Towards realistic 3D elastic models of Canadian channel and reef structures

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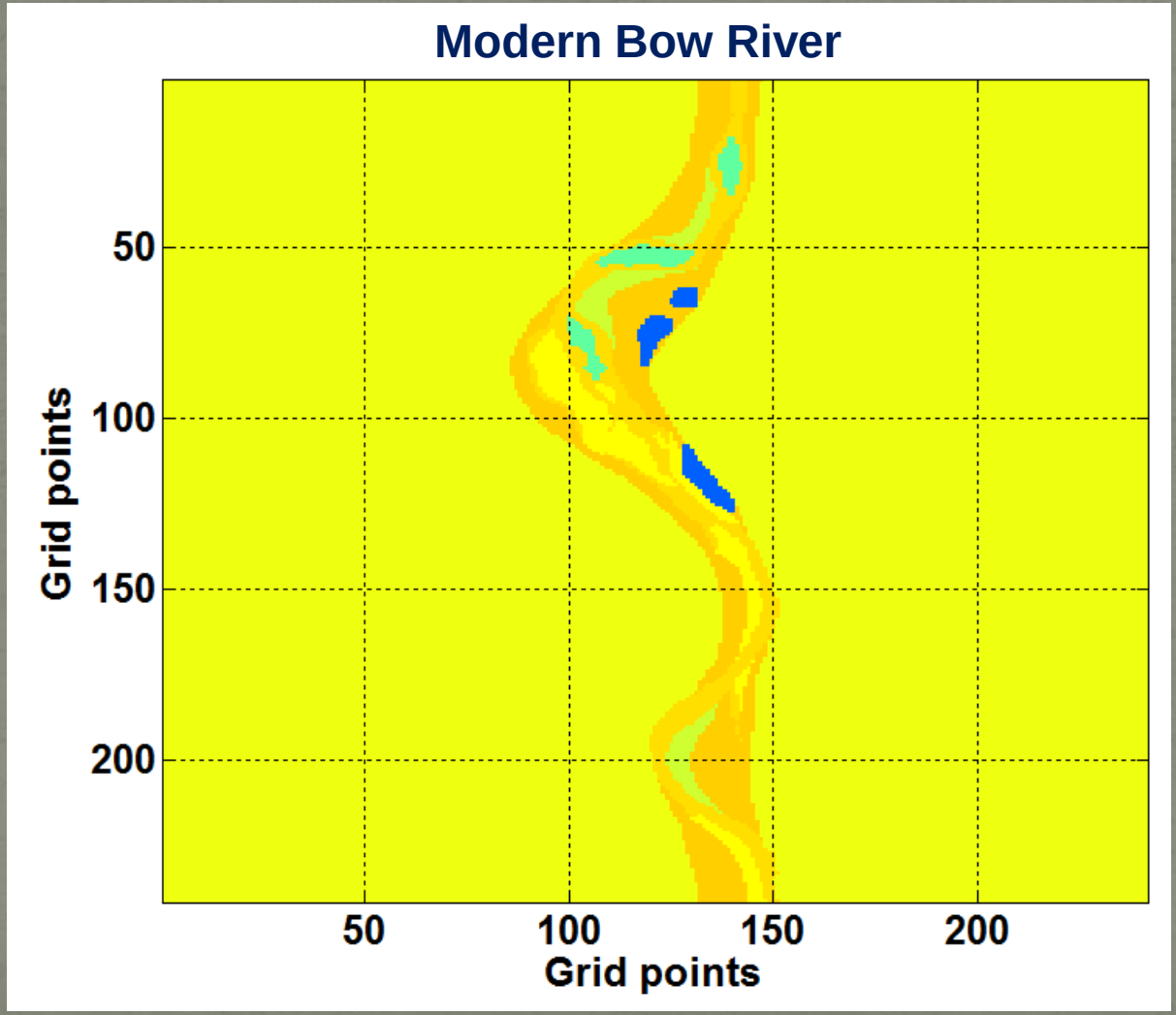
Plan

- Define 3D heterogeneous elastic models of important Canadian exploration targets.
- Models should be “typical” but not represent any specific structure.
- Channel model adapted from Bow River. Reef model adapted from Rainbow “Eh”.
- Create realistic 3D seismic response of the models.
- Use to test imaging algorithms, evaluate footprint, etc.

Strategy

- Hire a geologist.
- Create (draw) maps of a small number of depth levels in the structure.
- Maps define polygons of different lithologies. Assign values of Vp, Vs, and density to each lithology.
- Interpolate new levels between the original levels.
- Attach a laterally invariant background model defined from logs.
- Compute seismic.

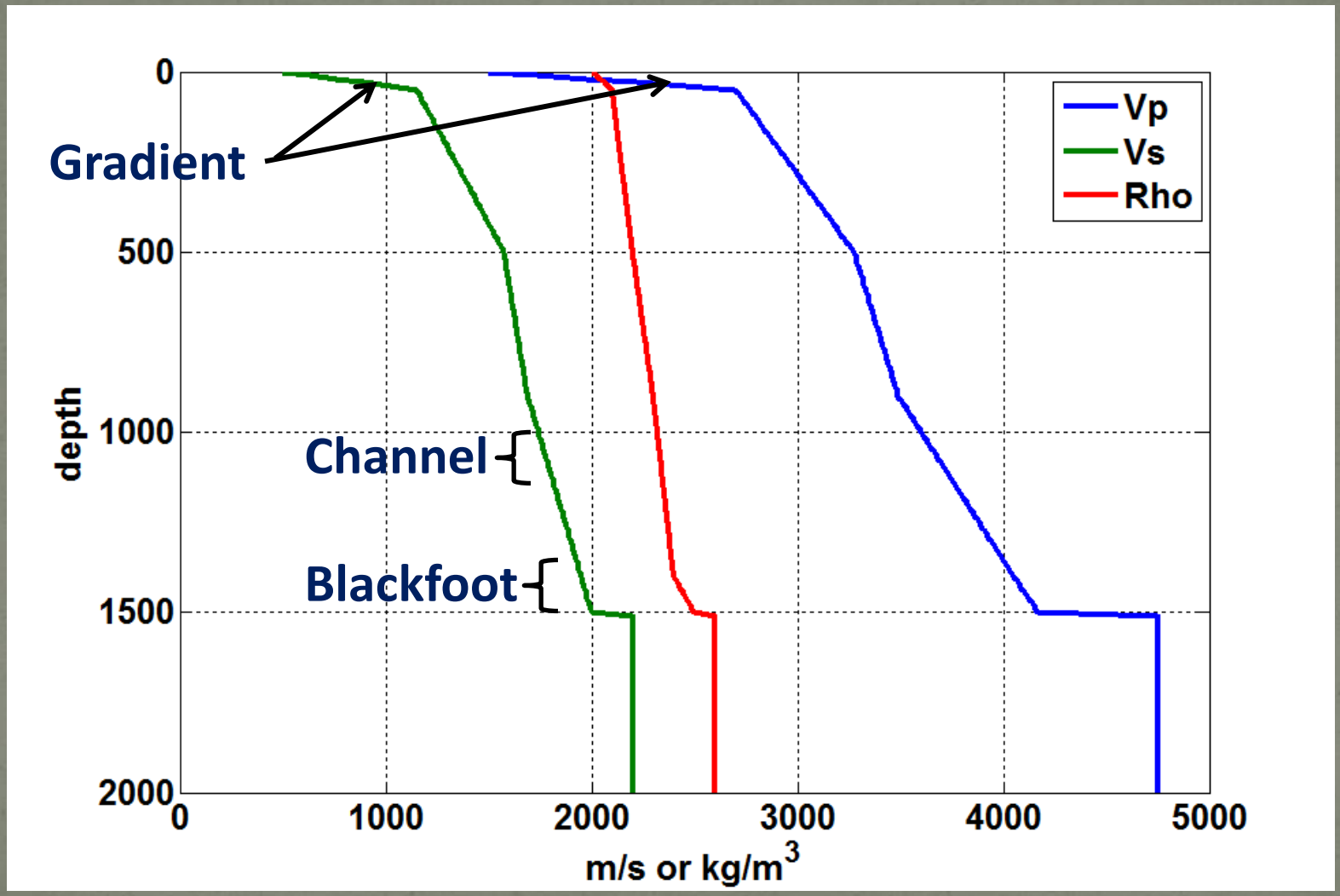
CREWES Channel Model



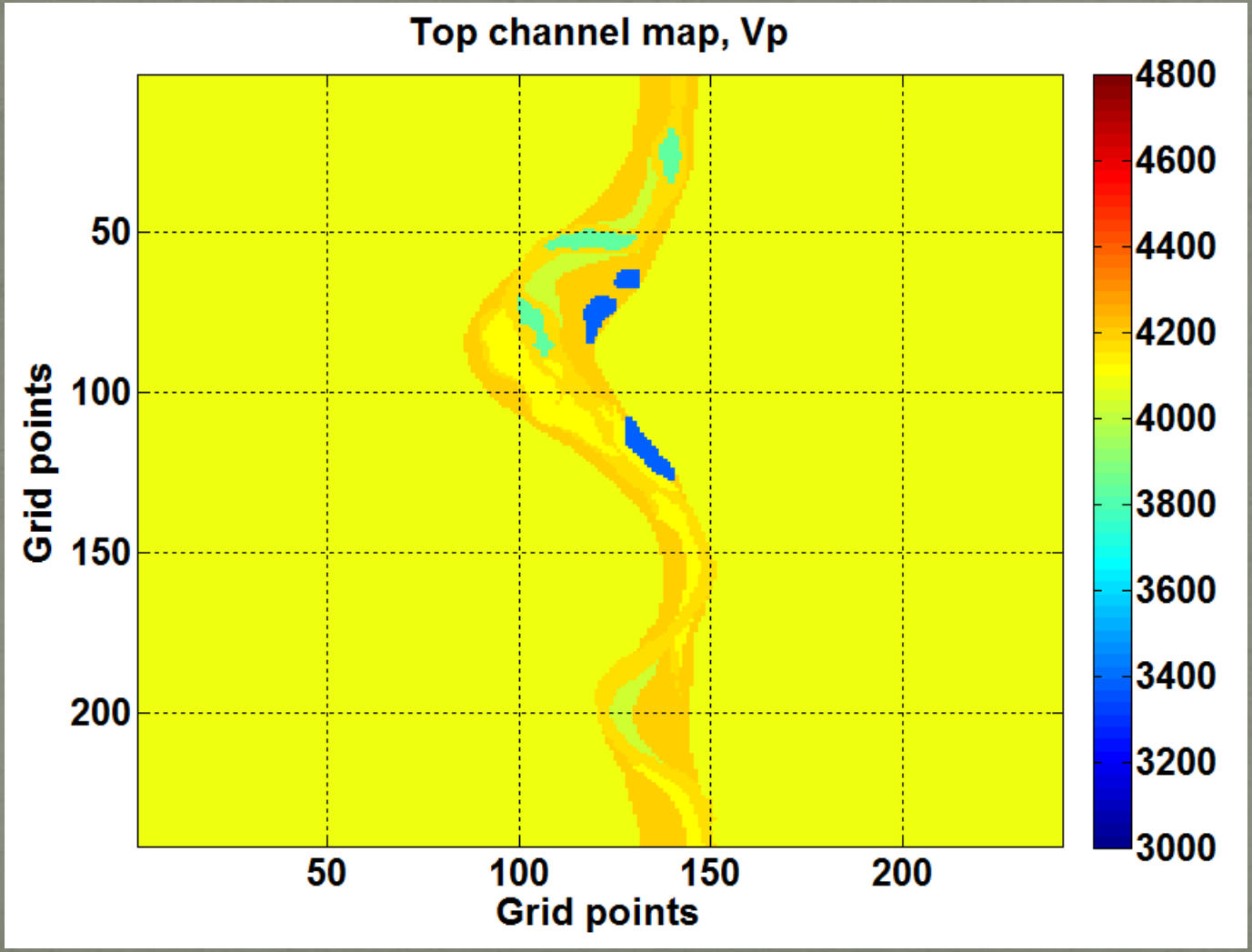
Model Construction

- Create vertically stratified, laterally invariant overburden from smoothed Blackfoot well logs.
- Five channel maps were drawn and digitized. Each channel map resulted in three parameter maps (Vp, Vs, and Rho) consisting of polygonal regions with constant material fill.
- Elastic parameters taken from Glauconitic channel at Blackfoot about 1.5 km depth. Rescaled to fit background model at 1 km.

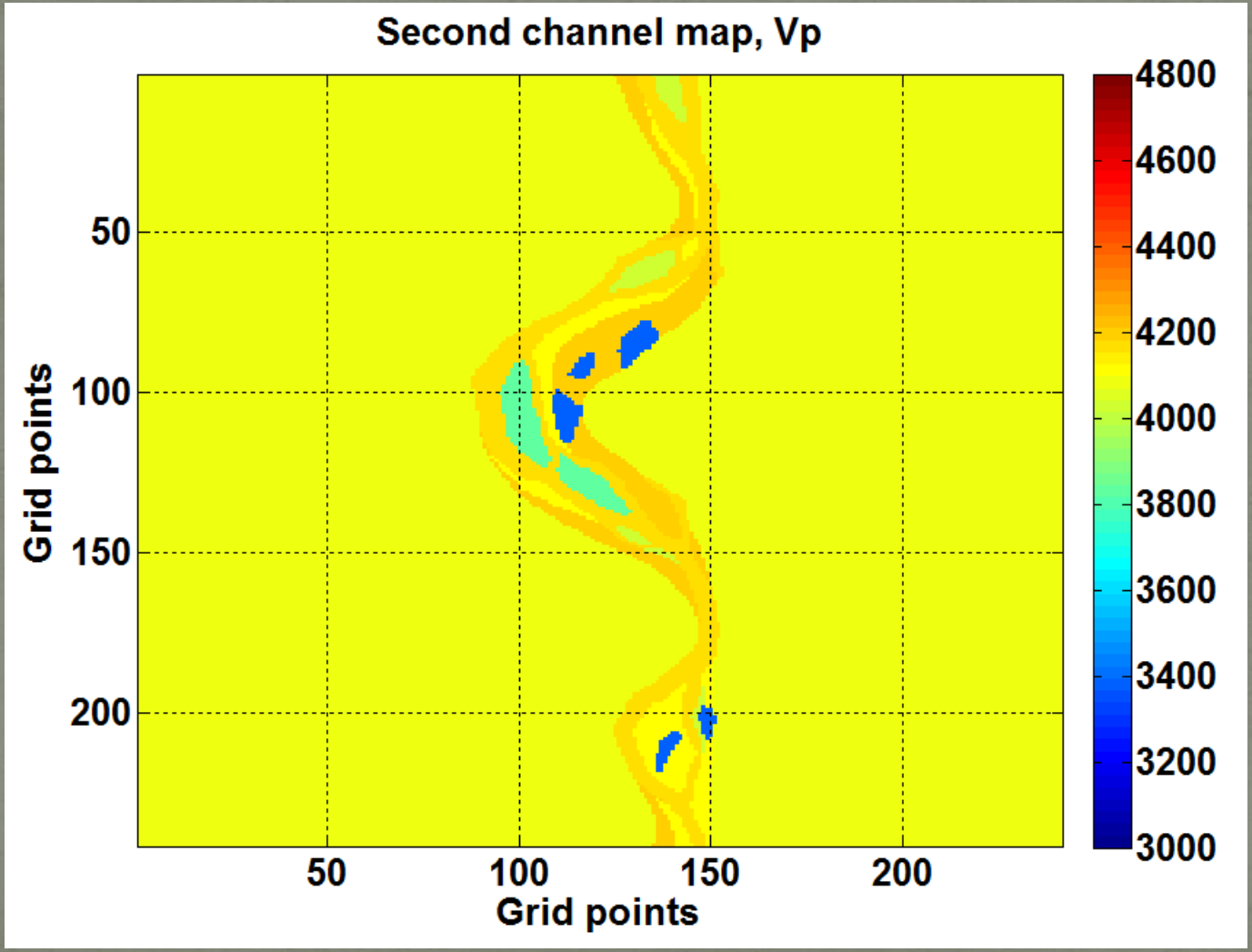
Background velocity and density Adapted from Blackfoot logs



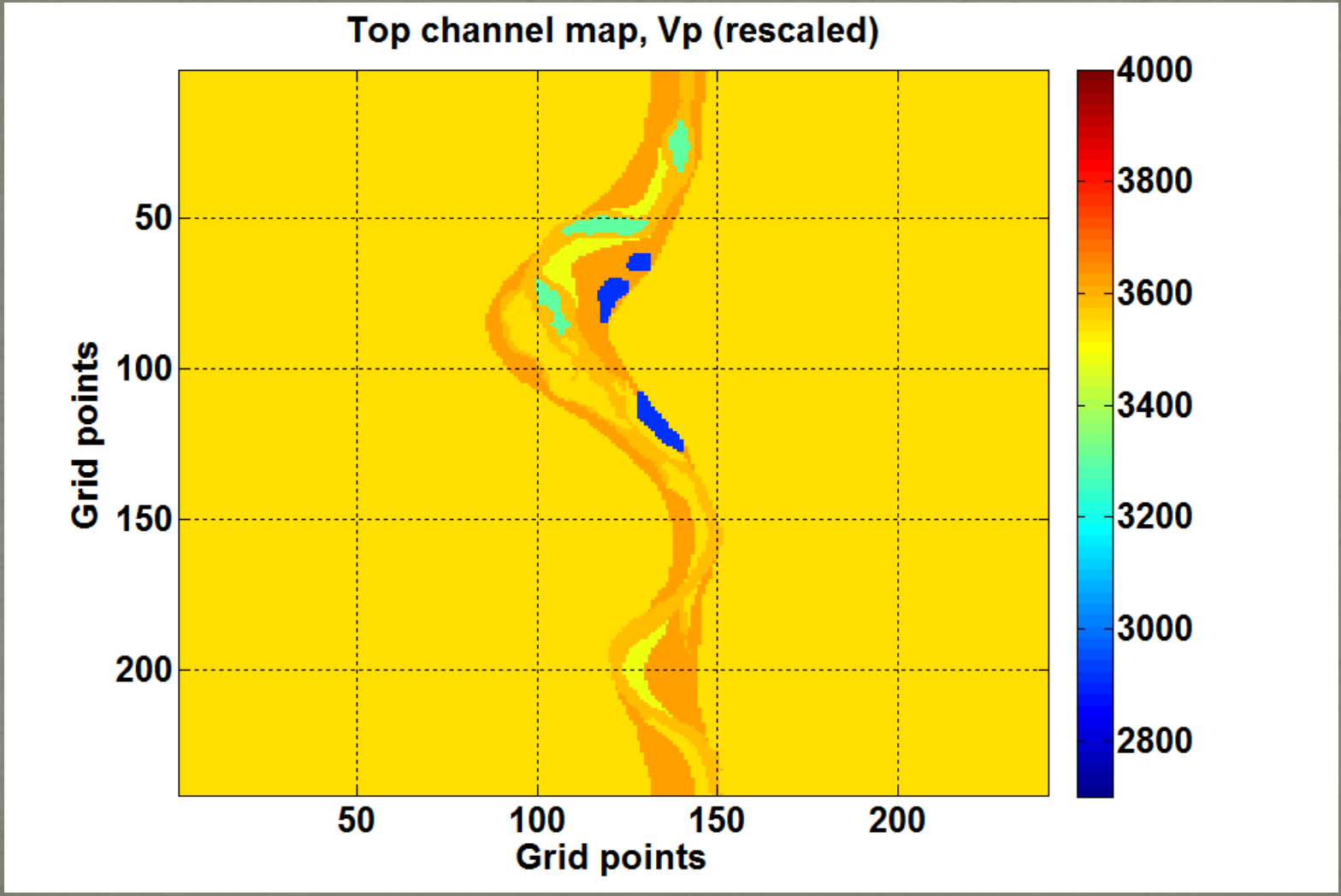
Upper Channel Vp



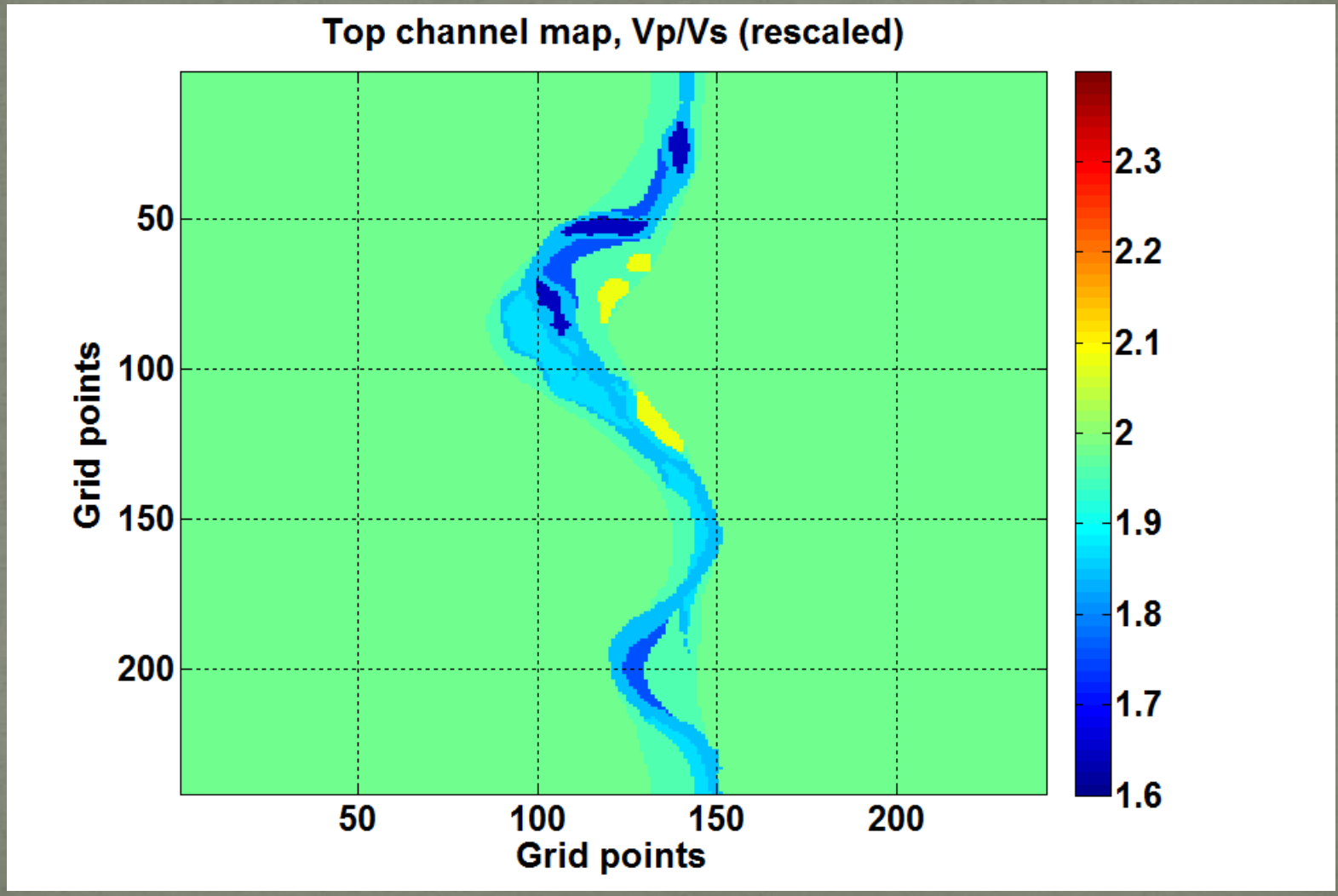
Second Channel Vp



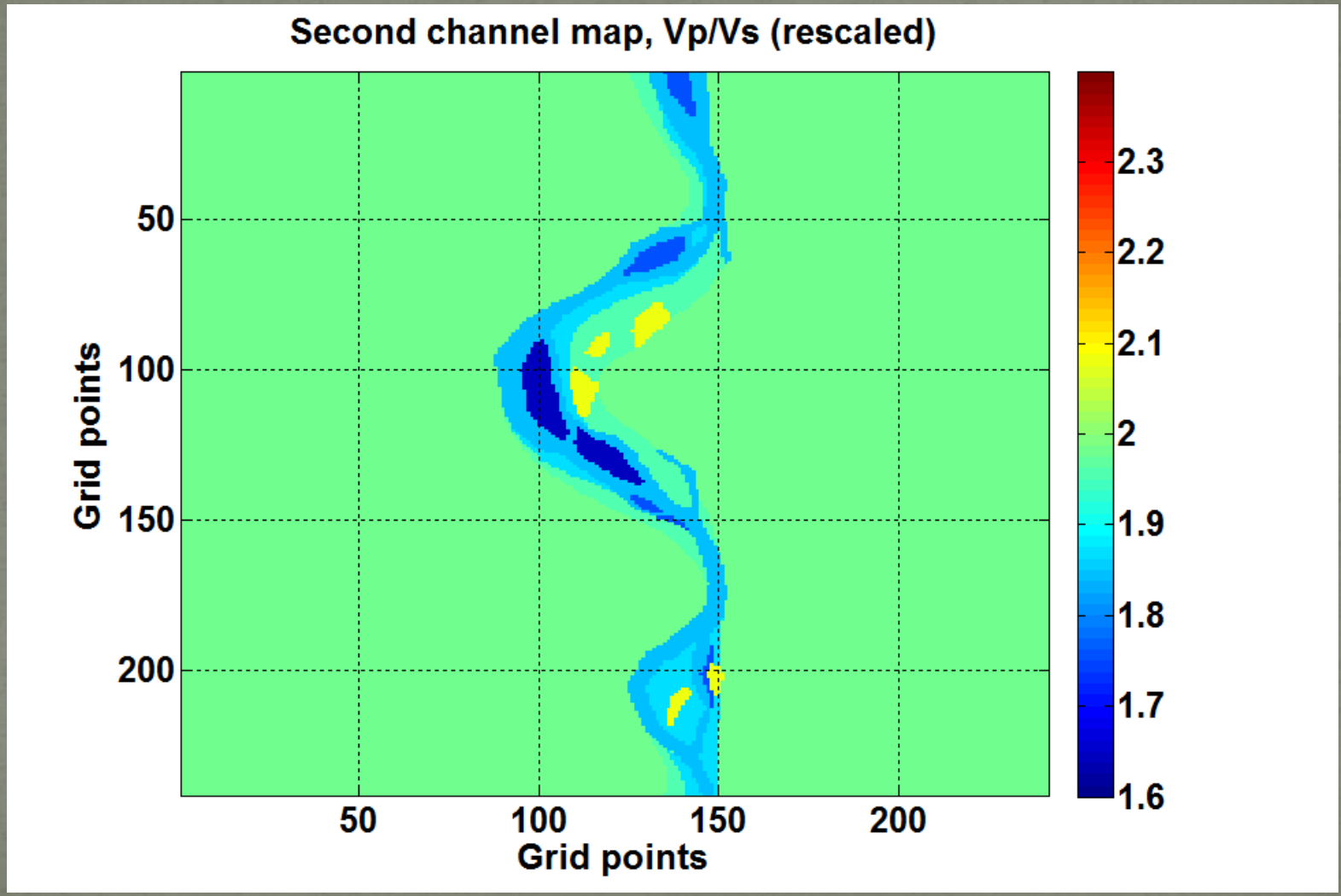
Upper Channel after rescaling



Upper Channel after rescaling



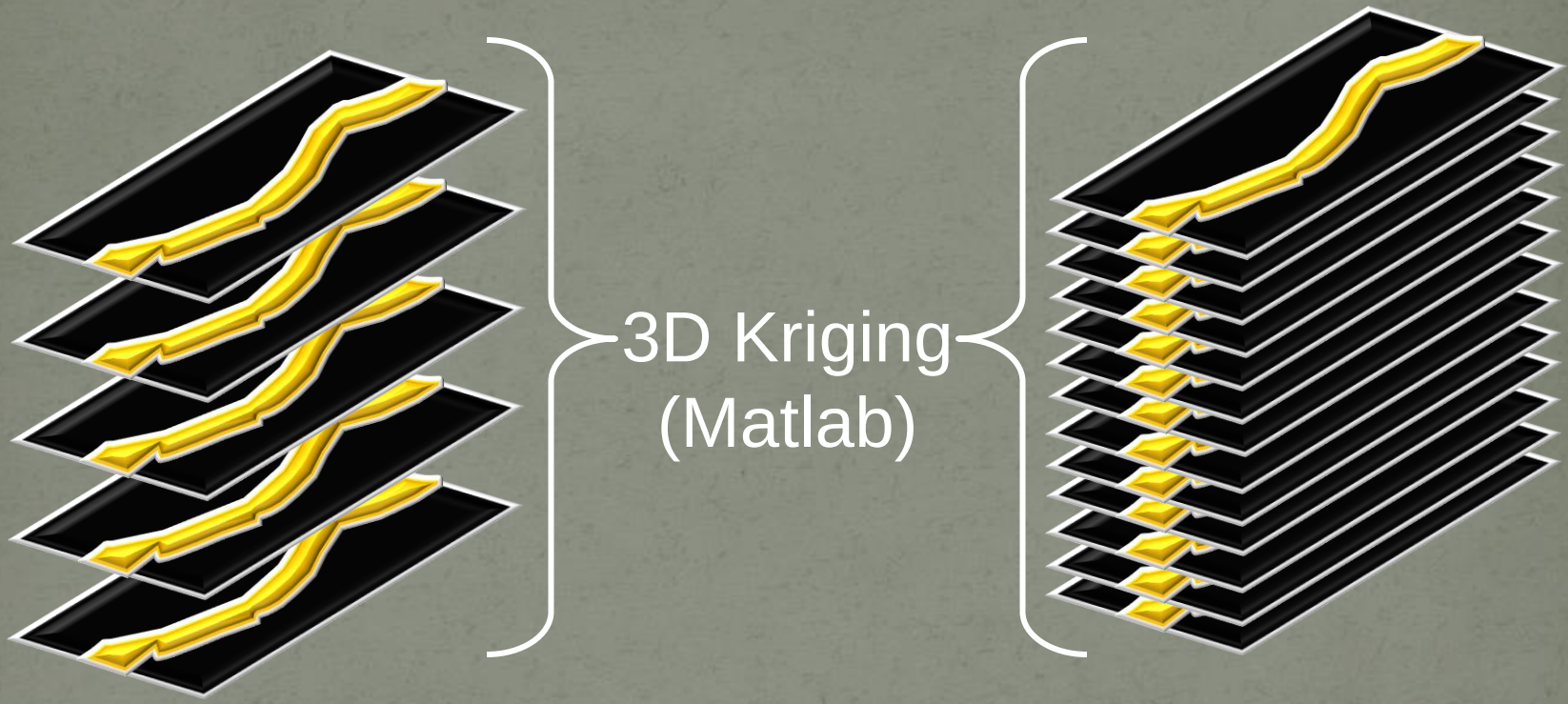
Upper Channel after rescaling



Model Construction

- **Sample each parameter map at several hundred discrete points, apply random fluctuations to each sampled point.**
- **Use 3D kriging to create 13 maps for each parameter, representing a channel sequence 120m thick.**

Model Construction

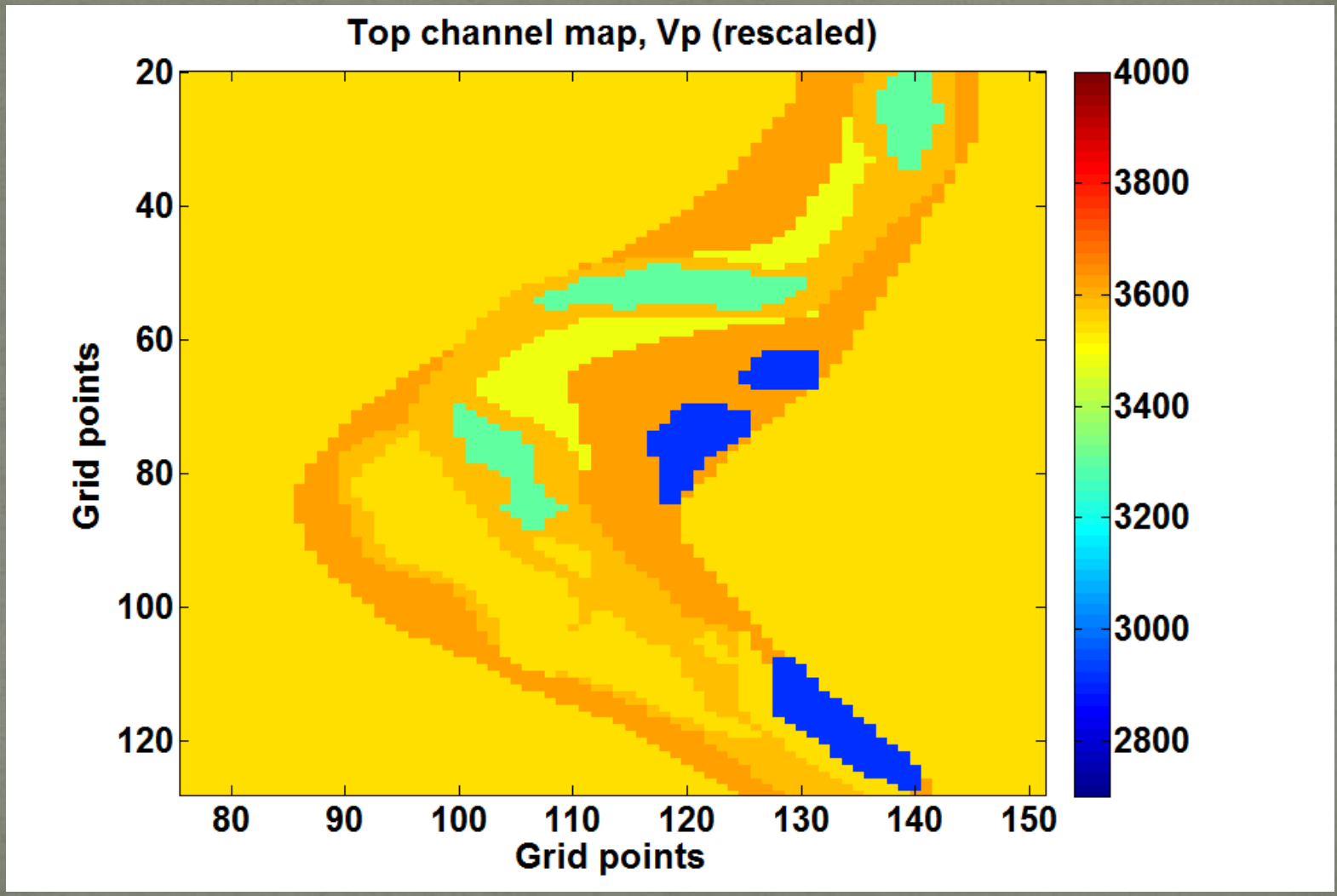


Five maps drawn and digitized

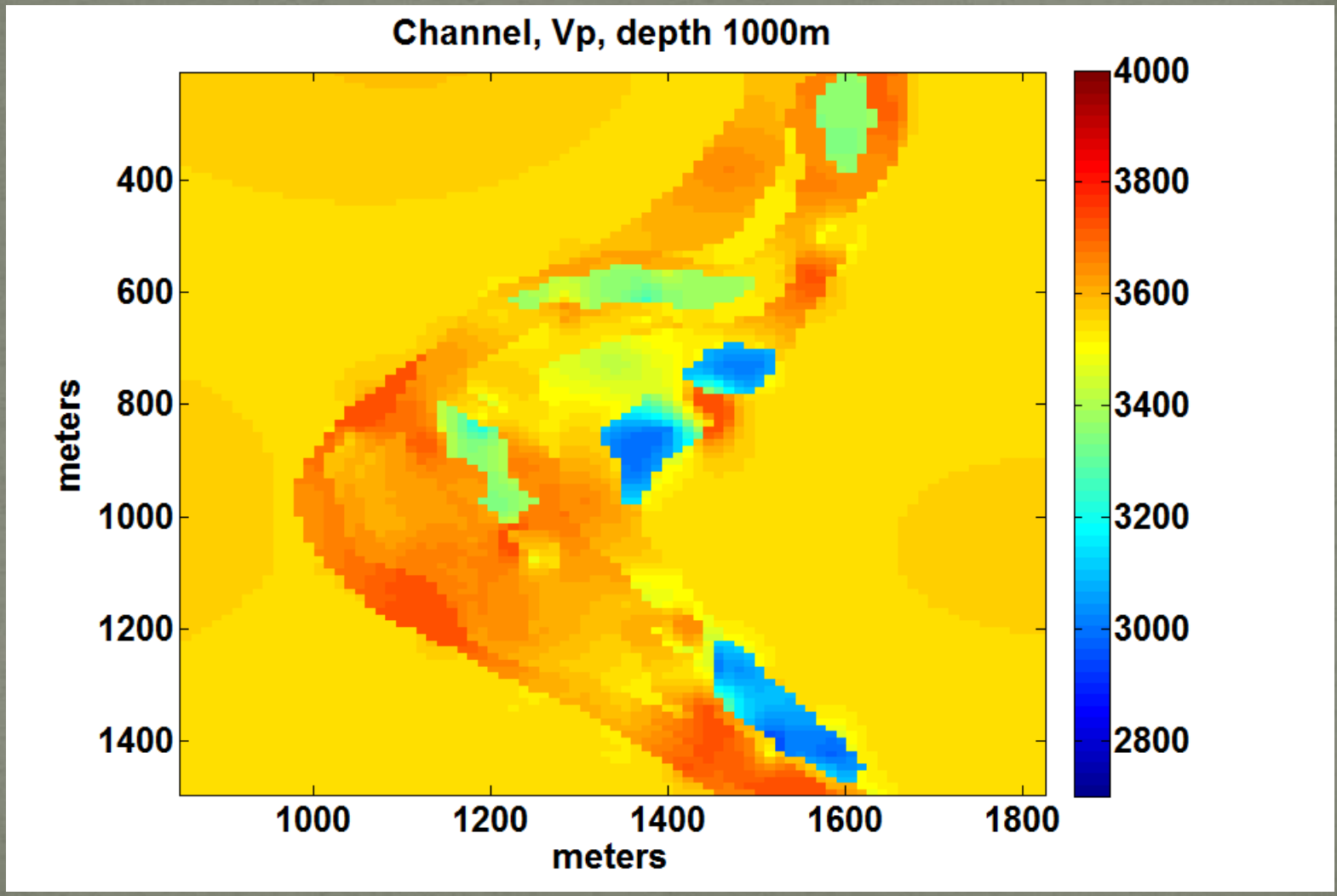
Two maps were kriged between each of the five original maps for 13 total.

Total channel thickness of 120 meters using a 10m separation.

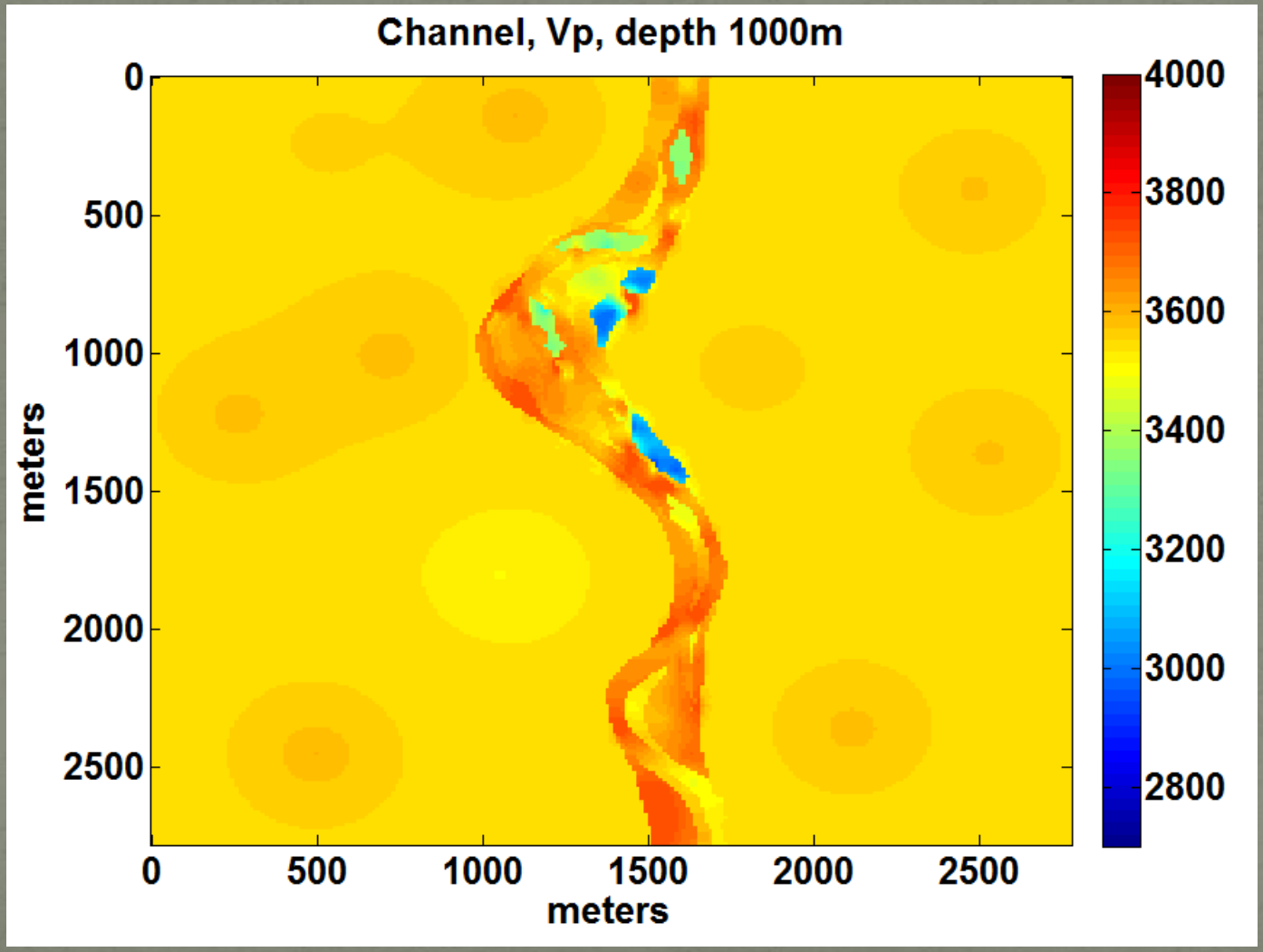
Upper Channel as Digitized (zoom)



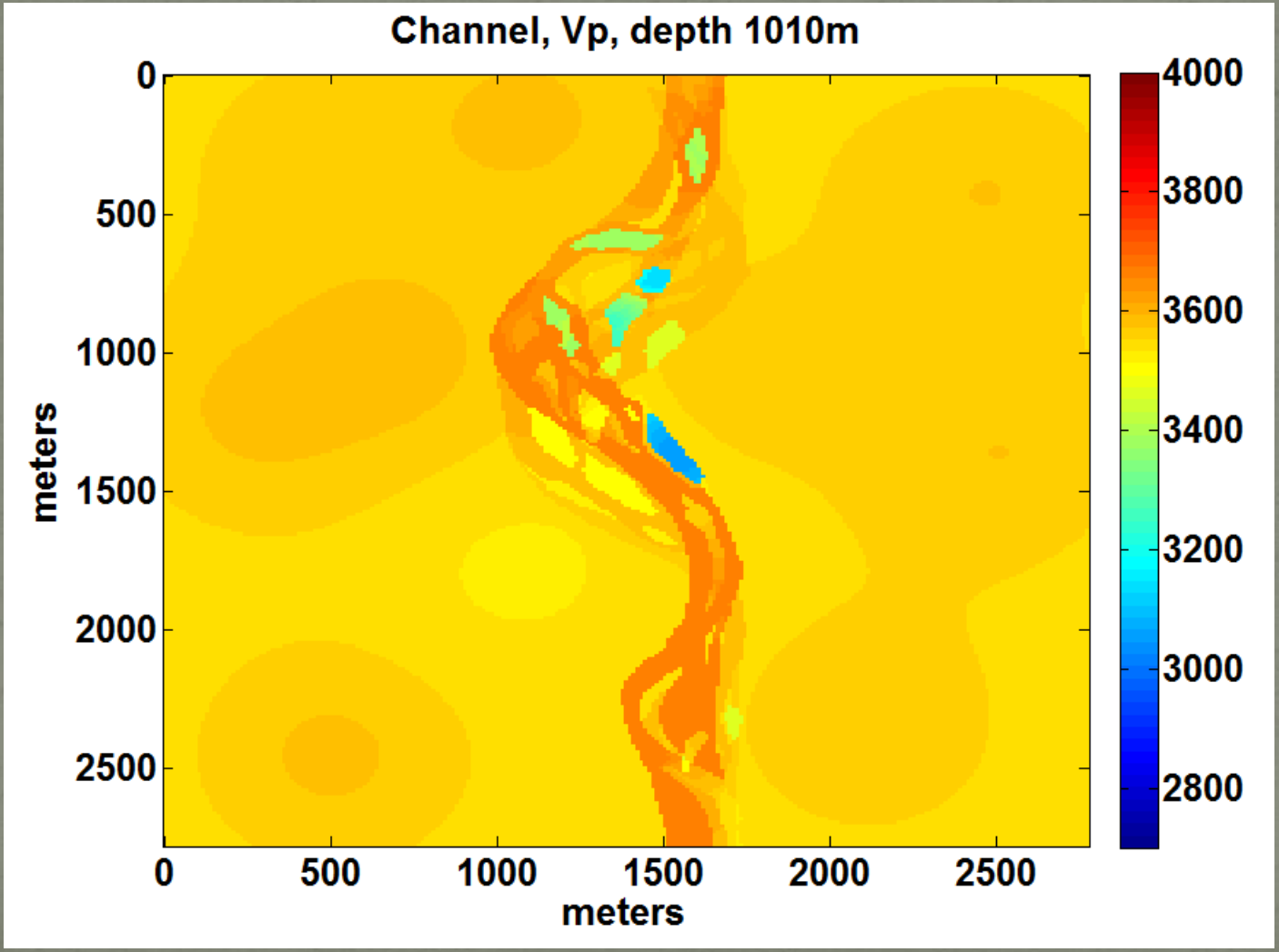
Upper Channel after krigging (zoom)



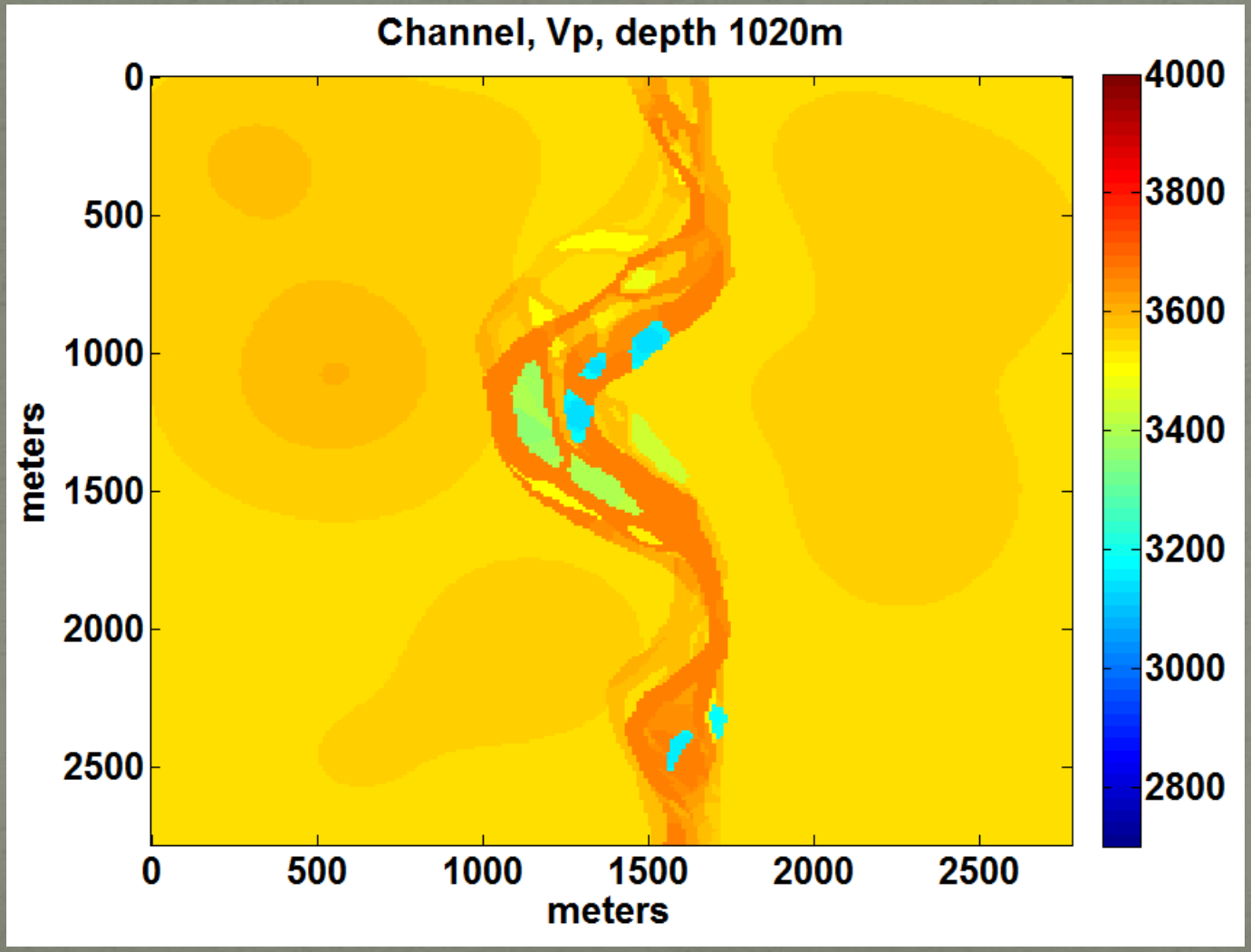
Vp Channel 1000m



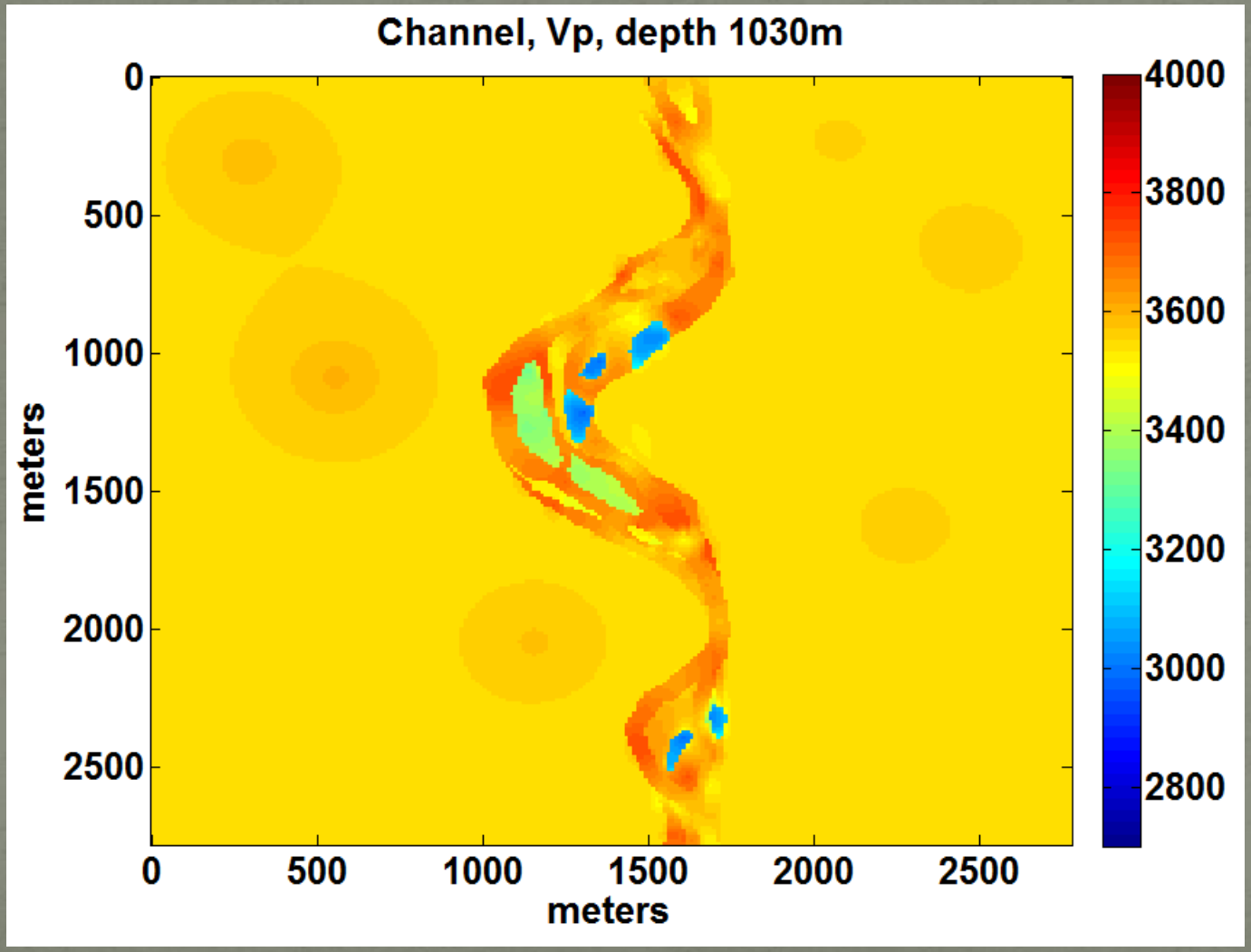
Vp Channel 1010m



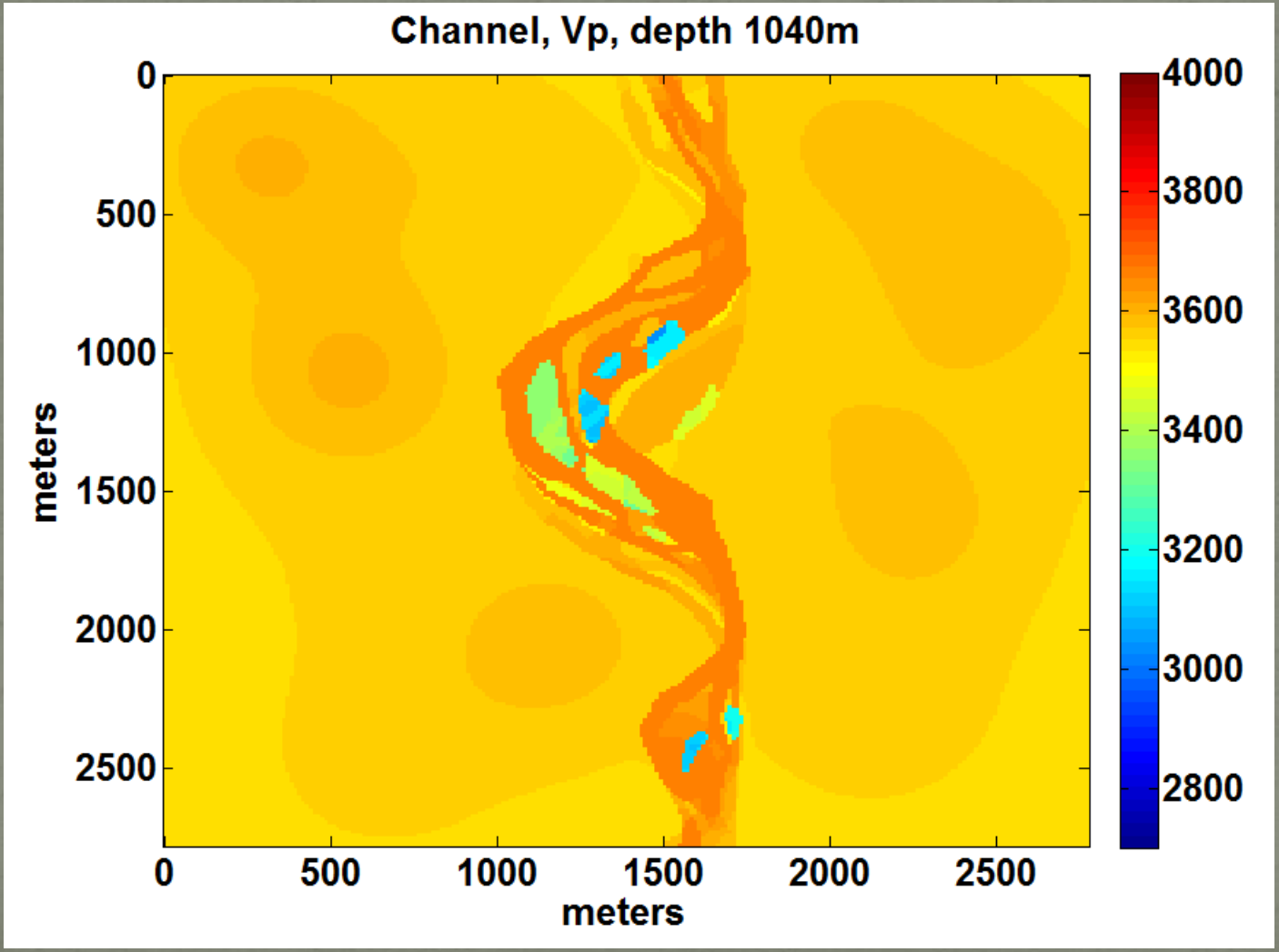
Vp Channel 1020m



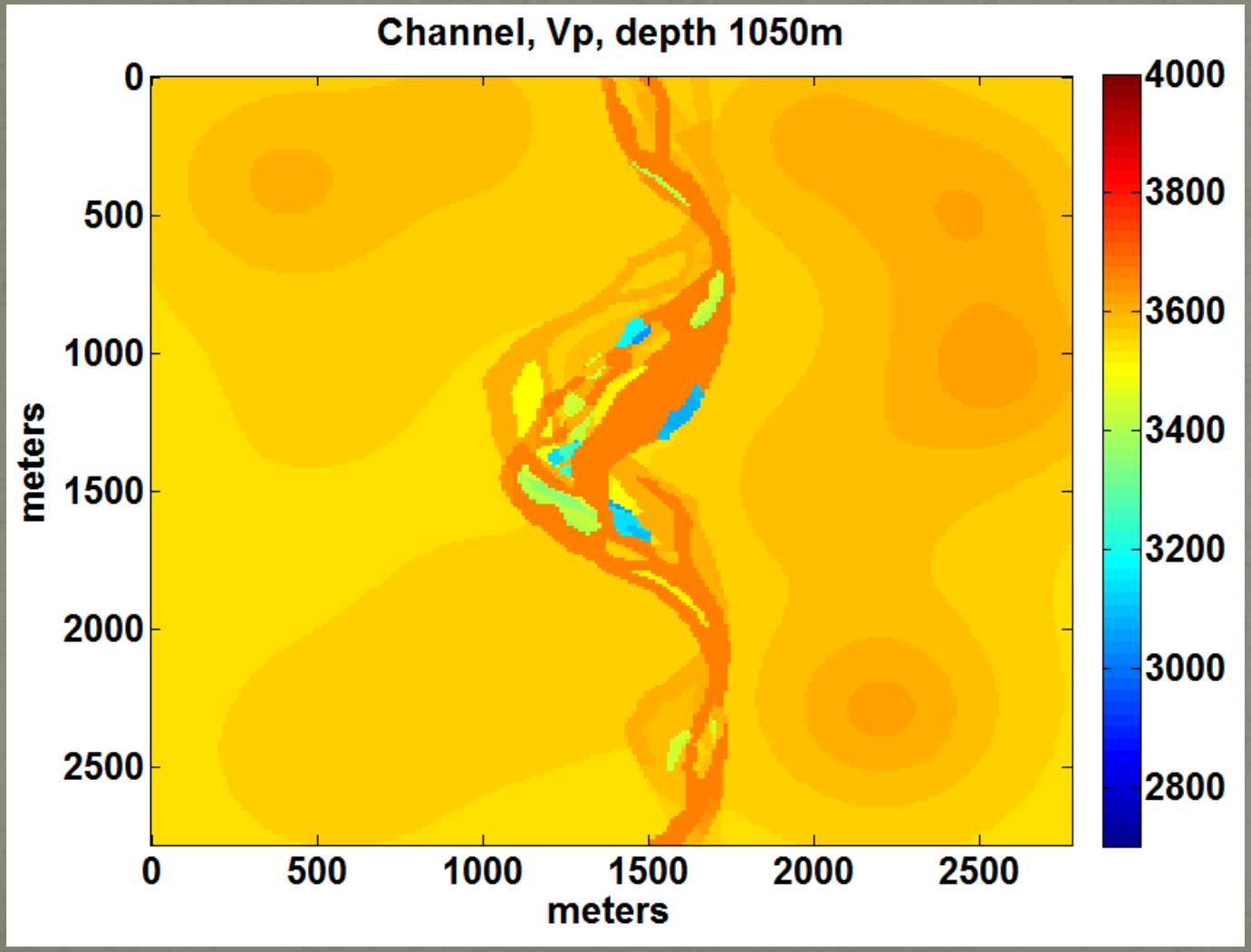
Vp Channel 1030m



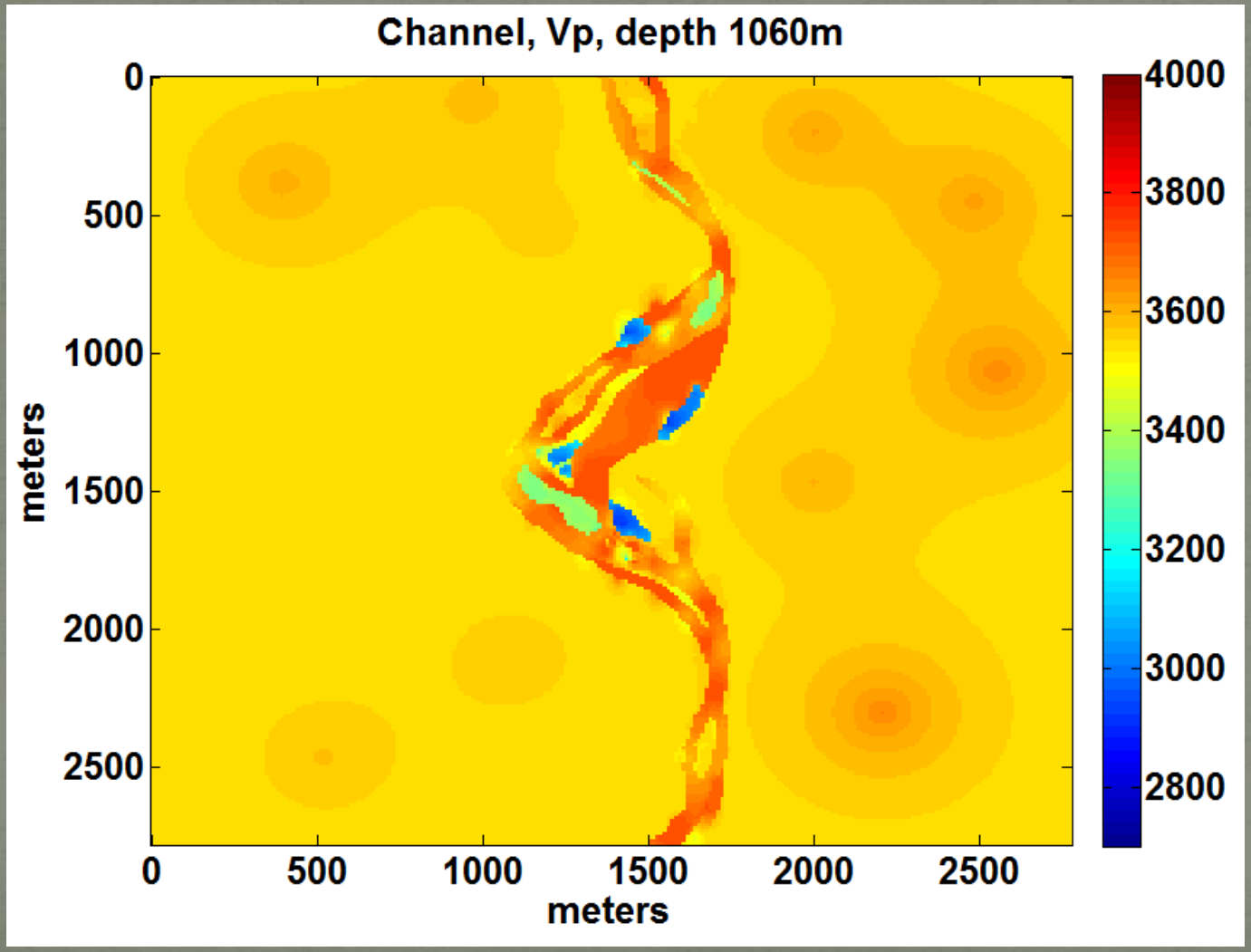
Vp Channel 1040m



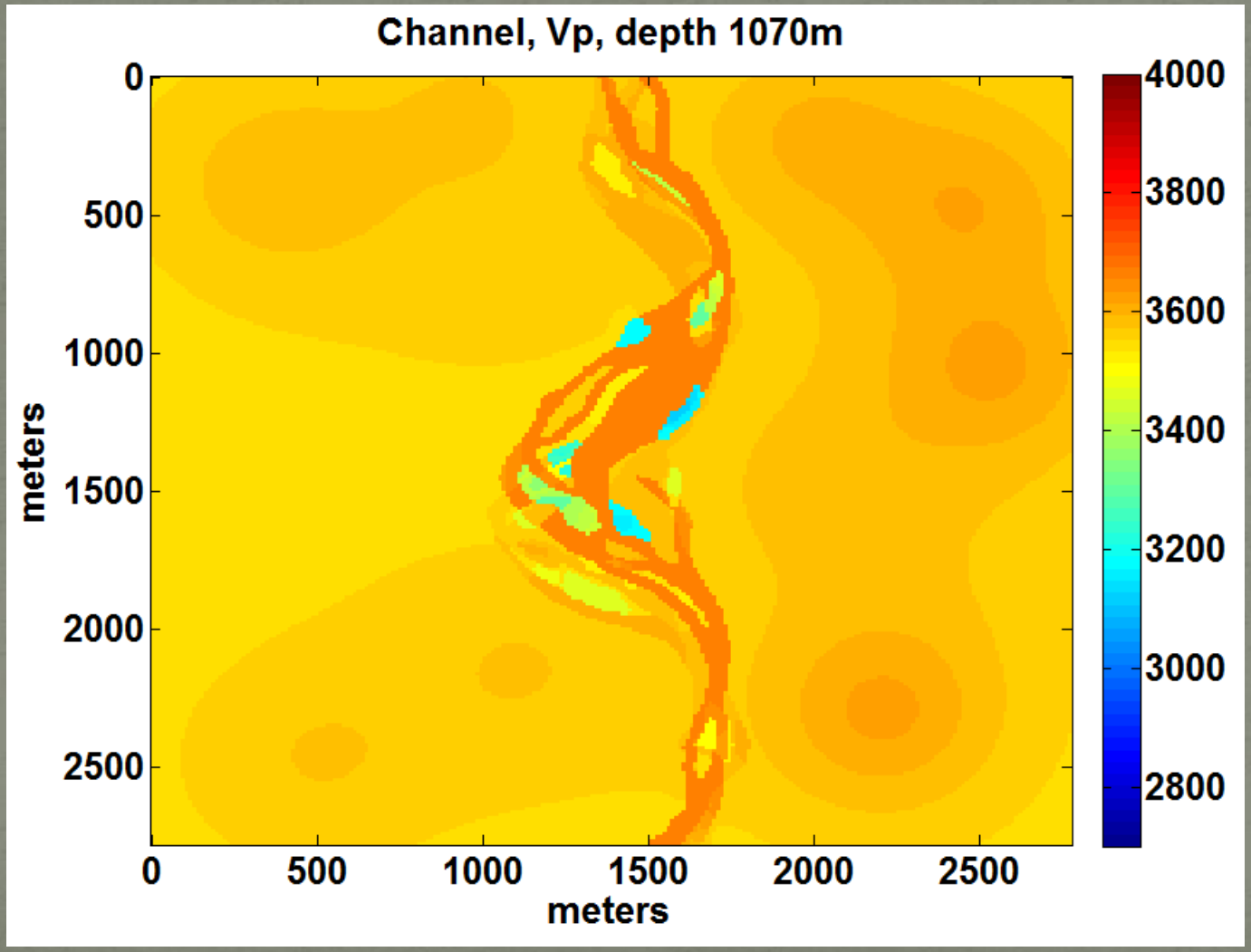
Vp Channel 1050m



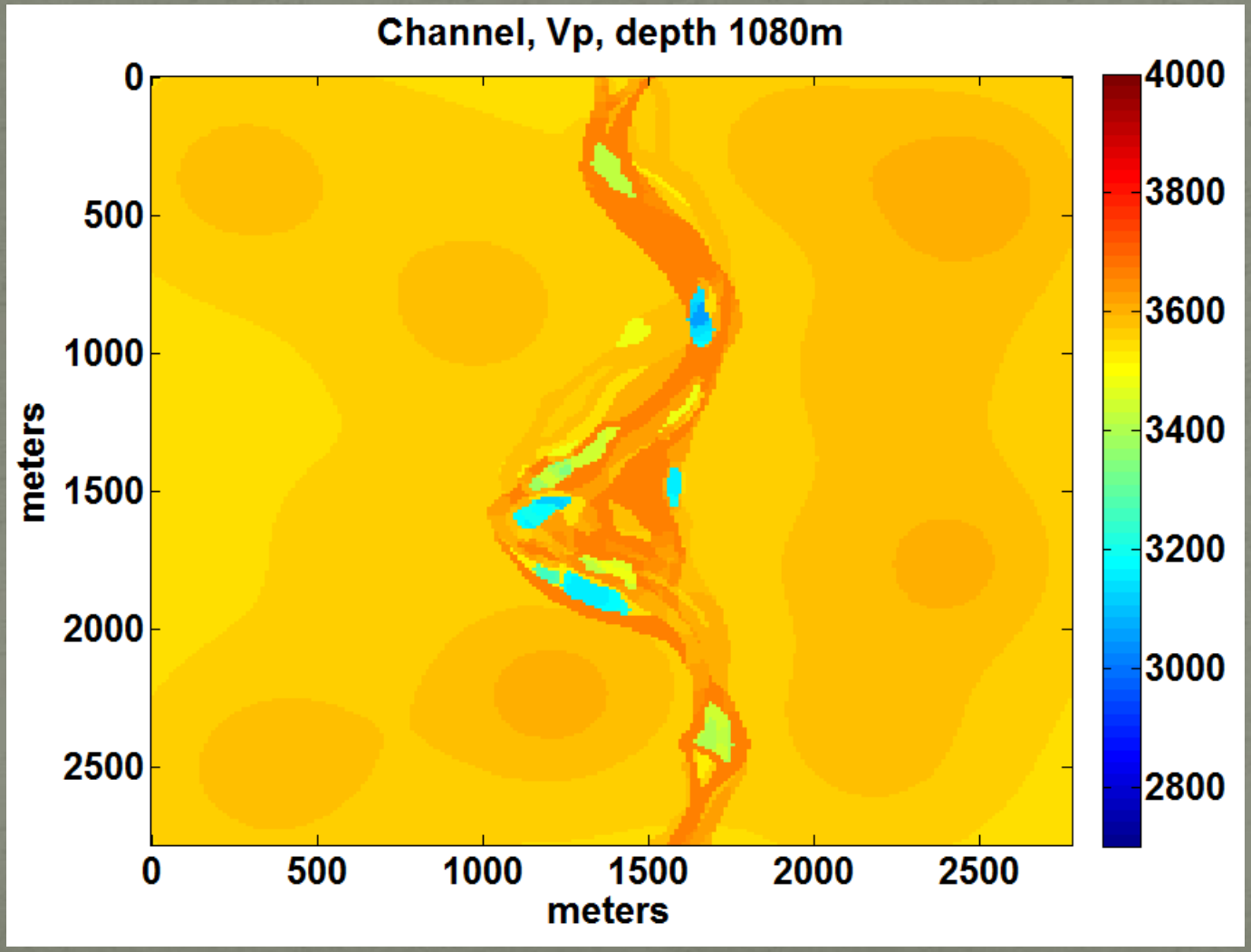
Vp Channel 1060m



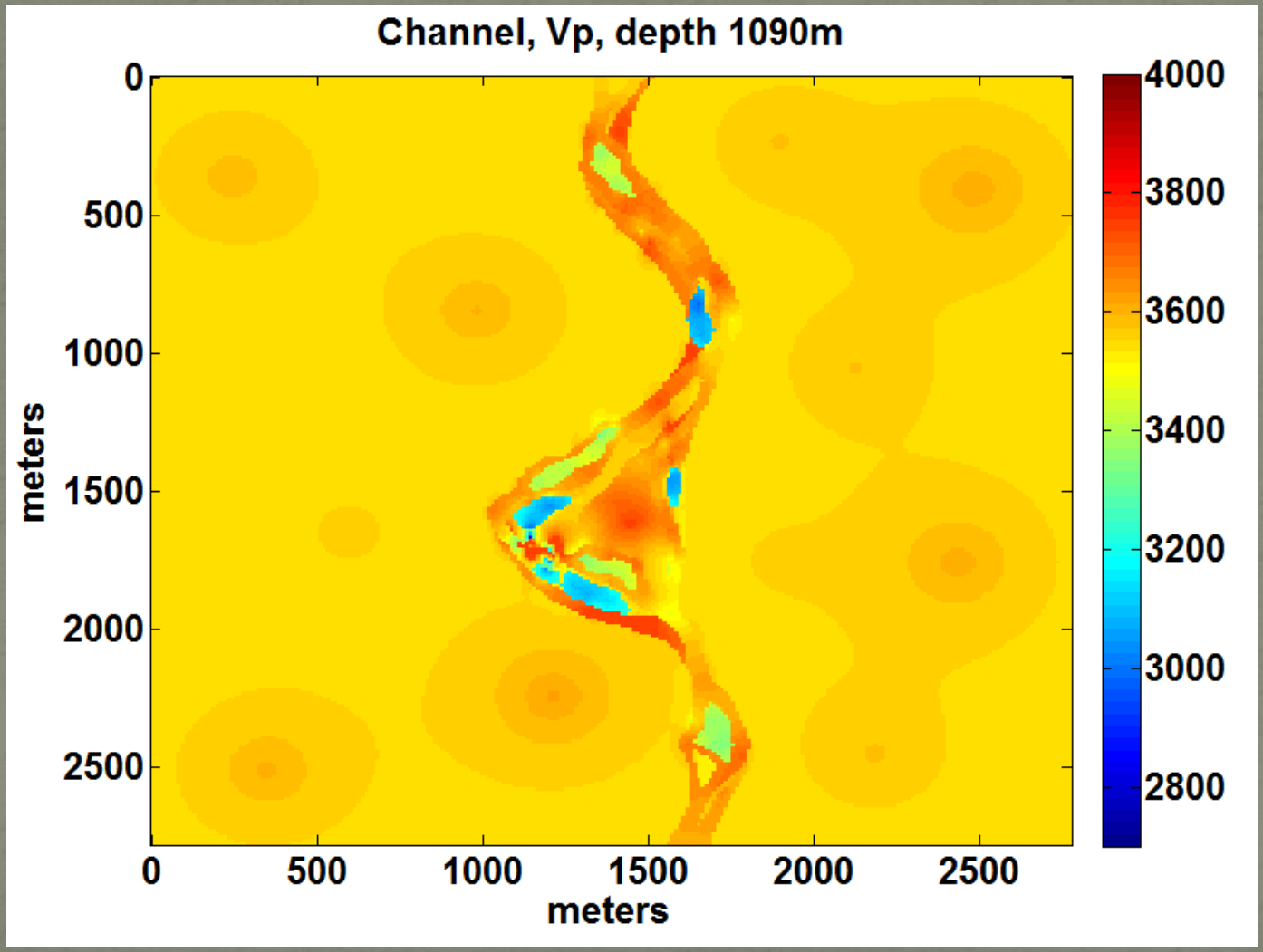
Vp Channel 1070m



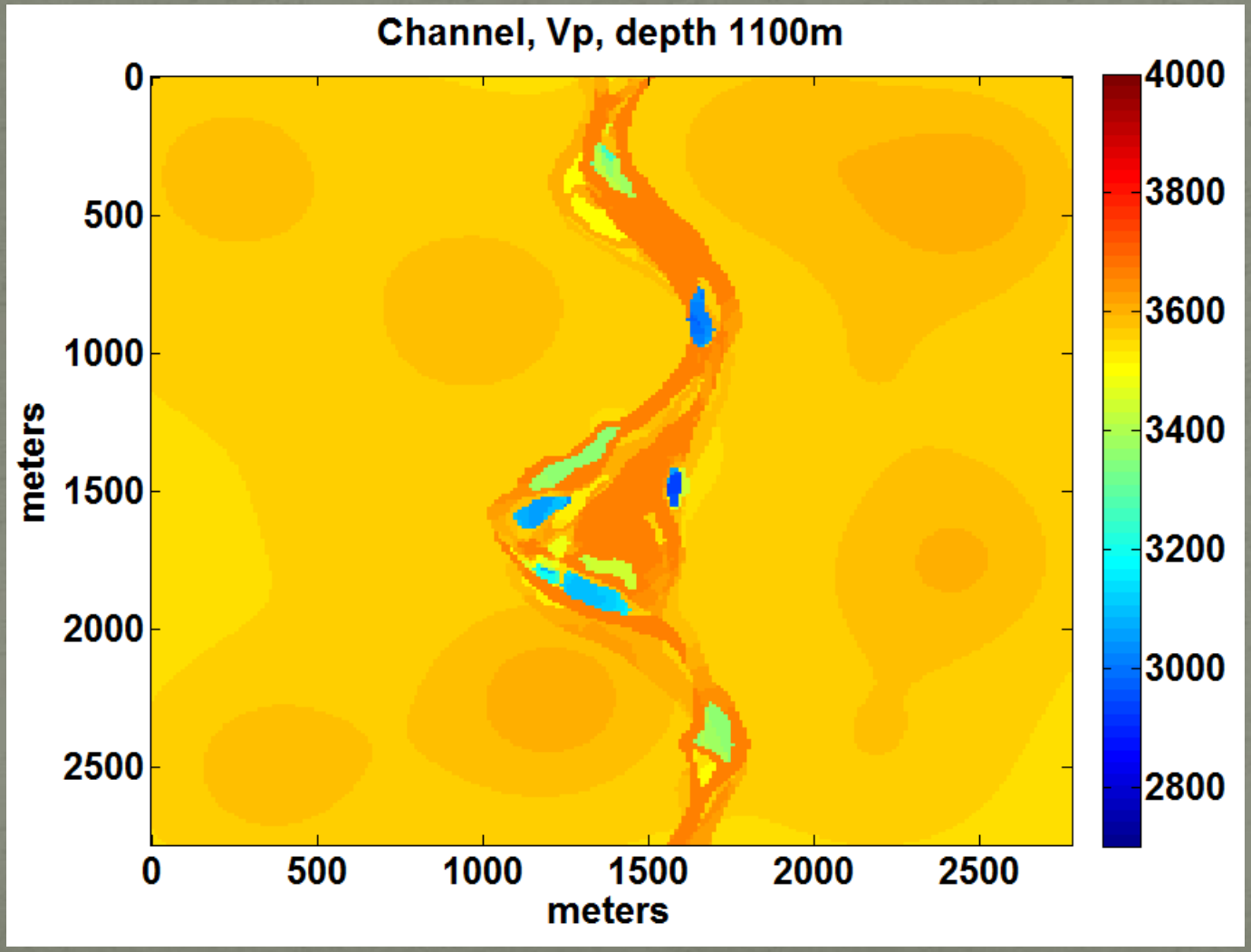
Vp Channel 1080m



Vp Channel 1090m



Vp Channel 1100m



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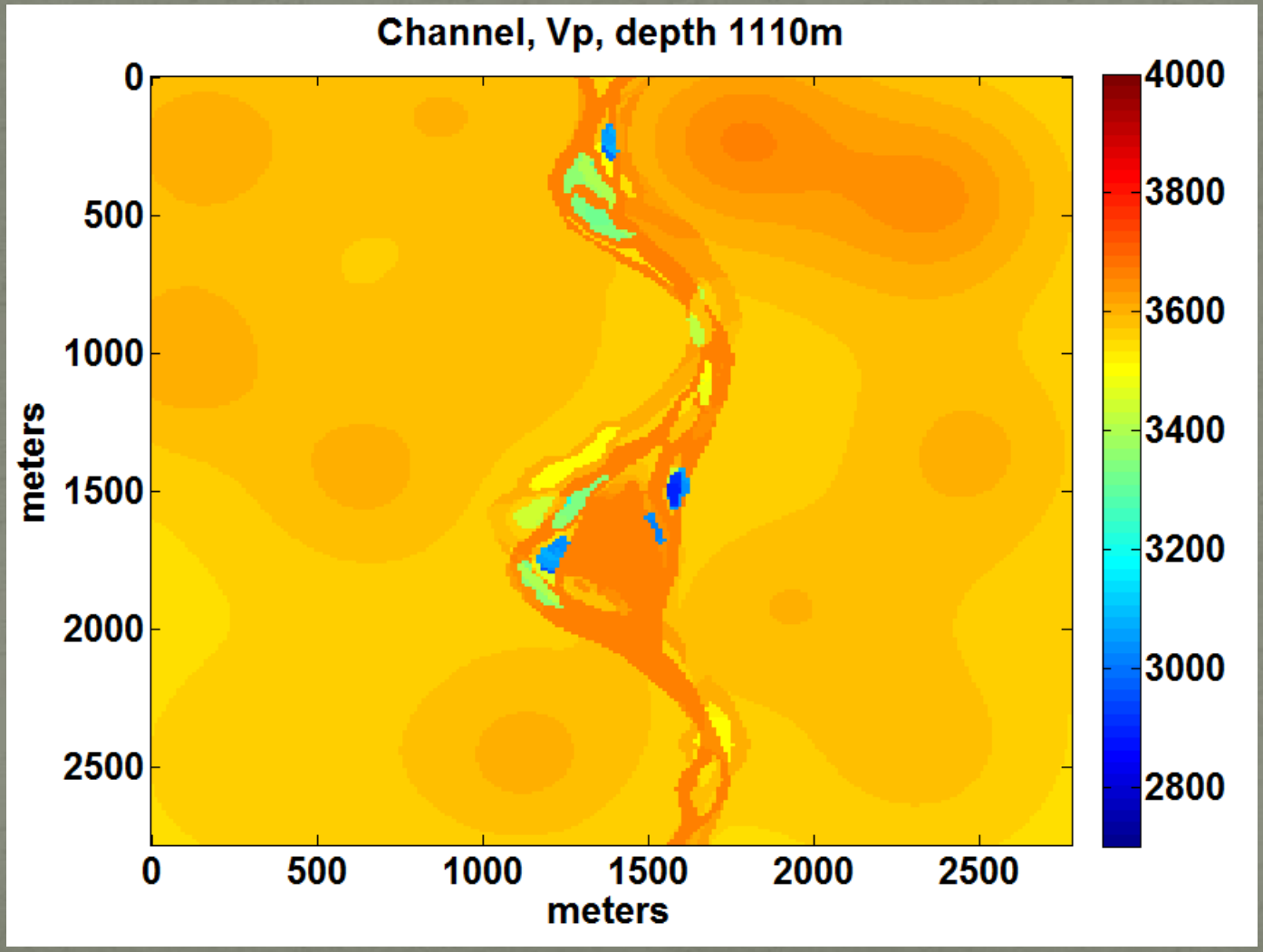
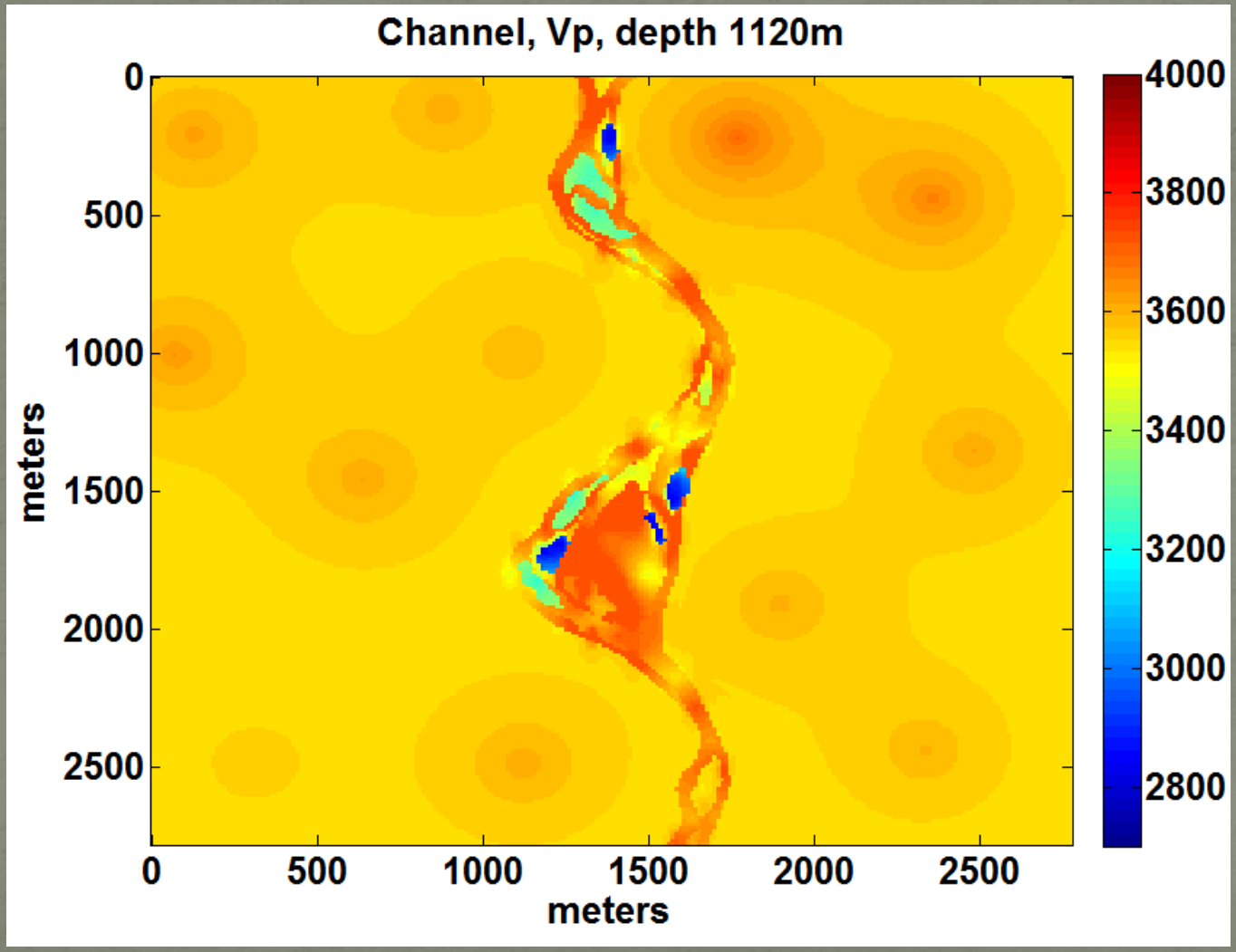
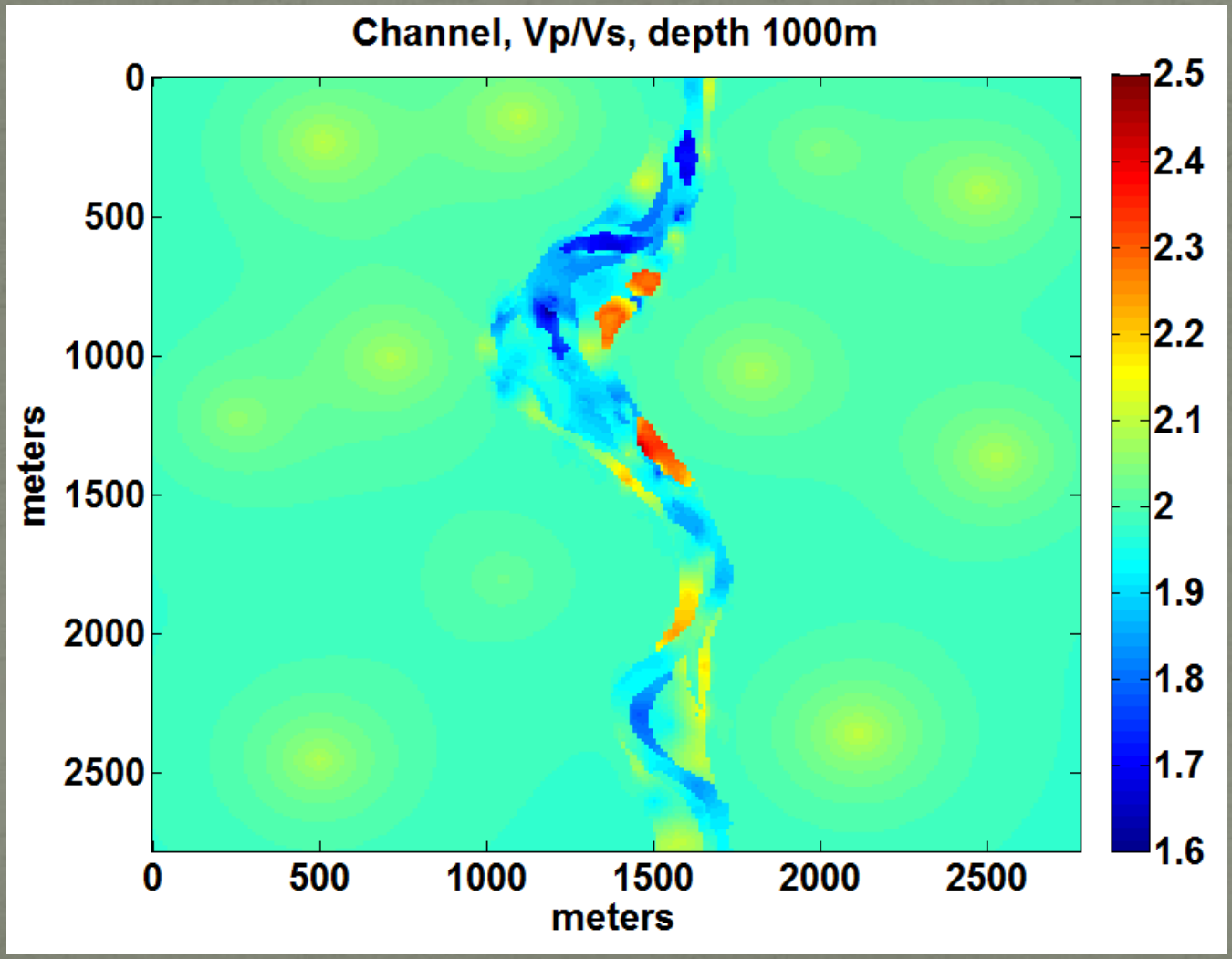


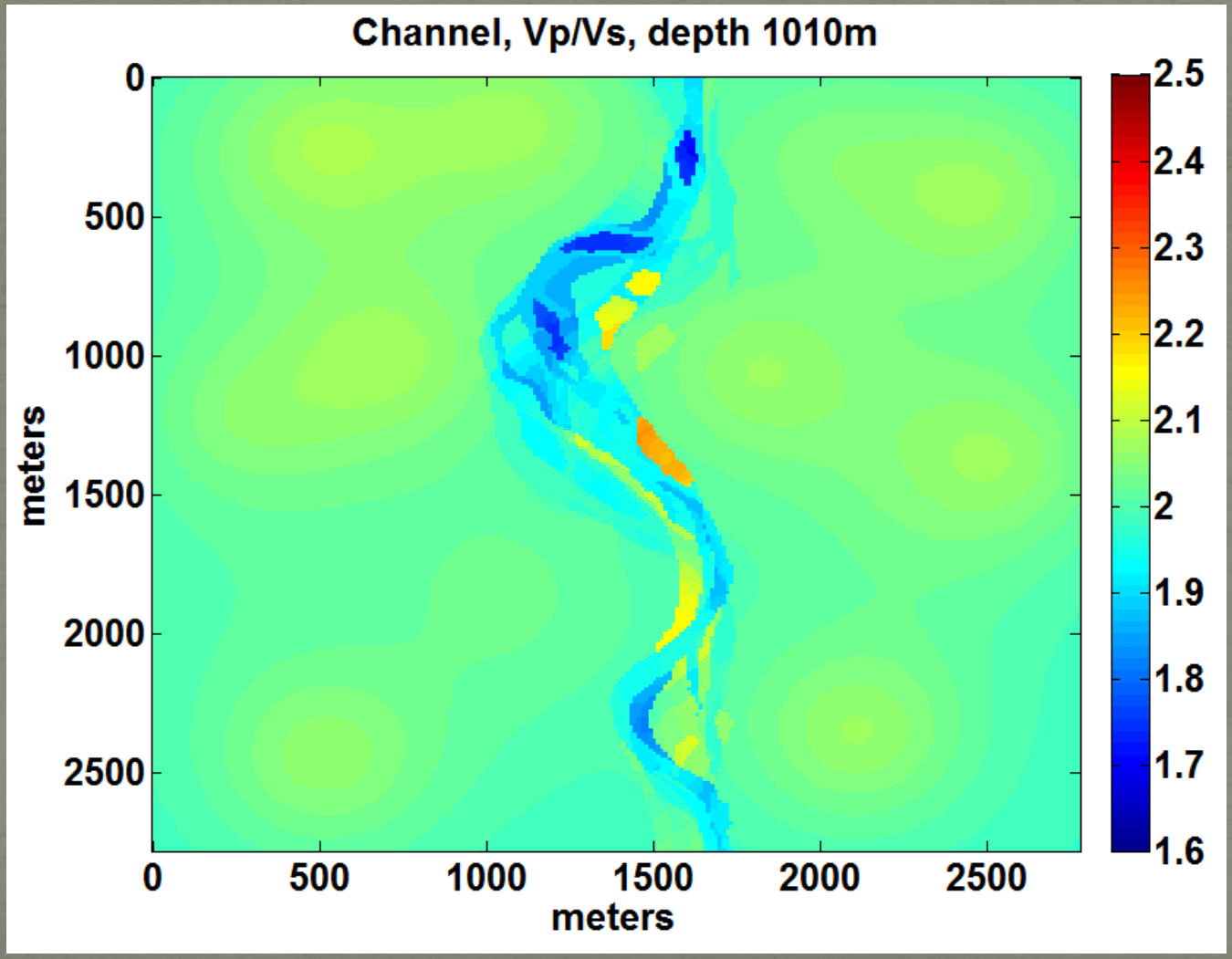
Vp Channel 1120m



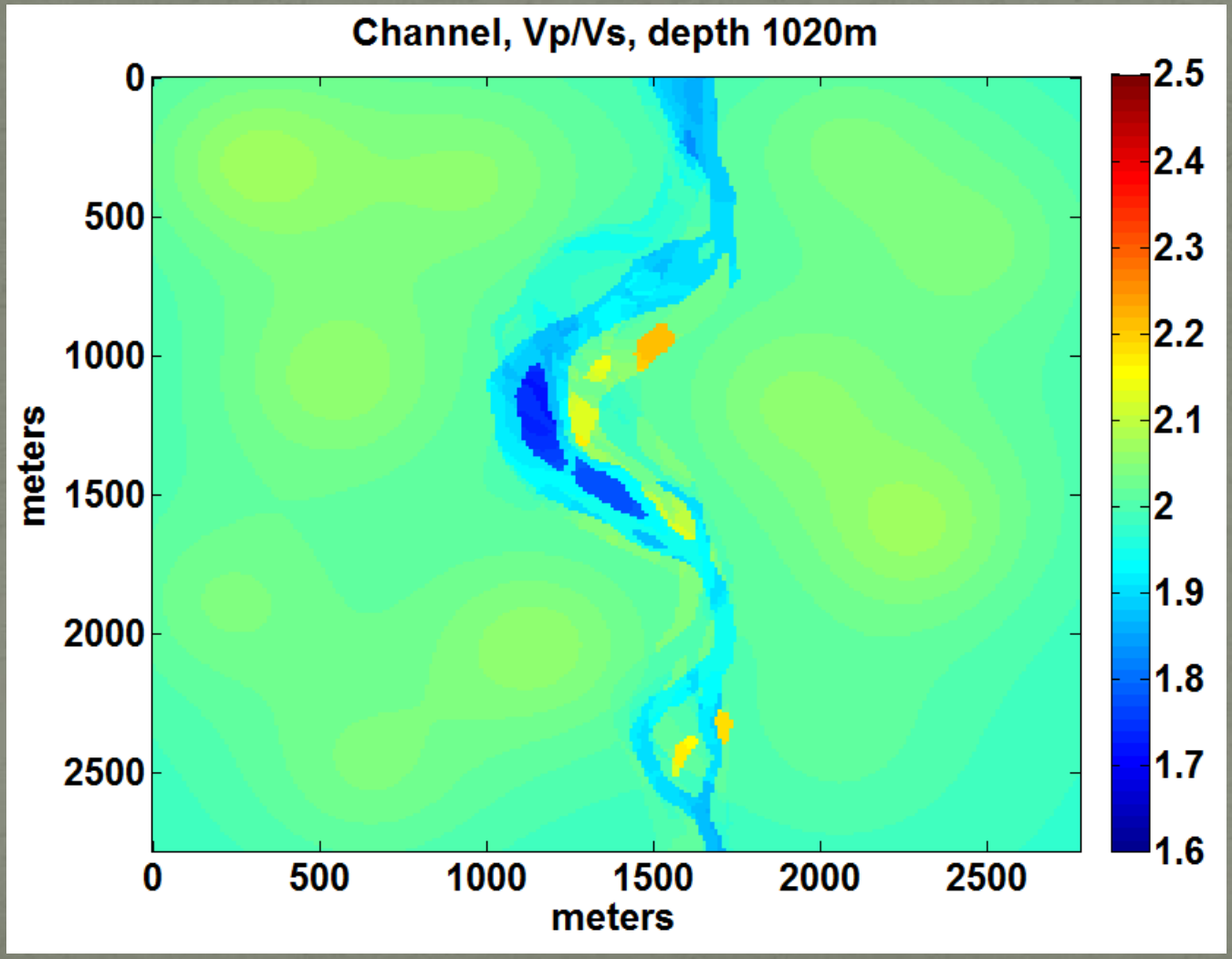
Vp/Vs Channel 1000m



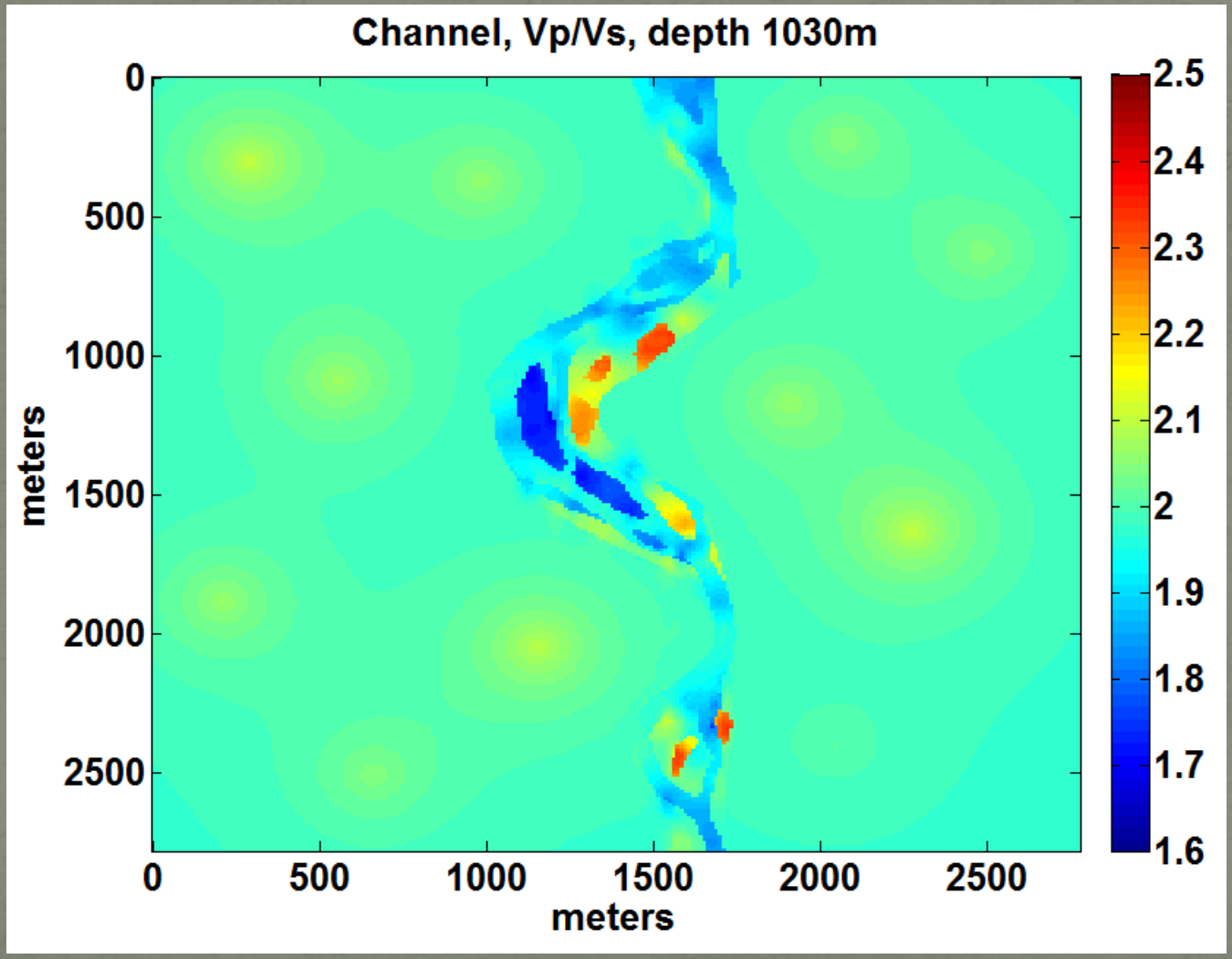
Vp/Vs Channel 1010m



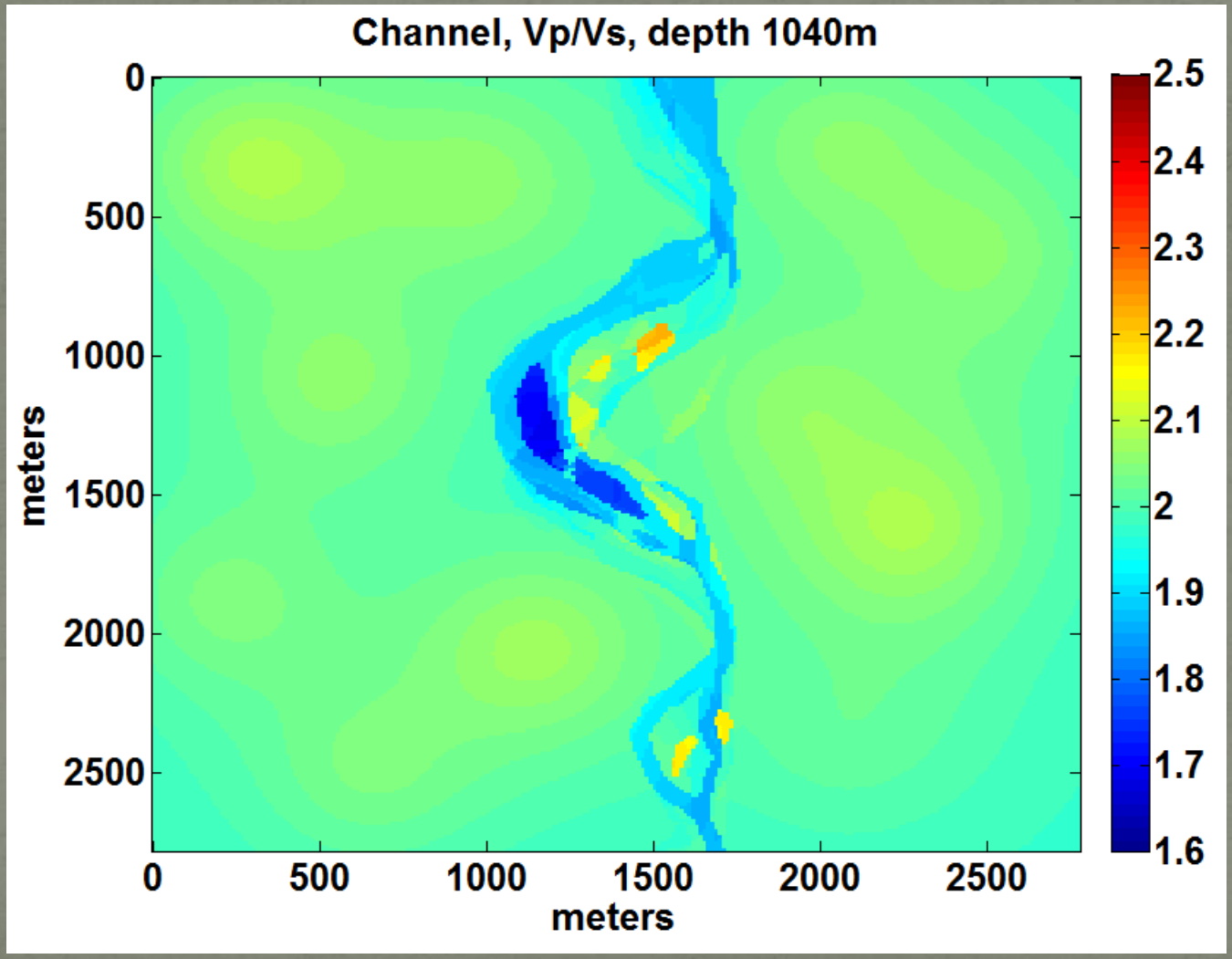
Vp/Vs Channel 1020m



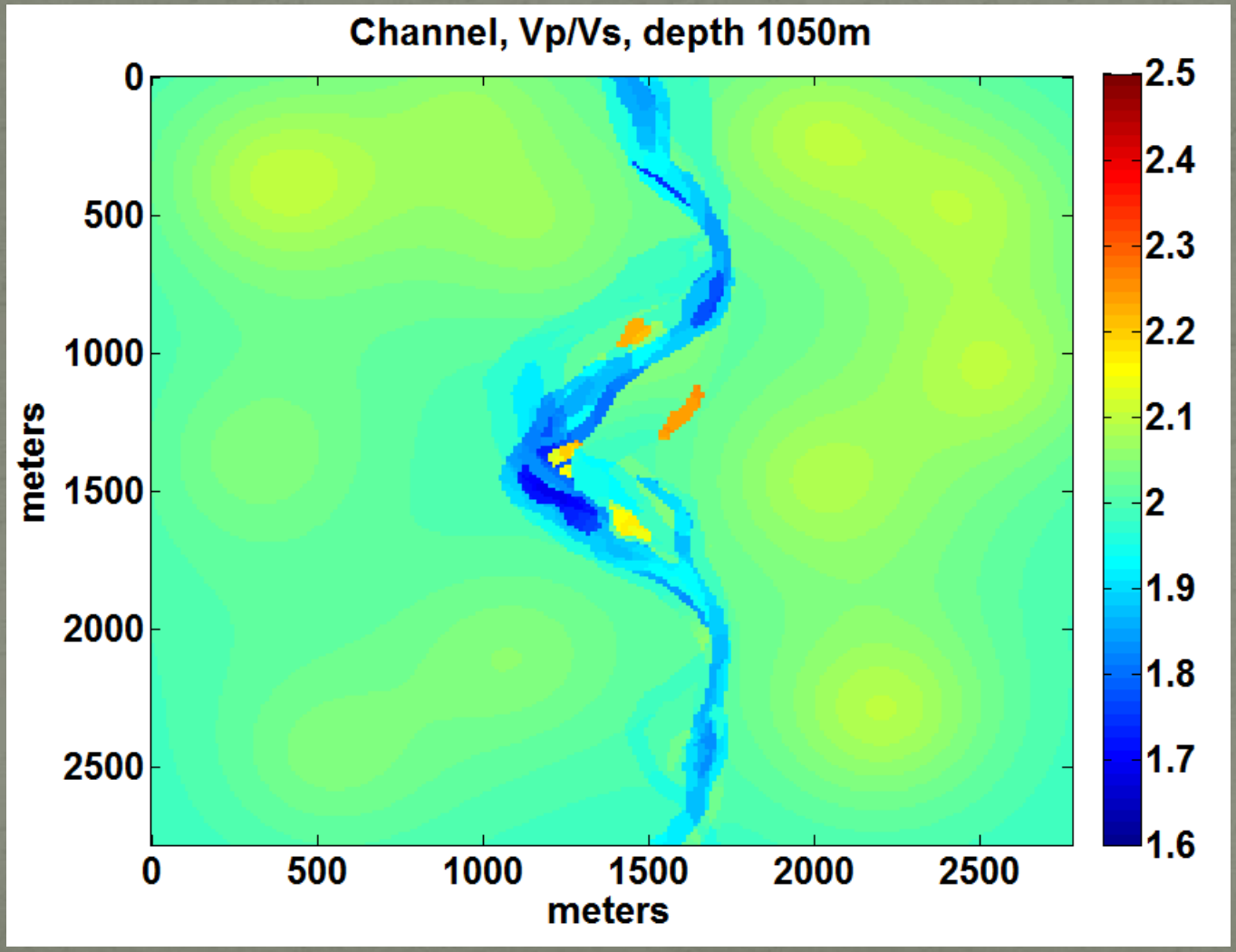
Vp/Vs Channel 1030m



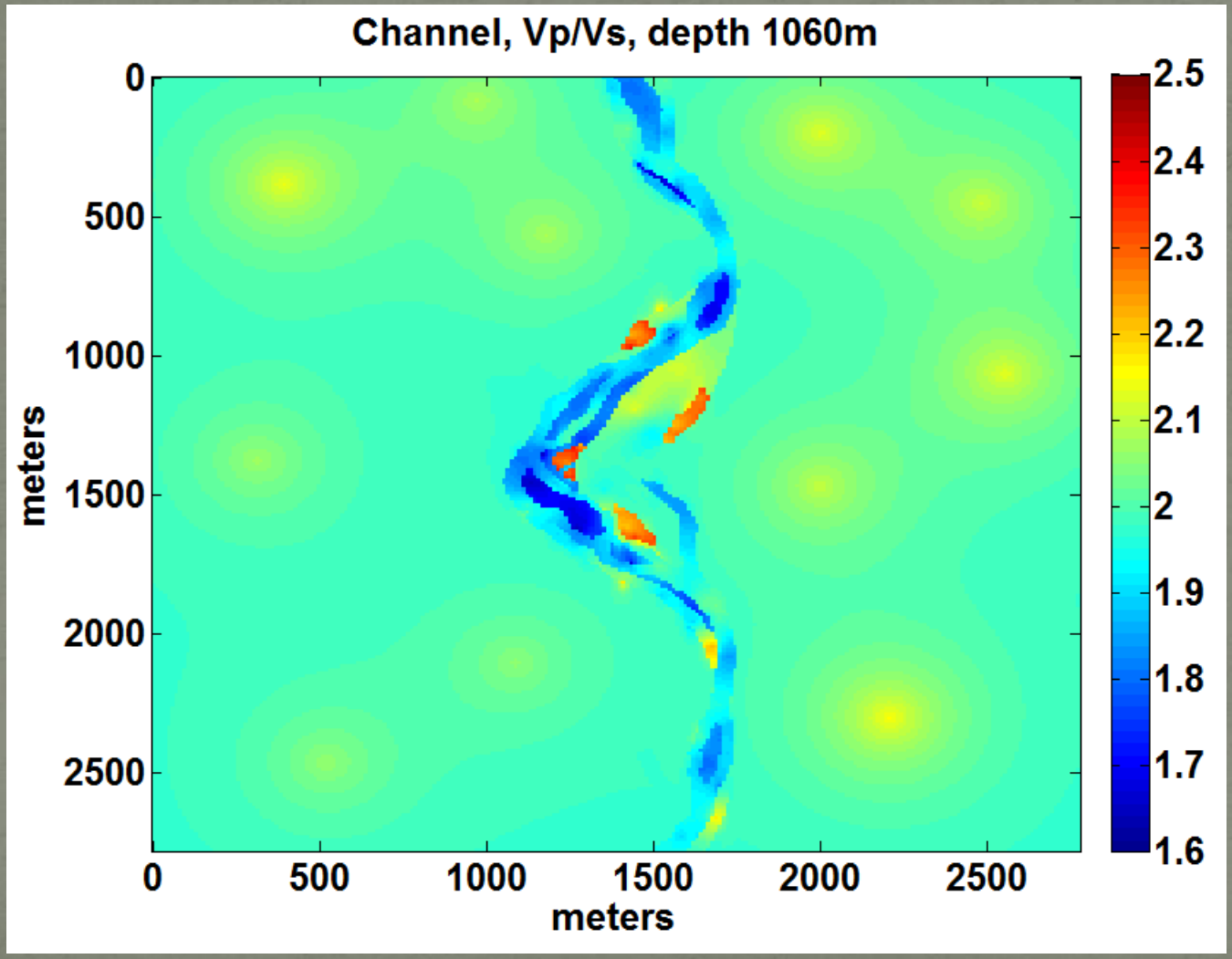
Vp/Vs Channel 1040m



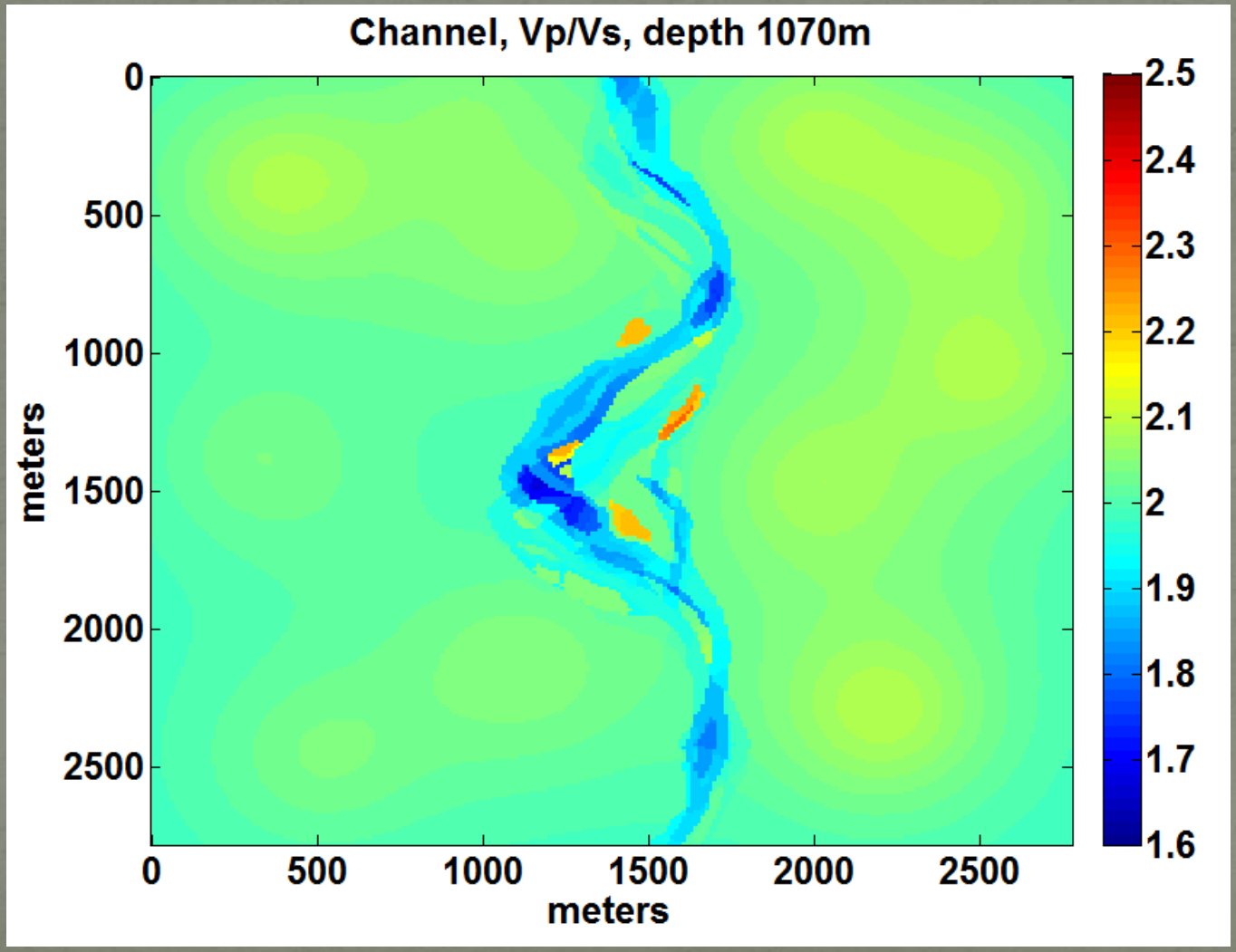
Vp/Vs Channel 1050m



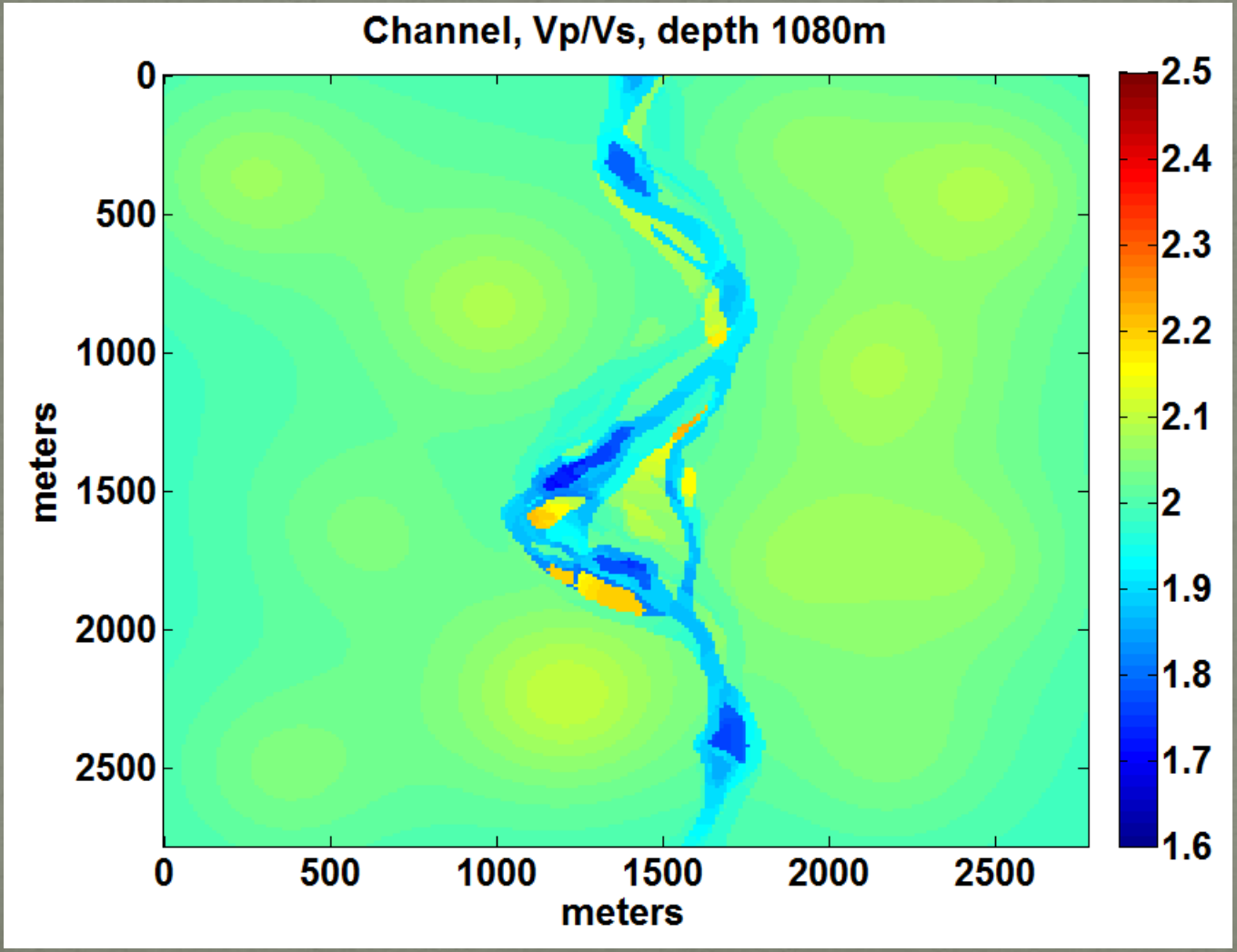
Vp/Vs Channel 1060m



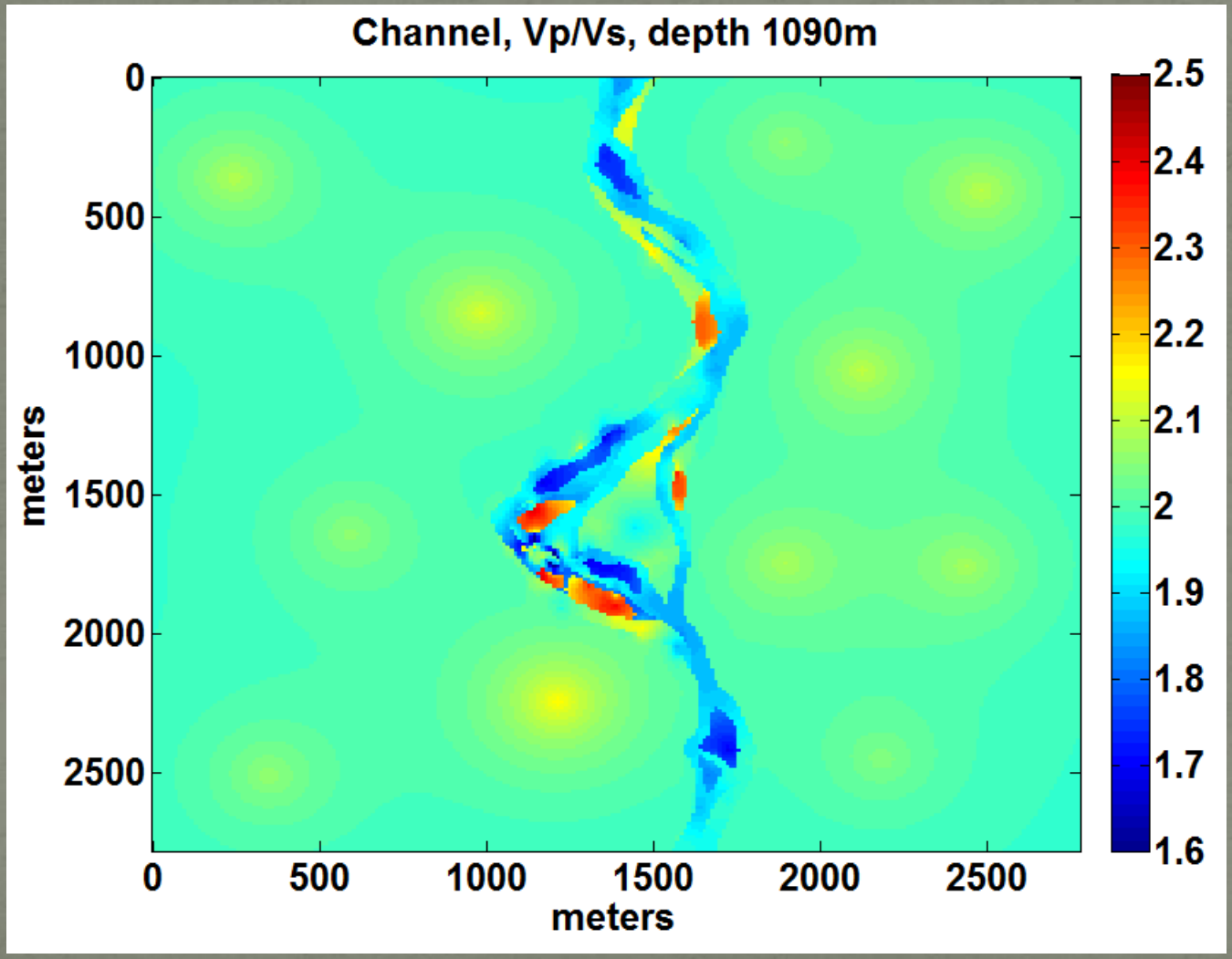
Vp/Vs Channel 1070m



Vp/Vs Channel 1080m



Vp/Vs Channel 1090m



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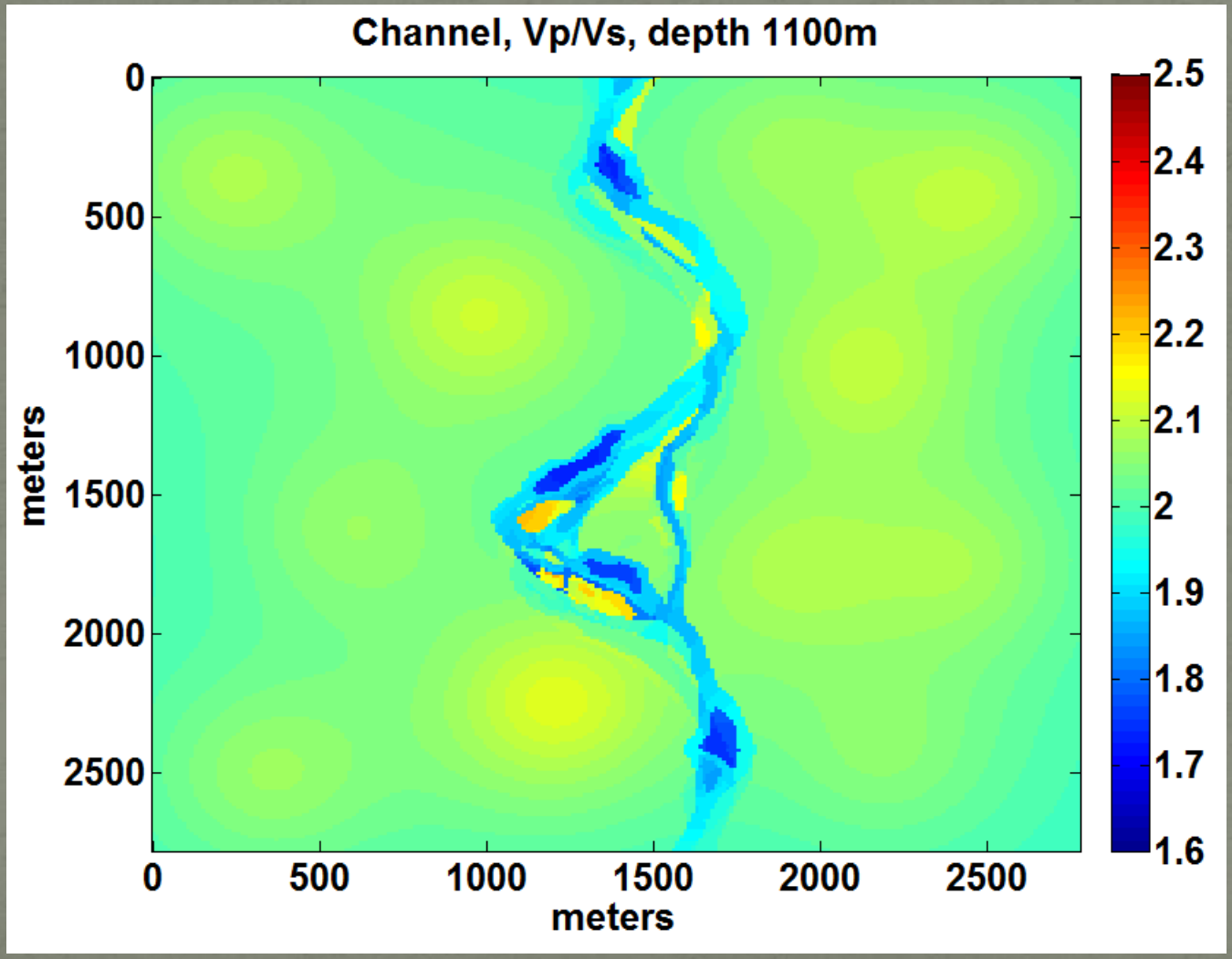

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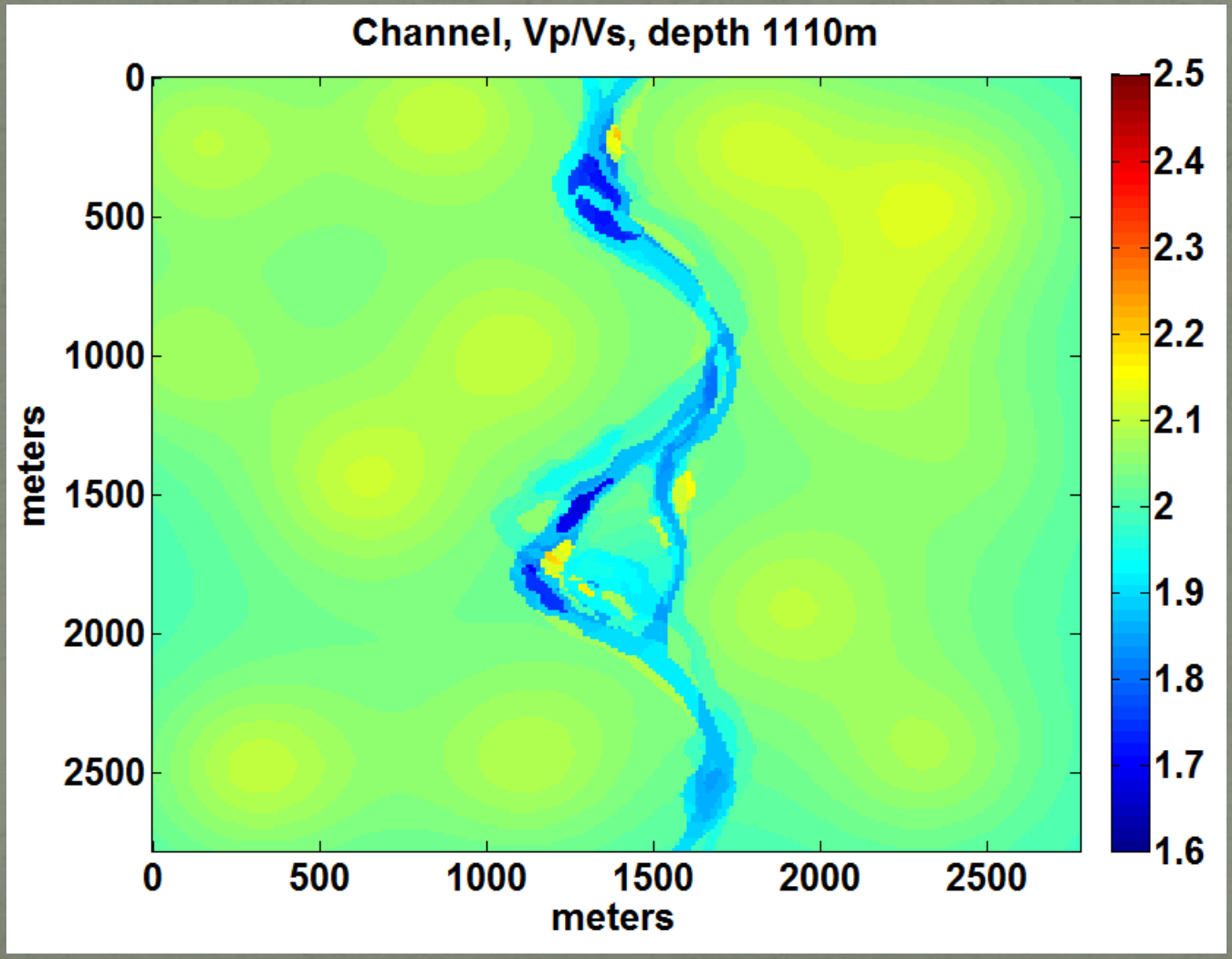
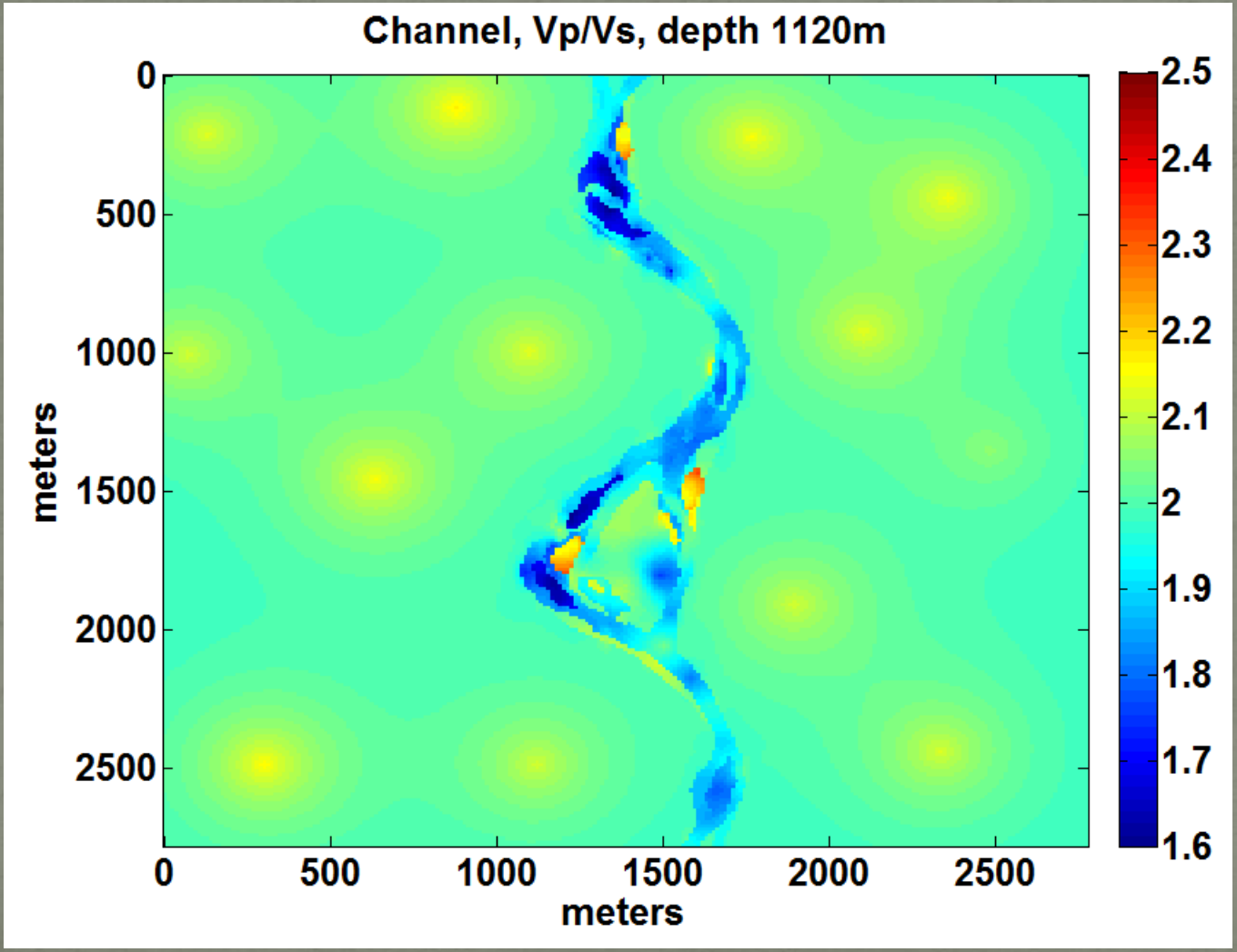
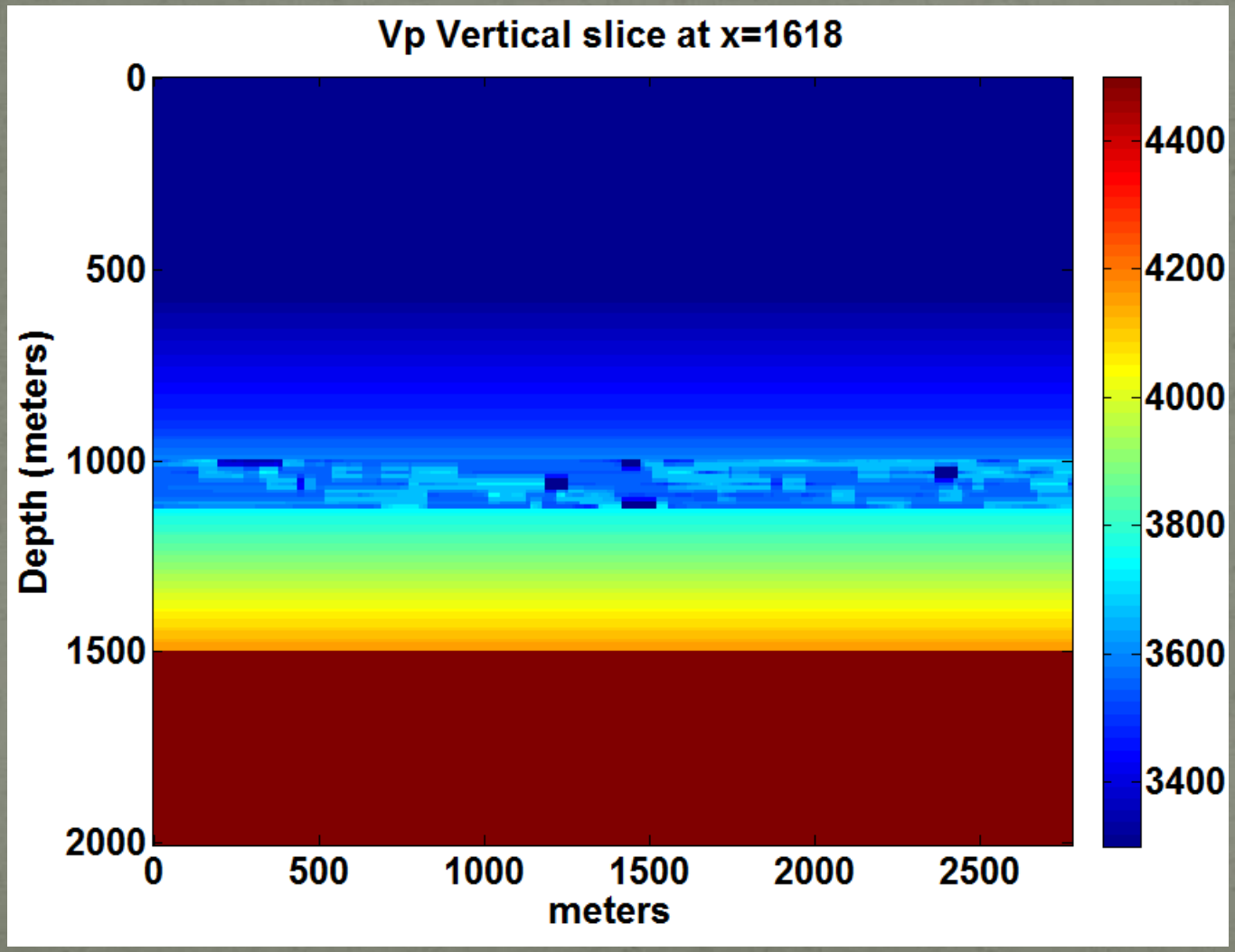


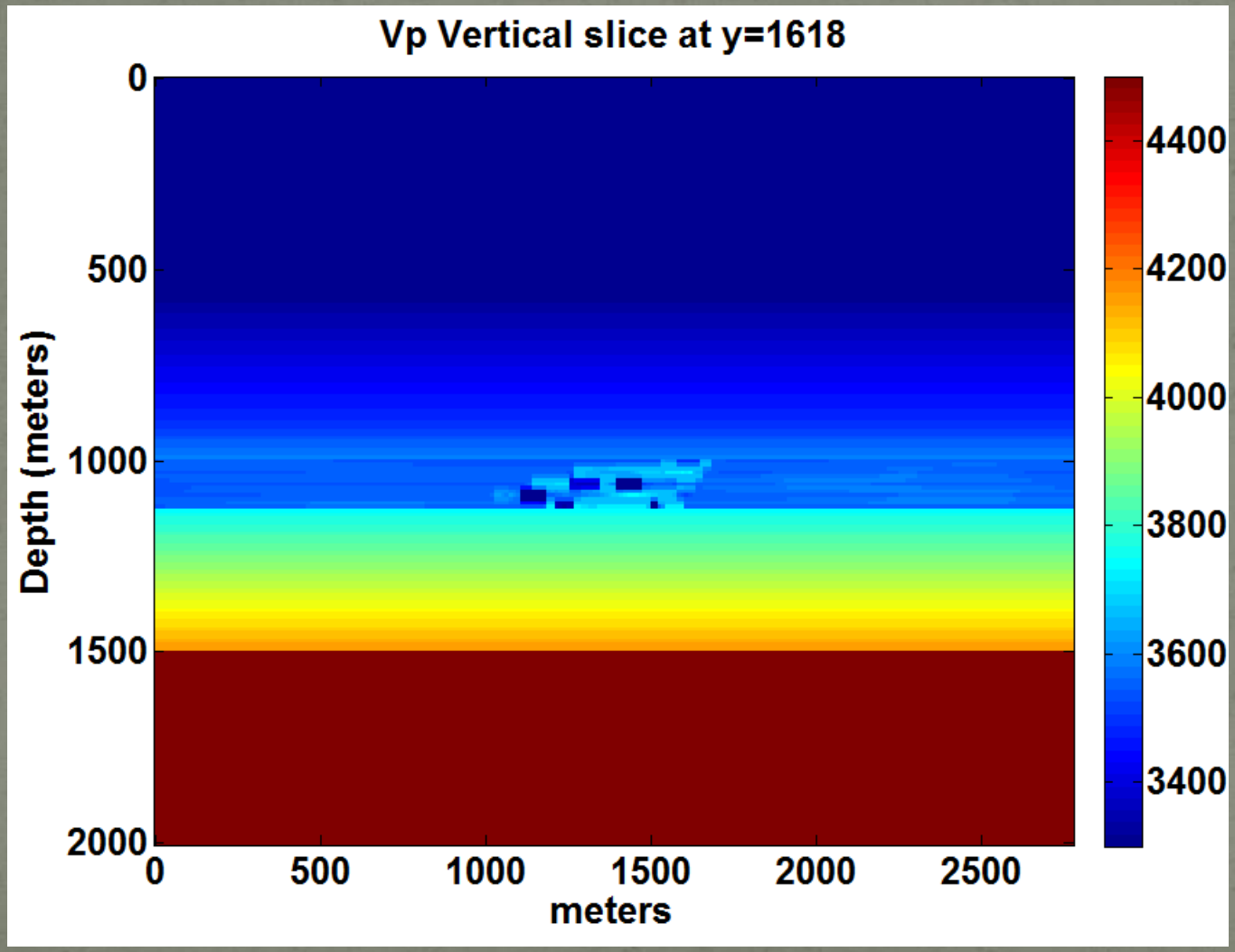
Vp/Vs Channel 1120m



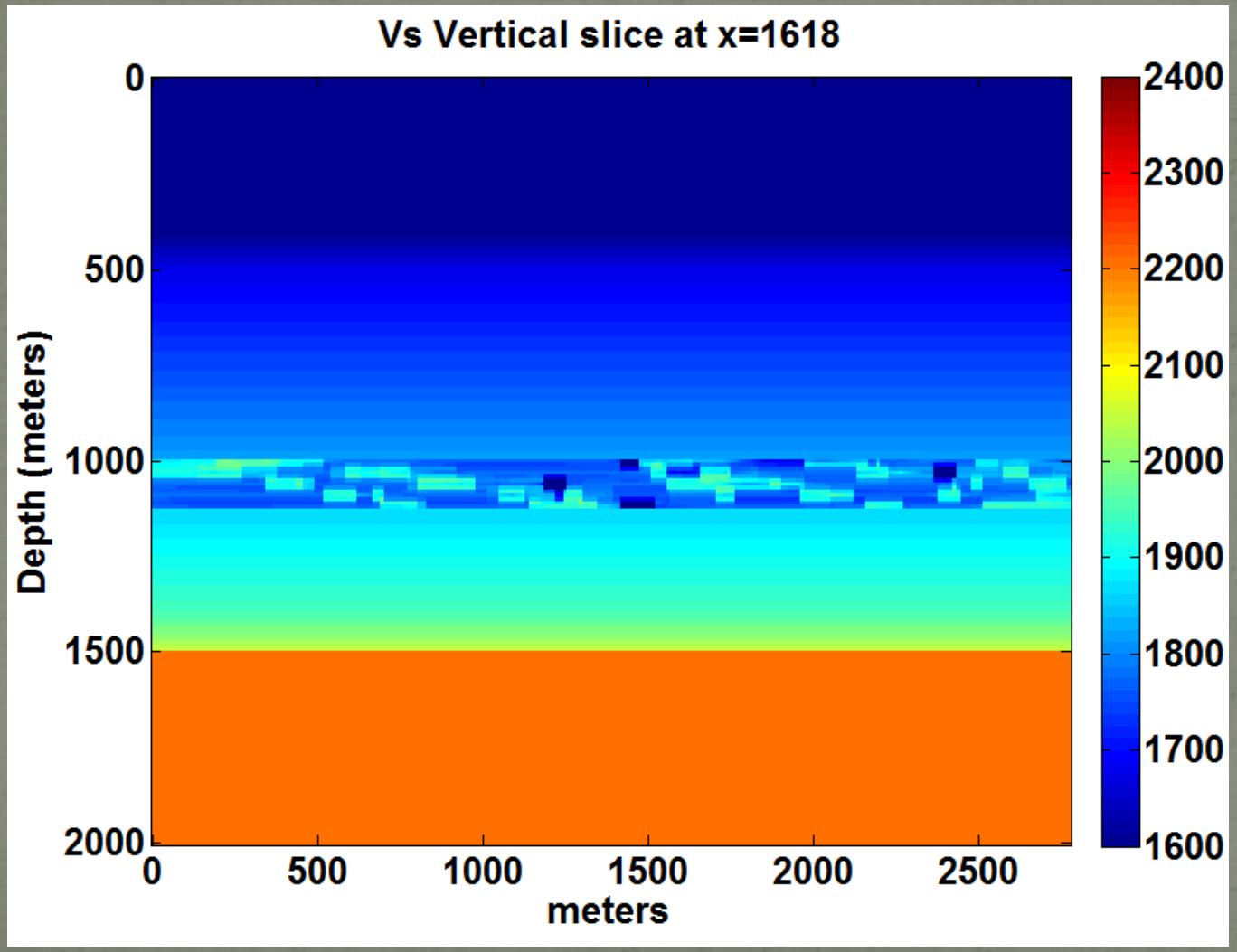
Vp Vertical Slice



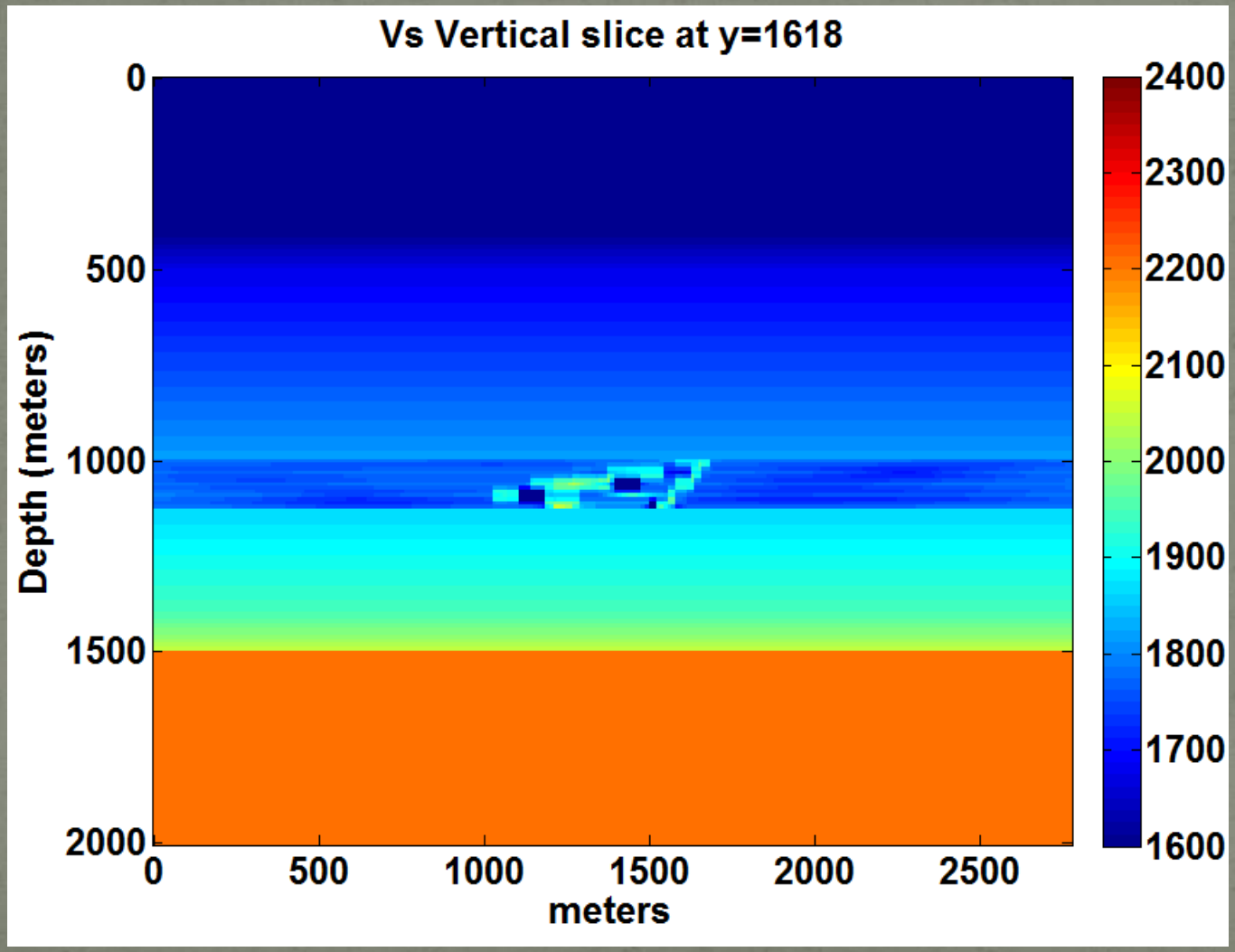
Vp Vertical Slice



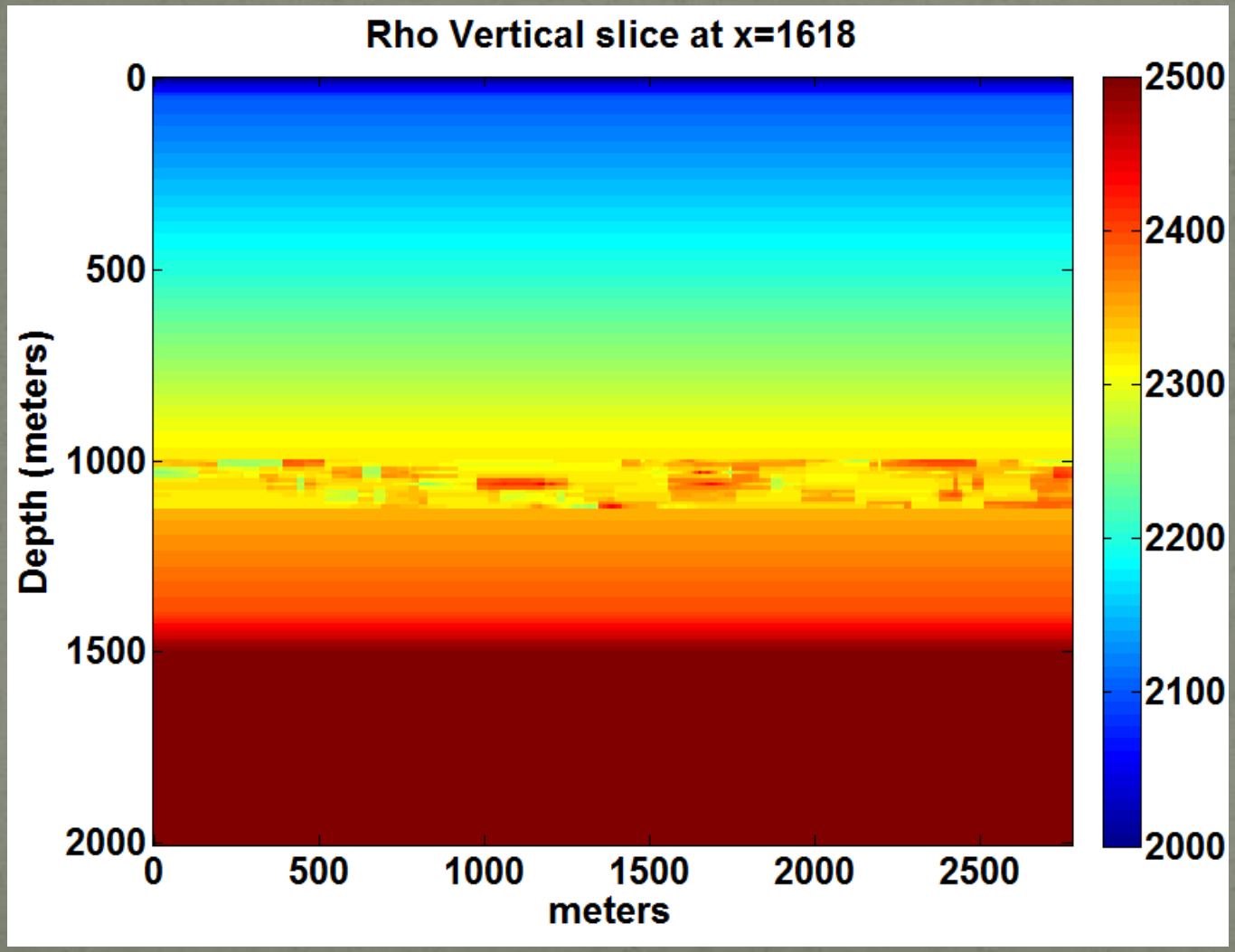
Vs Vertical Slice



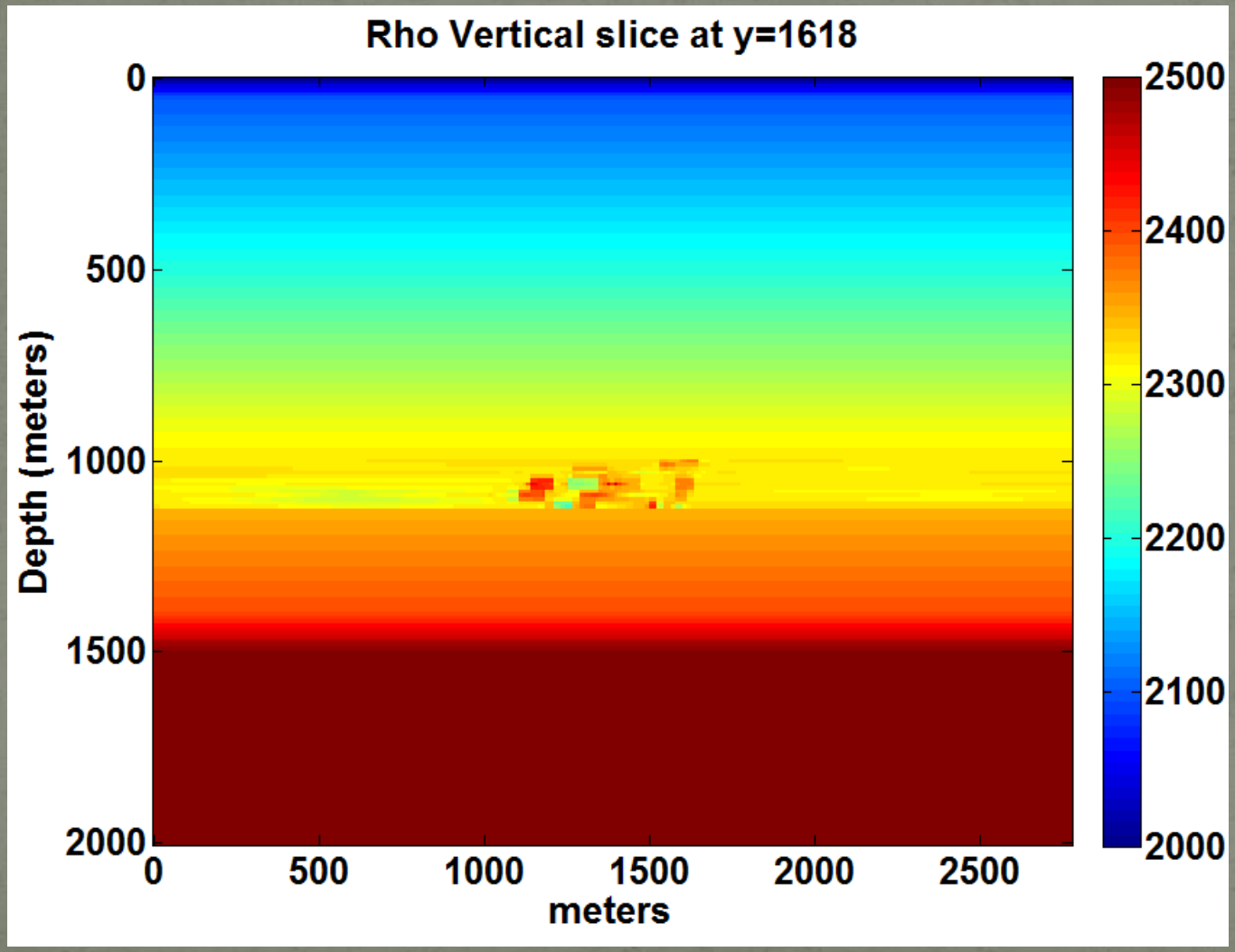
Vs Vertical Slice



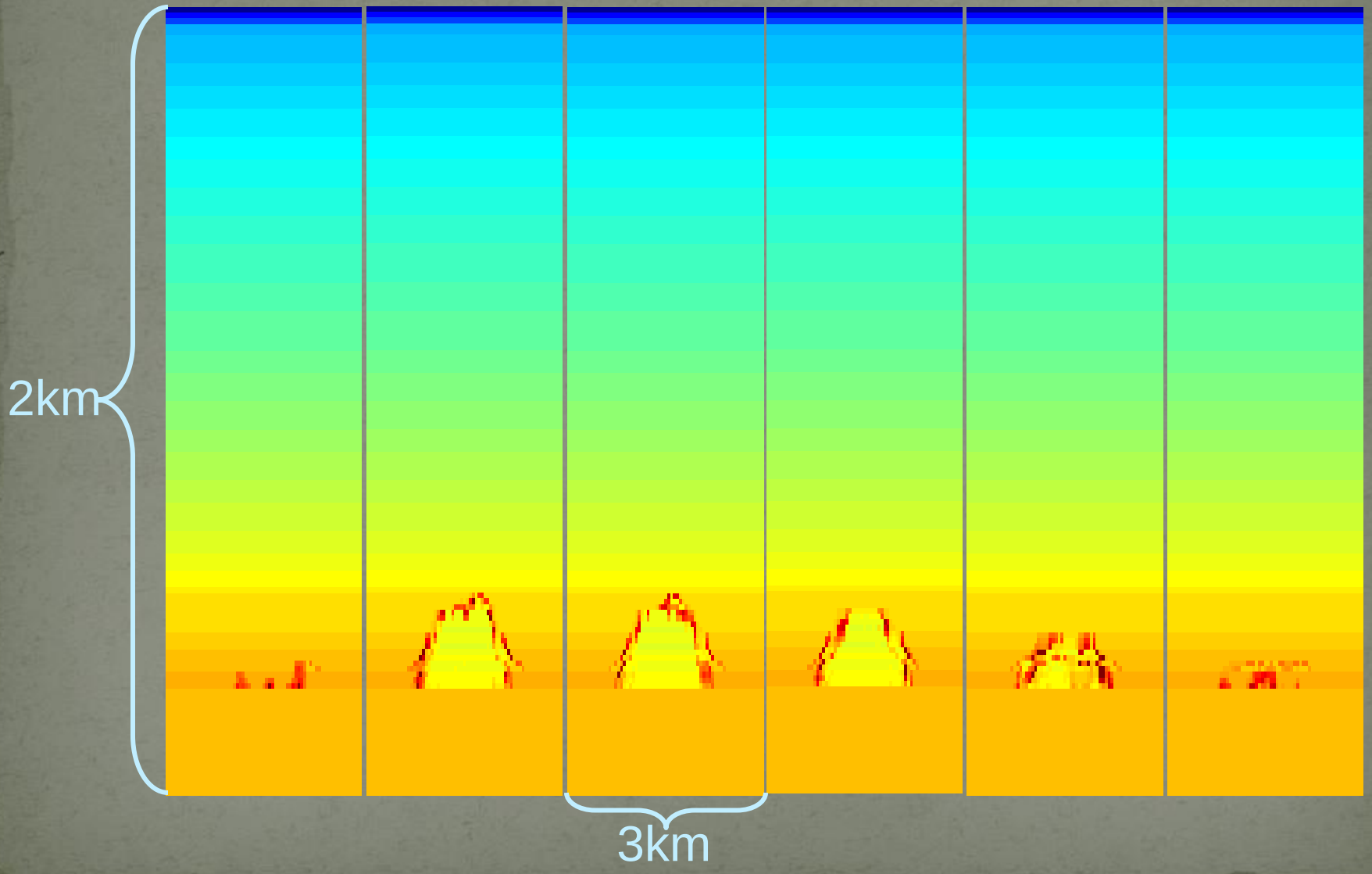
Density Vertical Slice



Density Vertical Slice



Reef
Parallel cross sections

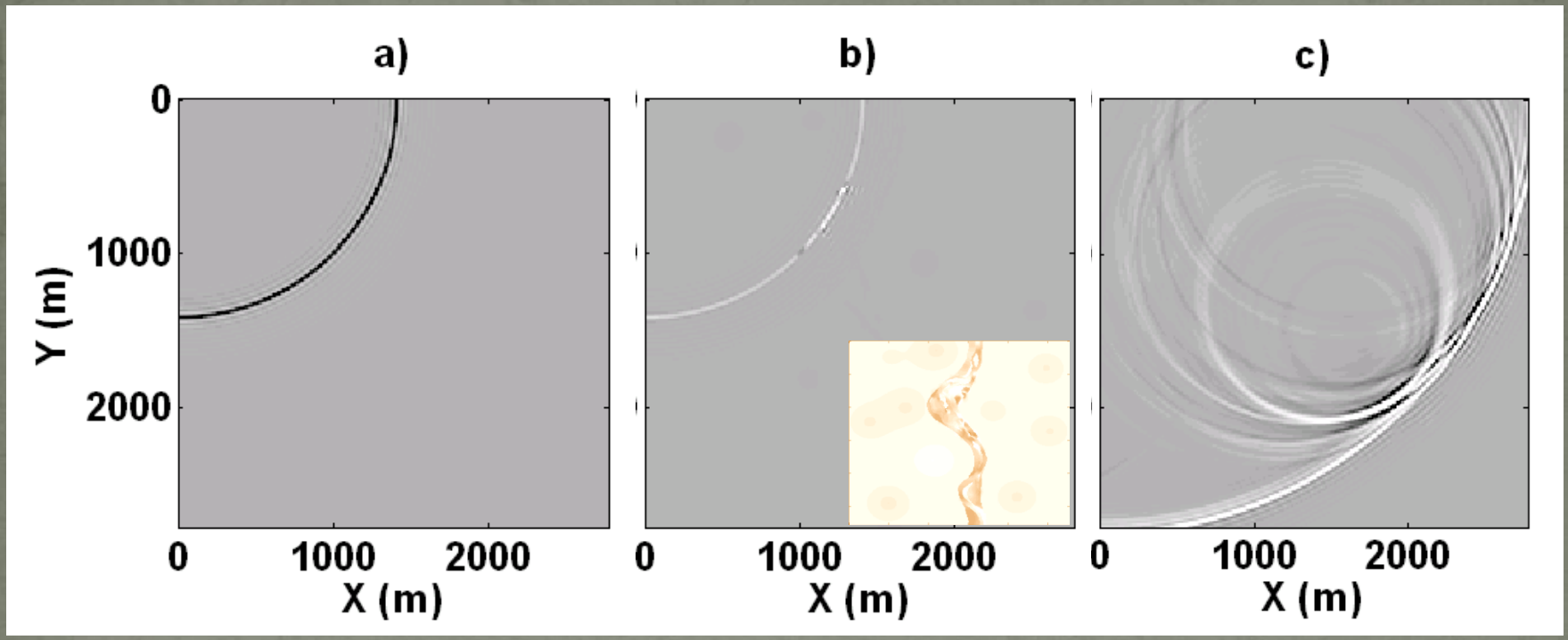


Seismic Modelling

- Tiger: full-featured finite difference software from SINTEF Petroleum Research of Trondheim, Norway.
  - Acoustic, Elastic, Aniso-elastic, Visco-elastic.
  - 3D Parameter volumes imported from Matlab.
  - Parallel execution on CREWES Linux cluster.
  - 8 days to compute 241 elastic shots.

- Rayleigh-Sommerfeld modelling (Margrave et al. 2007)
  - Modified for P-wave AVO (Cooper et al. 2008).
  - Parallel execution via parallel Matlab.
  - 10 hours to compute 241 P-P AVO shots

Rayleigh-Sommerfeld Modelling (Phase-shift migration backwards)



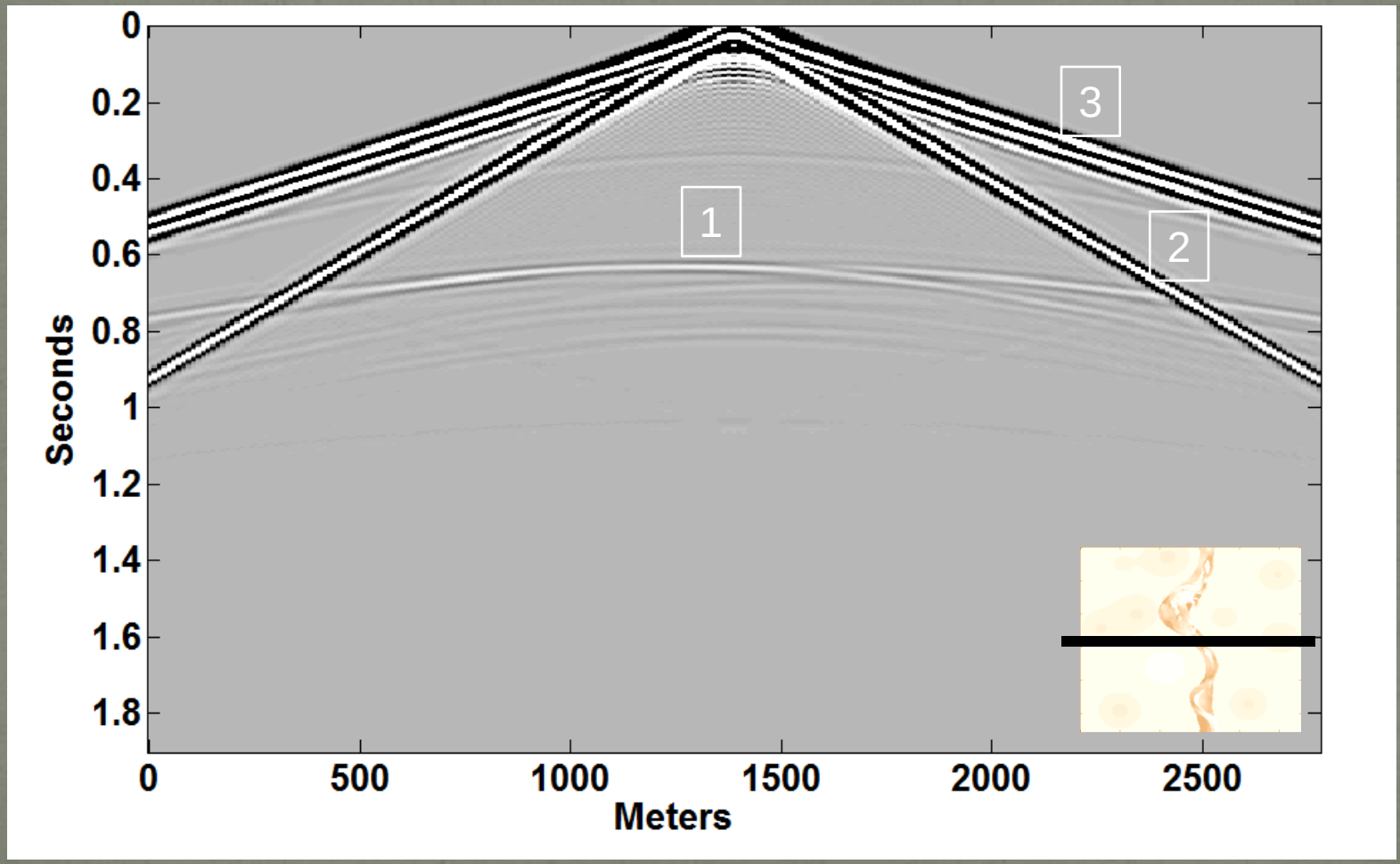
Wave hits channel

Wave scaled by reflectivity

Wave propagates to surface

Center Shot (Tiger Acoustic)

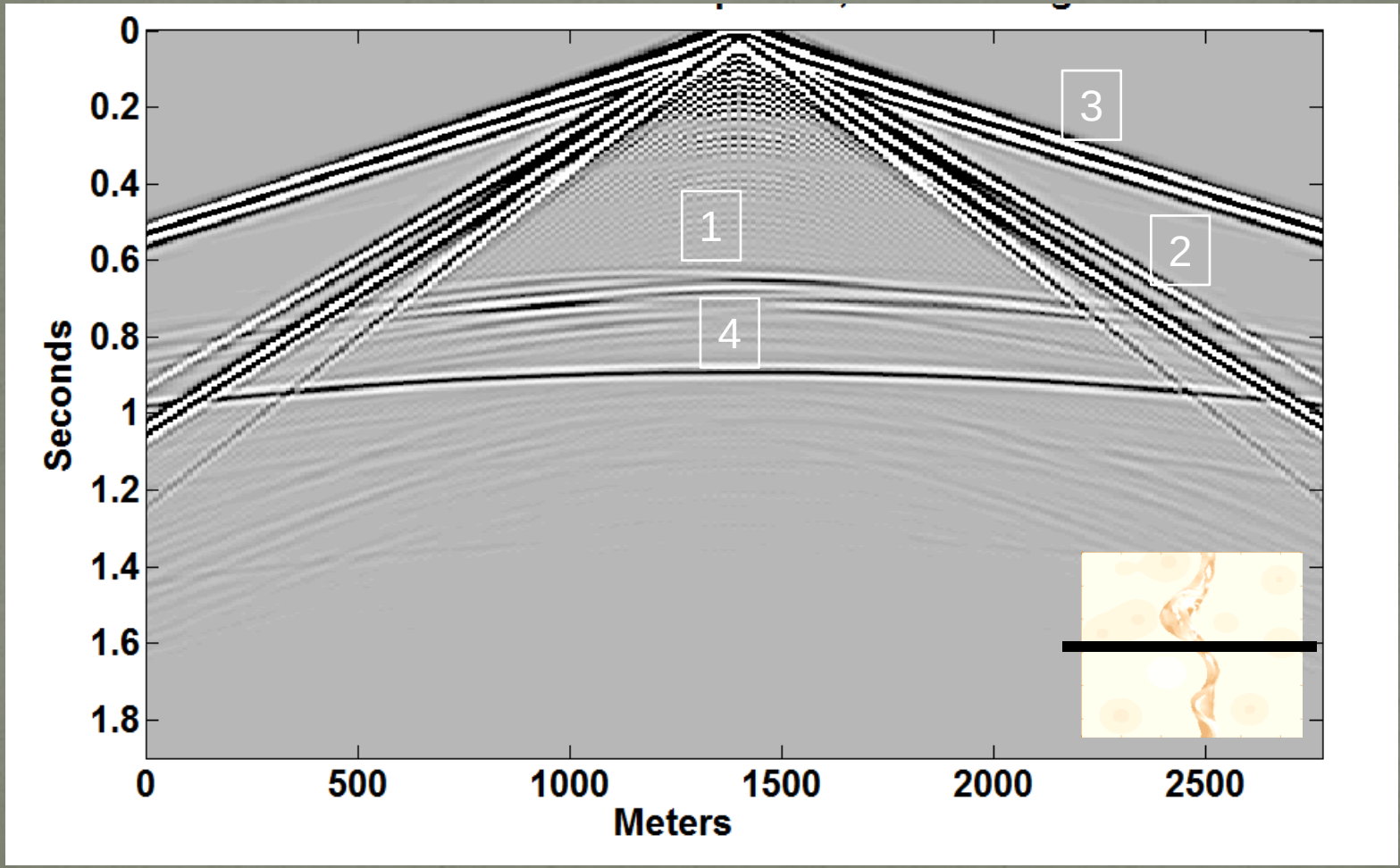
vertical displacement



Runs orthogonal to channel through center of model

Center Shot (Tiger Elastic)

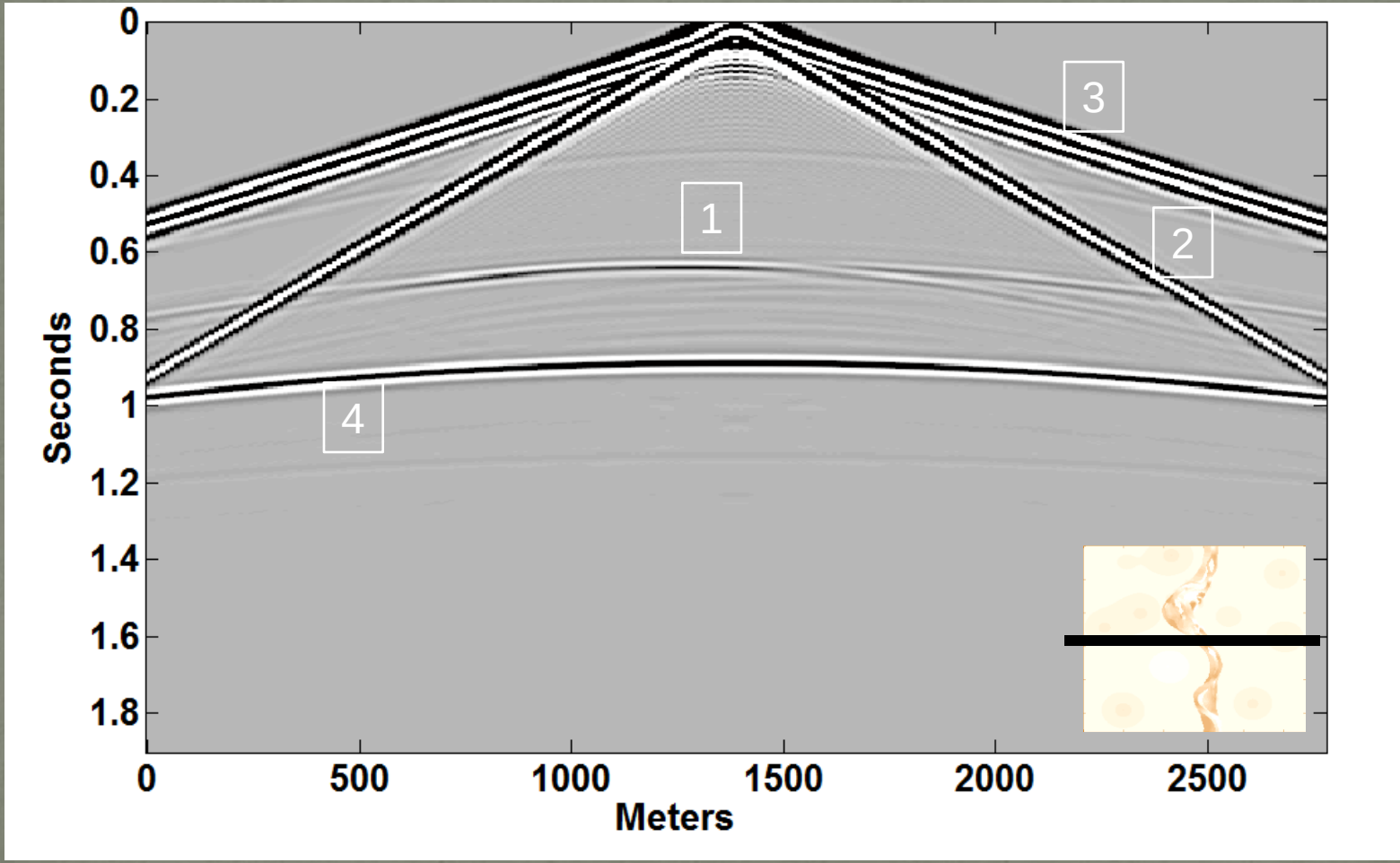
vertical displacement



Runs orthogonal to channel through center of model

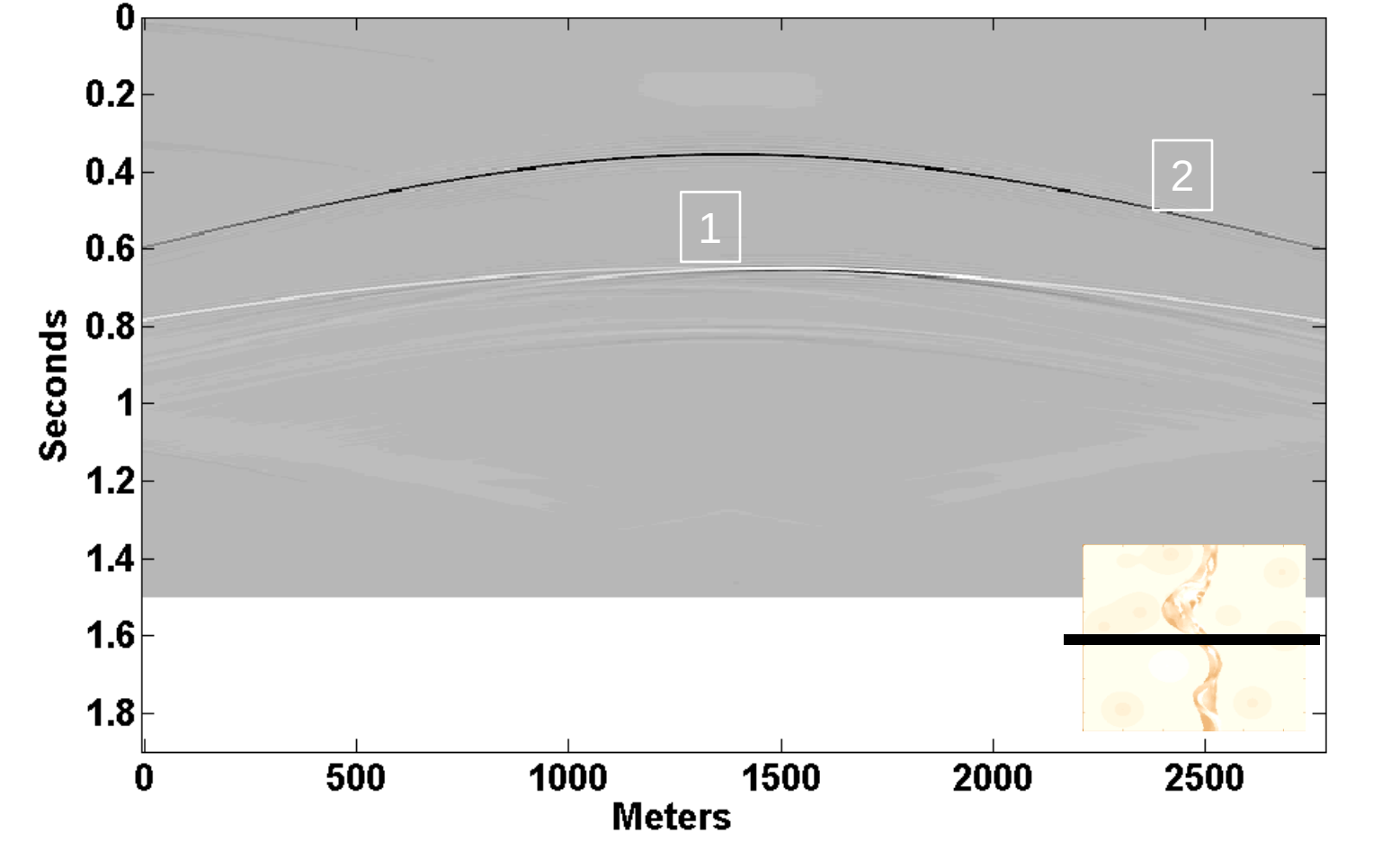
Center Shot (Tiger Acoustic 1chan)

vertical displacement



Runs orthogonal to channel through center of model

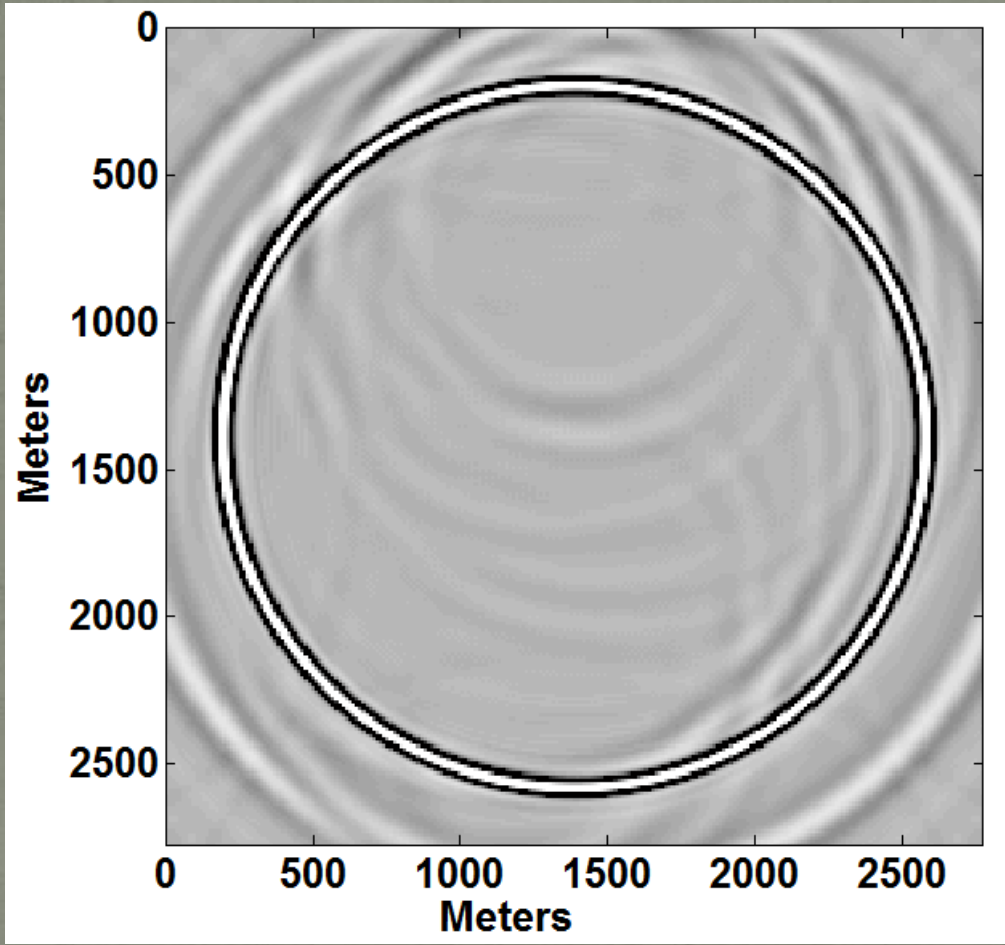
Center Shot (Rayleigh-Sommerfeld)



Runs orthogonal to channel through center of model

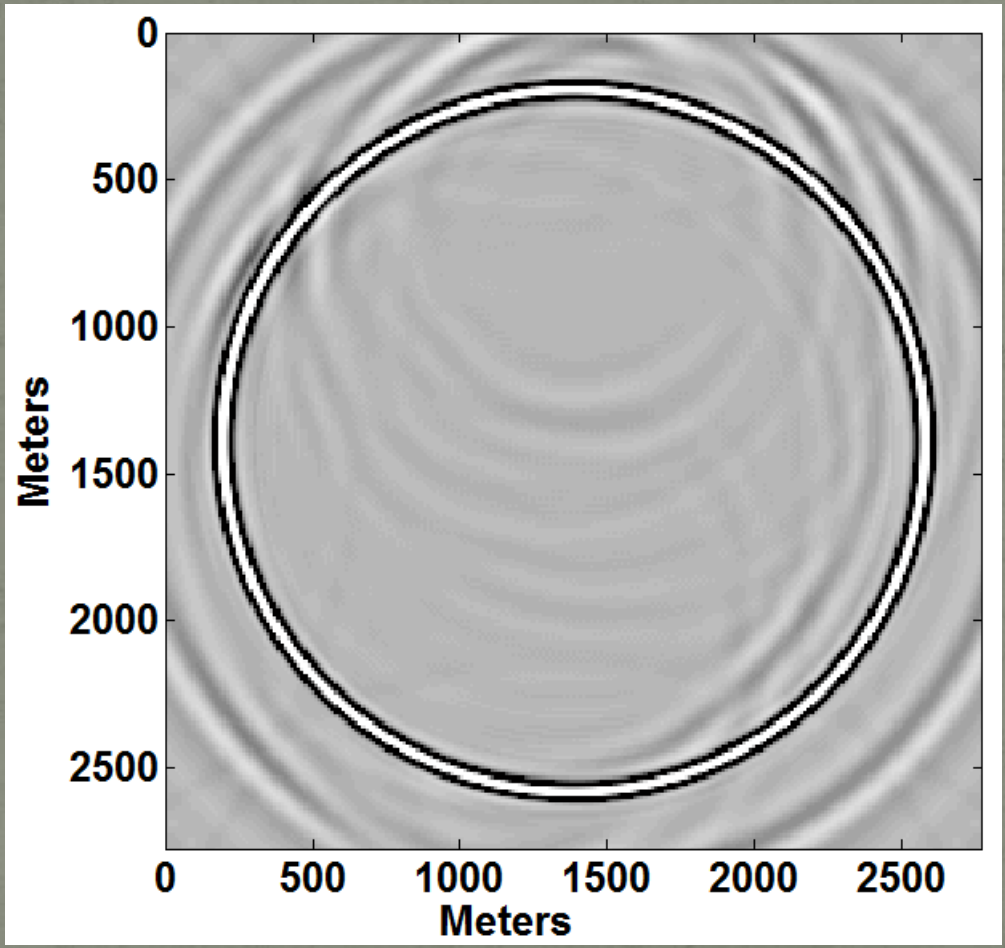
Center Shot (Tiger Acoustic)

time slice at 0.8 seconds



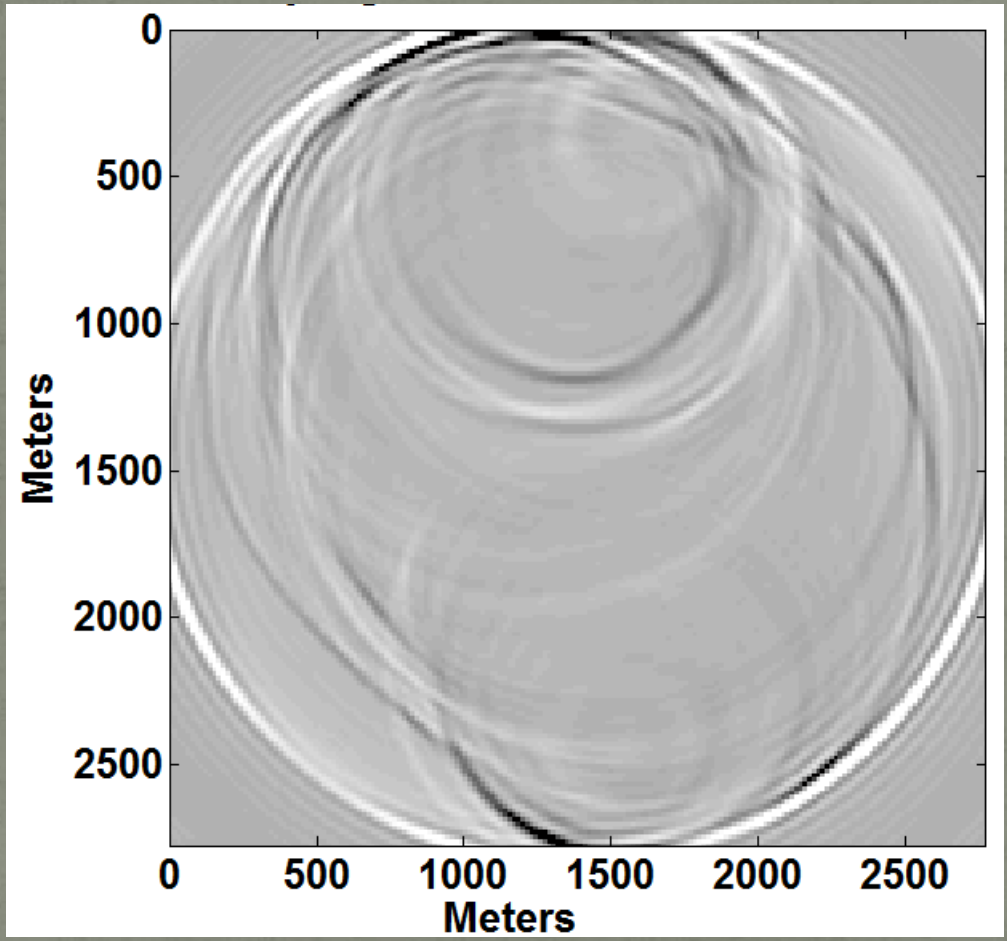
Center Shot (Tiger Acoustic 1chan)

time slice at 0.8 seconds



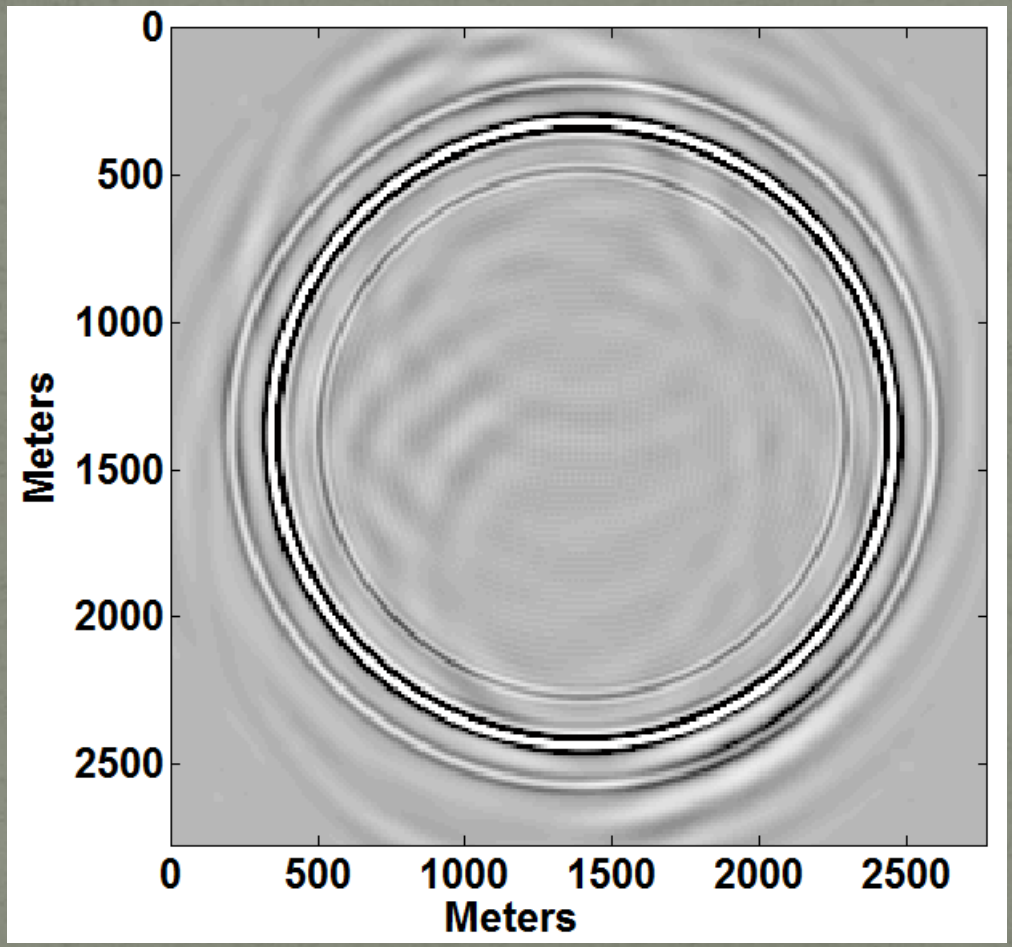
Center Shot (Rayleigh-Sommerfeld)

time slice at 0.8 seconds



Center Shot (Tiger Elastic)

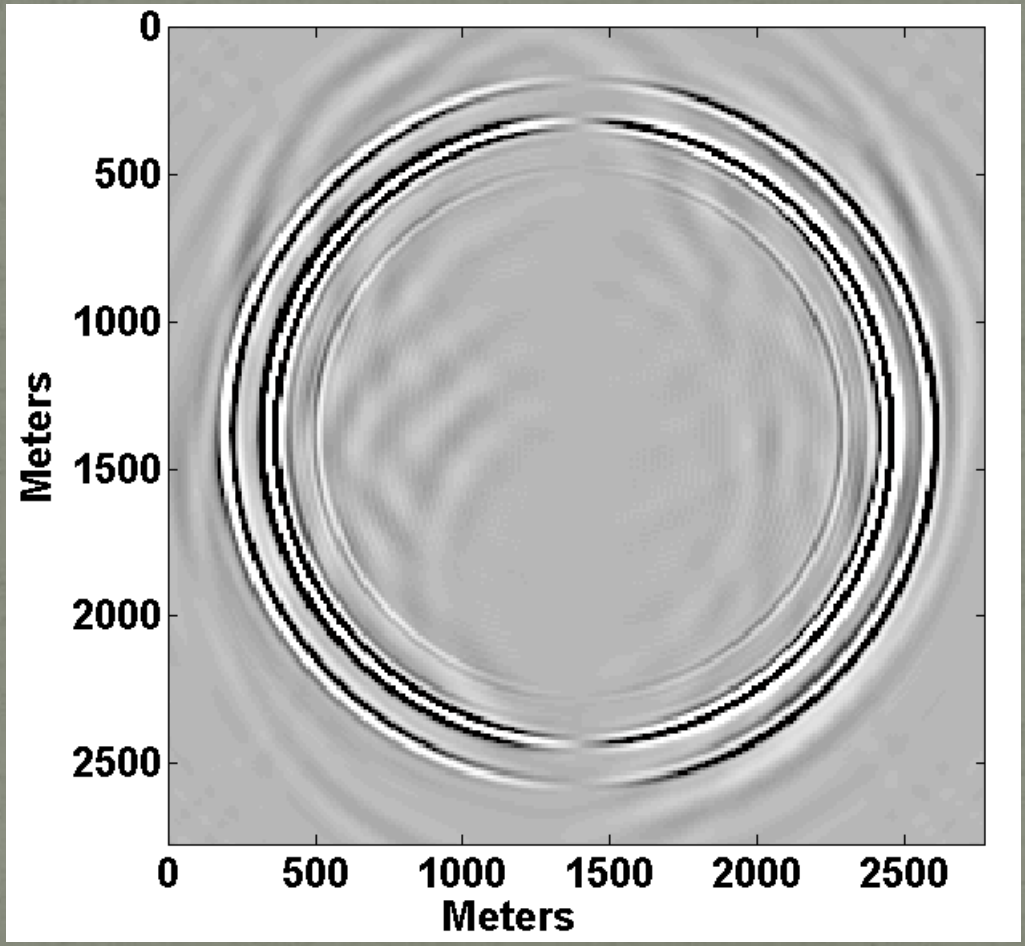
time slice at 0.8 seconds
Vertical Component



Center Shot (Tiger Elastic)

time slice at 0.8 seconds

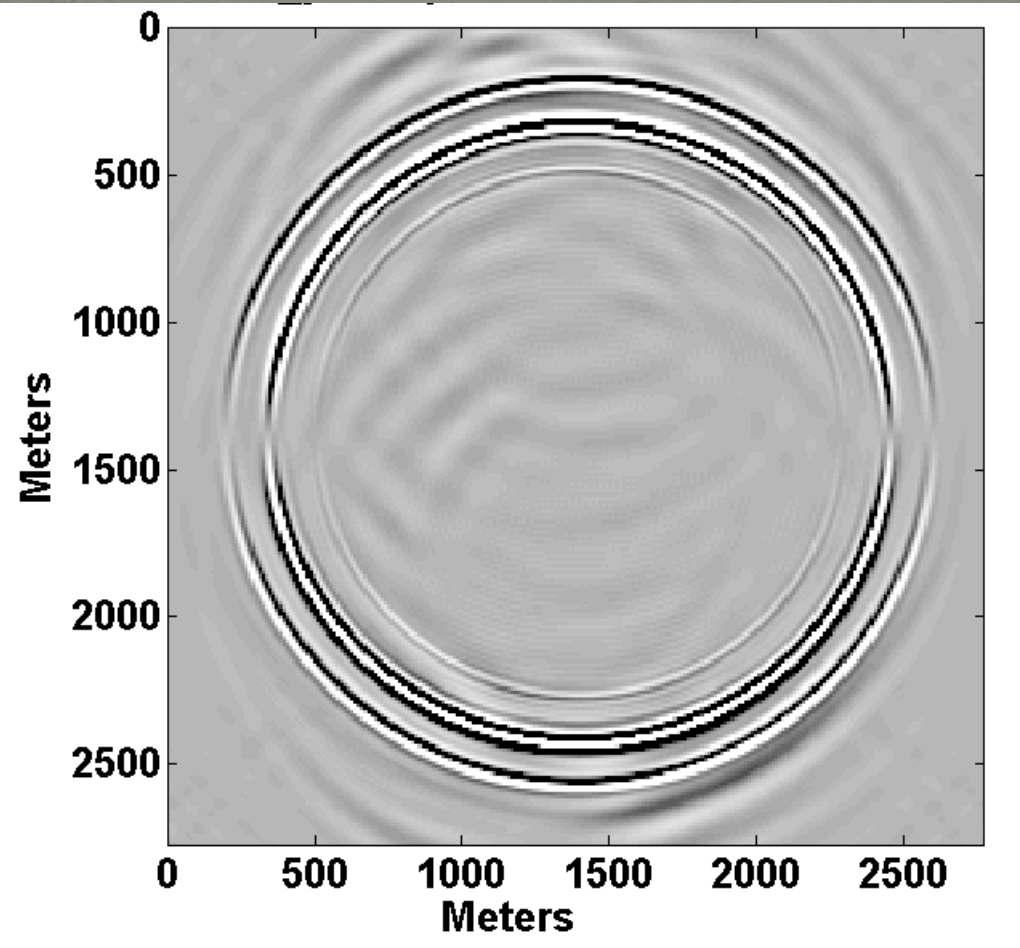
Horizontal (x) Component



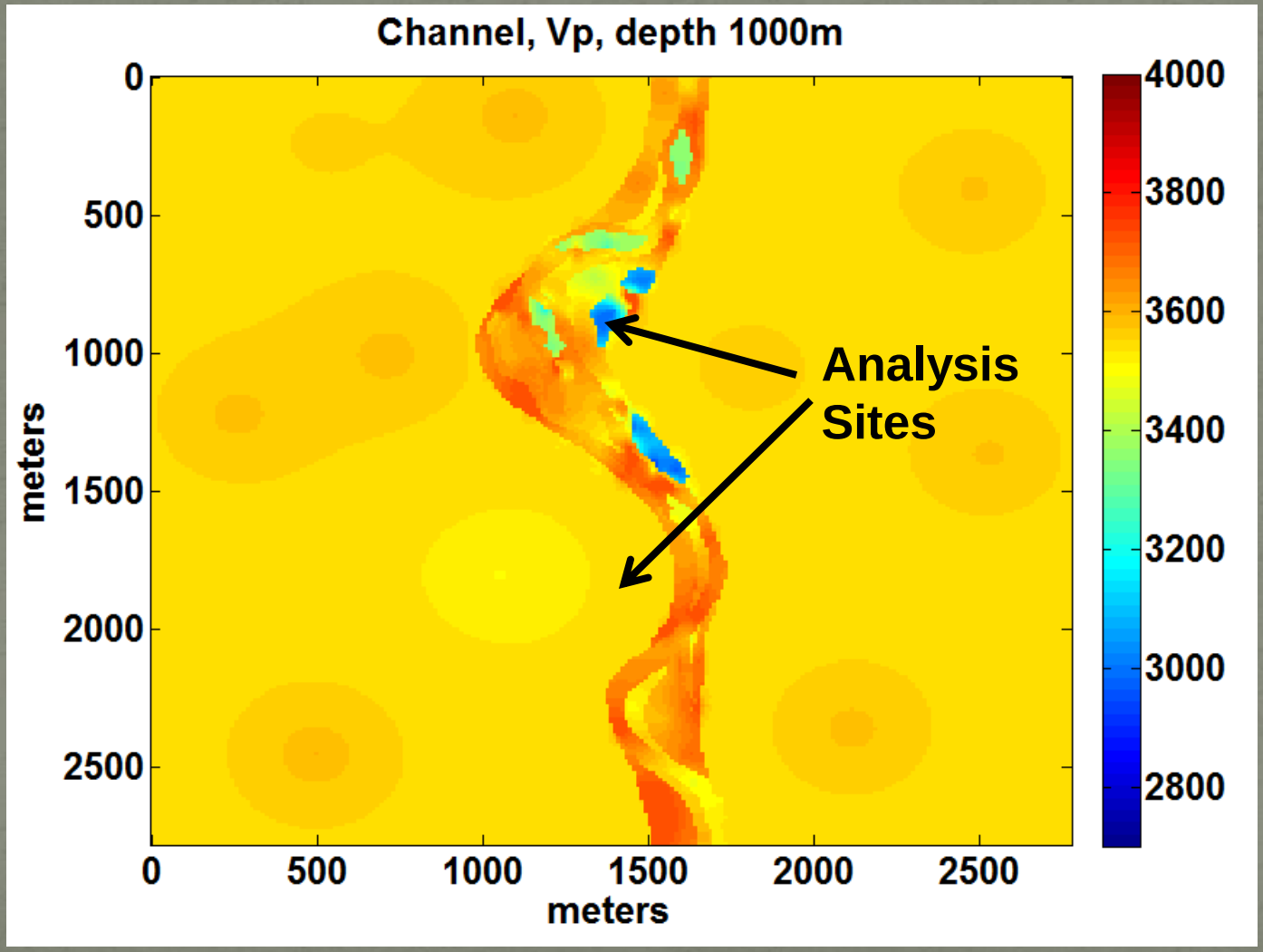
Center Shot (Tiger Elastic)

time slice at 0.8 seconds

Horizontal (y) Component

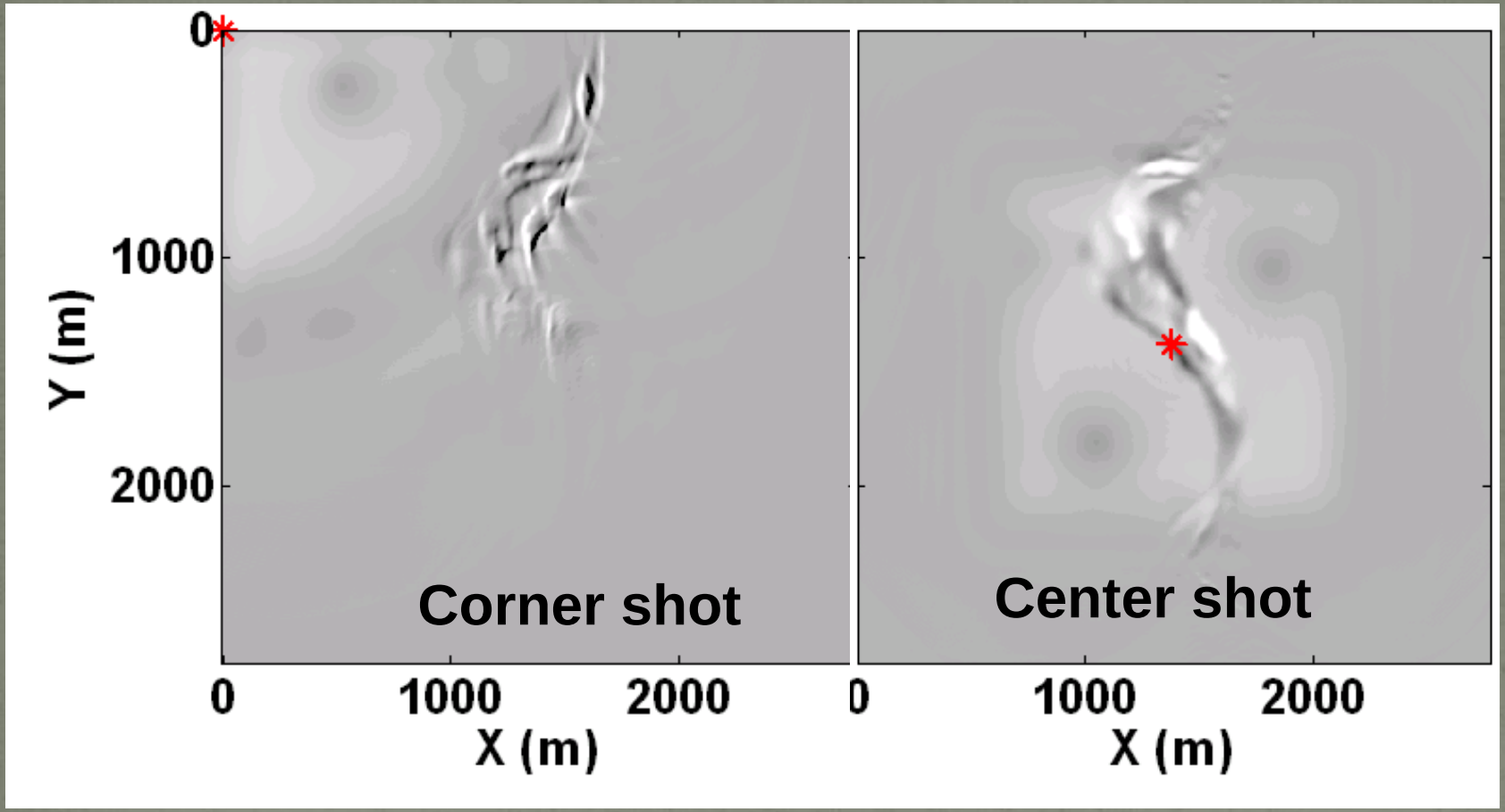


Post Migration AVO Analysis



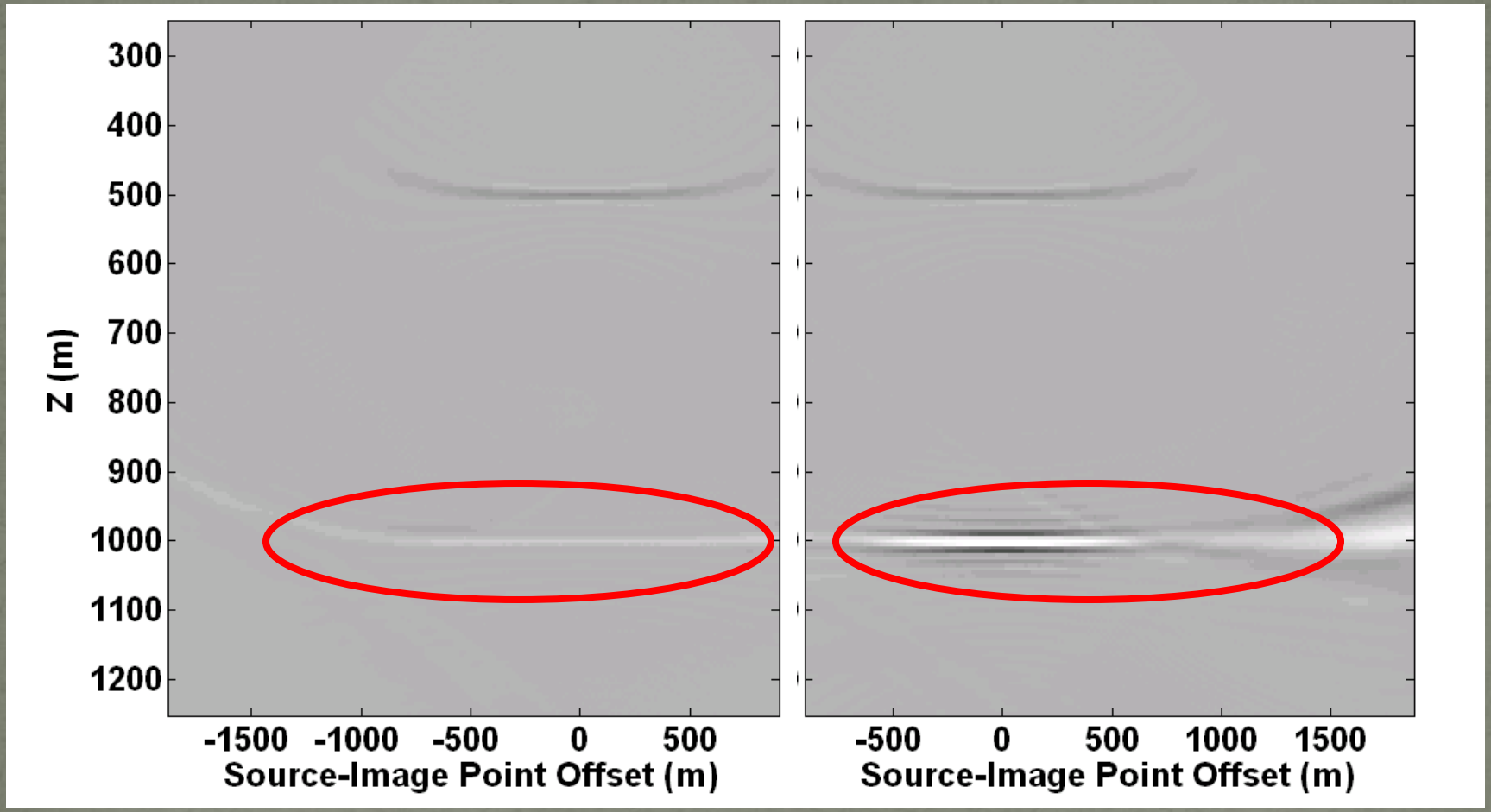
Migrations: Rayleigh-Sommerfeld Model

depth slices channel level

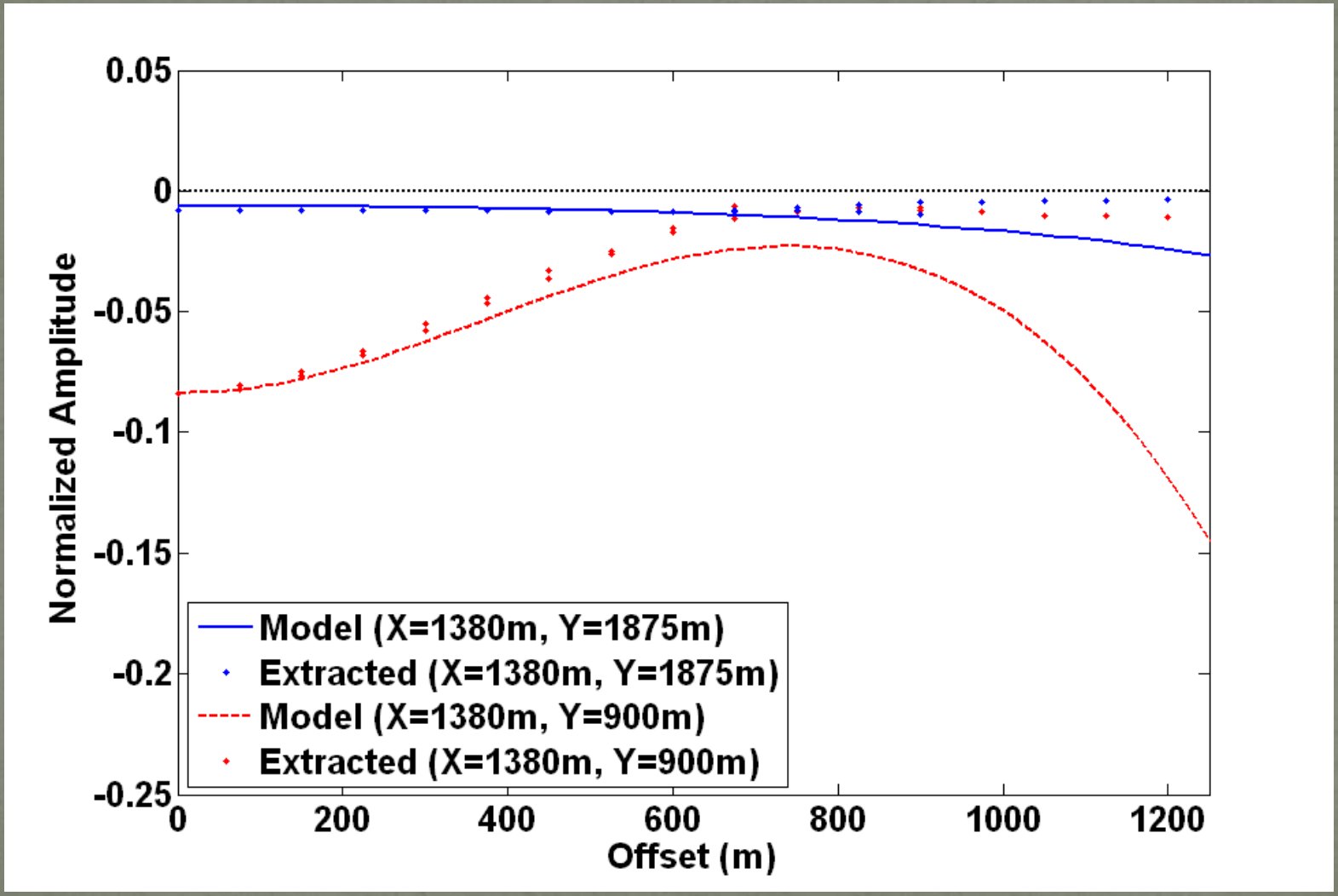


Common Image Gathers

189 Shots along channel axis



Extracted AVO



Conclusions

- Two Canadian stratigraphic models are being constructed representing channel and reef structures.
- Models have realistic elastic parameters and material gradients.
- Seismic data is now being calculated. Finite-difference elastic (60 Hz high frequency) and Rayleigh-Sommerfeld P-P AVO (120 Hz high frequency) are being created.
- Data should be available in the first quarter of 2009.
- Further models are planed and Sponsor input is desired.

Acknowledgements

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