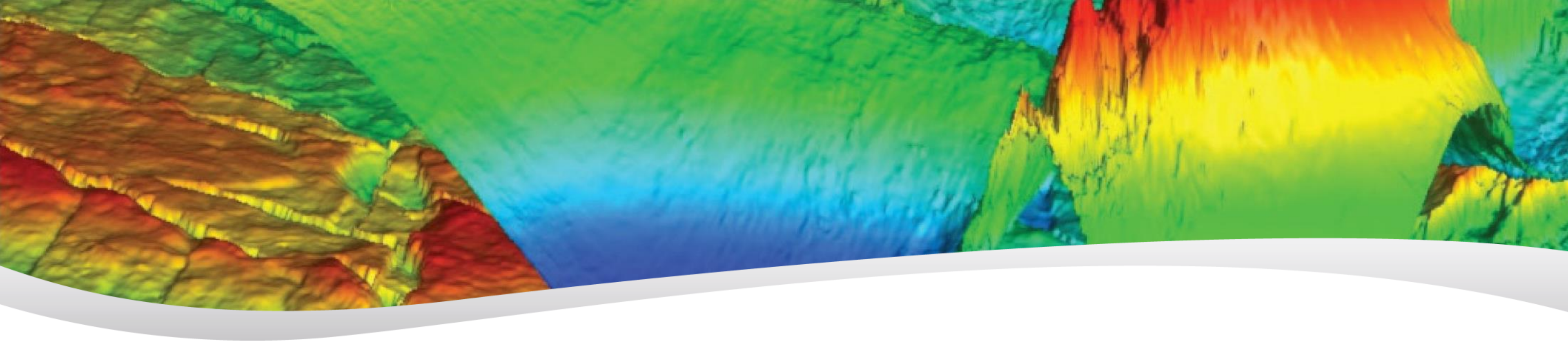


GPU Acceleration of Acquisition Footprint Removal in Post-Stack Seismic Data

Jonathan Marbach, Ph.D.,
Steve Dominguez, Jay Faulkner
CGG GeoSoftware

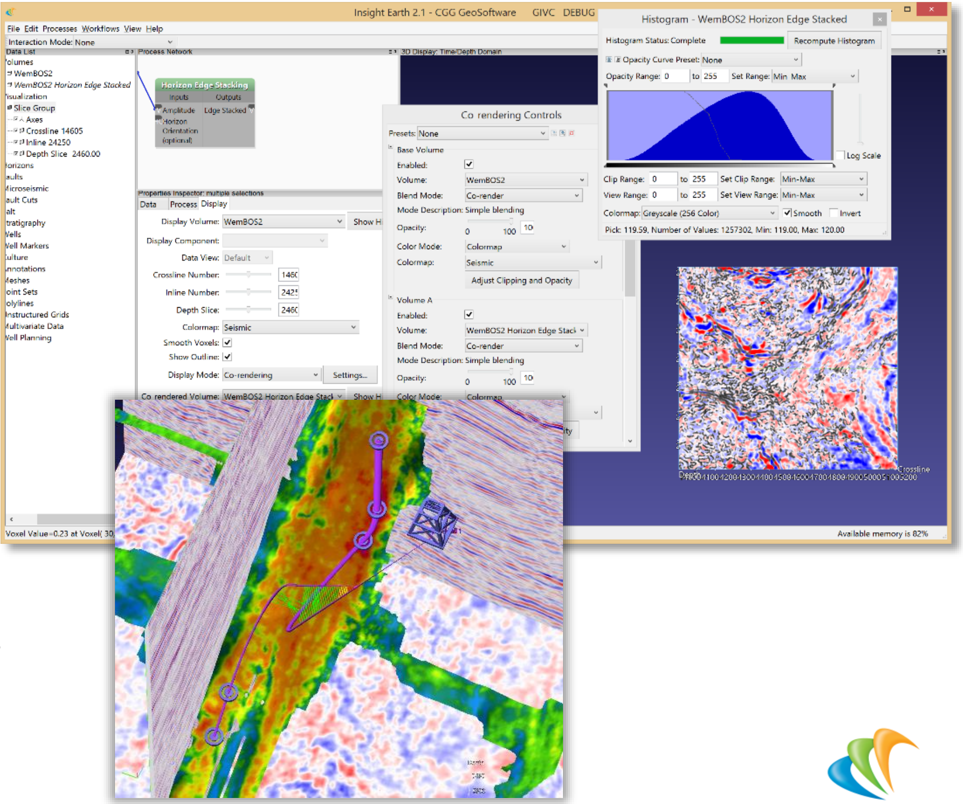
Passion for Geoscience

Footprint Removal on the GPU – Talk Outline

- Introductions
- Acquisition Footprint Removal
- GPU Port – Performance Impact
- GPU Port – User/Workflow Impact
- What we’ve learned

Footprint Removal on the GPU – Introductions

- What is Insight Earth?
  - CGG GeoSoftware’s Seismic and Stratigraphic Interpretation package
  - Workstation-class application
  - Several GPU-accelerated algorithms since 2012
- Who am I?
  - Insight Earth Team Lead
  - Background in graphics and GPUs



Interaction Mode: None

Display Volume: WemBOS2
Display Component:
Data View: Default
Crossline Number: 1460
Inline Number: 2425
Depth Slice: 2460
Colormap: Seismic
Smooth Voxels: ☑
Show Outline: ☑
Display Mode: Co-rendering
Co rendered Volume: WemBOS2 Horizon Edge Stack

Presets: None
Base Volume
Enabled: ☑
Volume: WemBOS2
Blend Mode: Co-render
Mode Description: Simple blending
Opacity: 0 100 10
Color Mode: Colormap
Colormap: Seismic
Volume A
Enabled: ☑
Volume: WemBOS2 Horizon Edge Stack
Blend Mode: Co-render
Mode Description: Simple blending
Opacity: 0 100 10
Color Mode: Colormap

Histogram Status: Complete
Opacity Curve Preset: None
Opacity Range: 0 to 255 Set Range: Min Max
Clip Range: 0 to 255 Set Clip Range: Min-Max
View Range: 0 to 255 Set View Range: Min-Max
Colormap: Greyscale (256 Color) ☑ Smooth □ Invert
Pick: 119.59, Number of Values: 1257302, Min: 119.00, Max: 120.00

Voxel Value=0.23 at Voxel(30

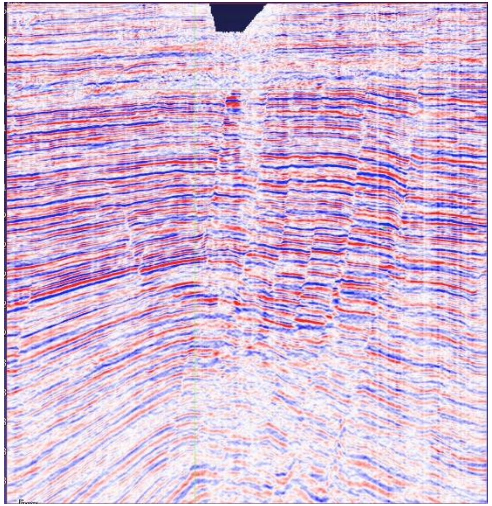
Acquisition Footprint Removal

Footprint Removal

- Acquisition Footprint
  - Appears as striping in amplitude data

- Acquisition Footprint Removal
  - Attenuates striping at a given spacing and direction
    - One spacing/direction per pass
  - Only changes amplitudes significantly in striped areas
  - Preserves RMS amplitudes
  - Proprietary, patented algorithm

Raw Seismic Data



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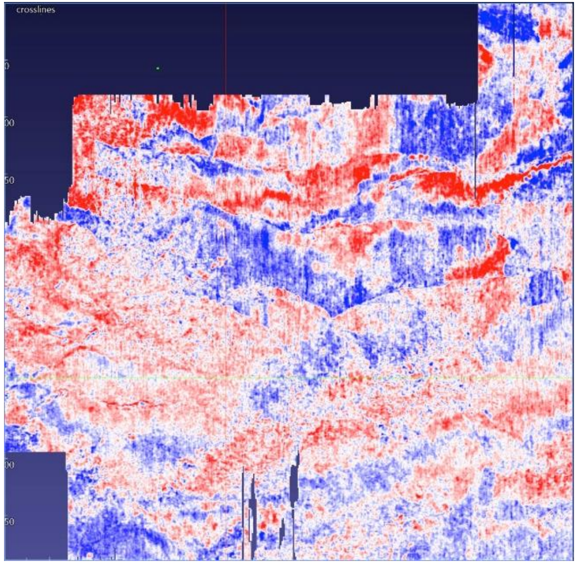
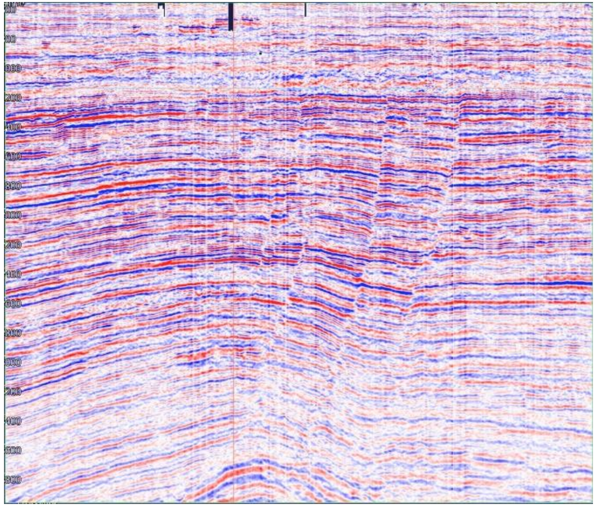
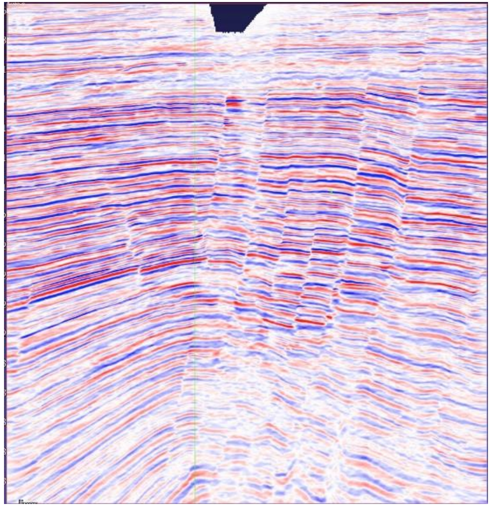


Time Slice 1180



Crossline 329

Footprint Removal Applied



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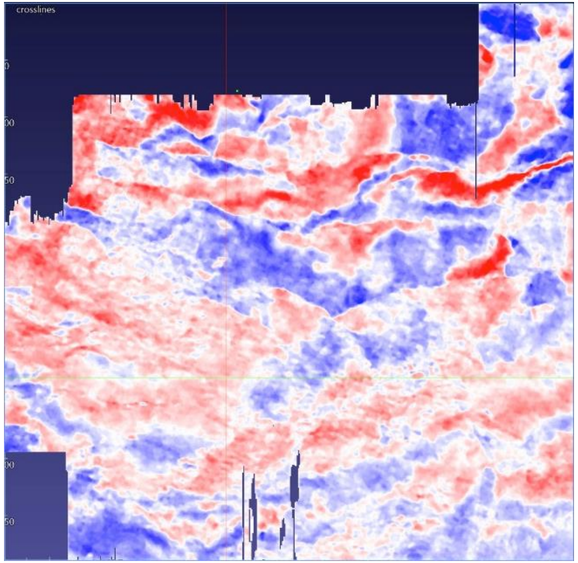
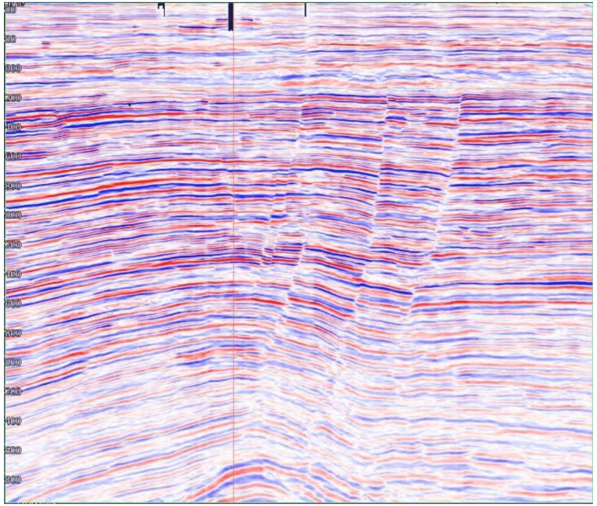
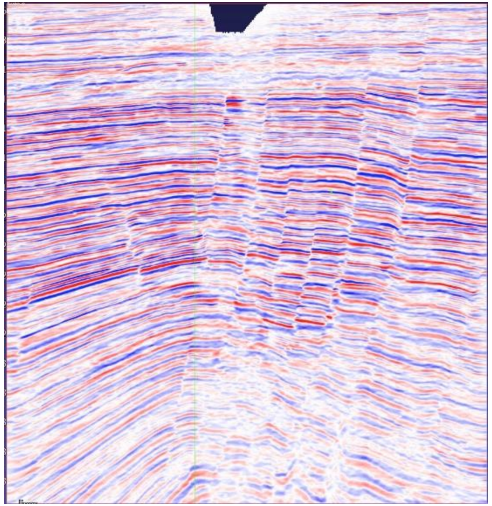


Time Slice 1180



Crossline 329

Footprint Removal Applied



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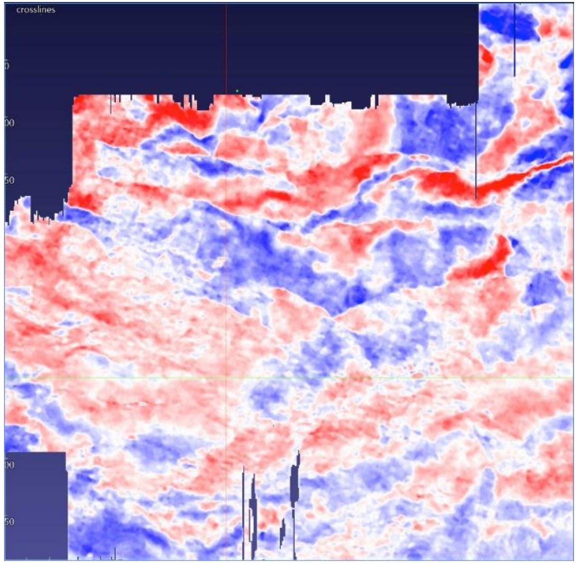

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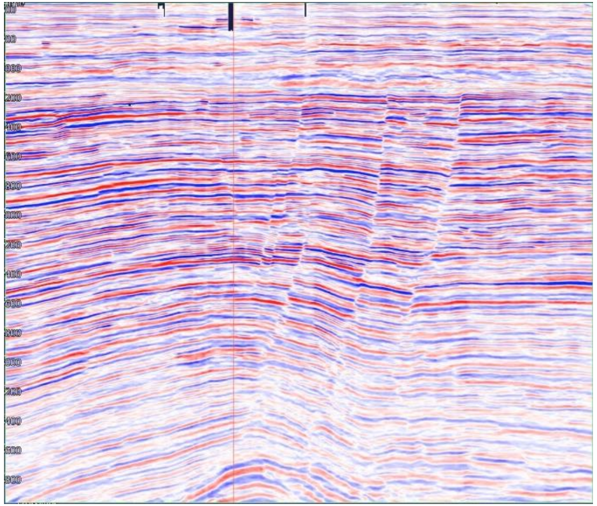
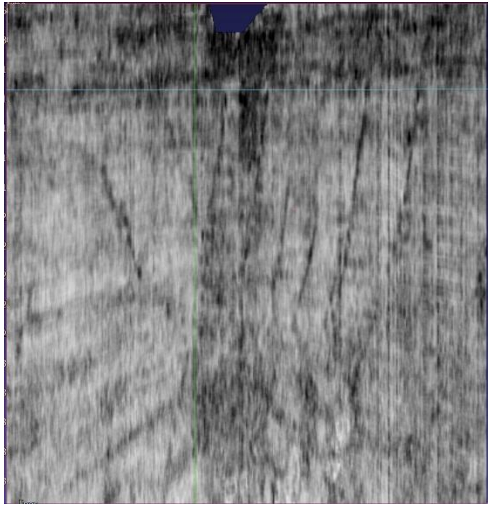


Crossline 329

- Footprint still exists on many modern surveys!

Horizon Edge Stack run on Raw Seismic Data



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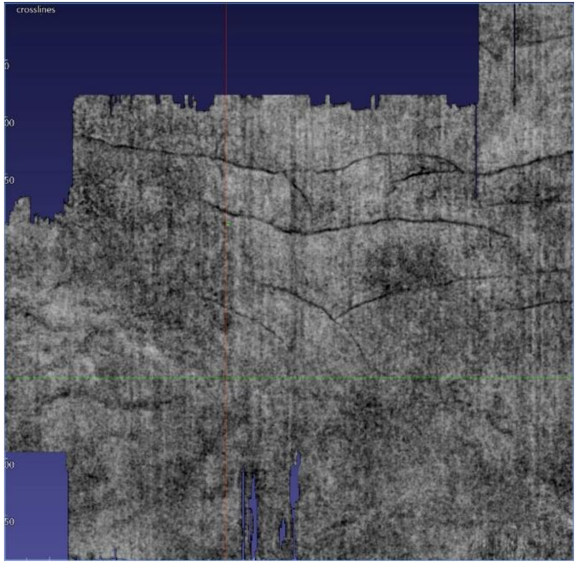
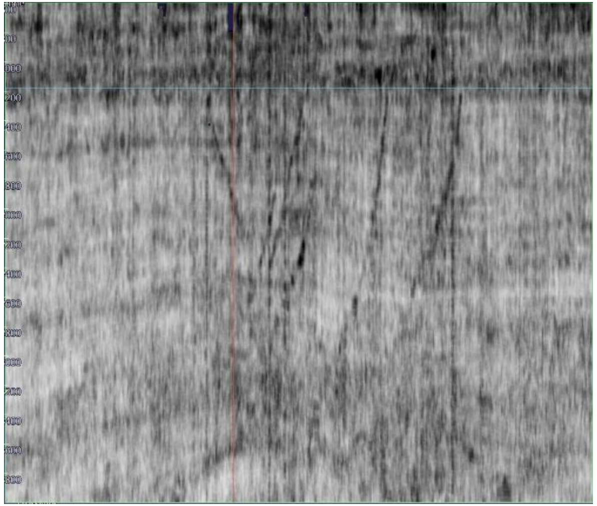
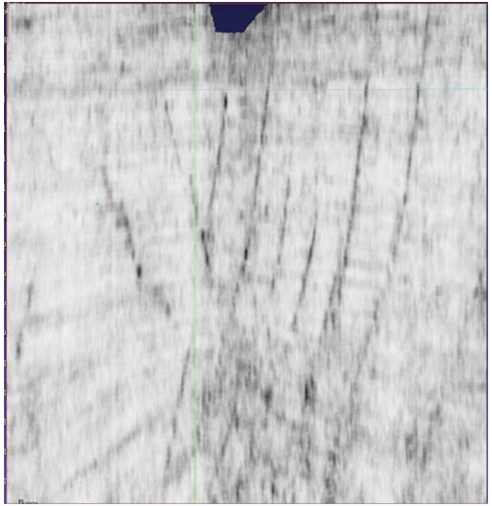


Time Slice 1180



Crossline 329

Horizon Edge Stack run on Filtered Seismic Data



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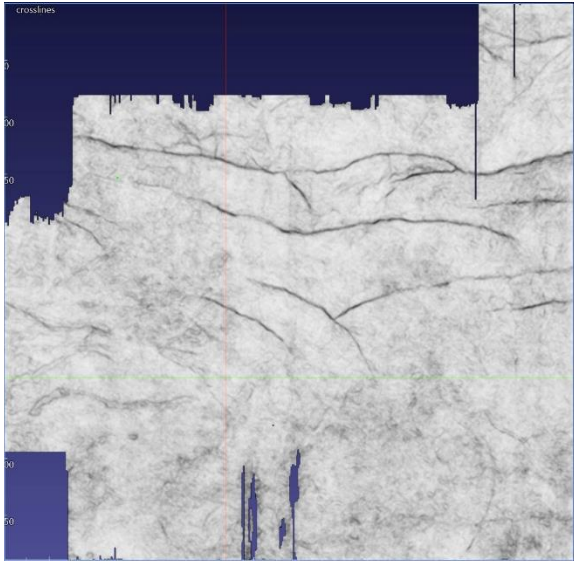
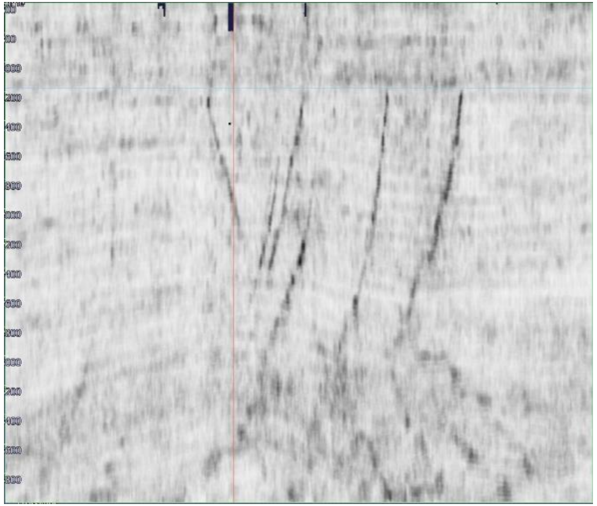
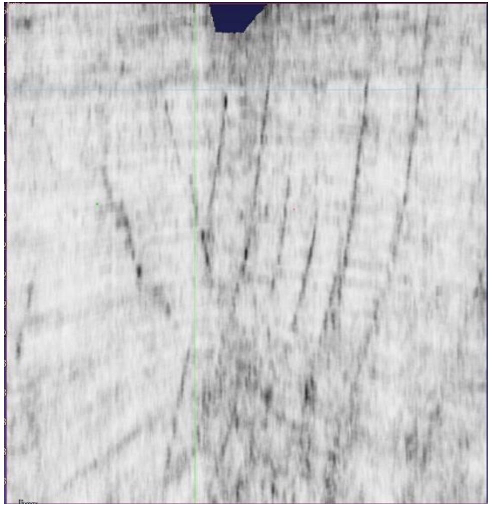


Time Slice 1180



Crossline 329

Horizon Edge Stack run on Filtered Seismic Data



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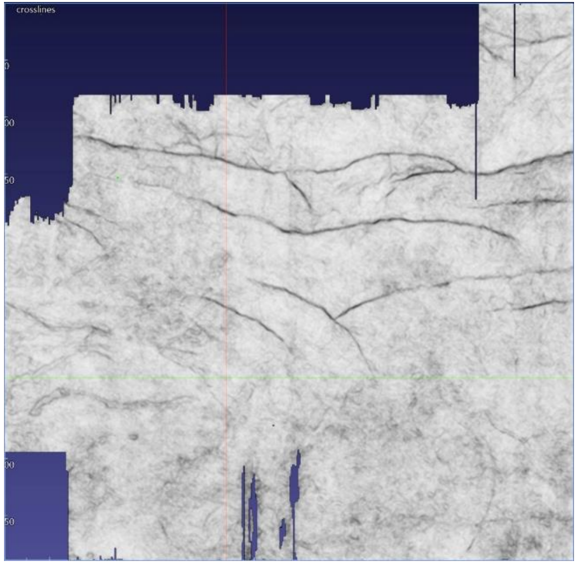
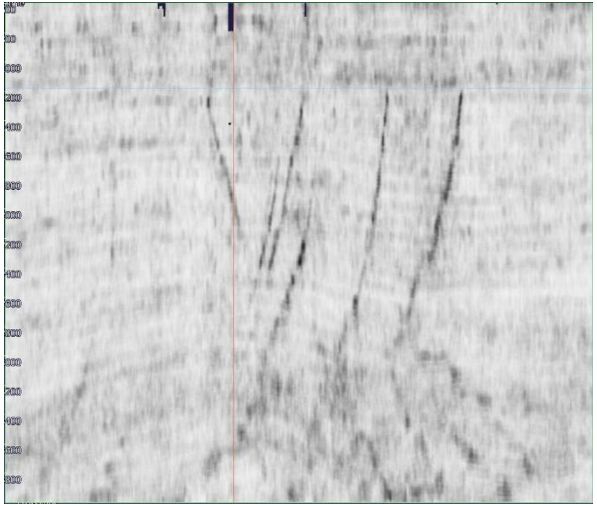


Time Slice 1180

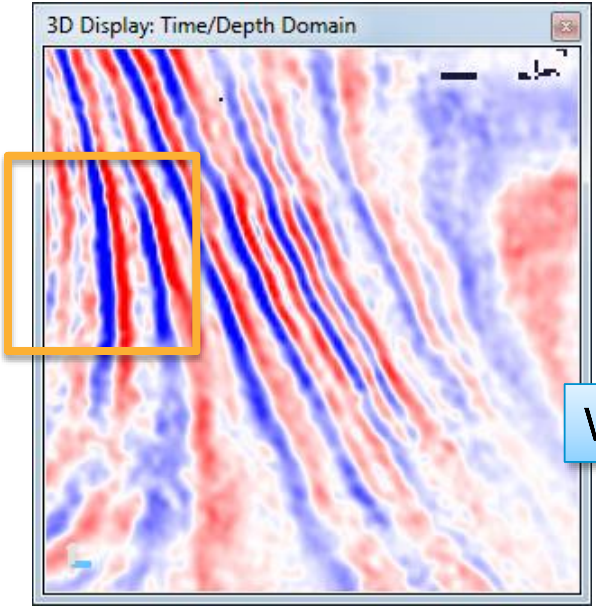


Crossline 329

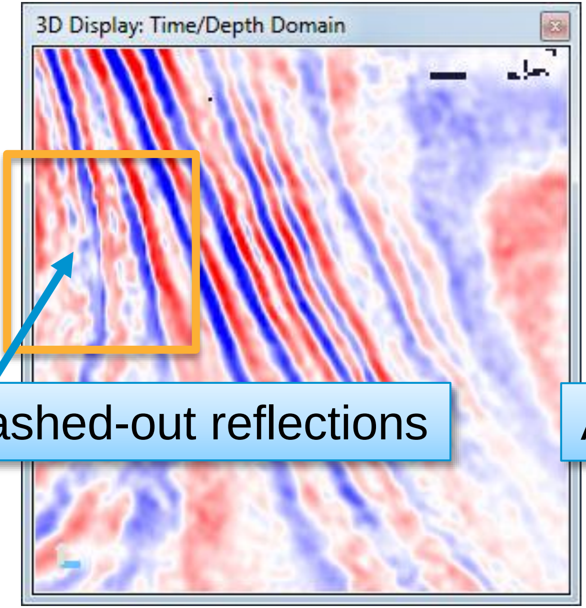
- Footprint Removal improves results later in the workflow
  - – Especially for edge-based algorithms

Footprint Removal – Dip Compensation

- Why is dip-compensation necessary?

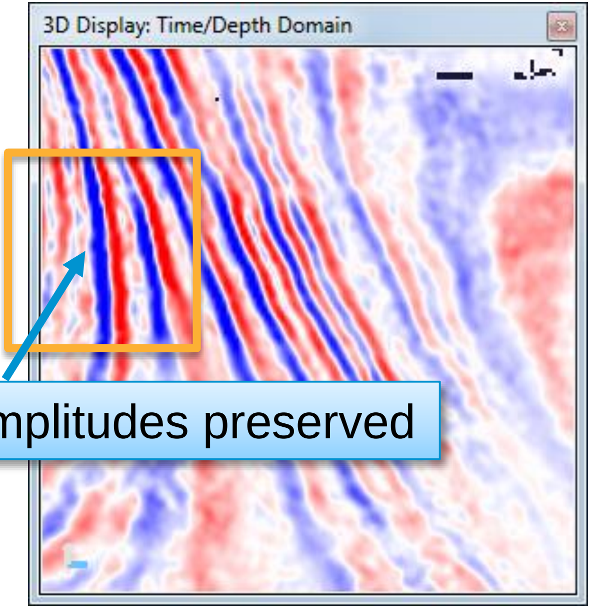


Input Amplitude Volume



Washed-out reflections

Non-dip-compensated Footprint Removal

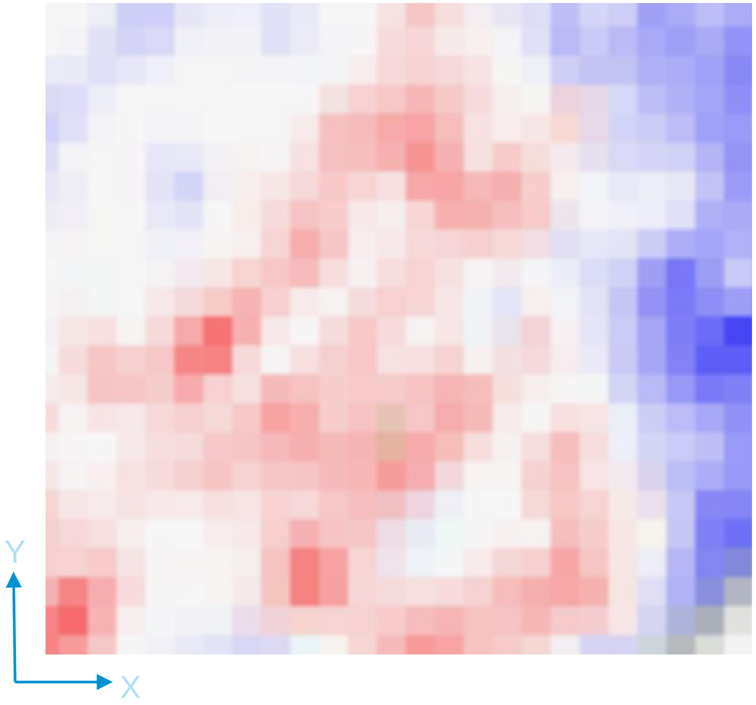


Amplitudes preserved

Dip-compensated Footprint Removal

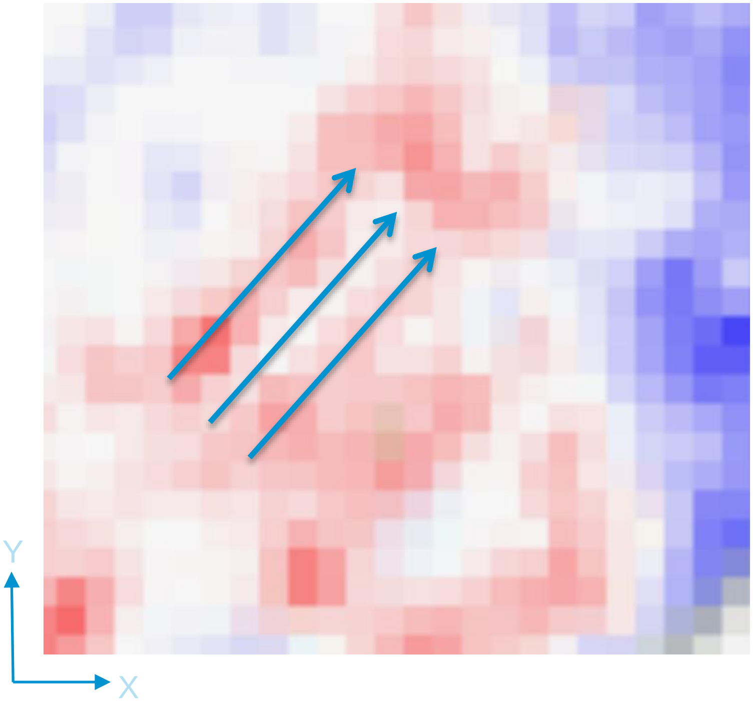
Footprint Removal – Oblique Angles

- Oblique-angle Footprint
  - Striping appears at an arbitrary angle in the time/depth slice



Footprint Removal – Oblique Angles

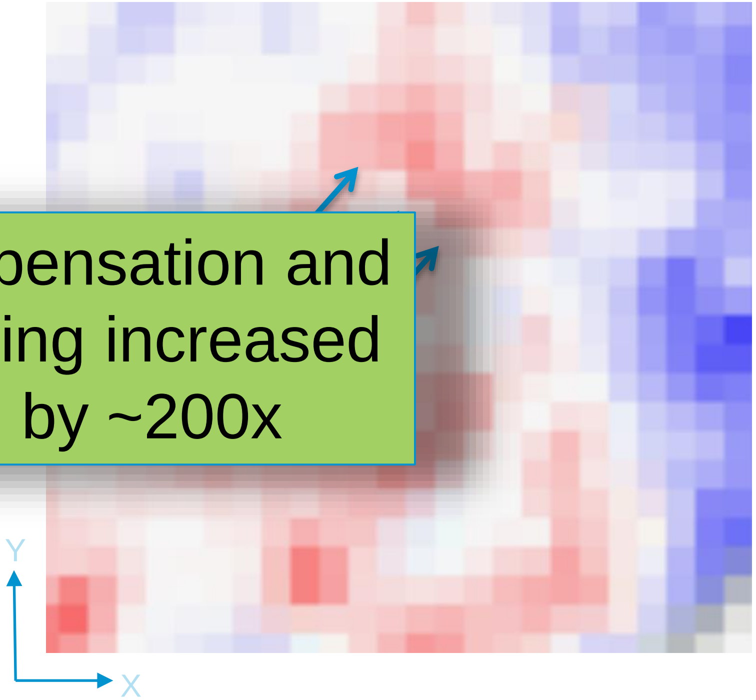
- Oblique-angle Footprint
  - Striping appears at an arbitrary angle in the time/depth slice
  - The algorithm would not “recognize” such a feature unless…
  - We rotate to sample parallel to the stripe
  - This can be combined (accurately) with dip-compensation



Footprint Removal – Oblique Angles

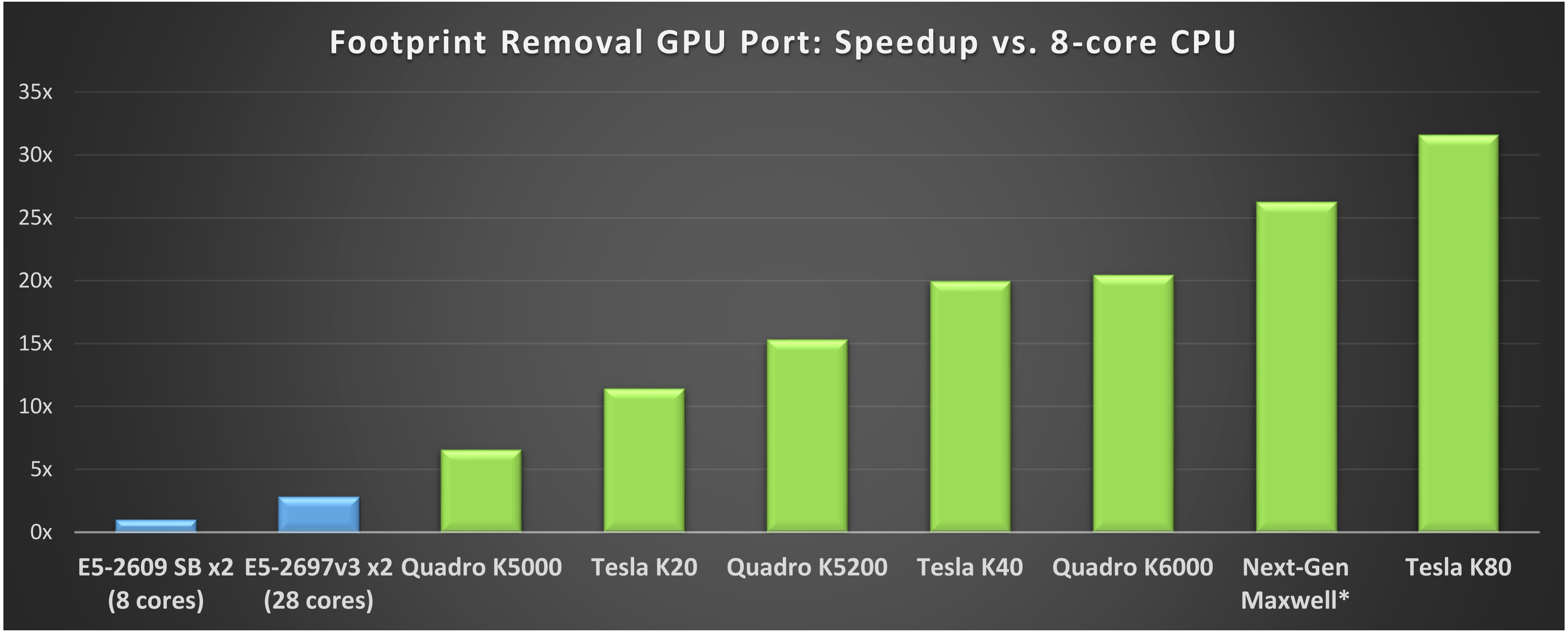
- Oblique-angle Footprint
  - Striping appears at an arbitrary angle in the time/depth slice
  - The algorit
    “recognize’
    unless…
  - We rotate t
    stripe
  - This can be combined (accurately) with dip-compensation

But adding dip compensation and oblique-angle handling increased runtime on the CPU by ~200x

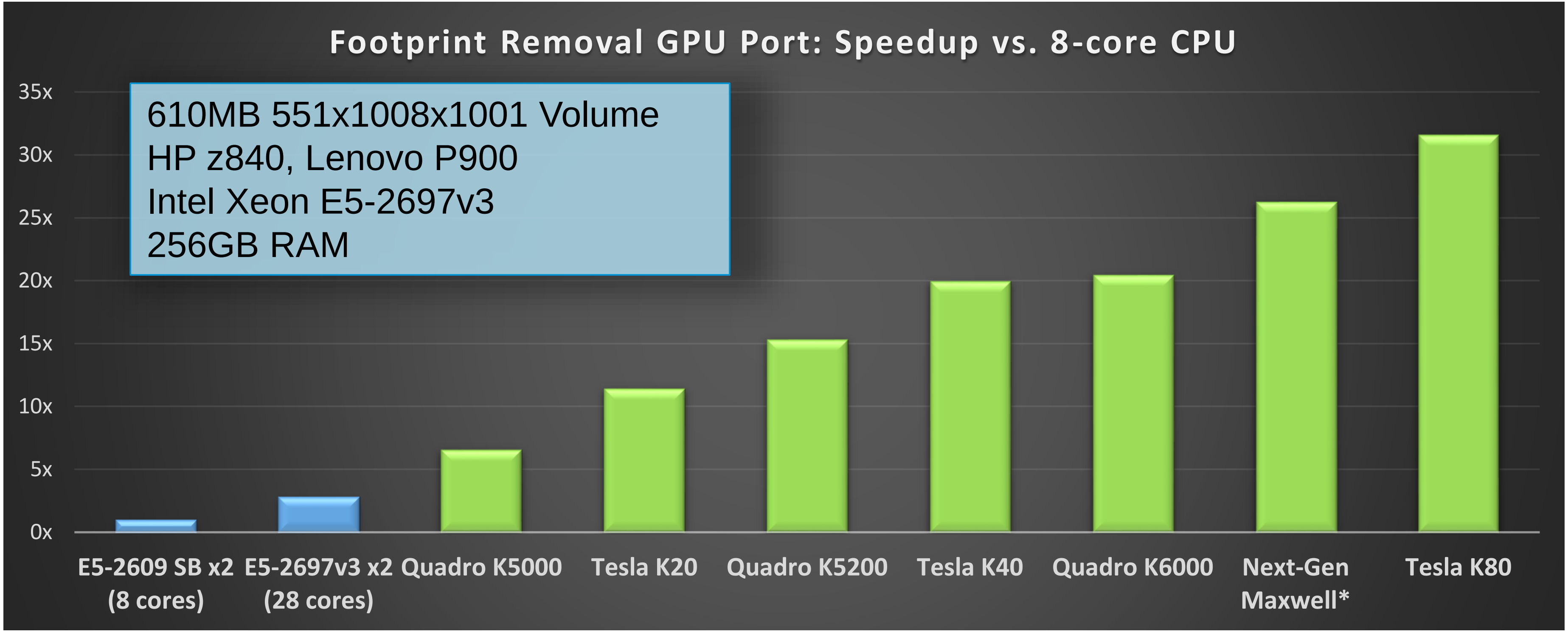


GPU Port
Performance and Workflow Impact

Footprint Removal on the GPU – Performance Impact



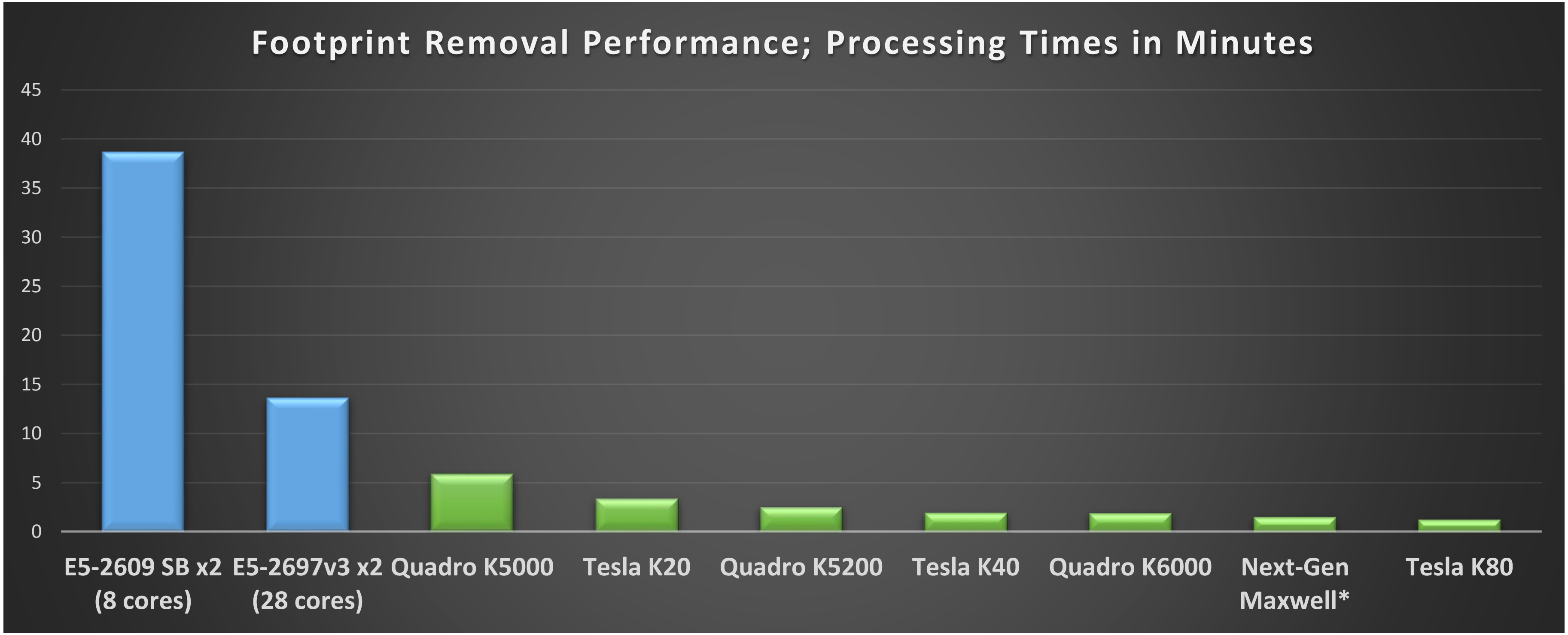
Footprint Removal on the GPU – Performance Impact



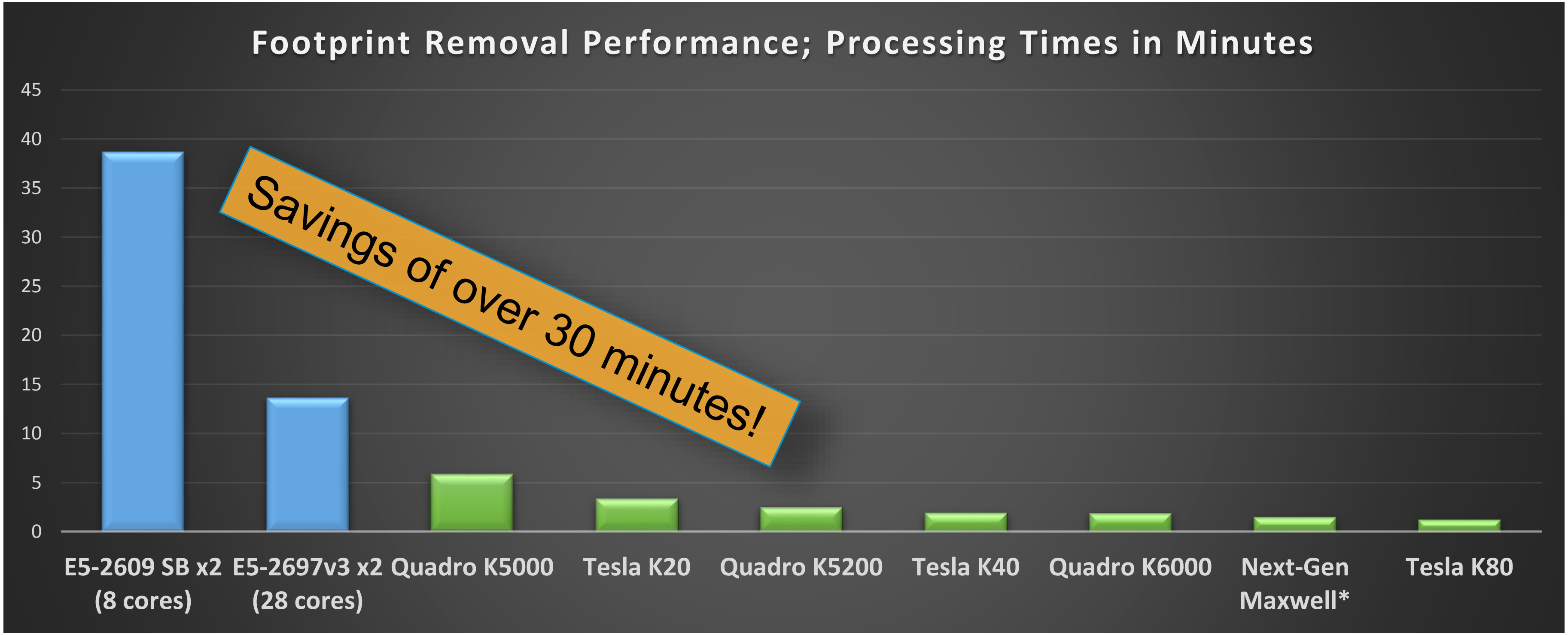
610MB 551x1008x1001 Volume
HP z840, Lenovo P900
Intel Xeon E5-2697v3
256GB RAM

*Quadro M6000

Footprint Removal on the GPU – Performance Impact



Footprint Removal on the GPU – Performance Impact



Footprint Removal on the GPU – Workflow Impact

1. Load Raw Seismic Volume
2. Create Horizon Orientation (Structural Dip) Volume
3. Remove Footprint
   - Parameterize footprint removal
     - Footprint Orientation, Wavelength, Time/Depth Range
   - Repeat steps 2 and 3 for each footprint orientation and each footprint wavelength
4. Create Horizon Orientation Volume
5. Remove Random Noise
   - Default is Statistical Filter – Median, 3x3x1

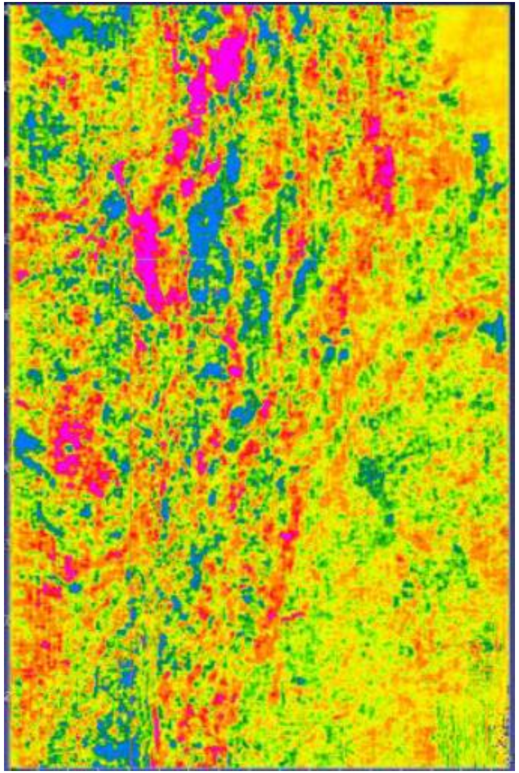
Footprint Removal on the GPU – Workflow Impact

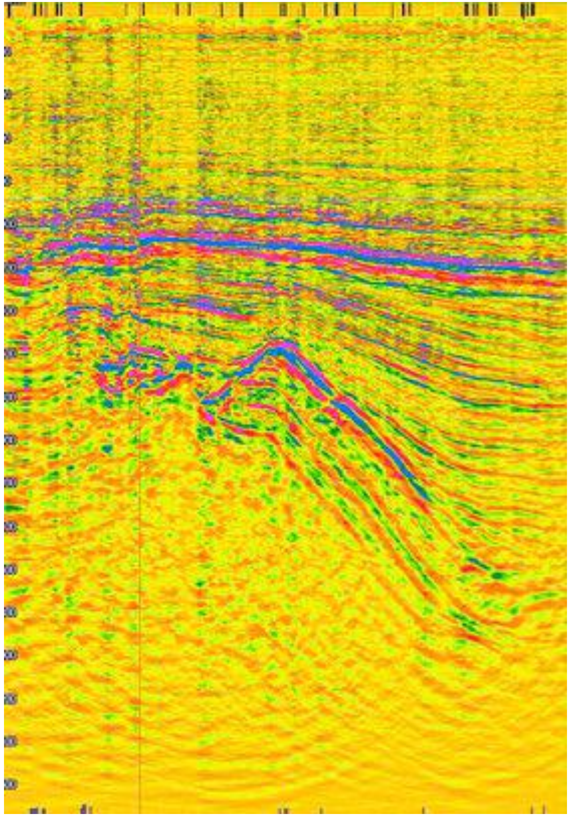
1. Load Raw Seismic Volume
2. Create Horizon Orientation (Strike and Dip) Volume
3. R
   - Parameterize footprint removal
     - Footprint Orientation, Wavelength, Time/Depth Range
   - Repeat steps 2 and 3 for each footprint orientation and each footprint wavelength
4. Create Horizon Orientation Volume
5. Remove Random Noise
   - Default is Statistical Filter – Median, 3x3x1

How many iterations might this take??

Footprint Removal – Real-world Example

Marine Data, 1990s
500x331x1000;





Footprint Removal – Real-world Example

Marine Data, 1990s
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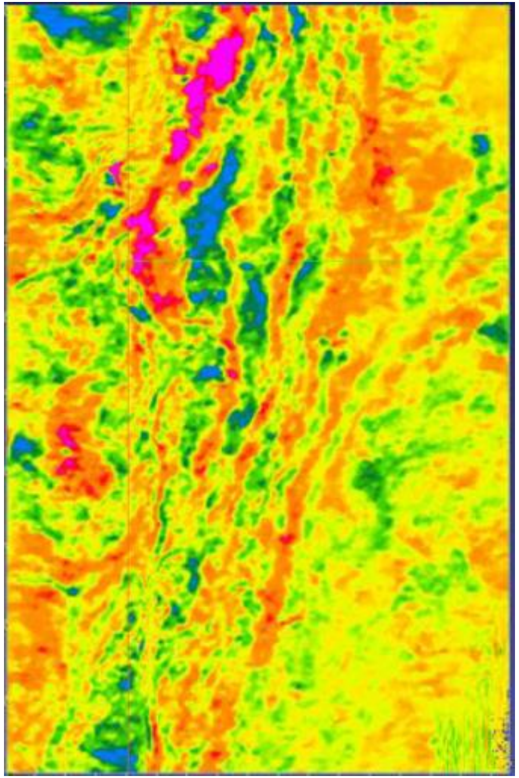

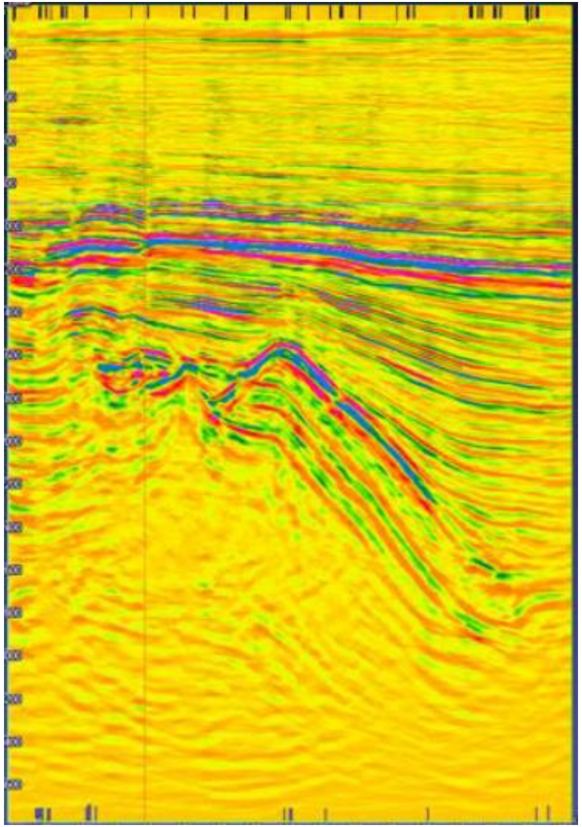

Footprint Removal – Real-world Example

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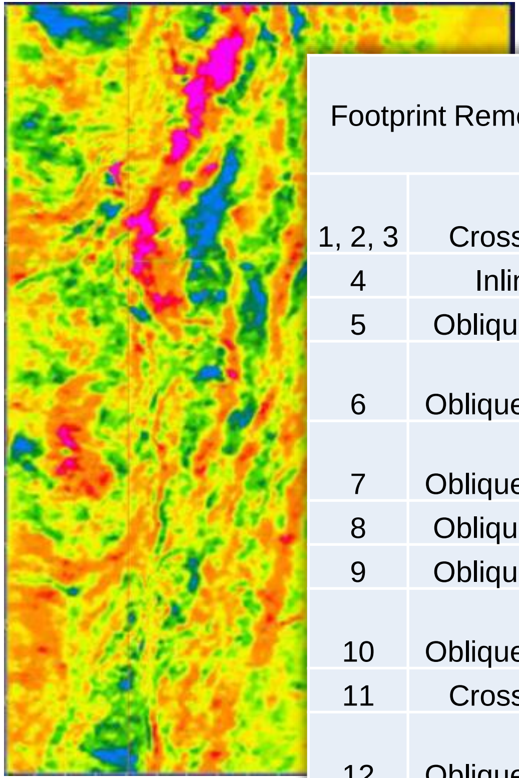
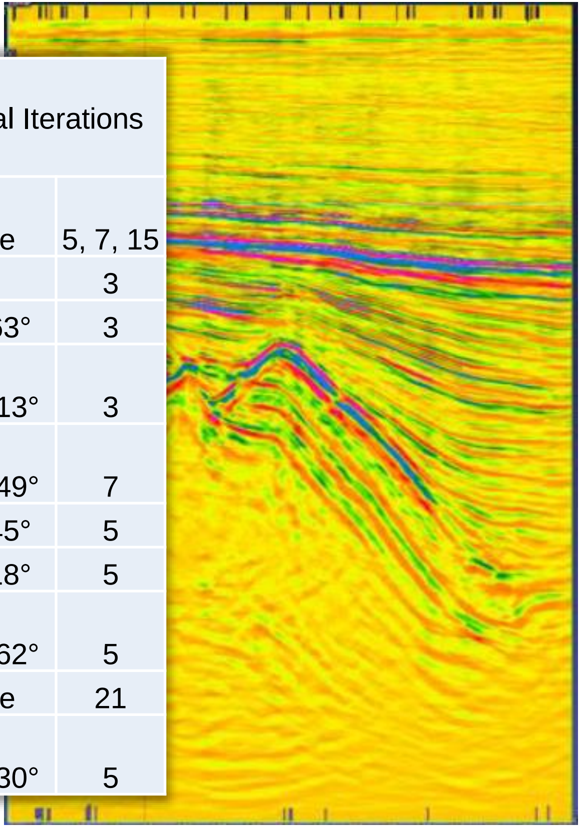
500x331x1000;



Footprint Removal Iterations

1, 2, 3	Crossline	5, 7, 15
4	Inline	3
5	Oblique 63°	3
6	Oblique 113°	3
7	Oblique 149°	7
8	Oblique 45°	5
9	Oblique 18°	5
10	Oblique 162°	5
11	Crossline	21
12	Oblique 130°	5



Footprint Removal – Real-world Example

Marine Data, 1990s
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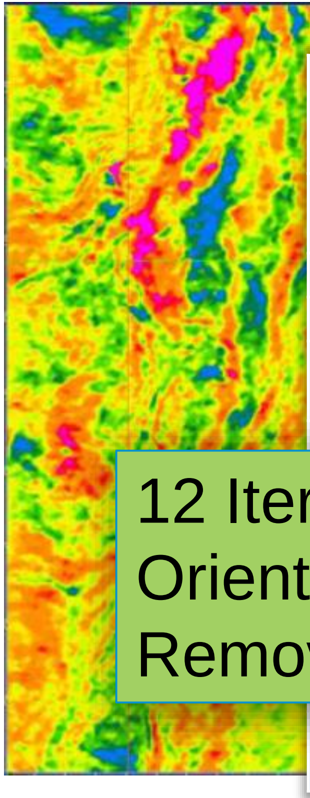
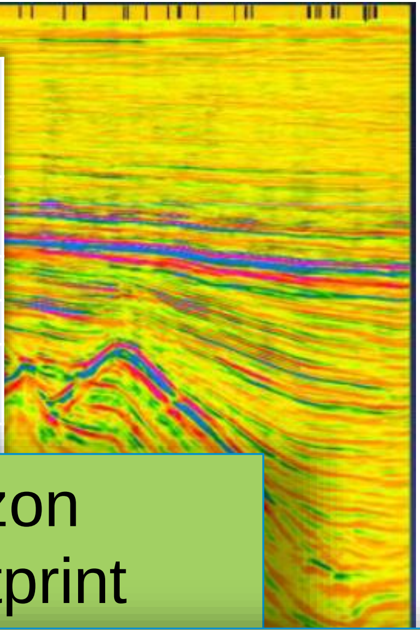




Footprint Removal Iterations		
1, 2, 3	Crossline	5, 7, 15
4	Inline	3
5	Oblique 63°	3
6	Oblique 113°	3
12	Ol	

12 Iterations of Horizon Orientation and Footprint Removal!

GPU acceleration cuts ~3 hours of runtime into ~10 minutes

What have we learned?

Footprint Removal on the GPU – What we've learned

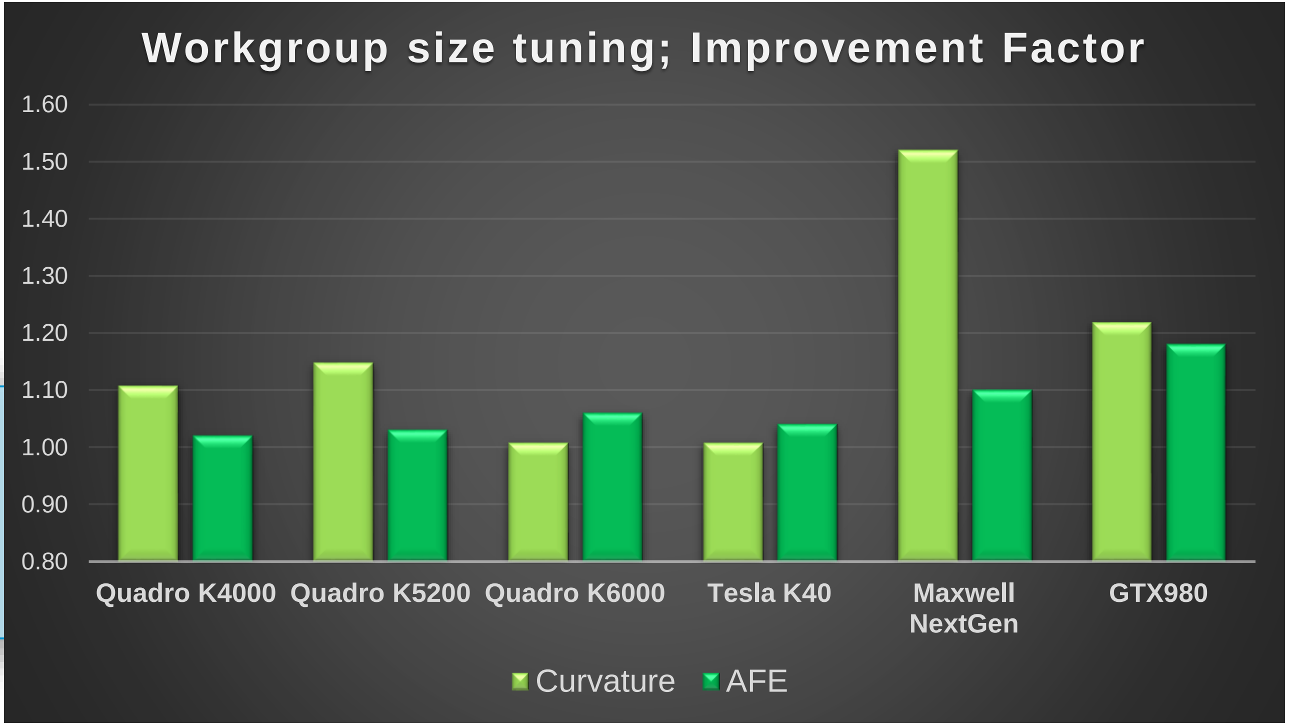
- GTC 2012 – Seismic Interpretation Algorithms on the GPU
  - Initial results on porting several algorithms
  - Recommended porting worst-performer algorithms
    - But start with the simplest of them
  - Recommended developers with at least graphics experience
- GTC 2013 – "Porting makes you stronger"
  - Porting to the GPU makes your non-GPU code faster and more accurate
- GTC 2015
  - …?

Footprint Removal on the GPU – What we’ve learned

- Don’t “Port and Forget” – 3 R’s:
- Revisit
  - Revisit GPU code annually; question previous decisions
- Re-tune
  - Sounds obvious, but new hardware will likely need re-tuning
- Re-optimize
  - Look for missed opportunities to optimize
  - Re-think the algorithm (fourth R?)

Footprint Removal on the GPU – What we've learned

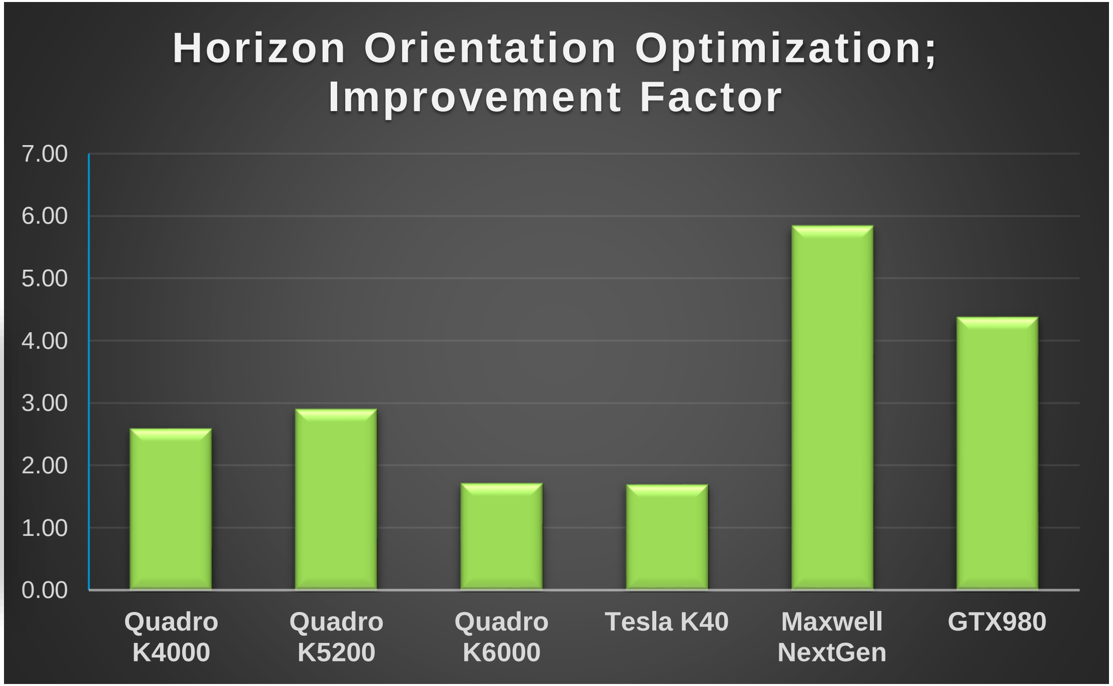
- Why not "Port and forget?" – Part 1
  - Workgroup/grid/block size tuning - Improvements between 2% and 52%



Benchmark Volume: 9MB, 131x131x256
Real-world Volume: 610MB, 551x1008x1001
HP z840, Lenovo P900
Intel Xeon E5-2697v3
256GB RAM

Footprint Removal on the GPU – What we've learned

- Why not "Port and forget?" – Part 2
  - Missed optimizations (a.k.a. "what were we thinking?!?")
  - Inefficient loop structure
  - Over-use of double-precision



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Footprint Removal on the GPU – What we’ve learned (Cont.)

- Although CPUs are continuing to improve, GPUs maintain their performance edge.
- CPU-only versions of the code are increasingly used only as a “reference implementation”
  - Similar to software rasterization
- Customers comparing performance of previous GPU algorithms to new GPU algorithms
  - “What have you done for me lately?”
- Our previous recommendation of prior graphics experience has been validated.
- Our approach of starting small with a GPU port, building up a framework, then leveraging it as it matures has also been validated.

Footprint Removal - Summary

Footprint Removal on the GPU – Summary

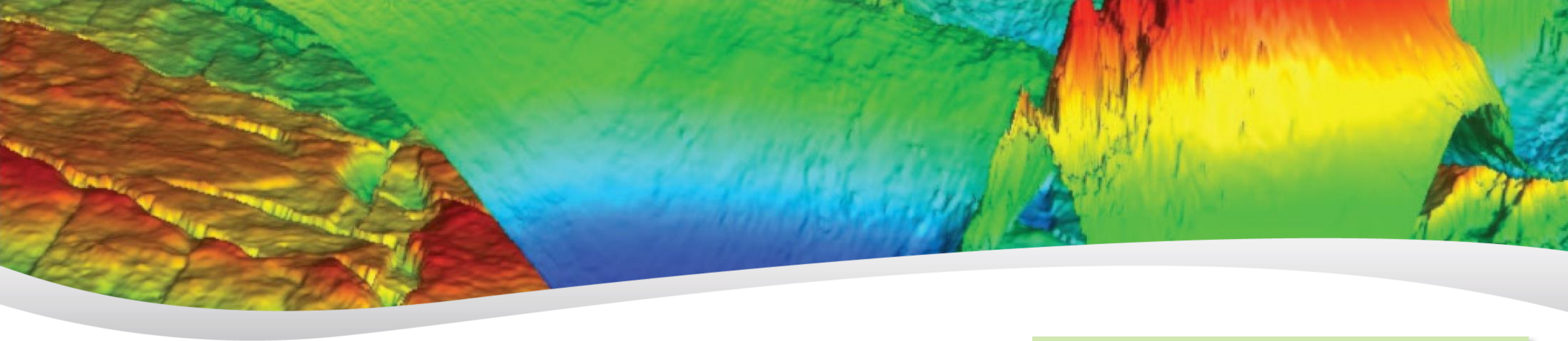
- Acquisition Footprint Removal
  – Striping artifacts, even on modern data
- GPU Port – Performance Impact
  – Up to 30x faster
- GPU Port – User/Workflow Impact
  – Users can run many passes, even dip compensated and/or oblique
- What we’ve learned
  – Don’t Port and Forget
  – Revisit / Retune / Reoptimize

Footprint Removal on the GPU – Acknowledgements

- Thanks to Steve Dominguez, Jay Faulkner, and CGG GeoSoftware Management
  - Benchmark testing, Development effort, R&D support

- Thanks to Nvidia, HP, Lenovo, Magma, and Advanced HPC
  - R&D hardware support, testing utilities, R&D consultation resources

- Thanks to our research sponsors
  - Conoco Phillips, Chevron, BP, BHP, Stone Energy, Apache, Repsol



Thank you

Please complete the Presenter Evaluation sent to you by email or through the GTC Mobile App. Your feedback is important!

- Jonathan Marbach, Ph.D., jonathan.marbach@cgg.com
  Steve Dominguez, Jay Faulkner
  CGG GeoSoftware

Passion for Geoscience
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