Harnessing harmonics for imaging thin shallow reflectors

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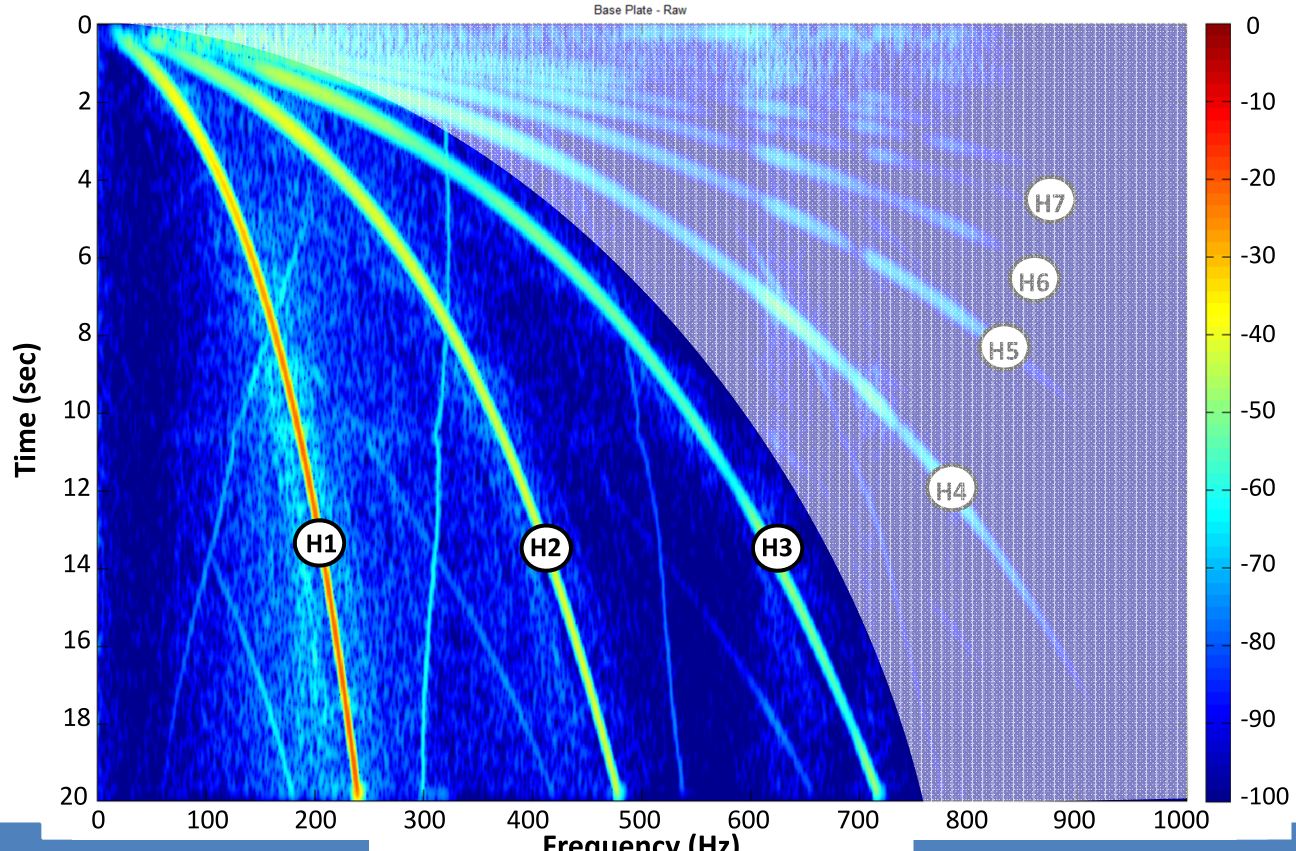
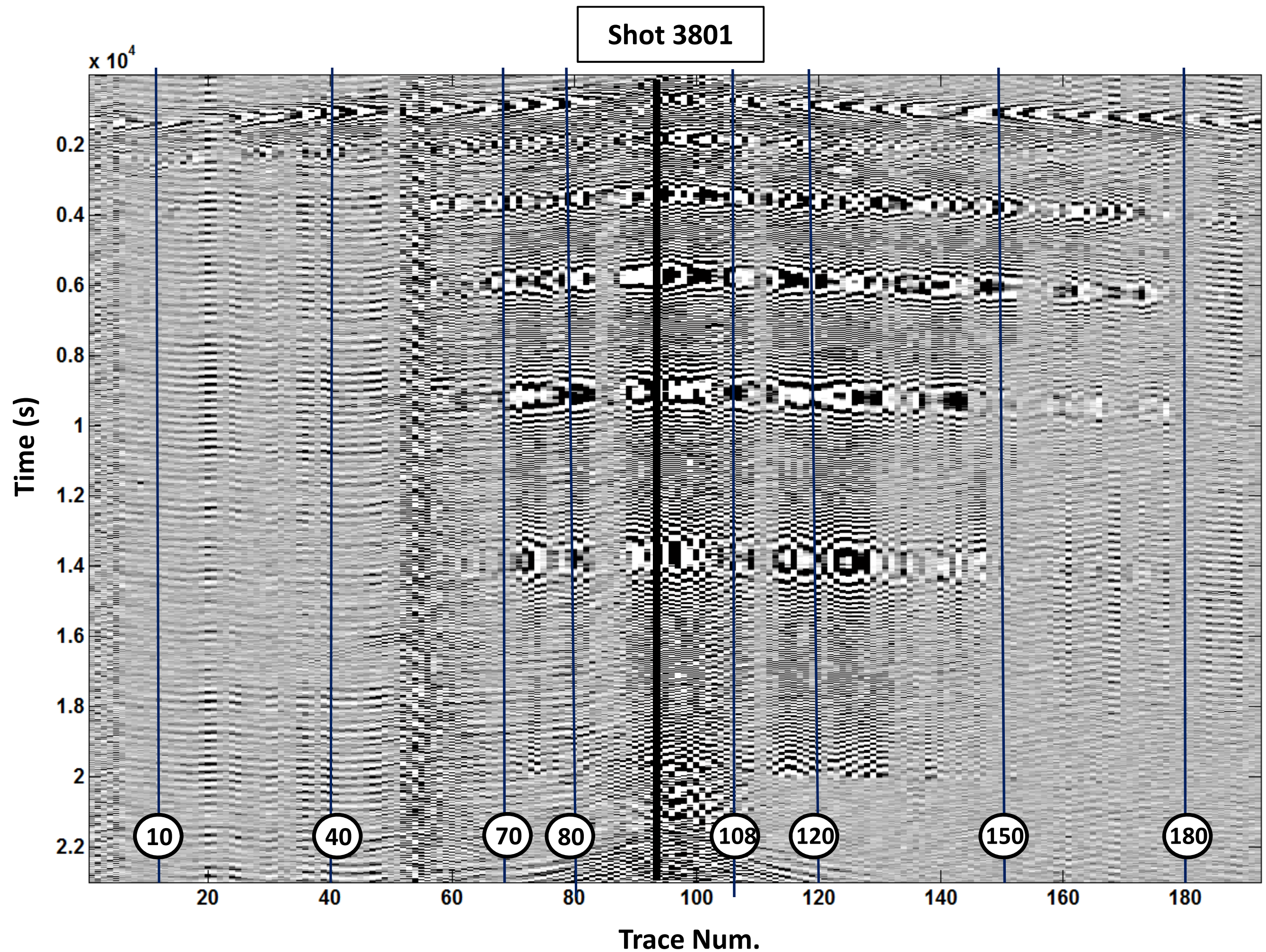
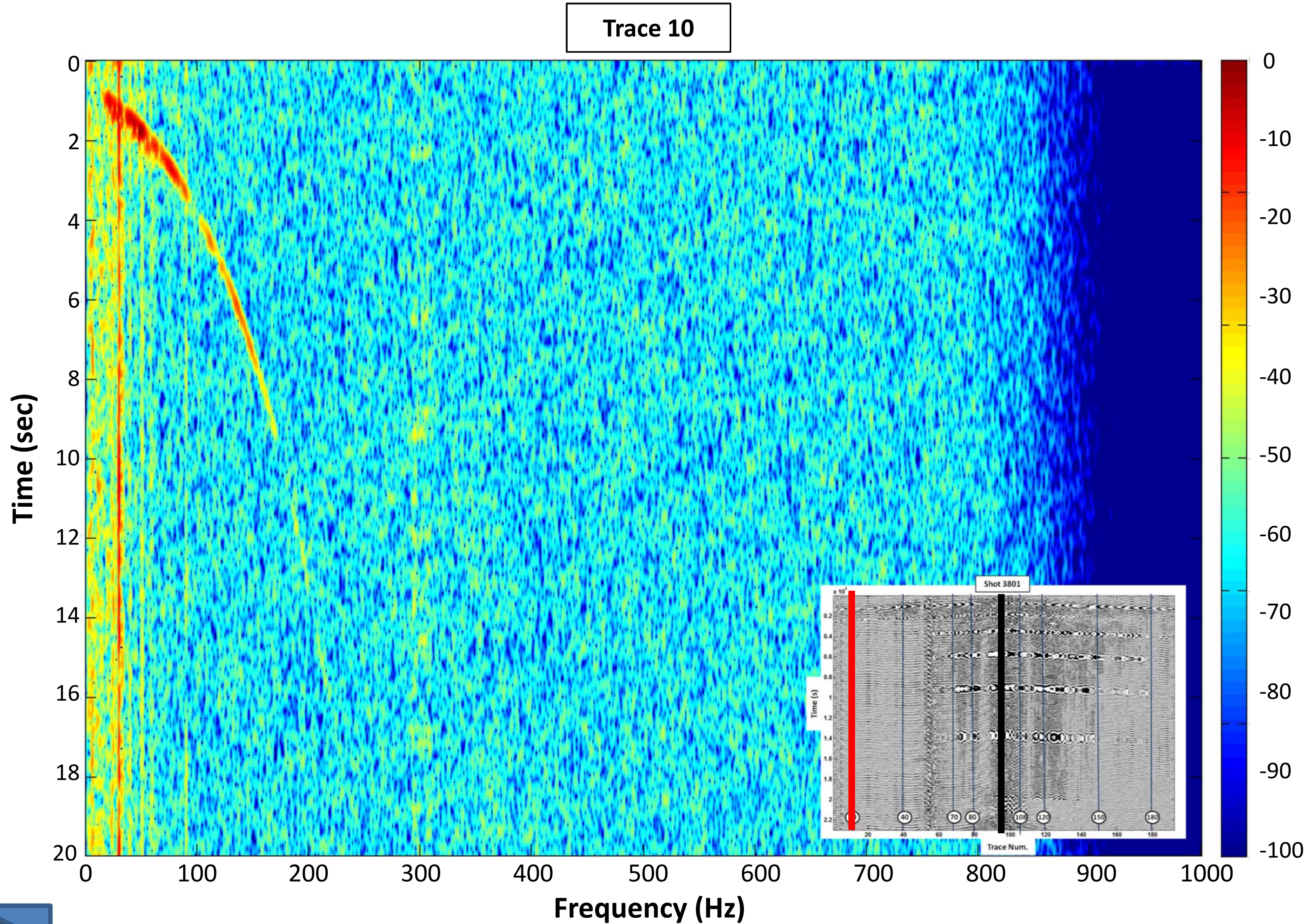
Structure

- Harmonics in Seismic Data
- Processing with Harmonics
- Comparative Results
- Conclusions
- Acknowledgements



- Fundamental
- Harmonics


Shot 3801
x 10^4
Time (s)
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
10
40
70
80
108
120
150
180
20
40
60
80
100
120
140
160
180
Trace Num.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Time (sec)
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Frequency (Hz)
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200
300
400
500
600
700
800
900
1000
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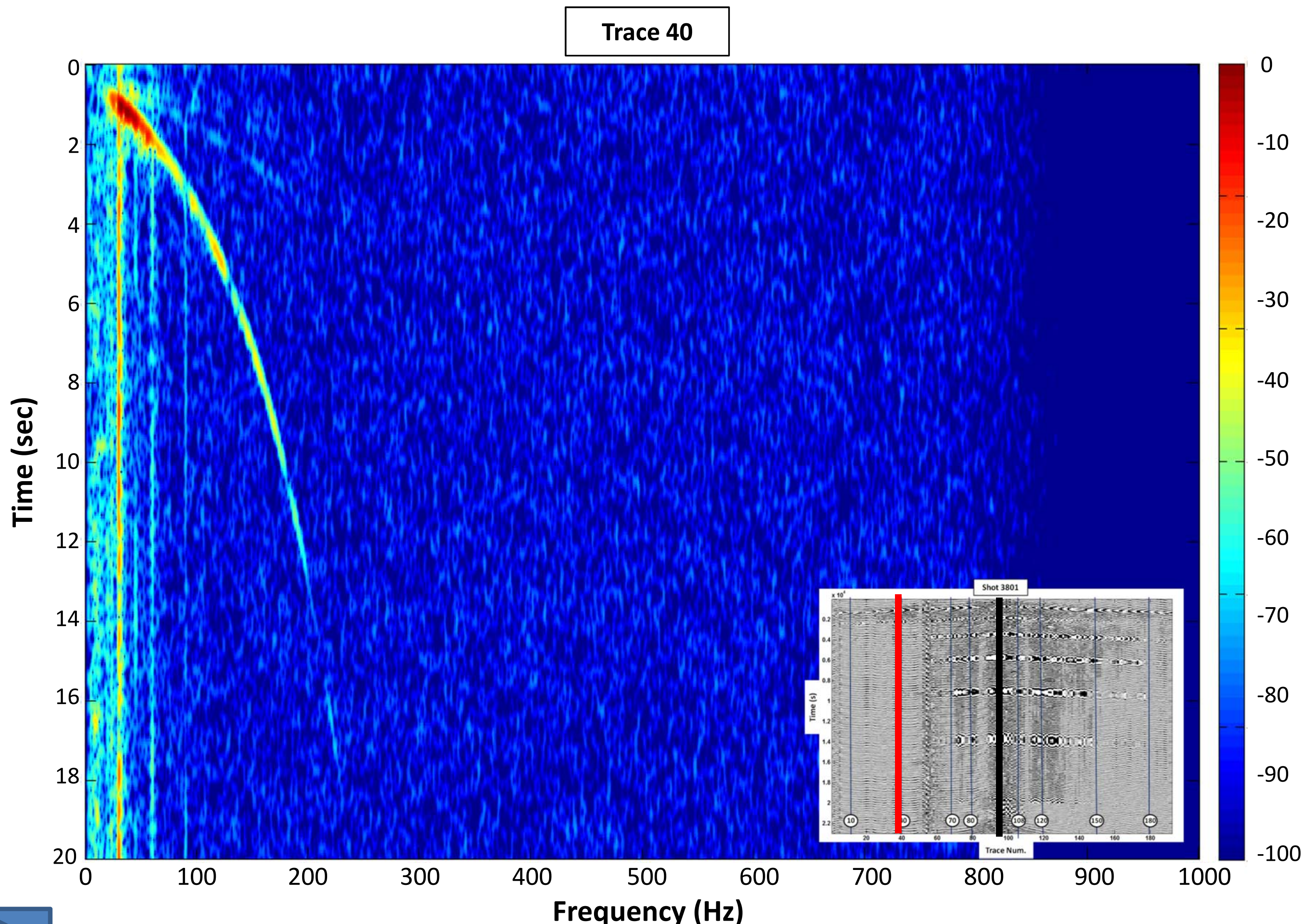
-20
-30
-40
-50
-60
-70
-80
-90
-100
Shot 3801
Time (s)
Trace Num.



Trace 40
Time (sec)
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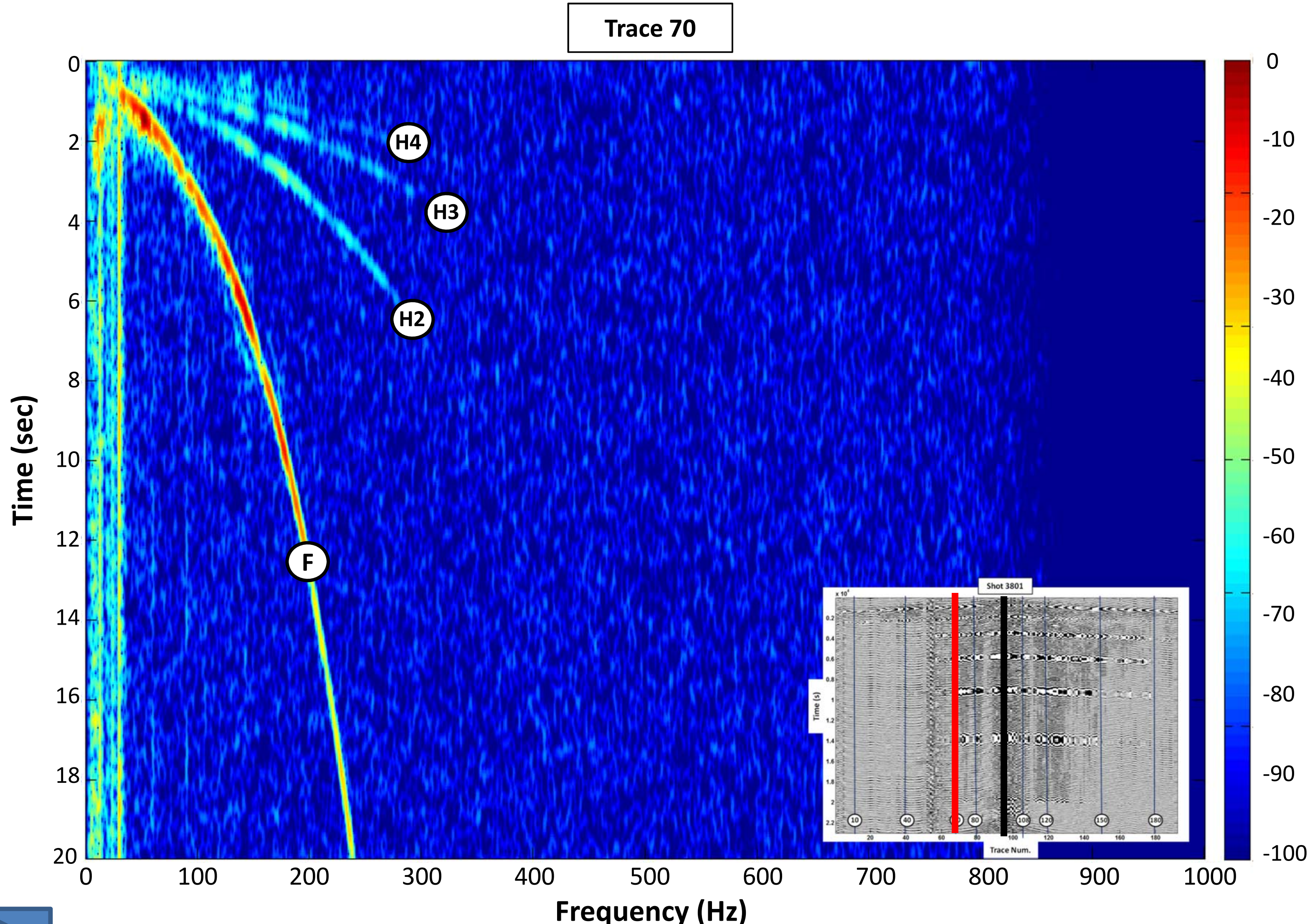
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Shot 3801
Time (s)
Trace Num.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H4
H3
H2
F
Time (sec)
Frequency (Hz)
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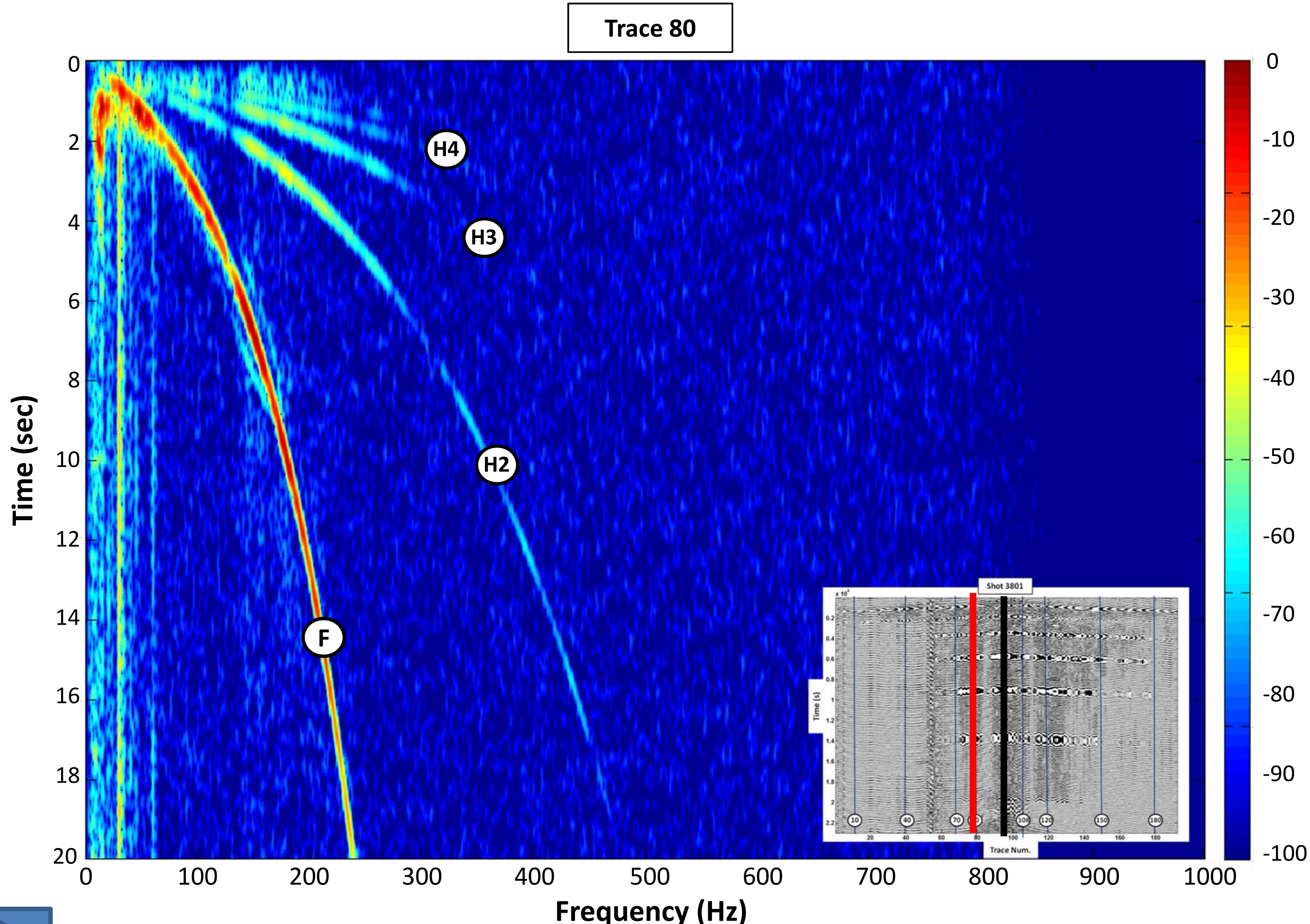
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Shot 3801
Time (s)
Trace Num.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Frequency (Hz)
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4
6
8
10
12
14
16
18
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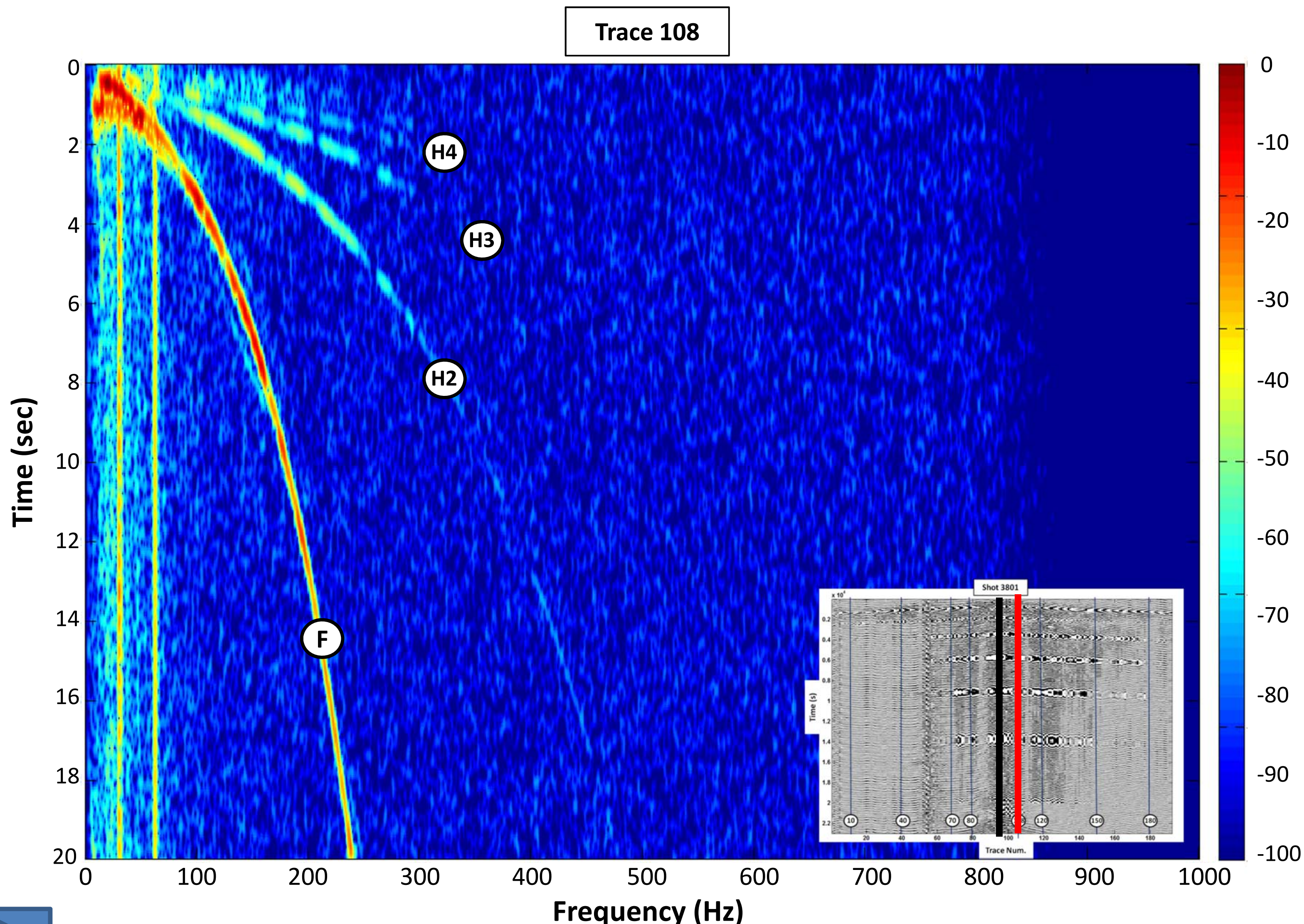
300
400
500
600
700
800
900
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
H4
H3
H2
F
Shot 3801
Time (s)
Trace Num.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6
8
10
12
14
16
18
20
Frequency (Hz)
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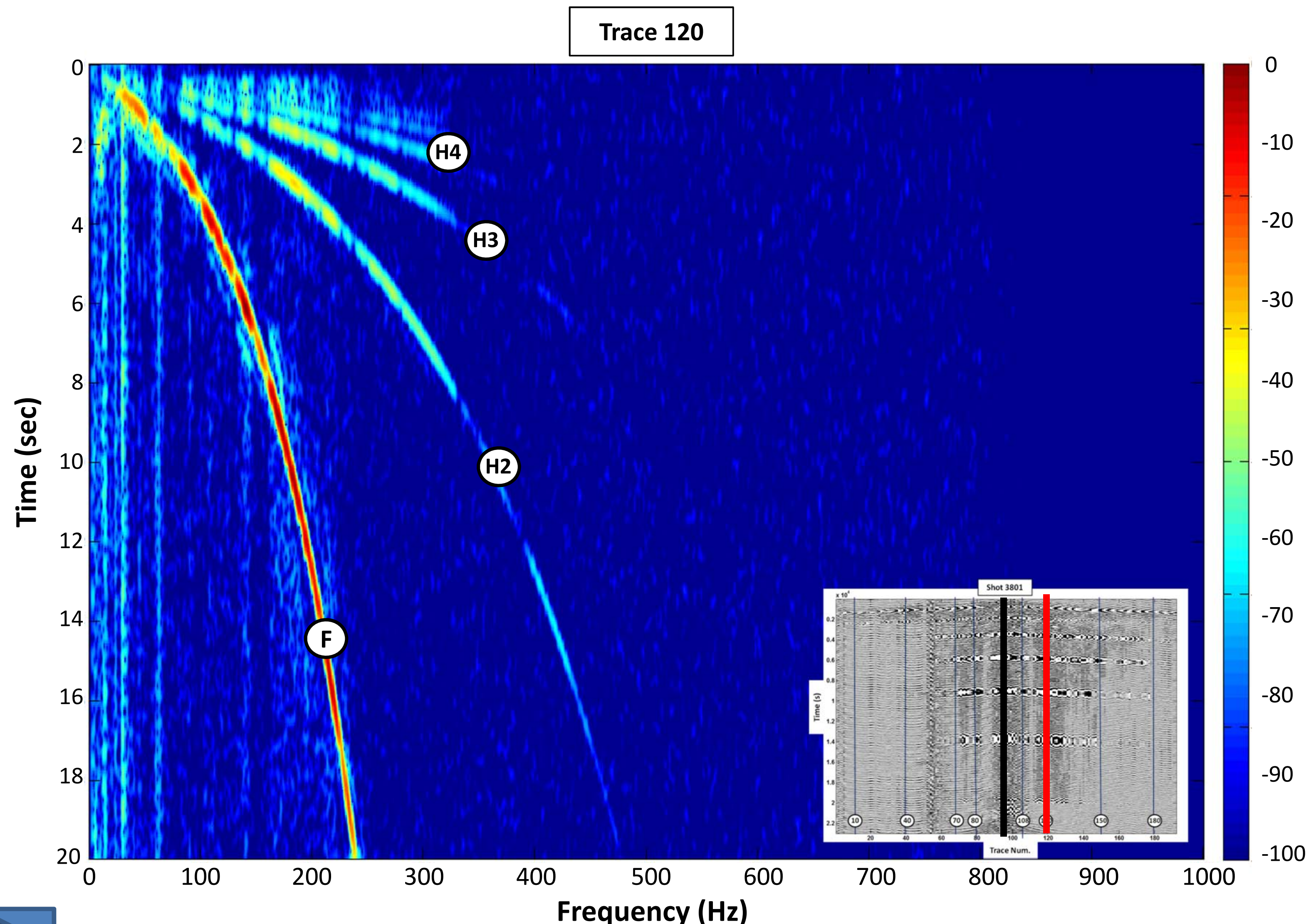
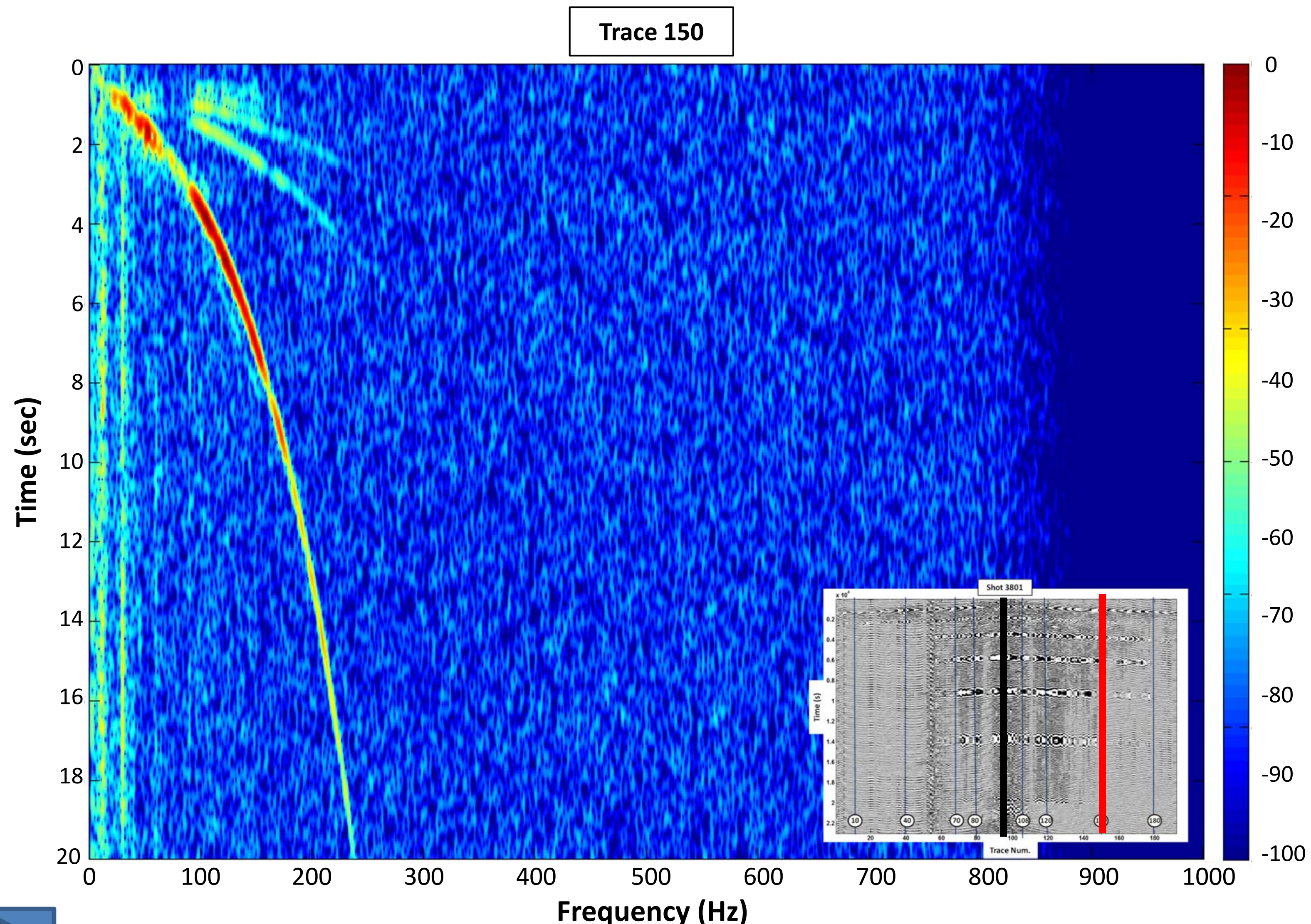
200
300
400
500
600
700
800
900
1000
H4
H3
H2
F
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Shot 3801
Time (s)
Trace Num.


Trace 120
Time (sec)
Frequency (Hz)
H4
H3
H2
F
Shot 3801
Trace Num.
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100



Trace 150
Time (sec)
Frequency (Hz)
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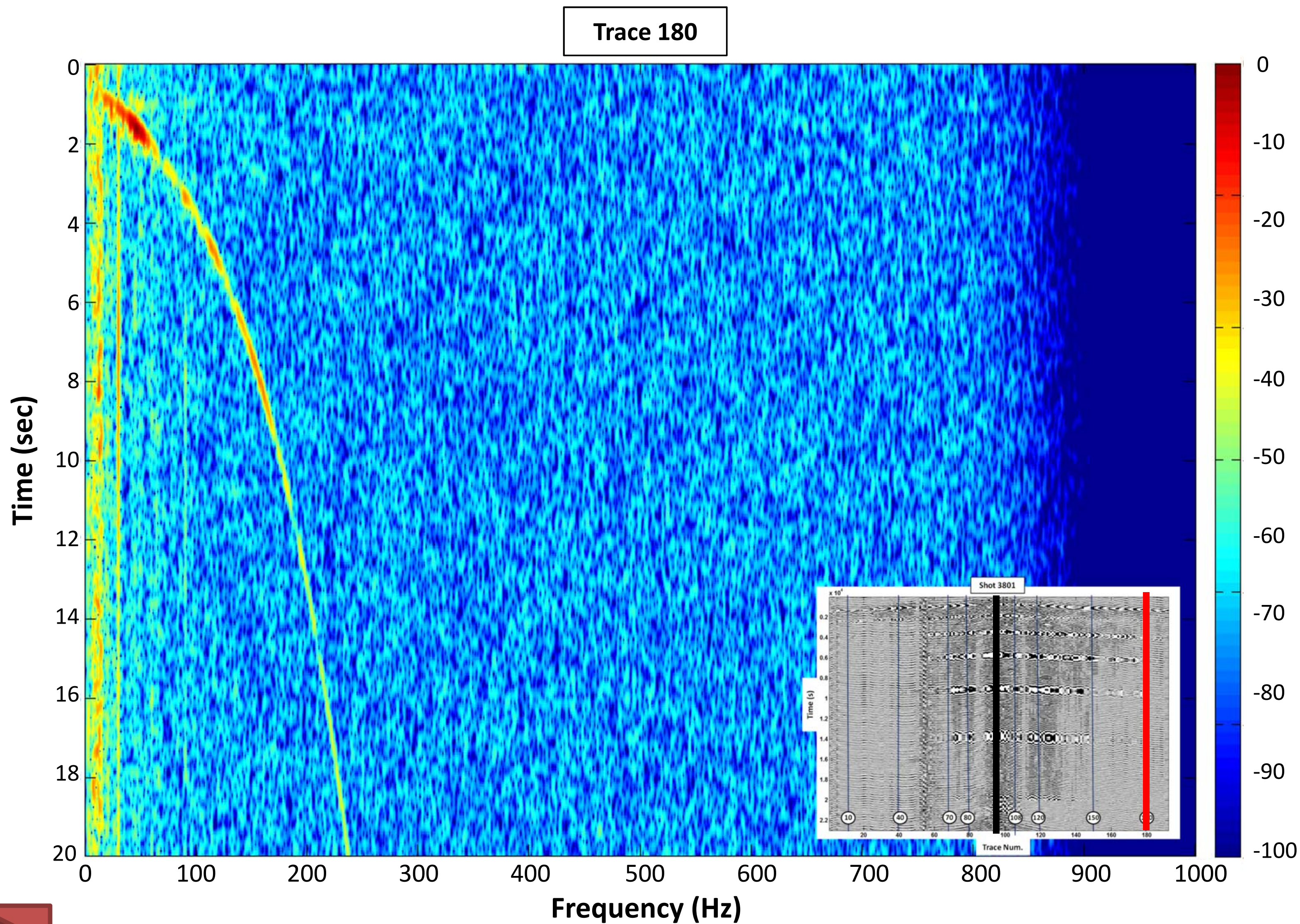
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
900
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Shot 3801
Trace Num.


Trace 180
Time (sec)
Frequency (Hz)
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4
6
8
10
12
14
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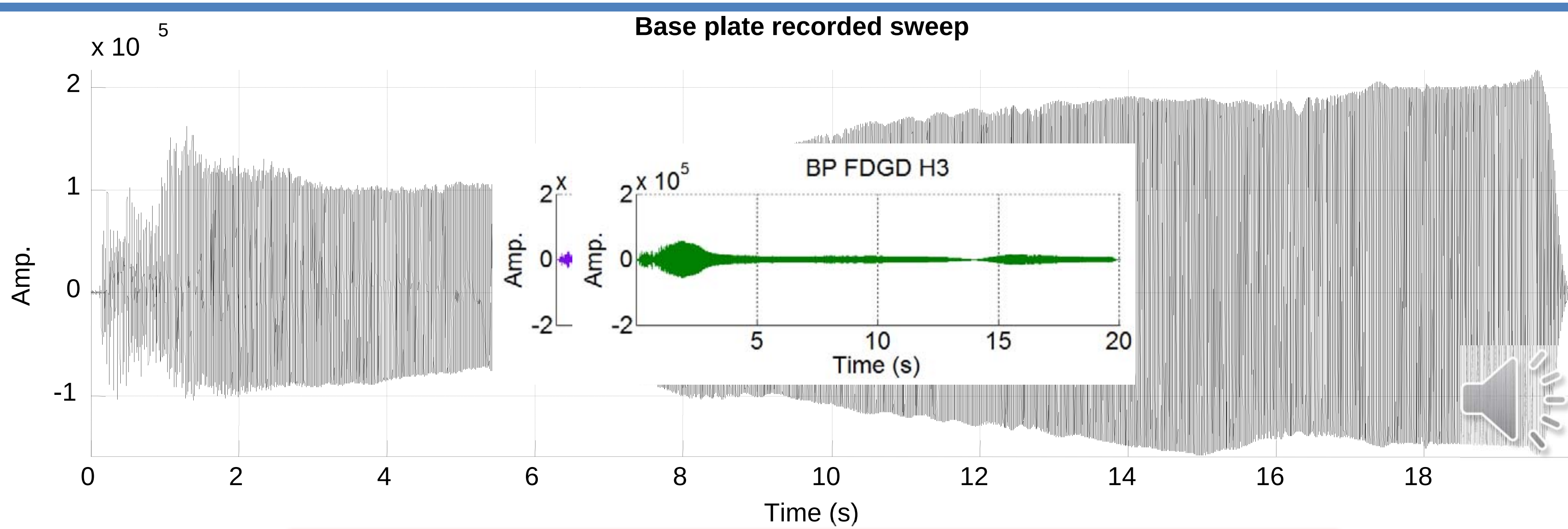
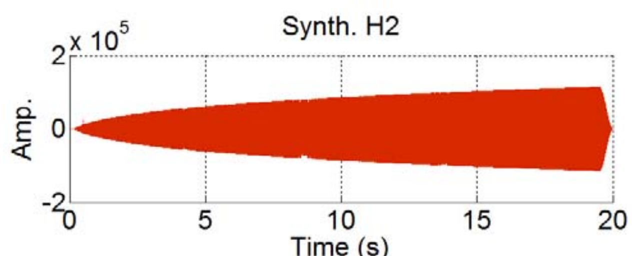
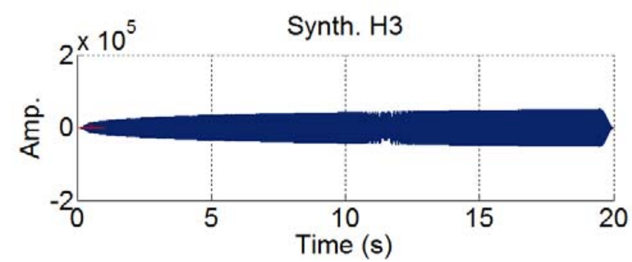
300
400
500
600
700
800
900
1000
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Shot 3801
Trace Num.



Time or Frequency Dependent Gabor Decomposition



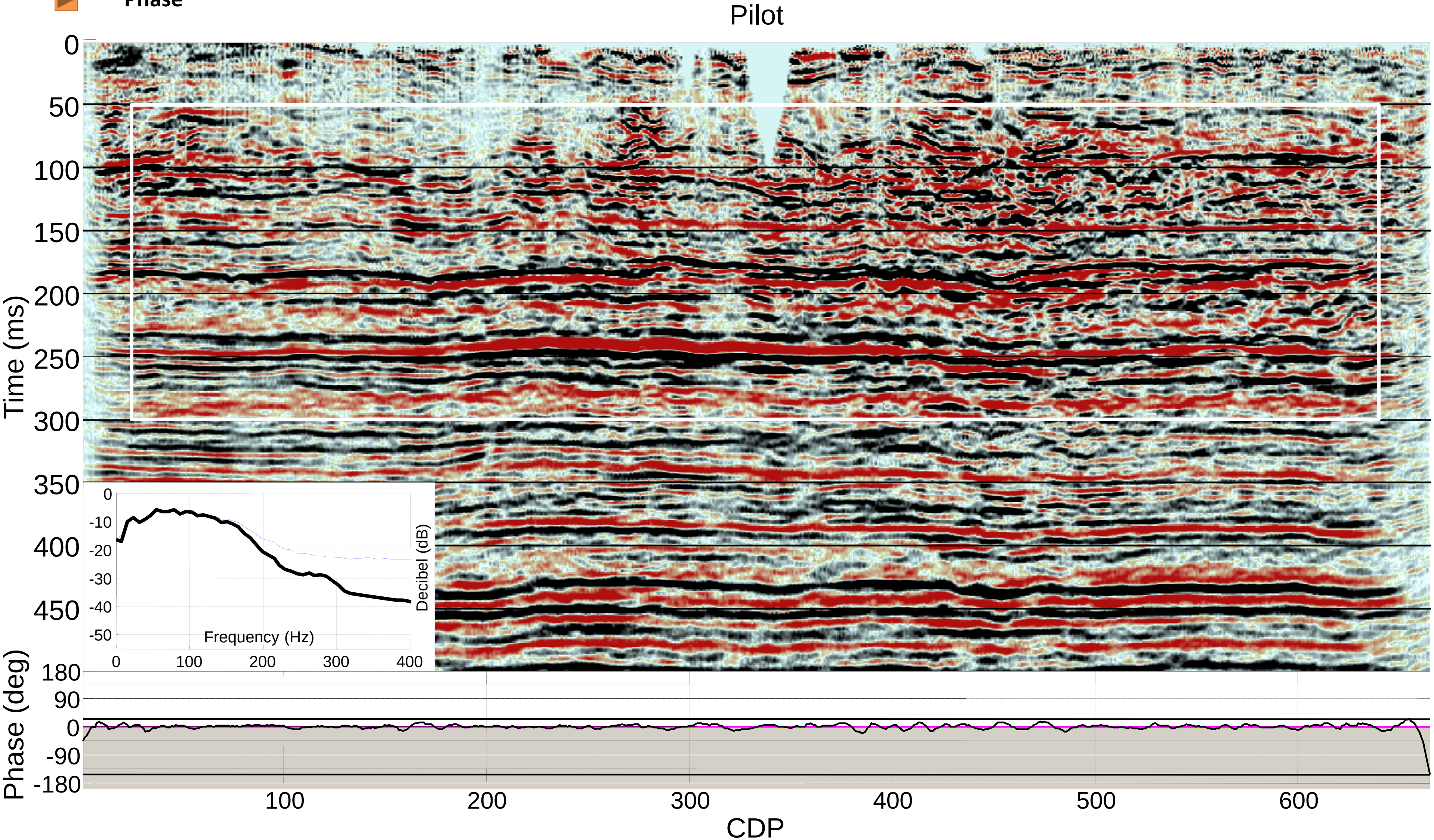


Processing Flow

- Correlation
- Geometry
- Gabor Decon.
- Velocity Analysis 1
- Velocity Analysis 2
- Apply Residual Statics
- NMO
- CDP Stack
- Kirchhoff Time Mig. – 1000Hz
- FX Decon. – 300Hz

Frequency

Phase



Pilot - Synth. H2 - Synth. H3

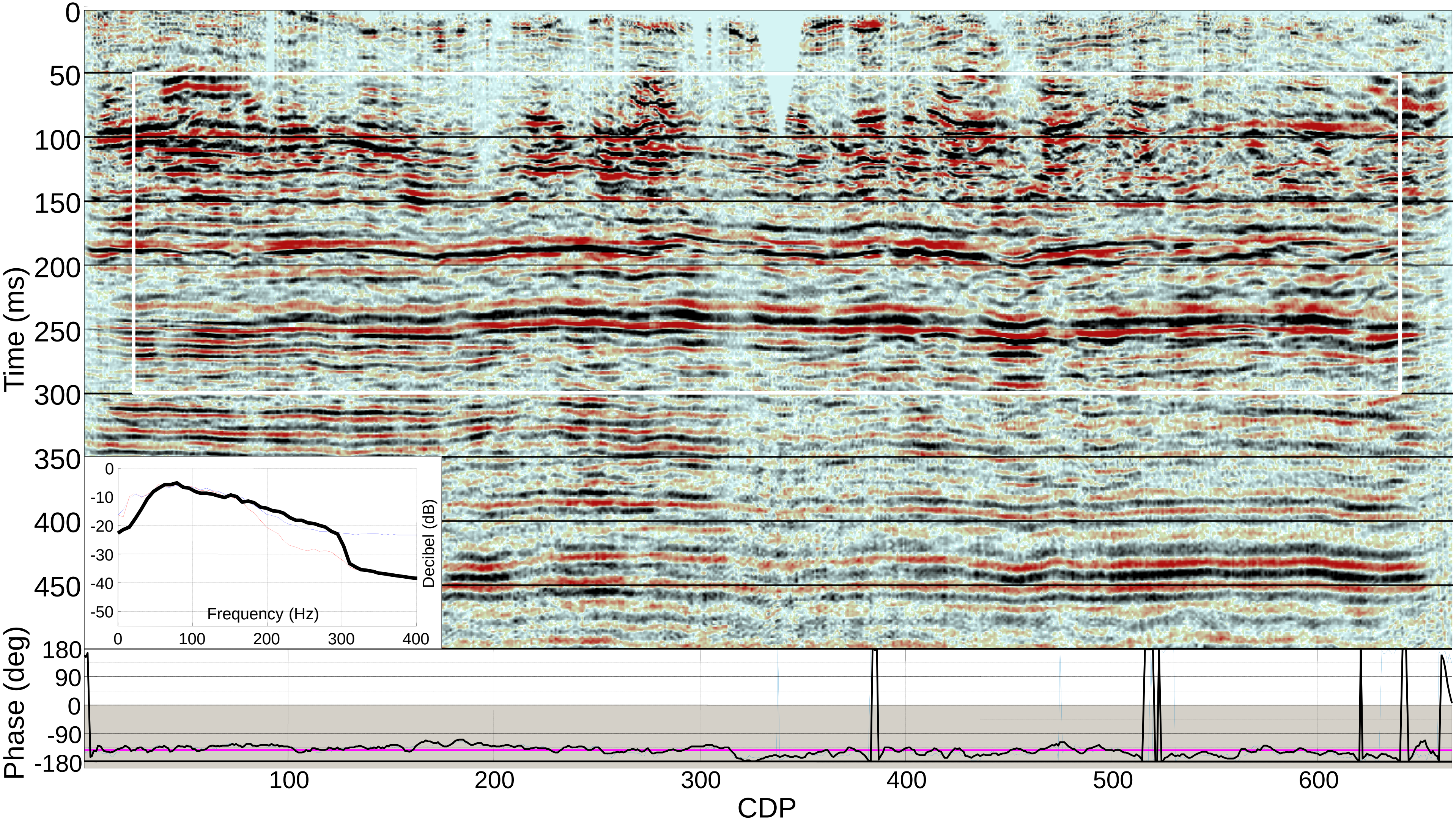
BP FDGD H1 - BP FDGD H2 - BP FDGD H3

GF FDGD H1 - GF FDGD H2 - GF FDGD H3

Frequency

Phase

Synth. H2



[Pilot](#) - [Synth. H2](#) - [Synth. H3](#)

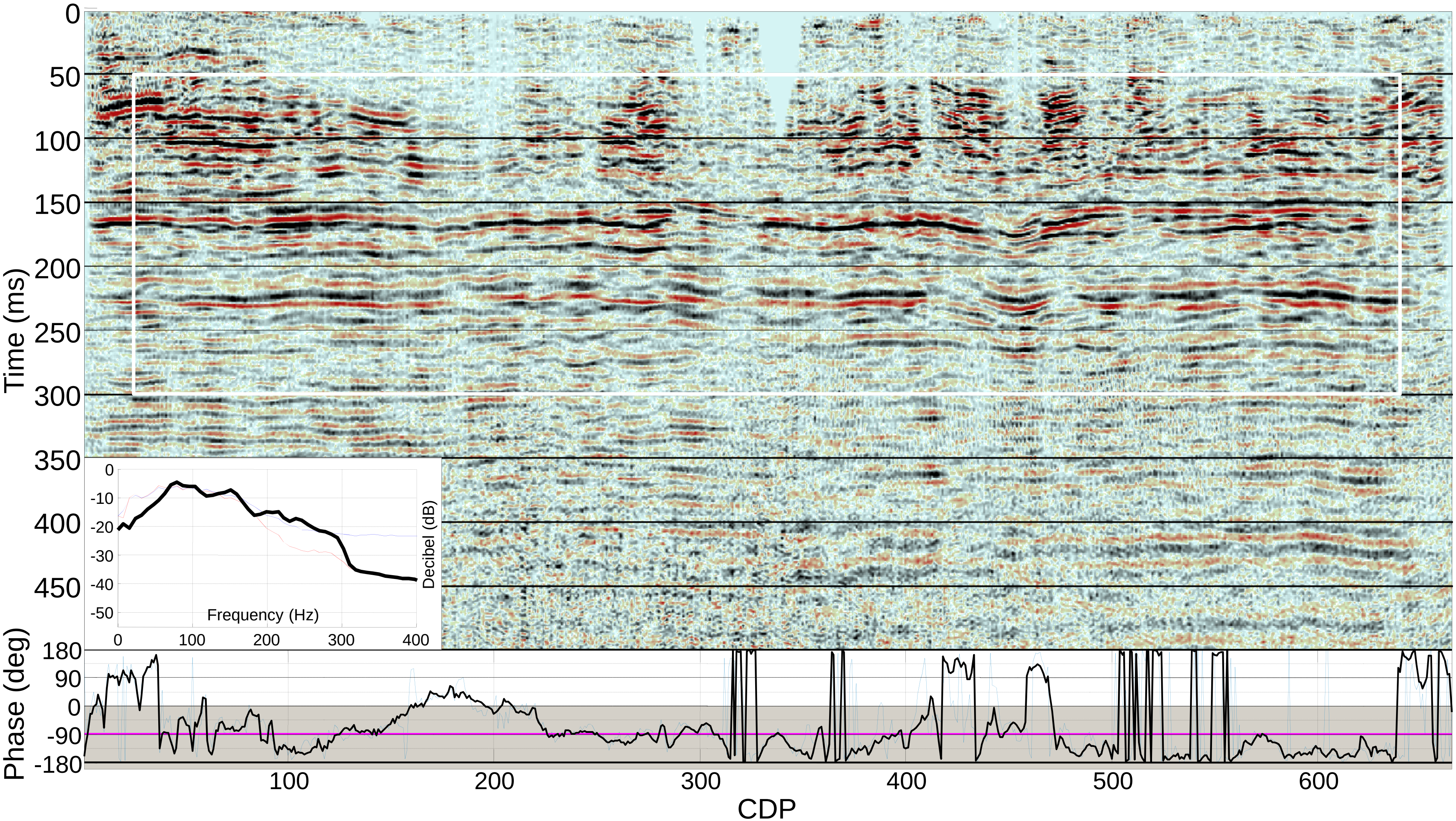
[BP FDGD H1](#) - [BP FDGD H2](#) - [BP FDGD H3](#)

[GF FDGD H1](#) - [GF FDGD H2](#) - [GF FDGD H3](#)

Frequency

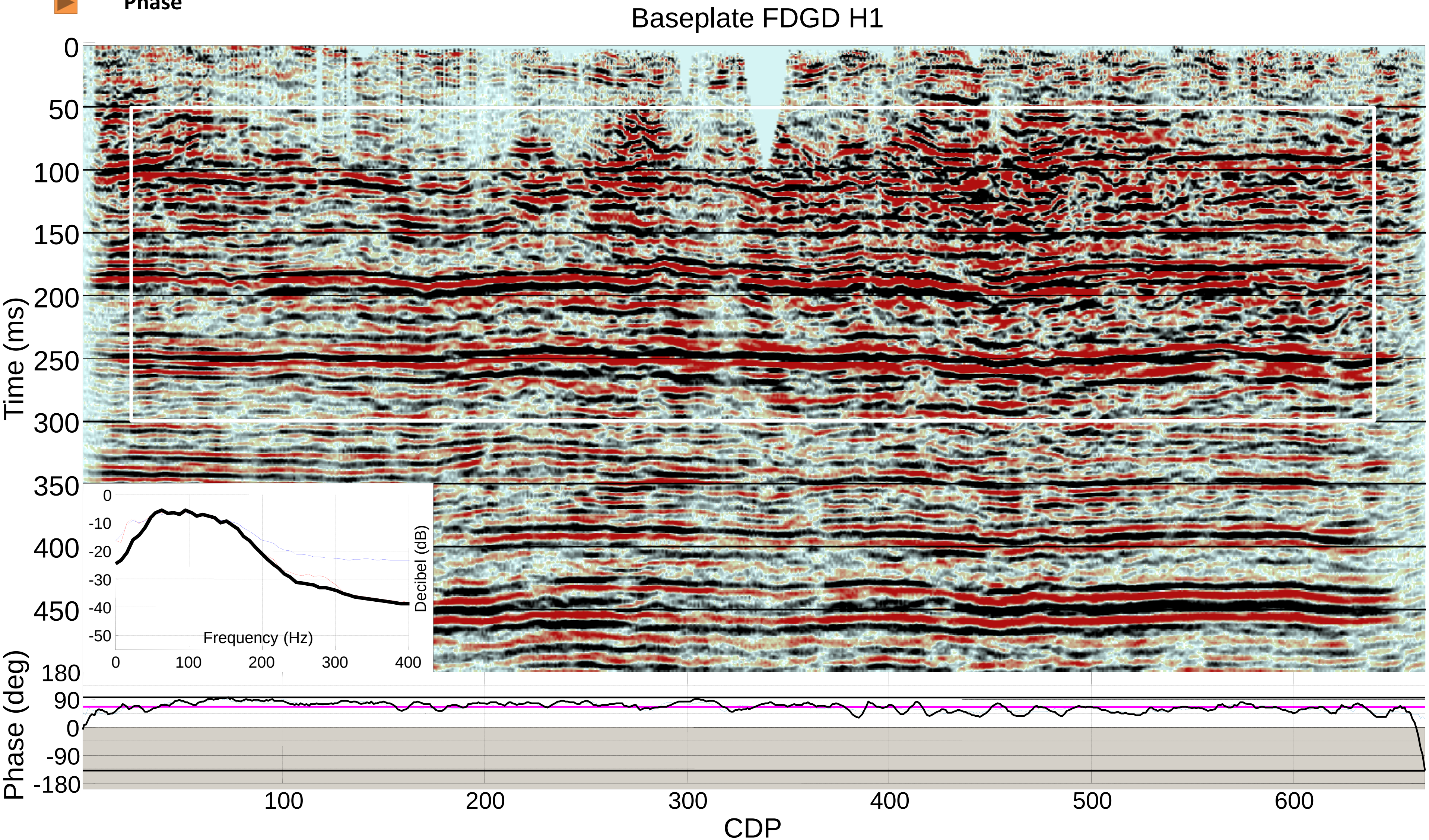
Phase

Synth. H3



Pilot - Synth. H2 - Synth. H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3
GF FDGD H1 - GF FDGD H2 - GF FDGD H3

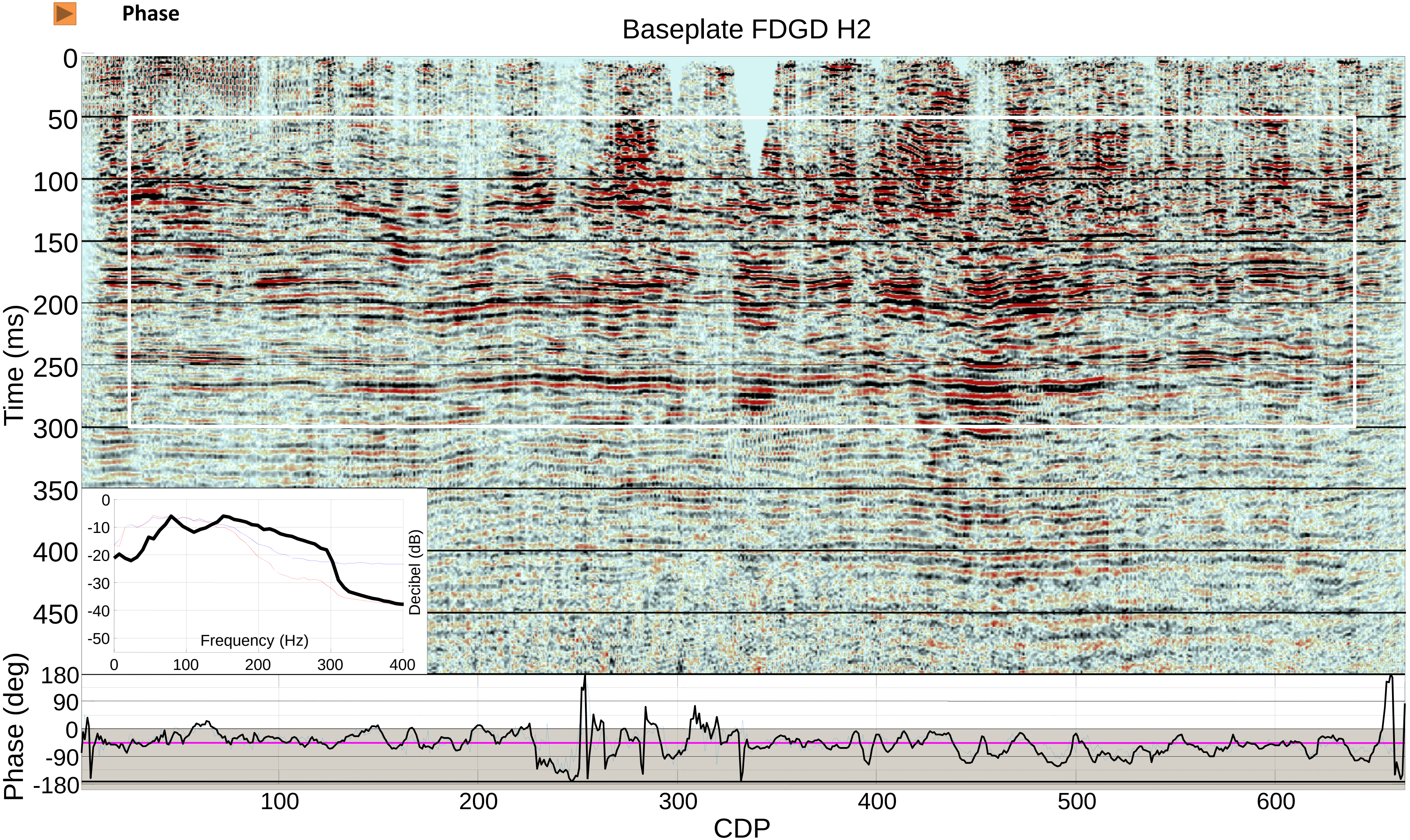
- Frequency
- Phase



Pilot - Synth. H2 - Synth. H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3
GF FDGD H1 - GF FDGD H2 - GF FDGD H3

Frequency

Phase



Pilot - Synth. H2 - Synth. H3

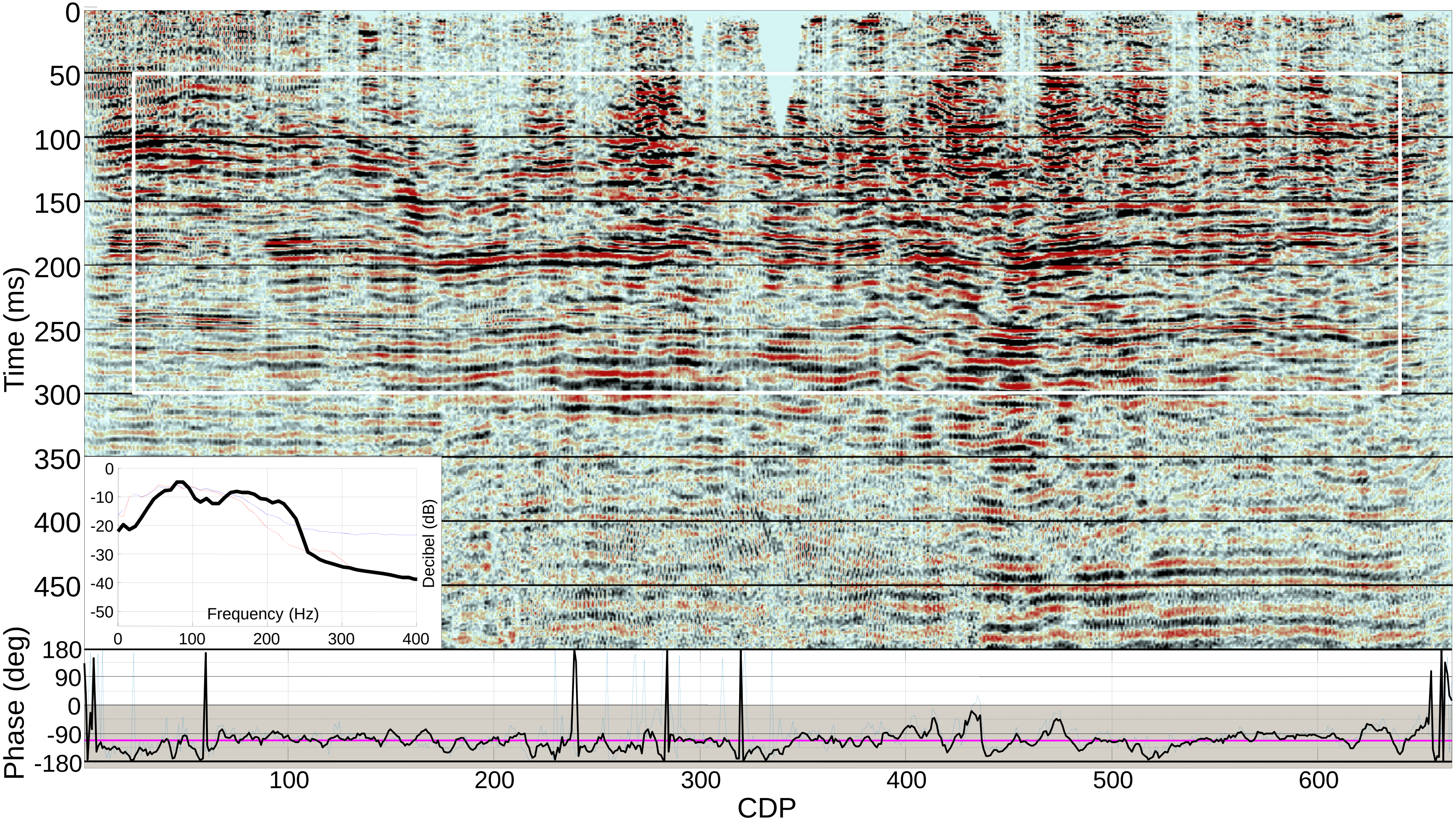
BP FDGD H1 - BP FDGD H2 - BP FDGD H3

GF FDGD H1 - GF FDGD H2 - GF FDGD H3

Frequency

Phase

Baseplate FDGD H3



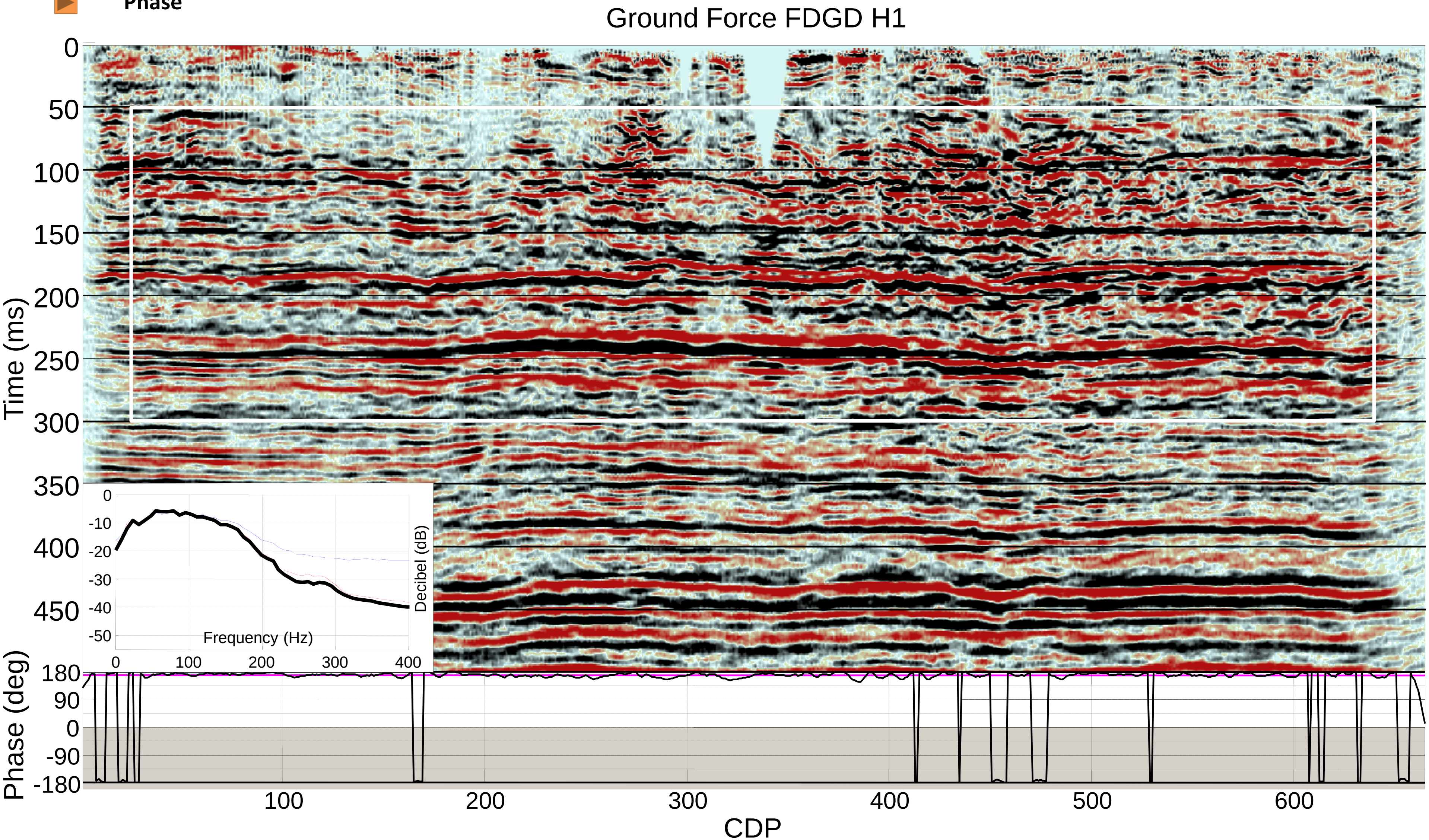
[Pilot](#) - [Synth. H2](#) - [Synth. H3](#)

[BP FDGD H1](#) - [BP FDGD H2](#) - [BP FDGD H3](#)

[GF FDGD H1](#) - [GF FDGD H2](#) - [GF FDGD H3](#)

Frequency

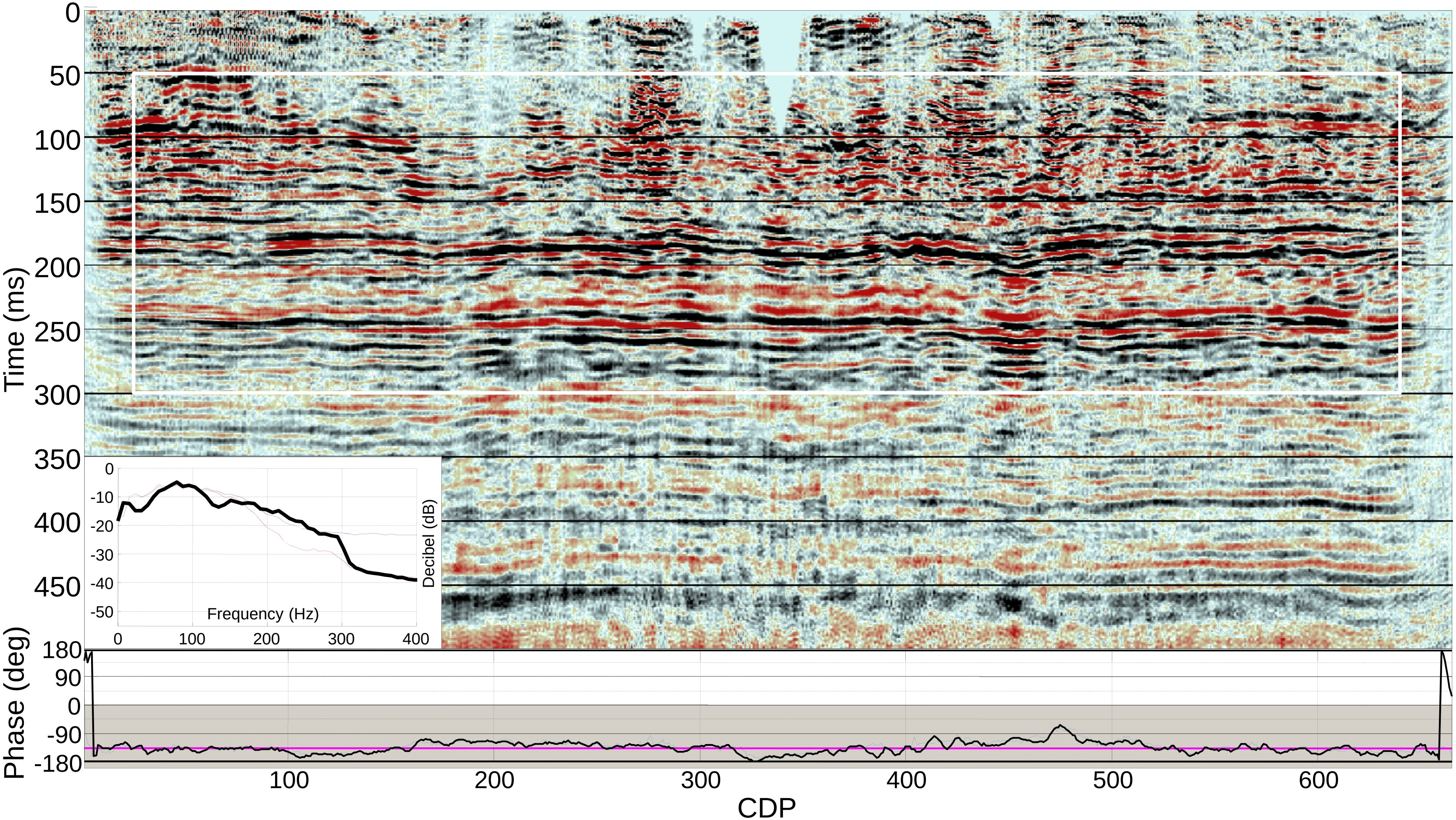
Phase



Pilot - Synth. H2 - Synth. H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3
GF FDGD H1 - GF FDGD H2 - GF FDGD H3

- Frequency
- Phase

Ground Force FDGD H3

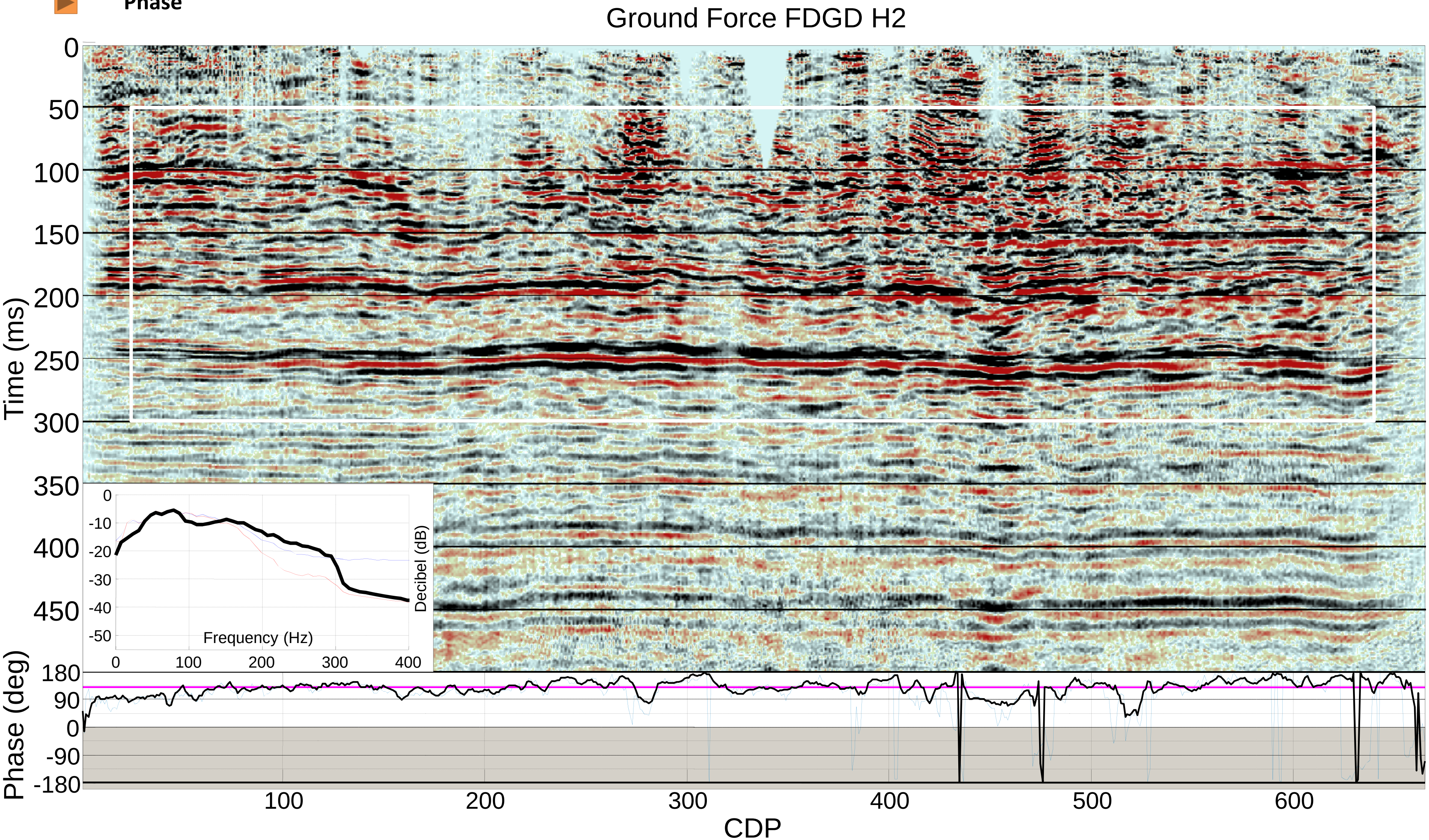


[Pilot](#) - [Synth. H2](#) - [Synth. H3](#)

[BP FDGD H1](#) - [BP FDGD H2](#) - [BP FDGD H3](#)

[GF FDGD H1](#) - [GF FDGD H2](#) - [GF FDGD H3](#)

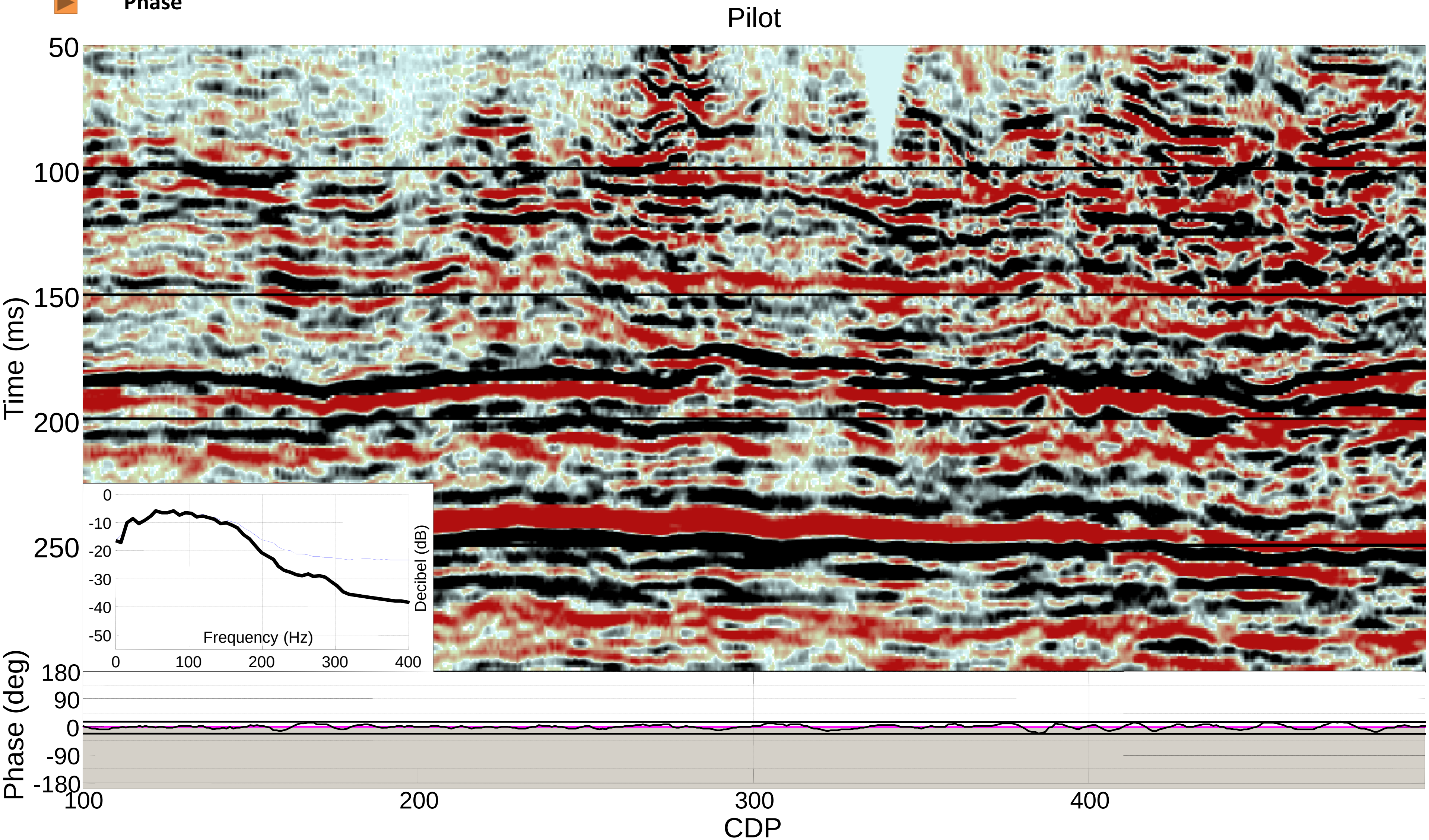
- Frequency
  - Phase



Pilot - Synth. H2 - Synth. H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3
GF FDGD H1 - GF FDGD H2 - GF FDGD H3

Frequency

Phase

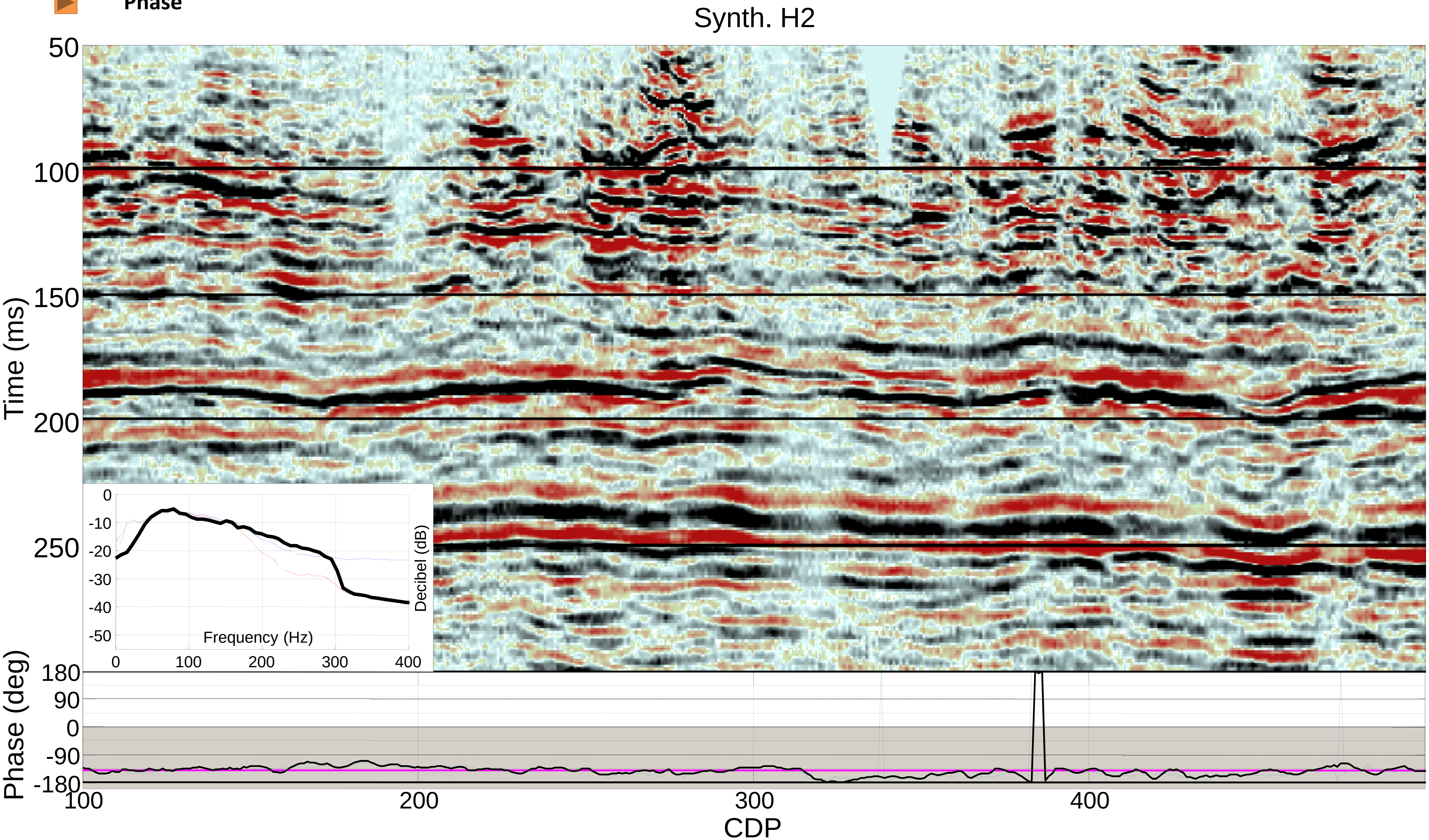


Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3

BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

Frequency

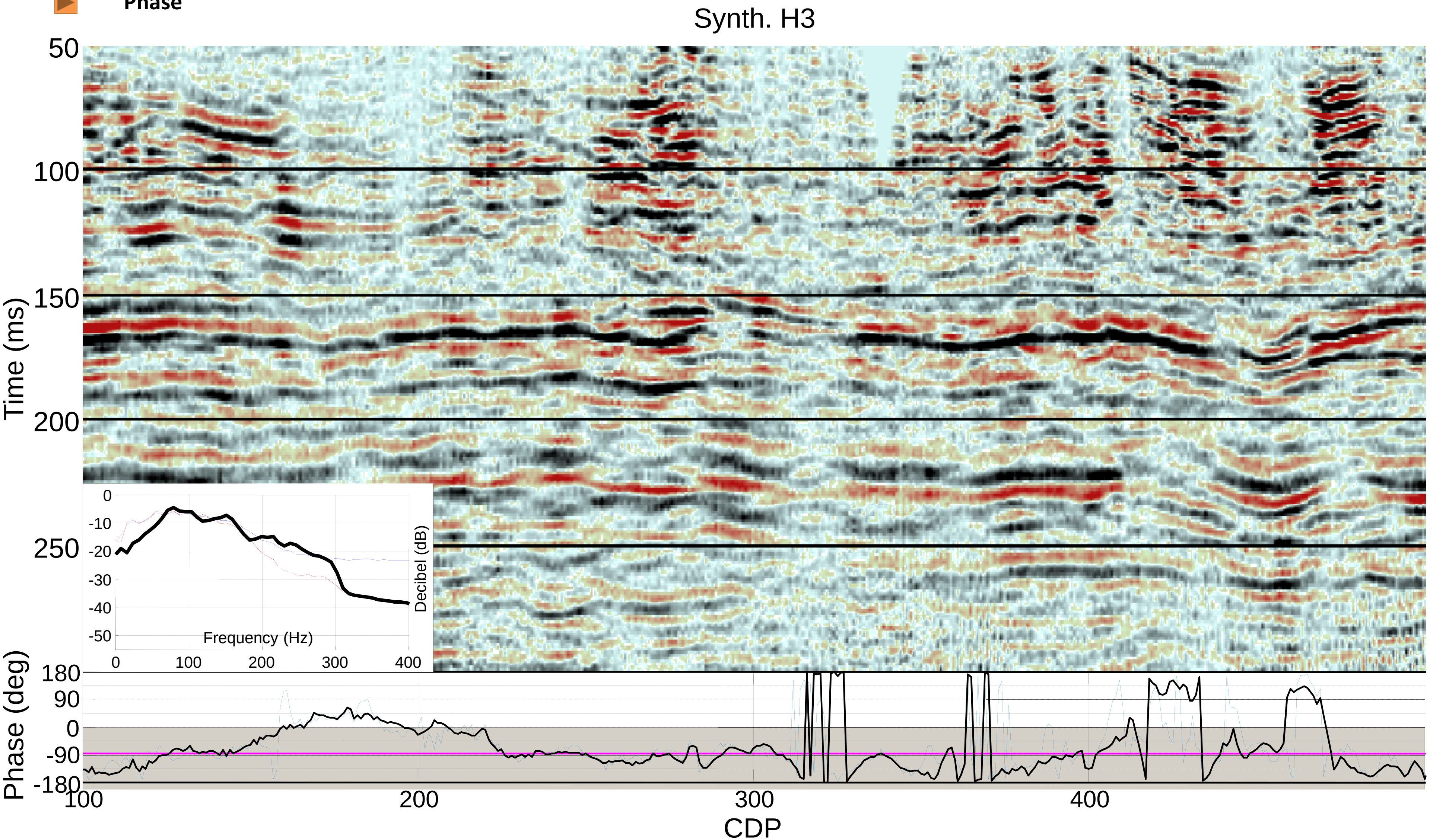
Phase



Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

Frequency

Phase

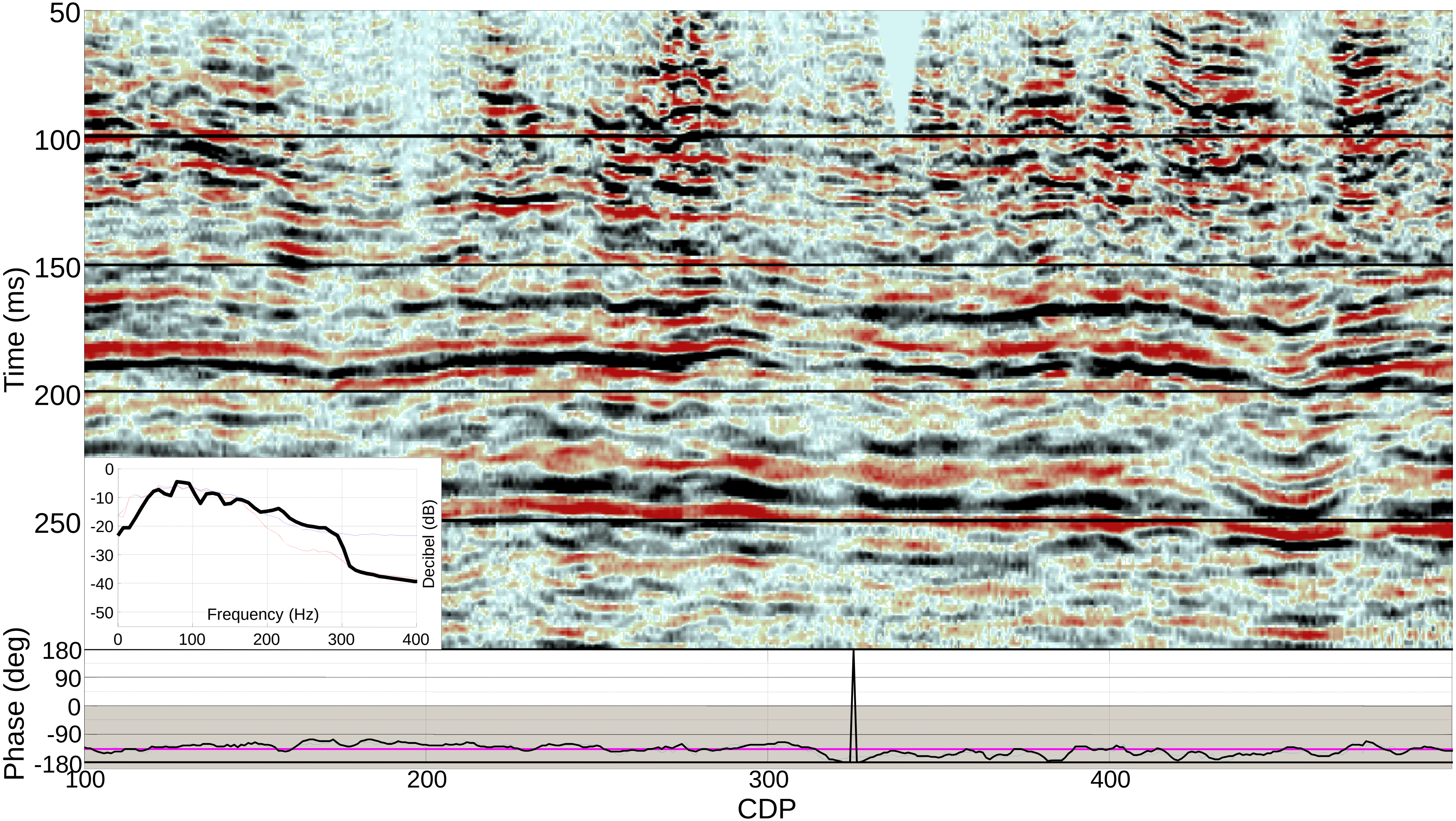


Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

Frequency

Phase

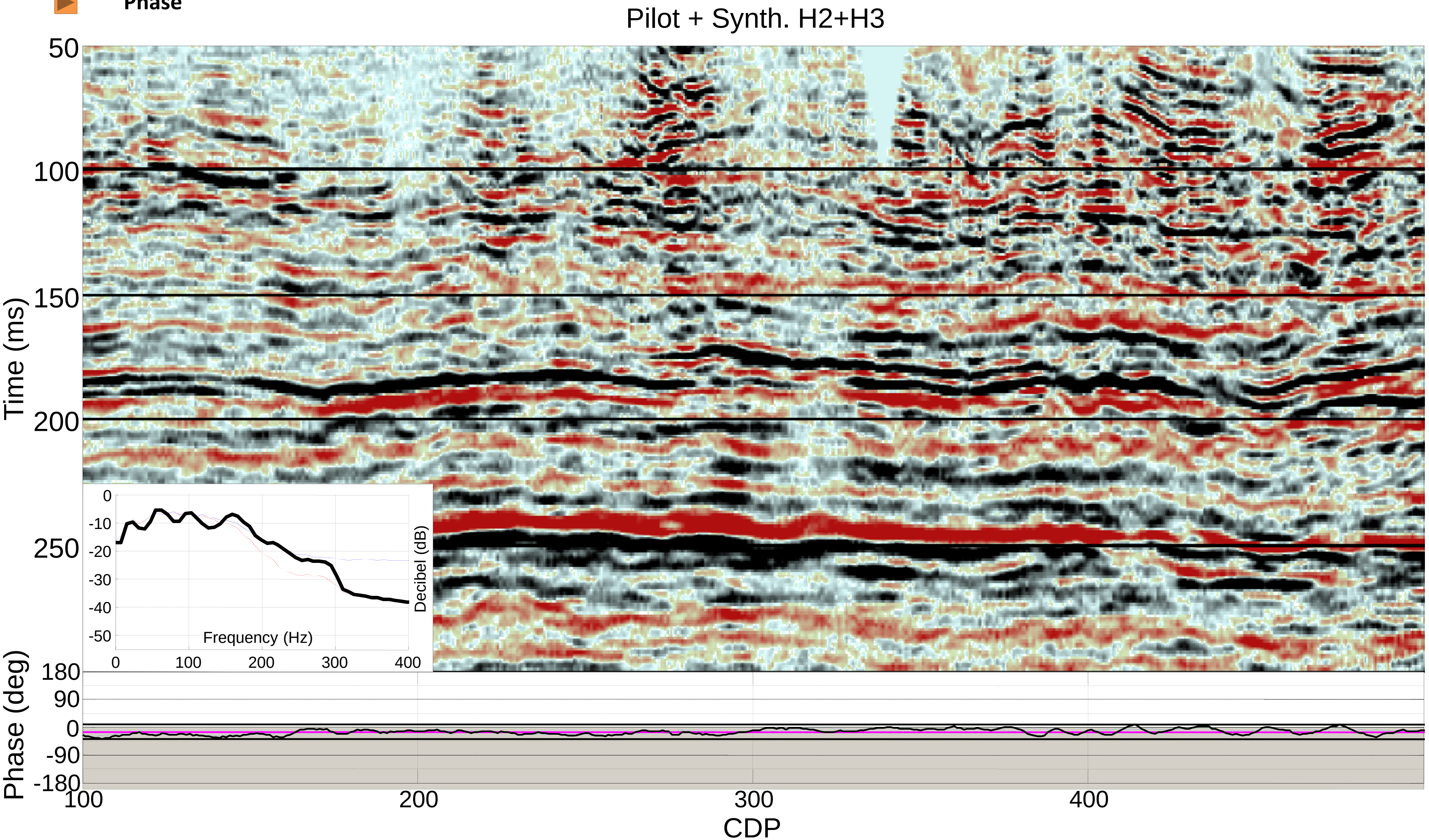
Synth. H2+H3



[Pilot](#) - [Synth. H2](#) - [Synth. H3](#) – [Synth. H2+H3](#) – [Pilot + Synth. H2+H3](#)
[BP FDGD H1](#) - [BP FDGD H2](#) - [BP FDGD H3](#) – [BP FDGD H2+H3](#) – [BP FDGD H1+H2+H3](#)

Frequency

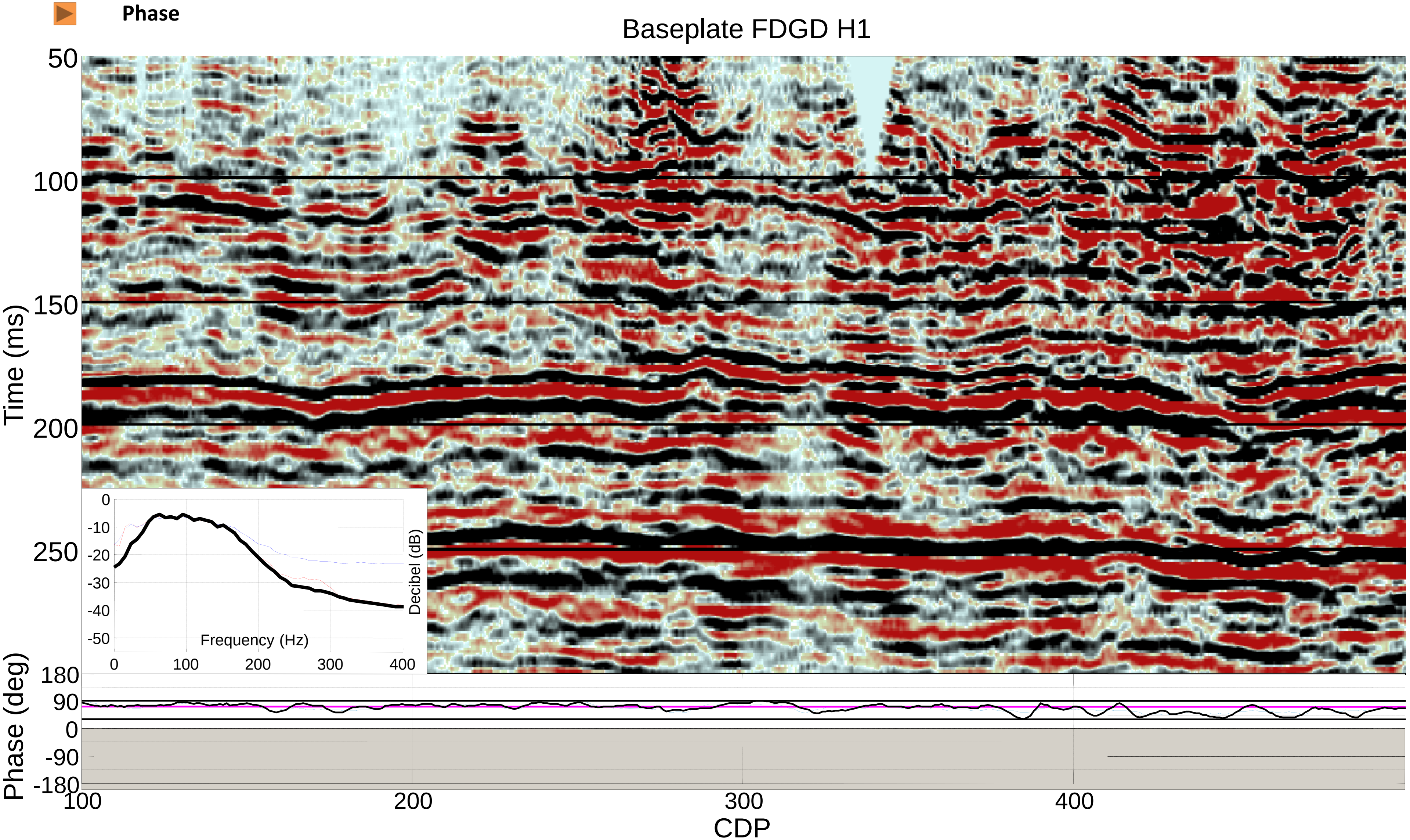
Phase



Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

Frequency

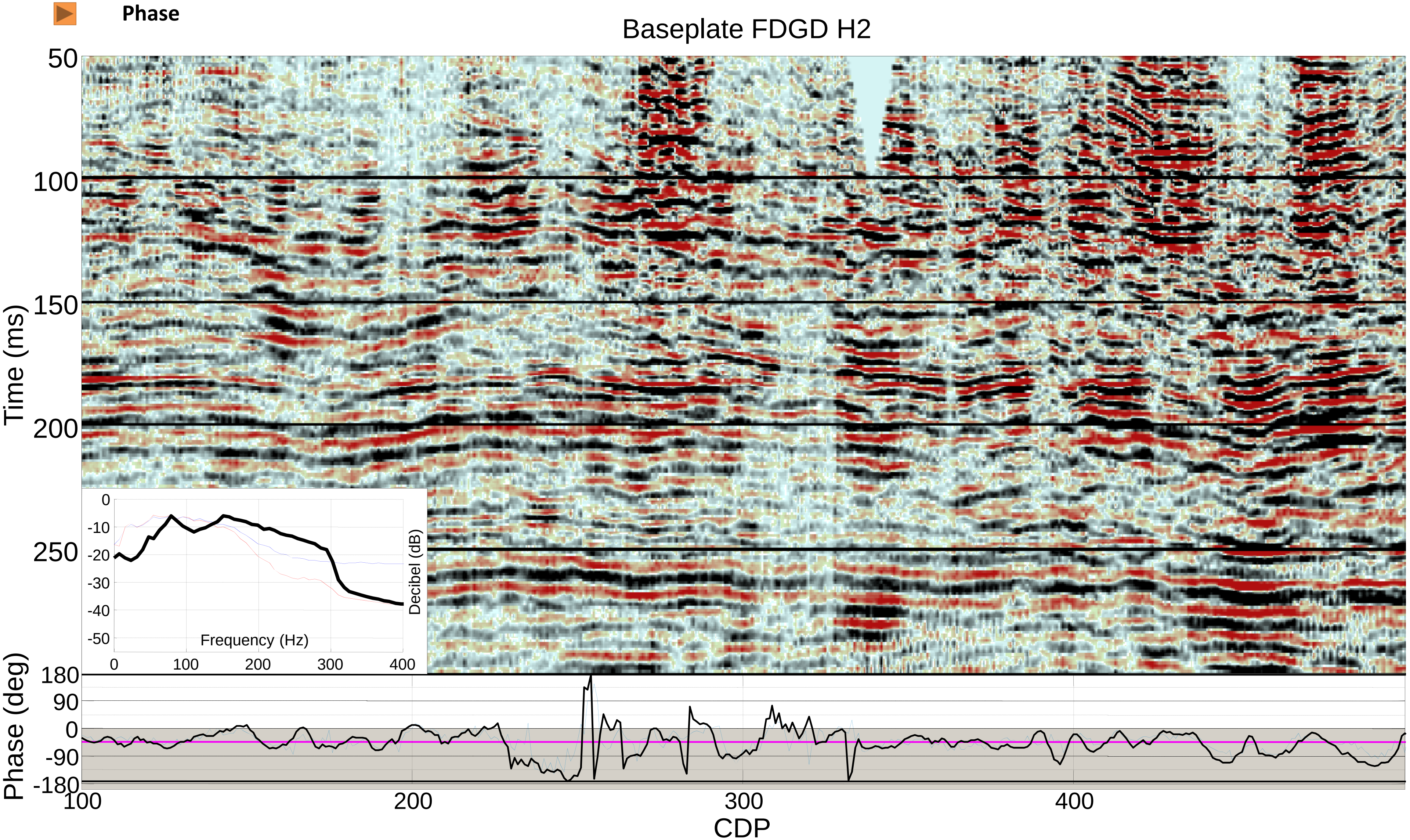
Phase



Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3

BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

- Frequency
- Phase

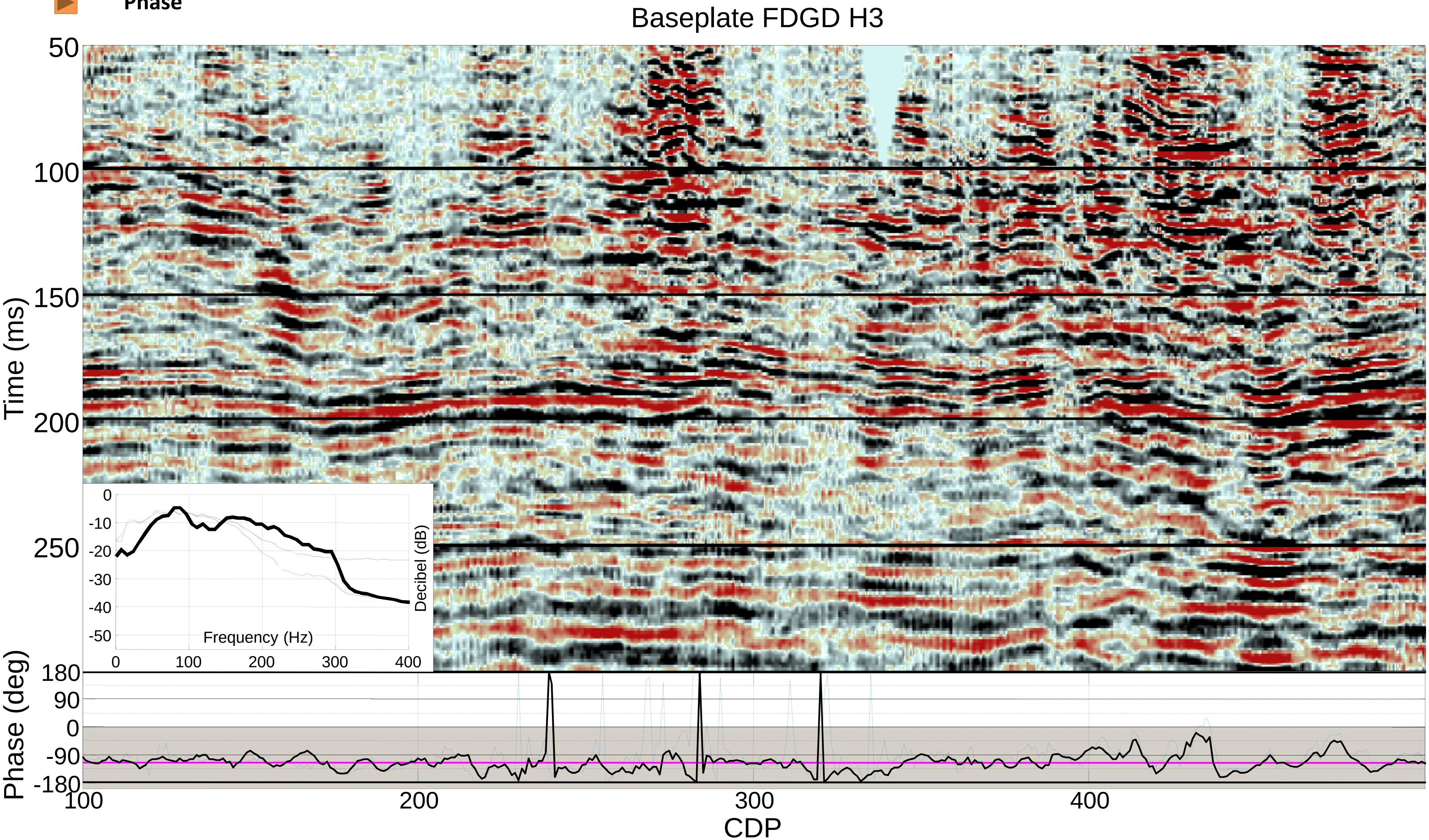


Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3

BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

Frequency

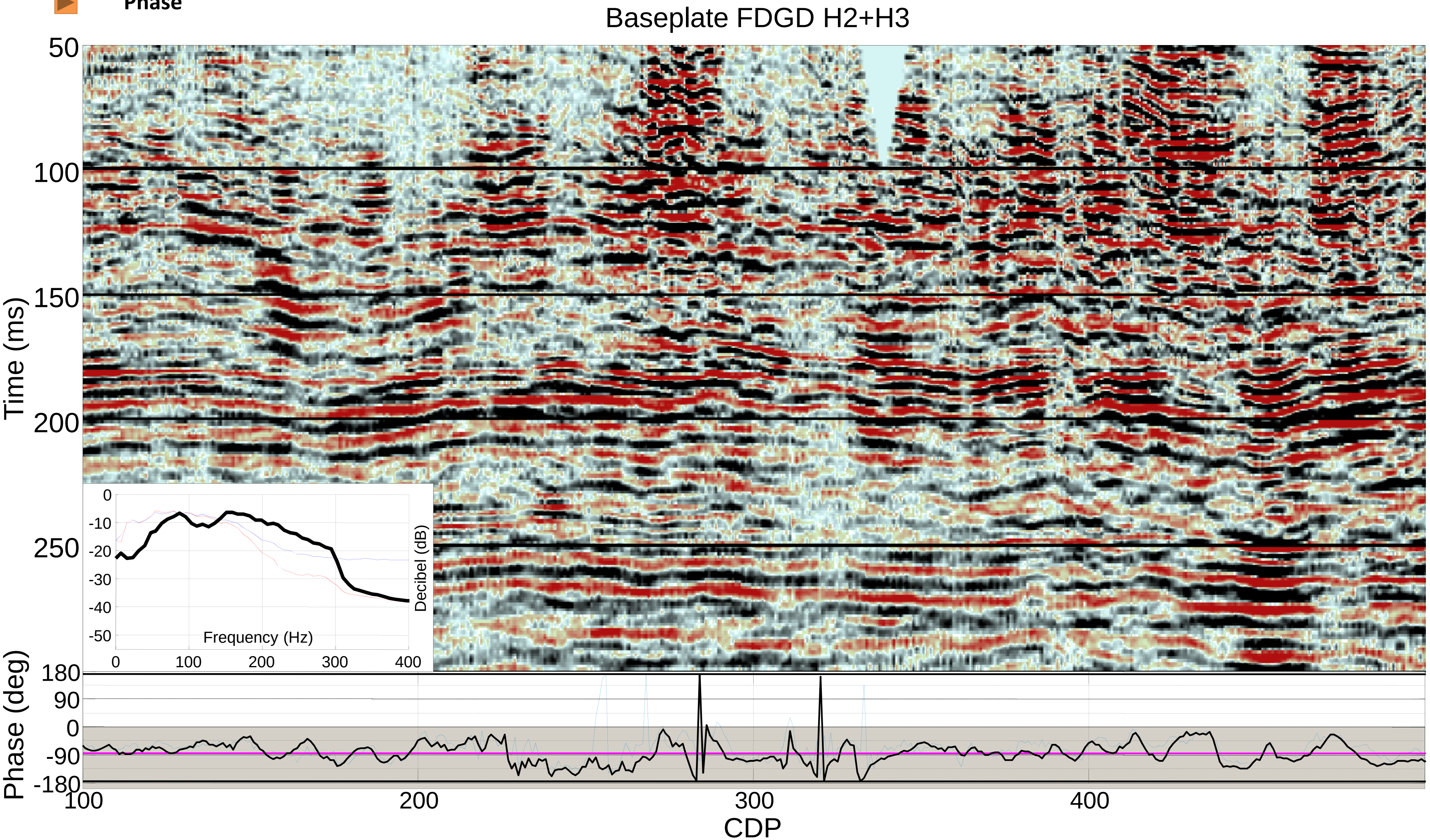
Phase



Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3

BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

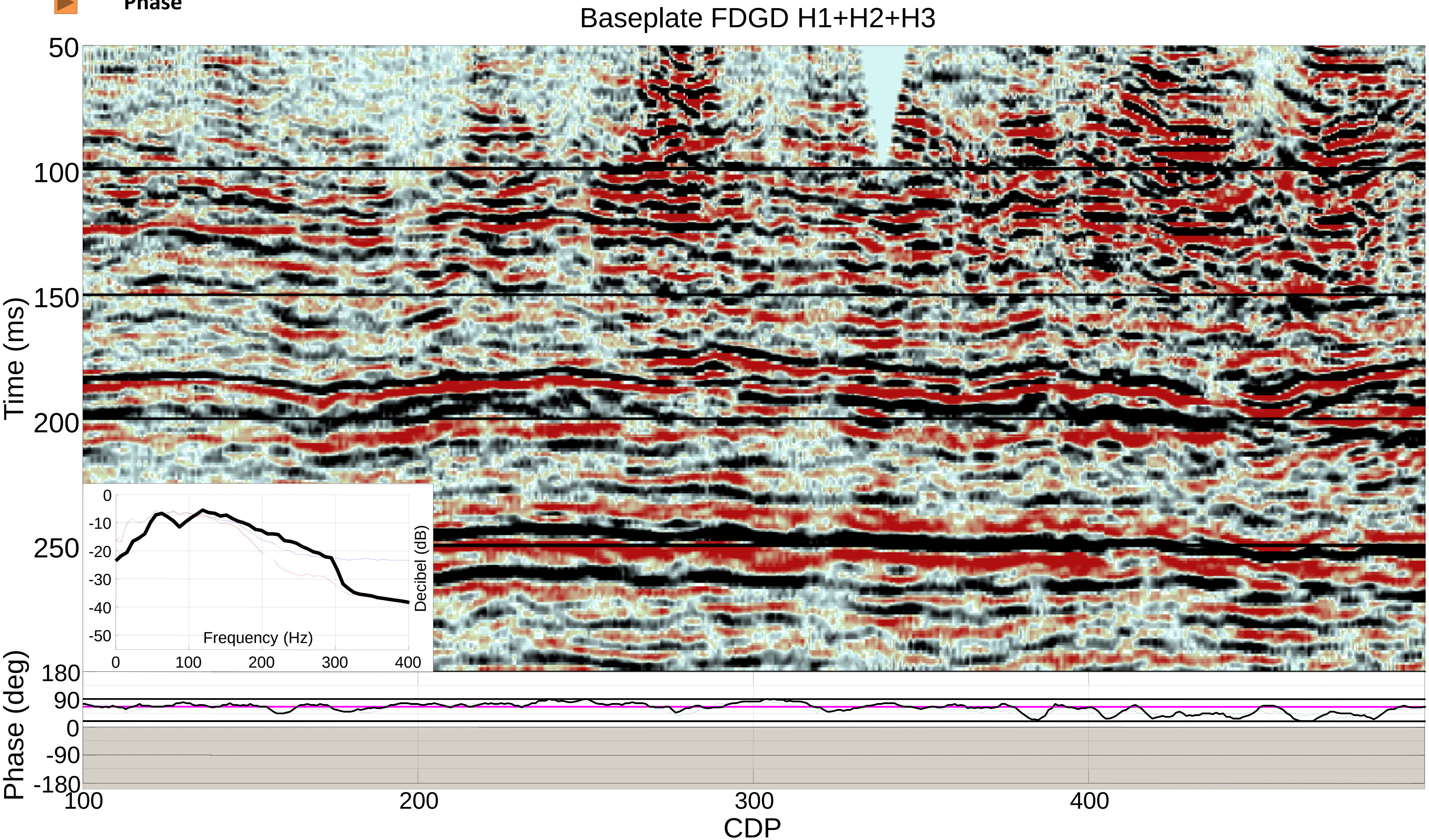
- Frequency
- Phase



Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3

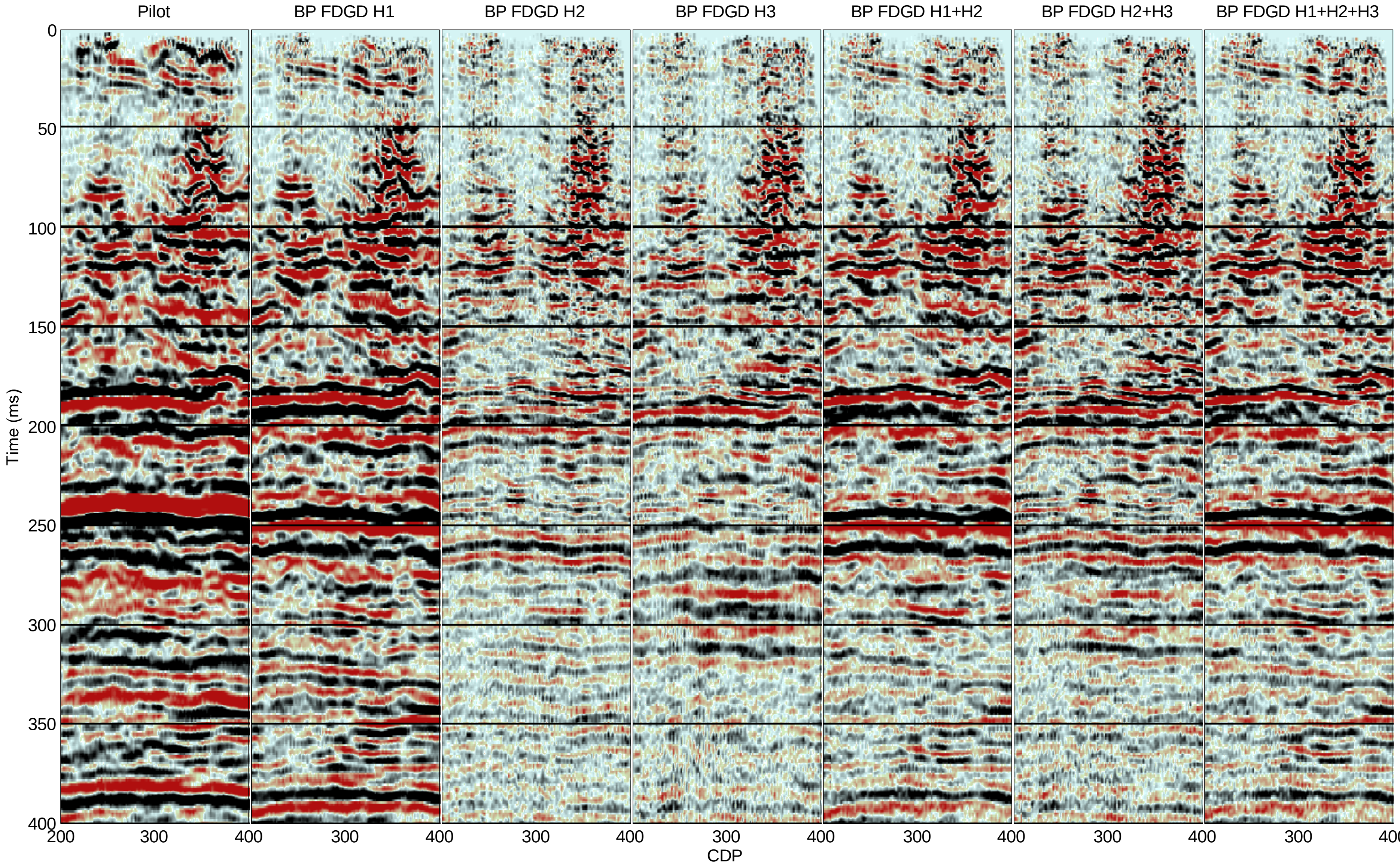
BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

- Frequency
- Phase



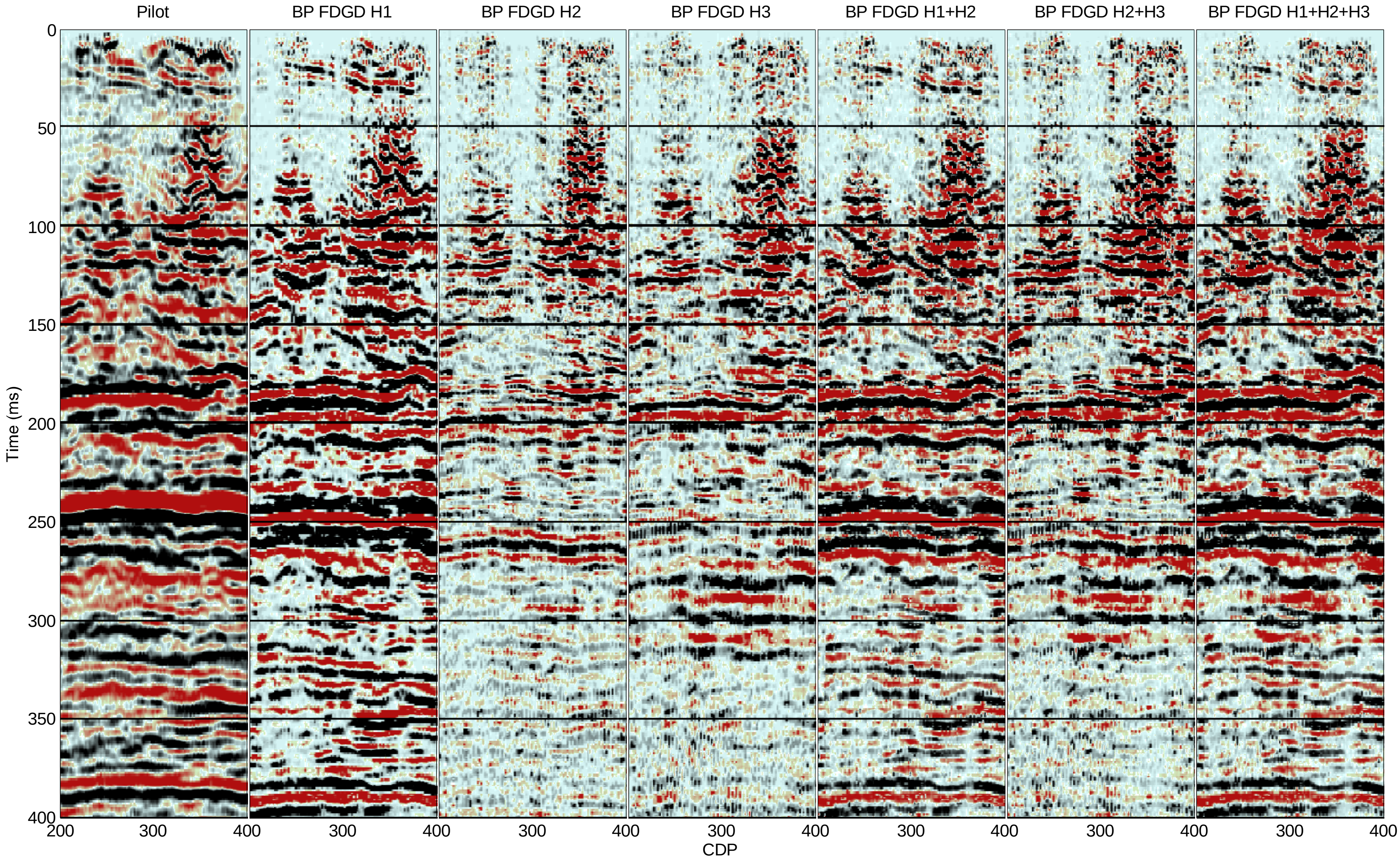
Pilot - Synth. H2 - Synth. H3 – Synth. H2+H3 – Pilot + Synth. H2+H3
BP FDGD H1 - BP FDGD H2 - BP FDGD H3 – BP FDGD H2+H3 – BP FDGD H1+H2+H3

Unrotated



Unrotated - Rotated

Bulk Rotated



Unrotated - Rotated

Conclusions

- Harnessing harmonics is achievable
  - Near surface thin reflectors imaged
- Survey Parameters
  - Vibrator
  - High resolution acquisition
- Processing
  - Same processing flow, different correlation operator
  - Frequency Dependent Gabor Decomposition
    - H1, H2, H3
    - Synthetic H2 and H3
- Future work
  - Address phase
  - H4… H5 as correlation operator?

CREWES

POTSI

PSEUDODIFFERENTIAL OPERATOR THEORY & SEISMIC IMAGING

CMC

Statoil

NSERC CRSNG

UNIVERSITY OF CALGARY

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