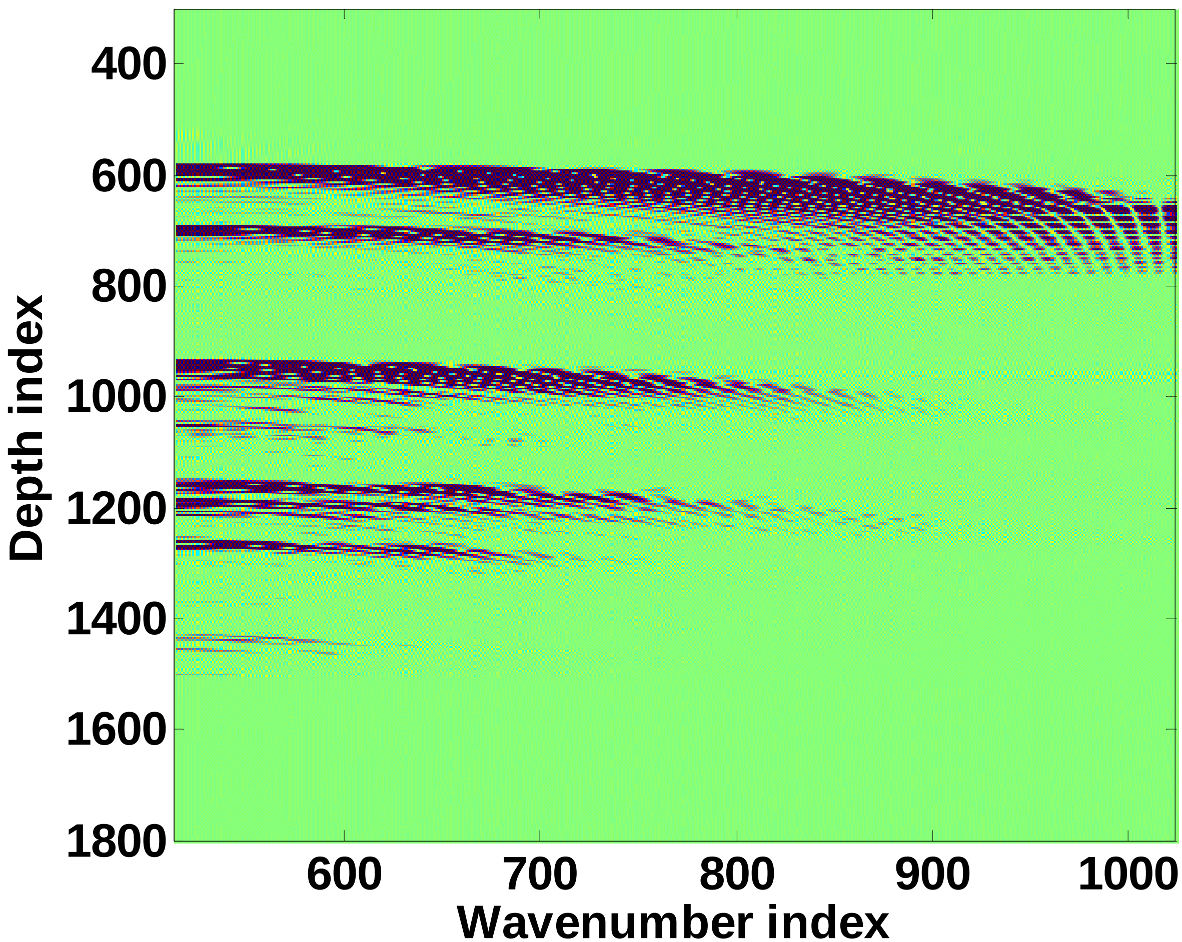
Comparison of two internal multiple prediction outputs with different frequency bands.

Analysis of the three parameters chosen



Fourier amplitude spectrum of the zero-offset trace using a decibel scale.

Analysis of the three parameters chosen



The algorithm input $b_1(k_g, z)$

- Depth index range: [540-1020]
- Wavenumber index range: [513-1024]

Analysis of the three parameters chosen

Table 3: Time costs with different parameters chosen

Exp #	freBEG (Hz)	freEND (Hz)	zBEG	zEND	kxBEG	kxEND	Time (s)
1	25	80	540	1020	513	1024	1256.96
2	25	80	560	1015	513	1024	1189.85
3	25	80	560	1015	513	900	856.57
4	25	80	560	1015	513	800	636.24
5	30	80	560	1015	513	800	588.51

- Comparing experiments 5 and 1, which shows a time cost savings of 114%.

Conclusions

- Prediction results show good agreement with both synthetic data and physical modeling data.
- Even if subtraction is problematic, prediction results can lead us to obtain an “internal multiple probability map”.
- Choosing the beginning and ending integration points in the nested integrals optimally leads to considerable computational savings.

Acknowledgements

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ANY
QUESTIONS
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