

Sub-salt overpressure detection before drilling using wave equation migration technologies

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Wave Imaging Technology Inc.

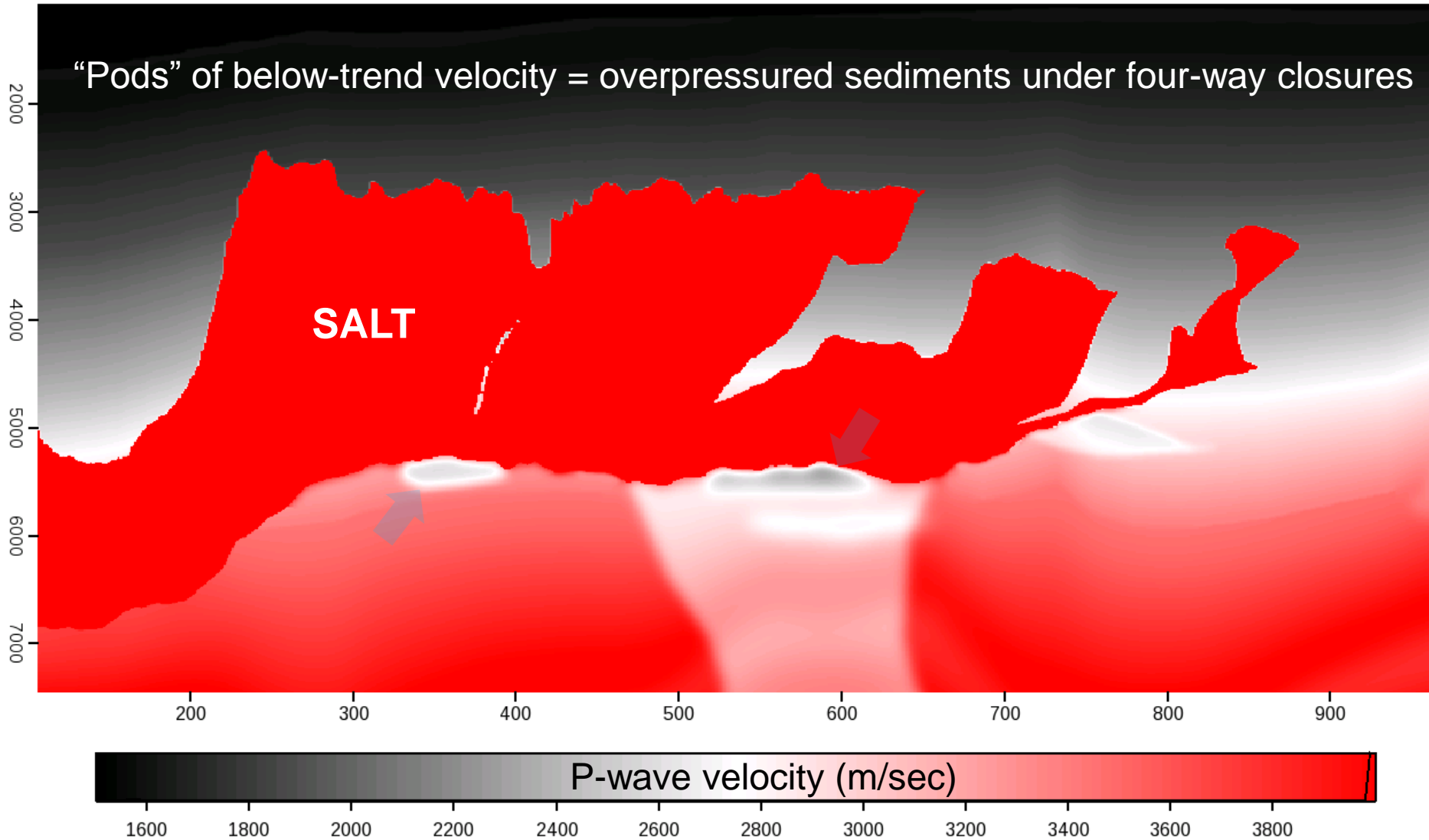
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2009 SEG International Conference – Houston





BP Velocity Benchmark Model





Overpressure ~ Velocity

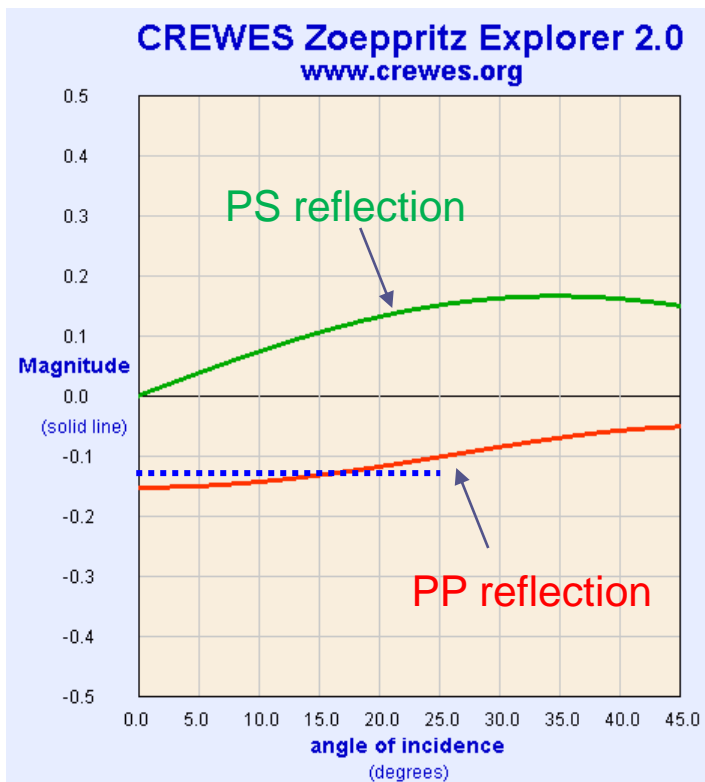
- Deviation of VP from a “background” trend
- Phase 1:
 - High BoS amplitude ~ VP just under BoS
 - Normalize BoS amplitude by overburden illumination
 - Feasibility study for Phase 2...
- Phase 2:
 - WEM focusing analysis – measure sub-salt VP



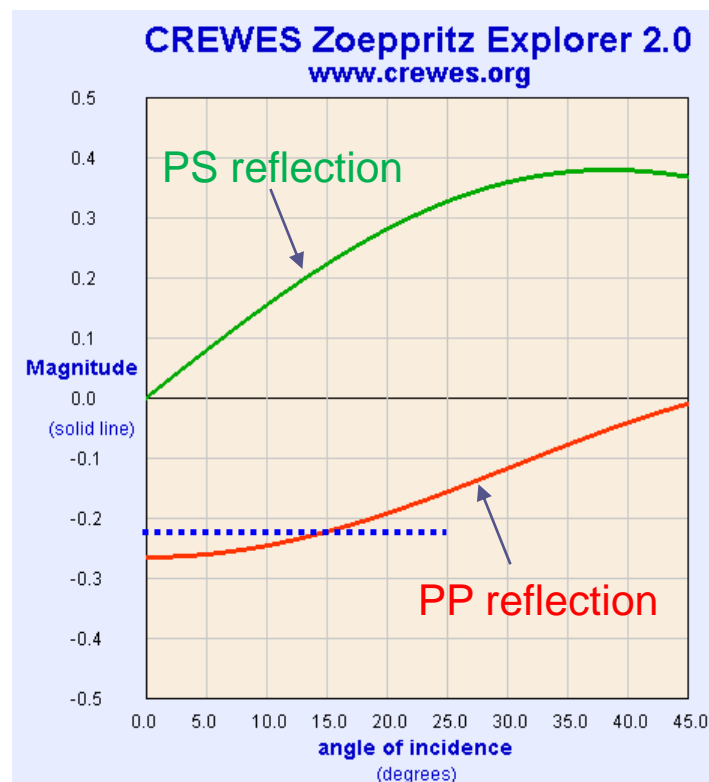
Zoeppritz BoS Reflection Modeling

Overpressure beneath salt → BoS reflection increases ~ 1.5-3X

- Normal pressure case
 - $VP=9,500$ ft/sec, $VP/VS=2$

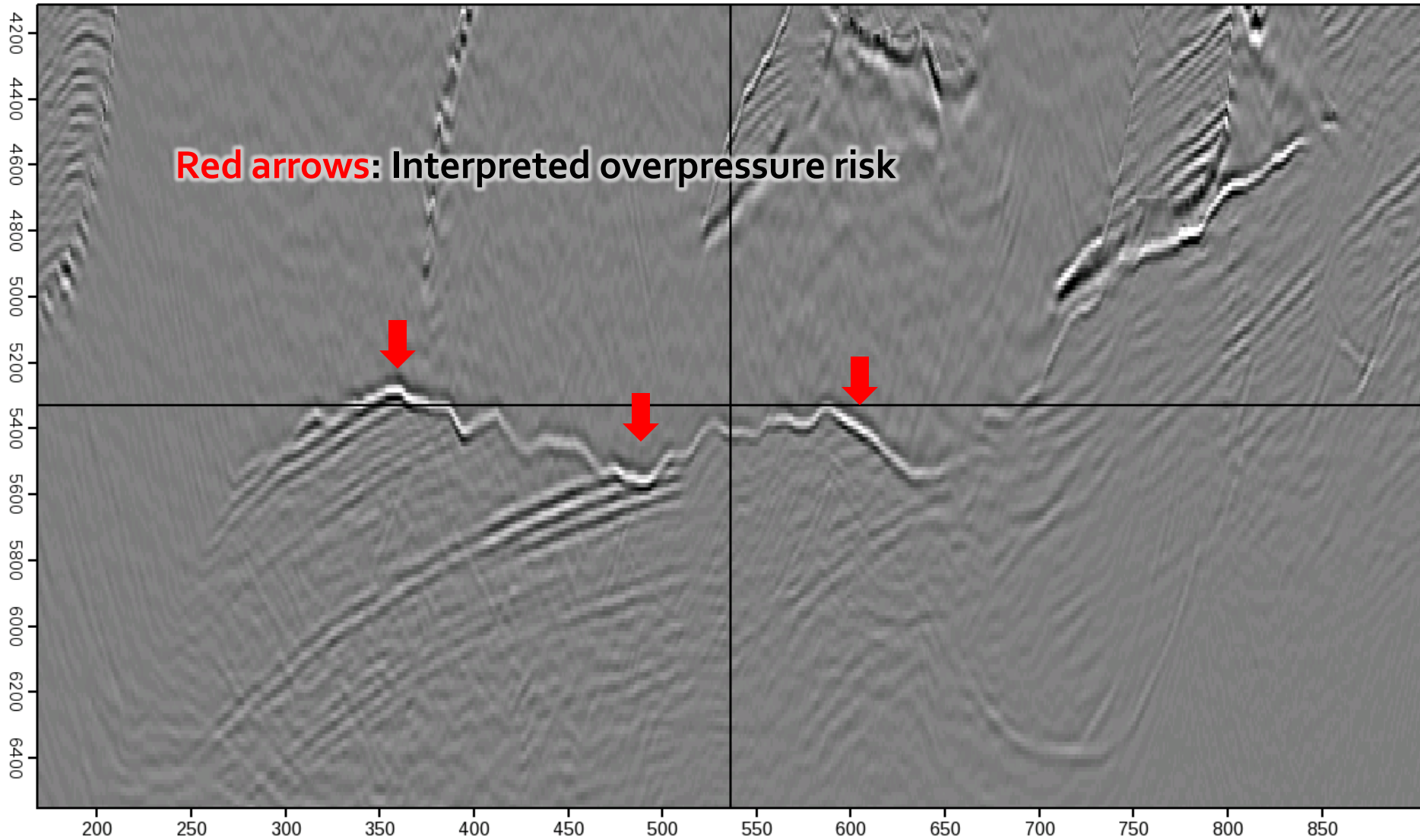


- Overpressure case
 - $VP=7,500$ ft/sec, $VP/VS=3$



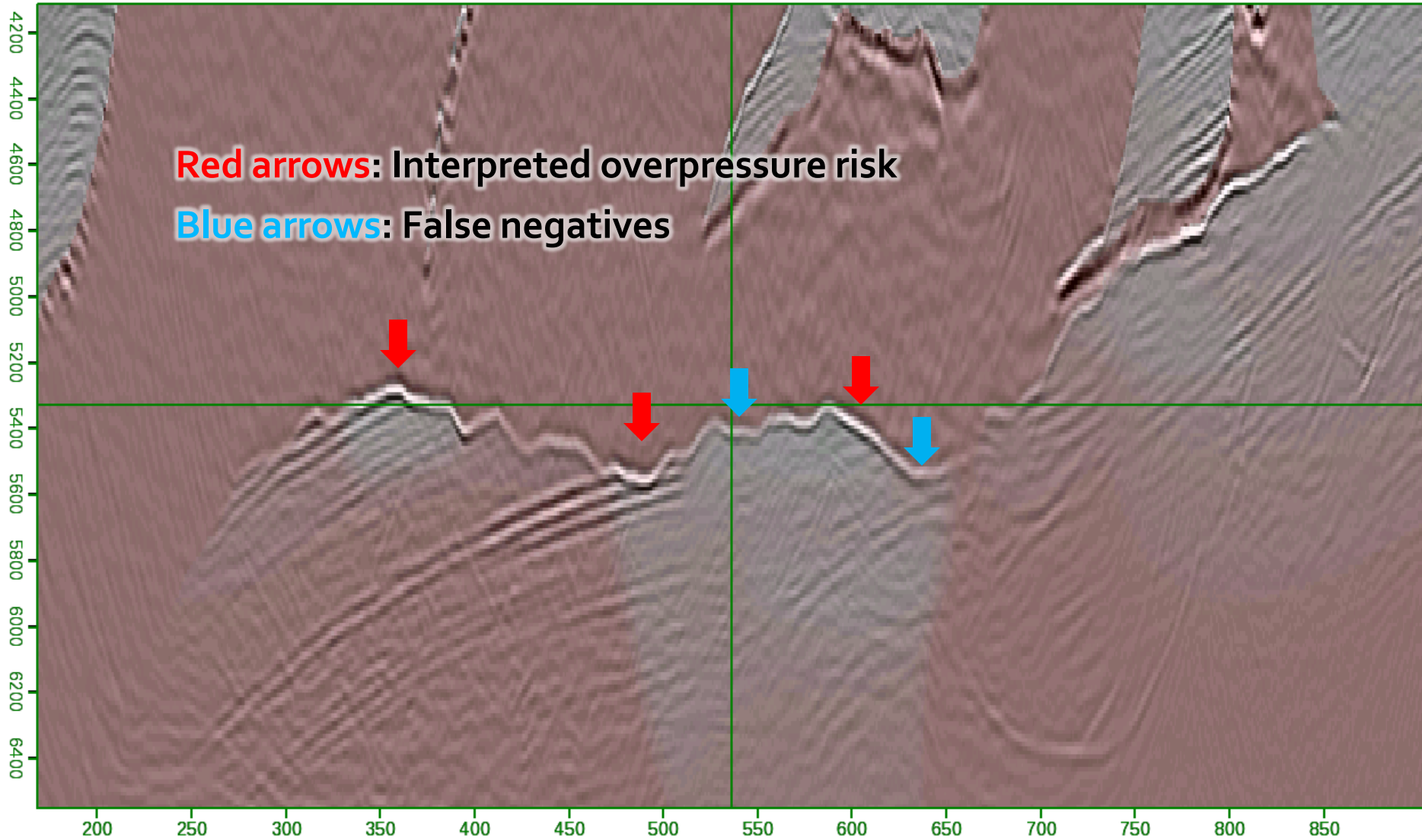


WEM with Known Velocity



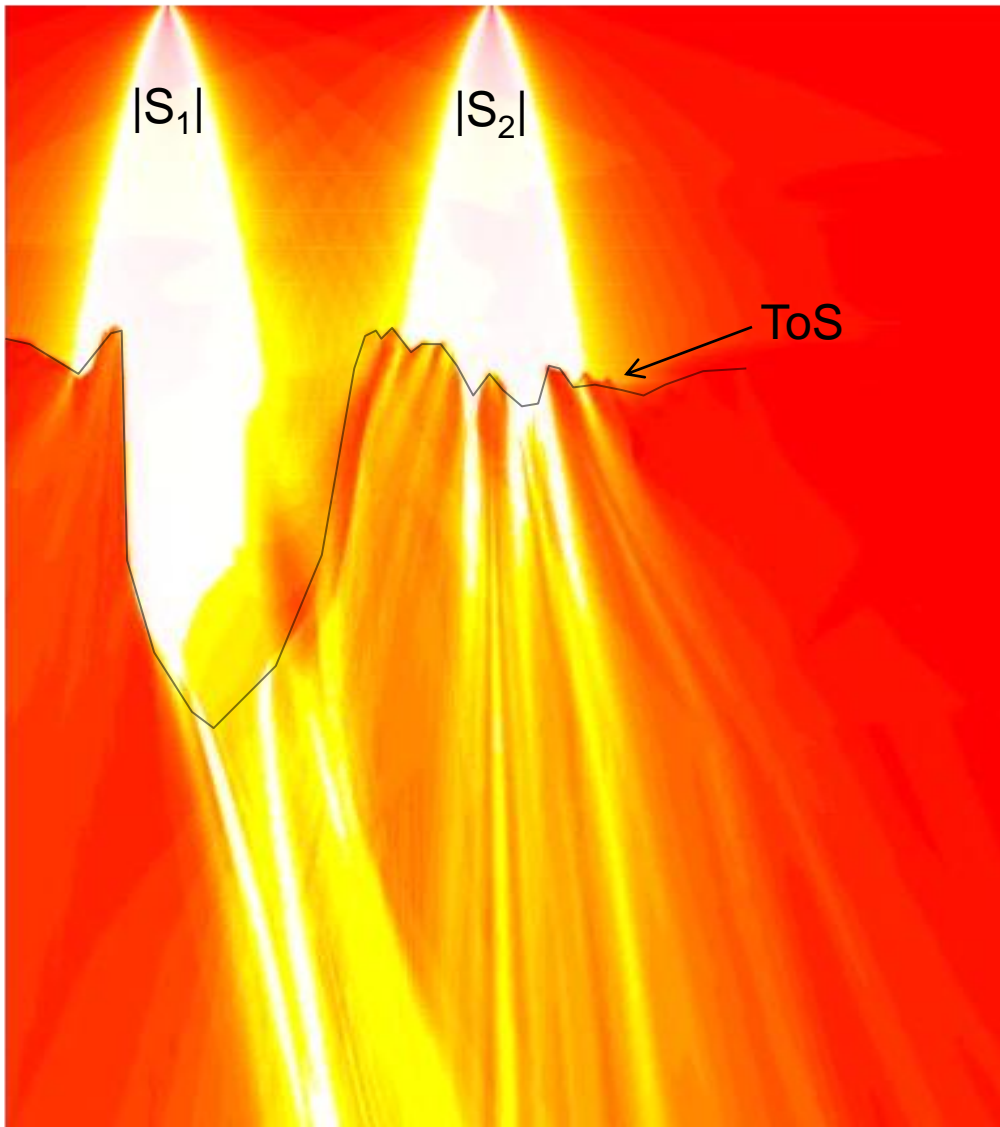


WEM with Known Velocity





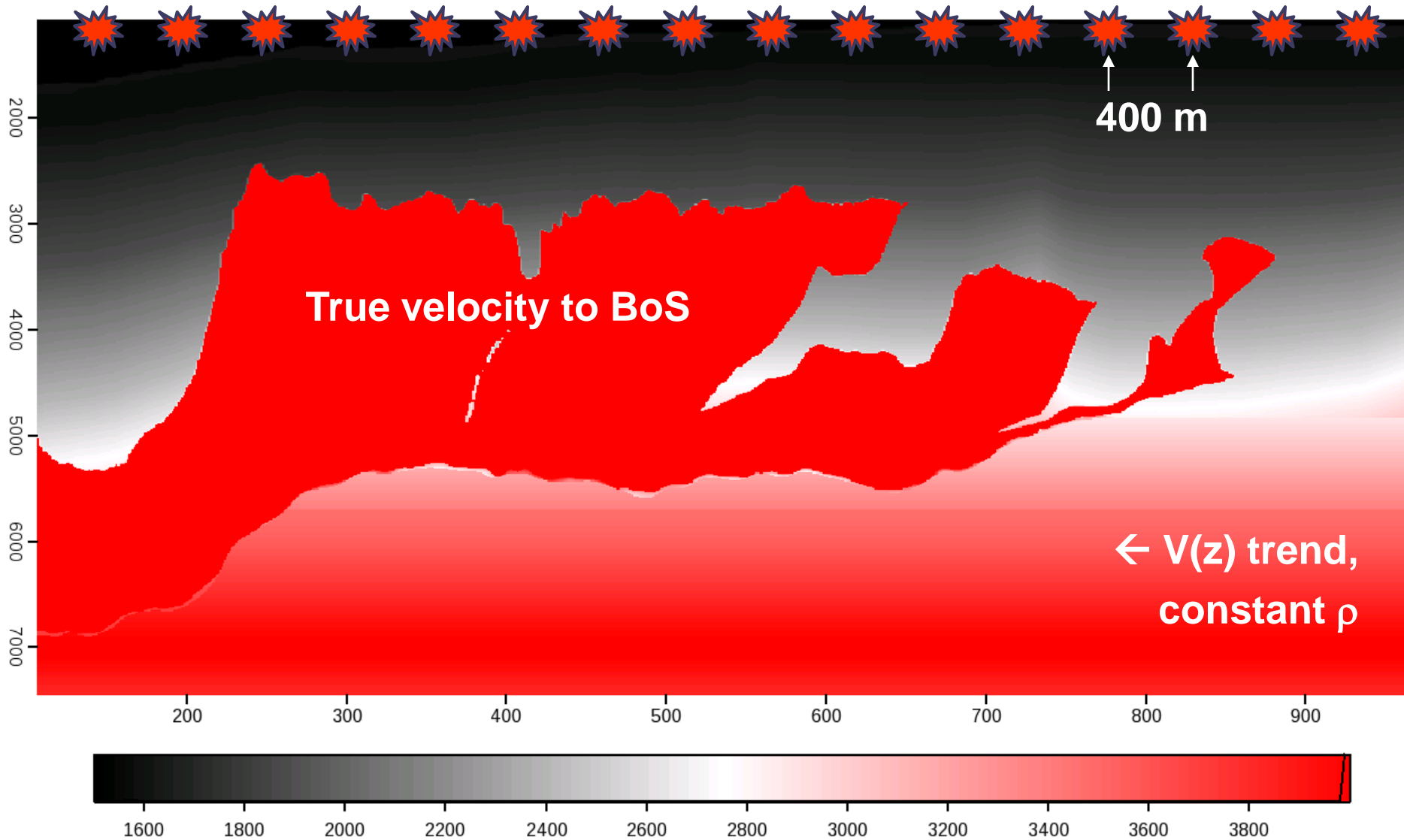
Overburden Illumination Correction



- False negatives → overburden effects
- Normalization by $|S|$ – only half the story
- Full-wave simulation and WEM to measure BoS illumination

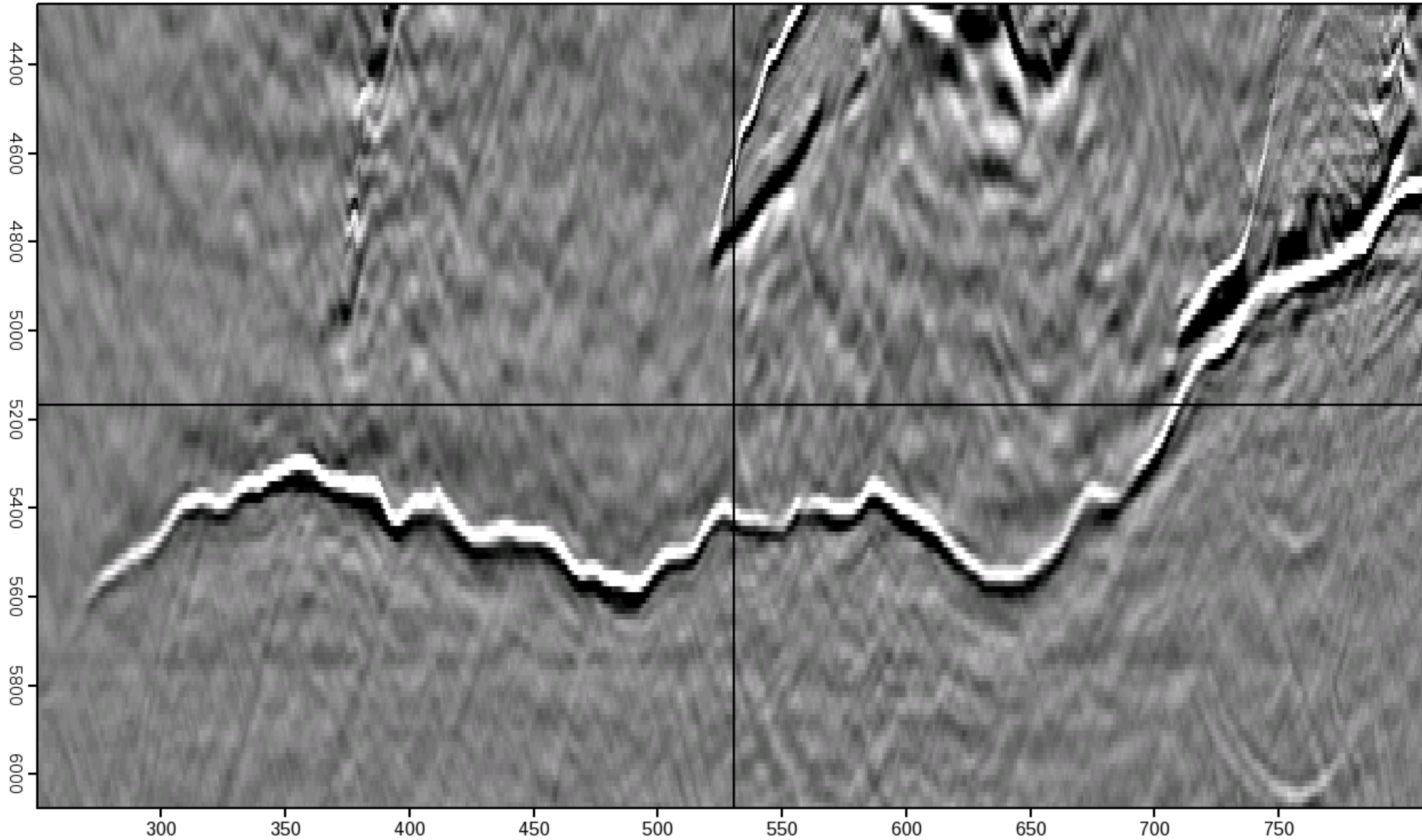


Phase 1: Model Acoustic Shots



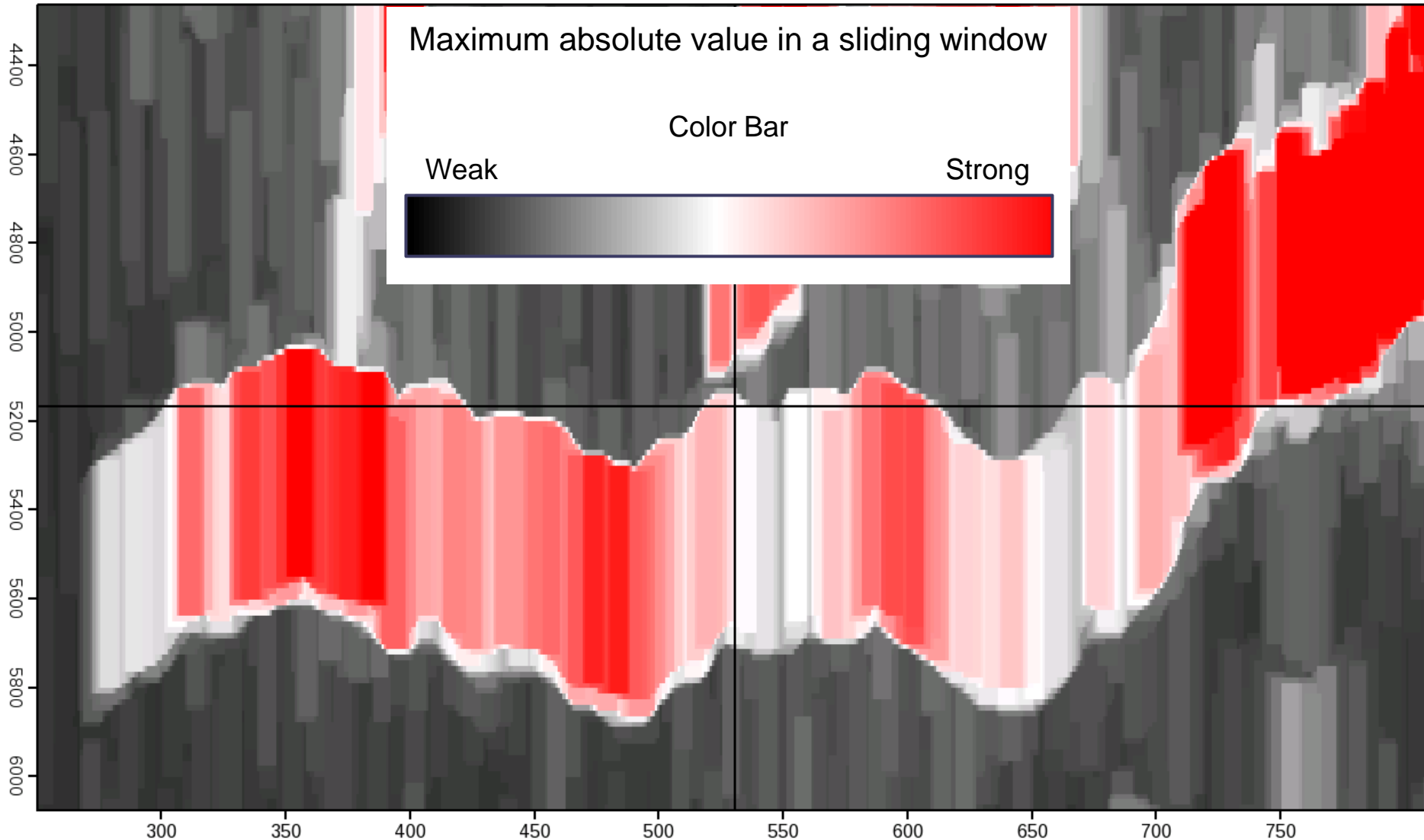


Phase 1: WEM of modeled shots



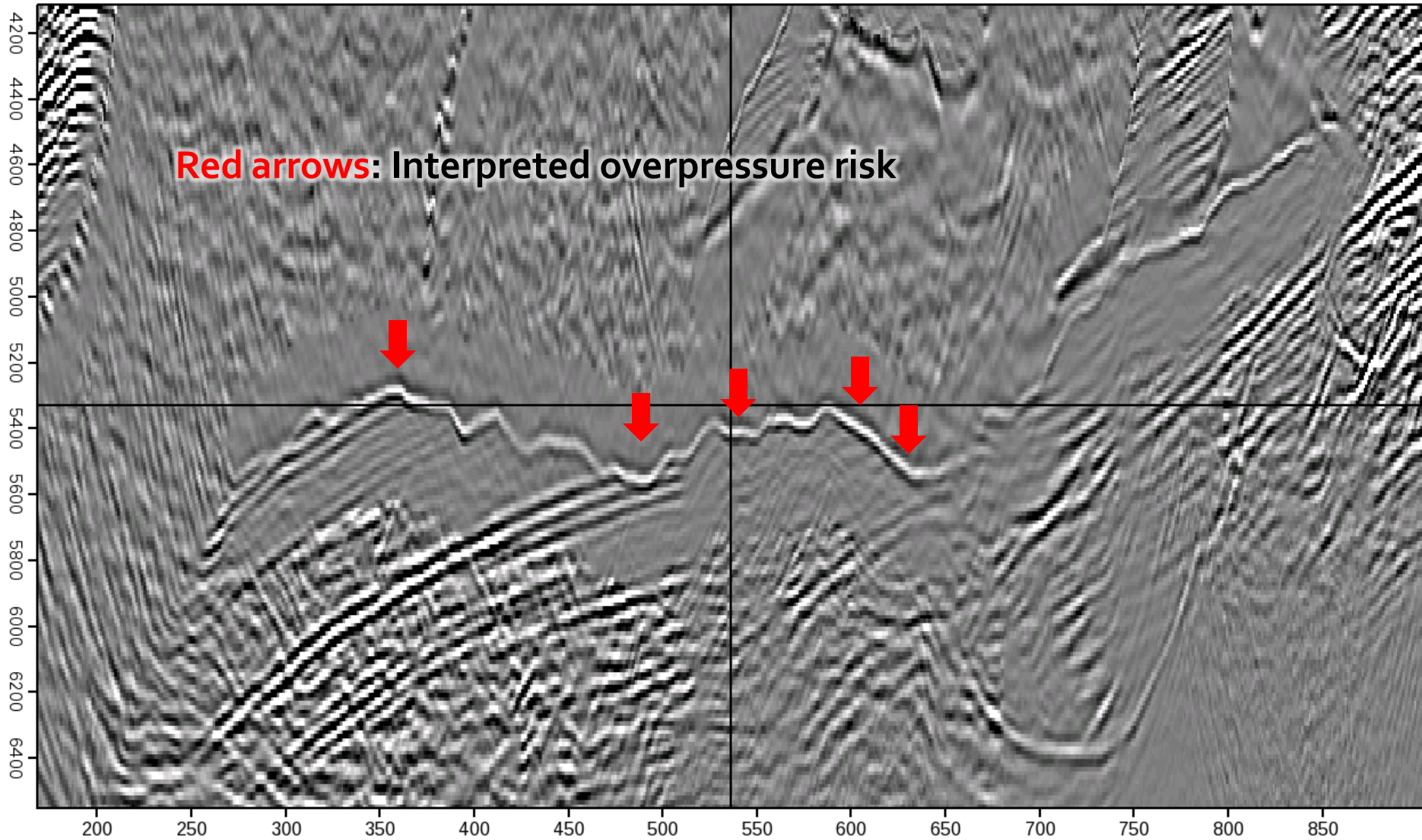


Phase 1: Normalization Function



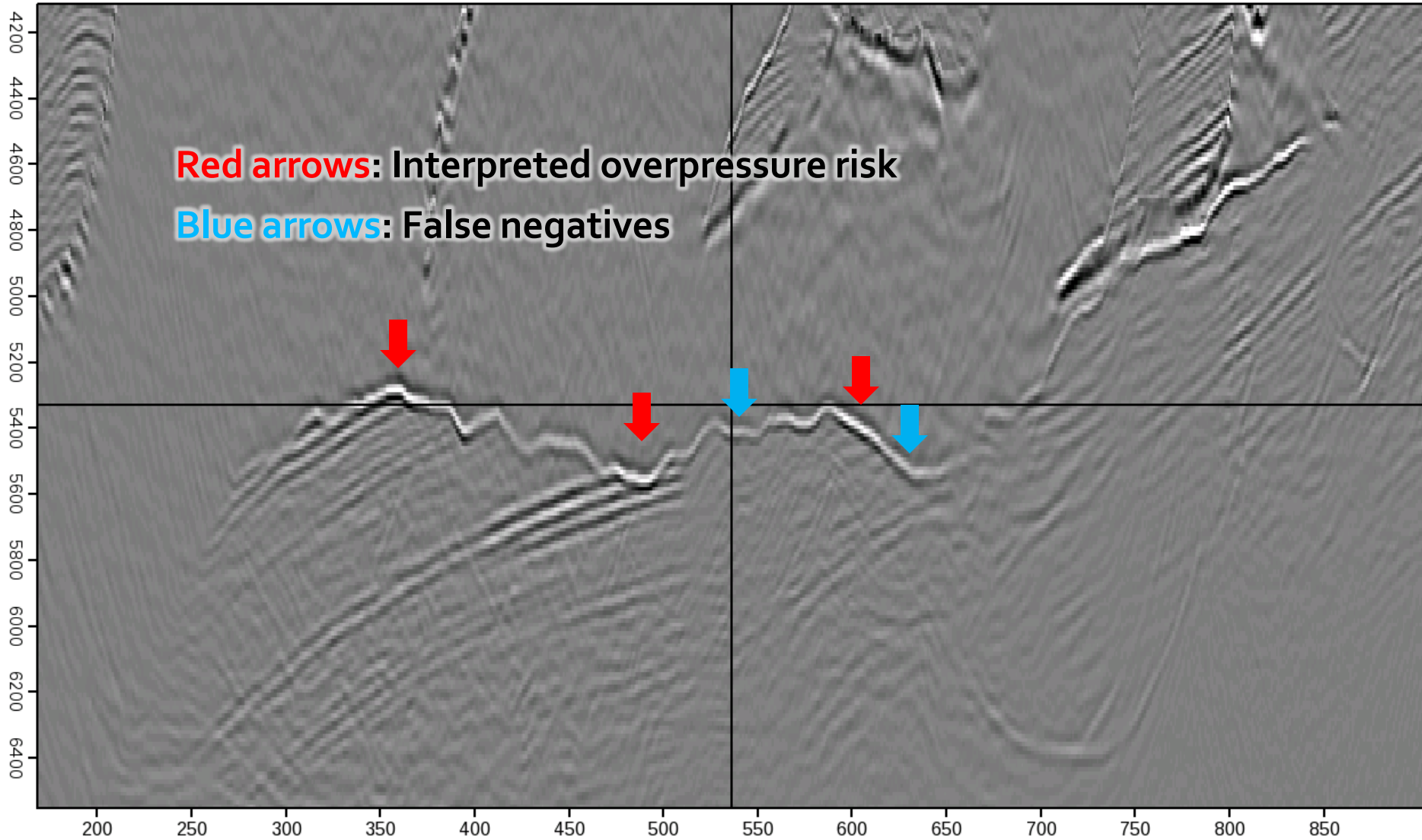


Phase 1: Normalized WEM Image



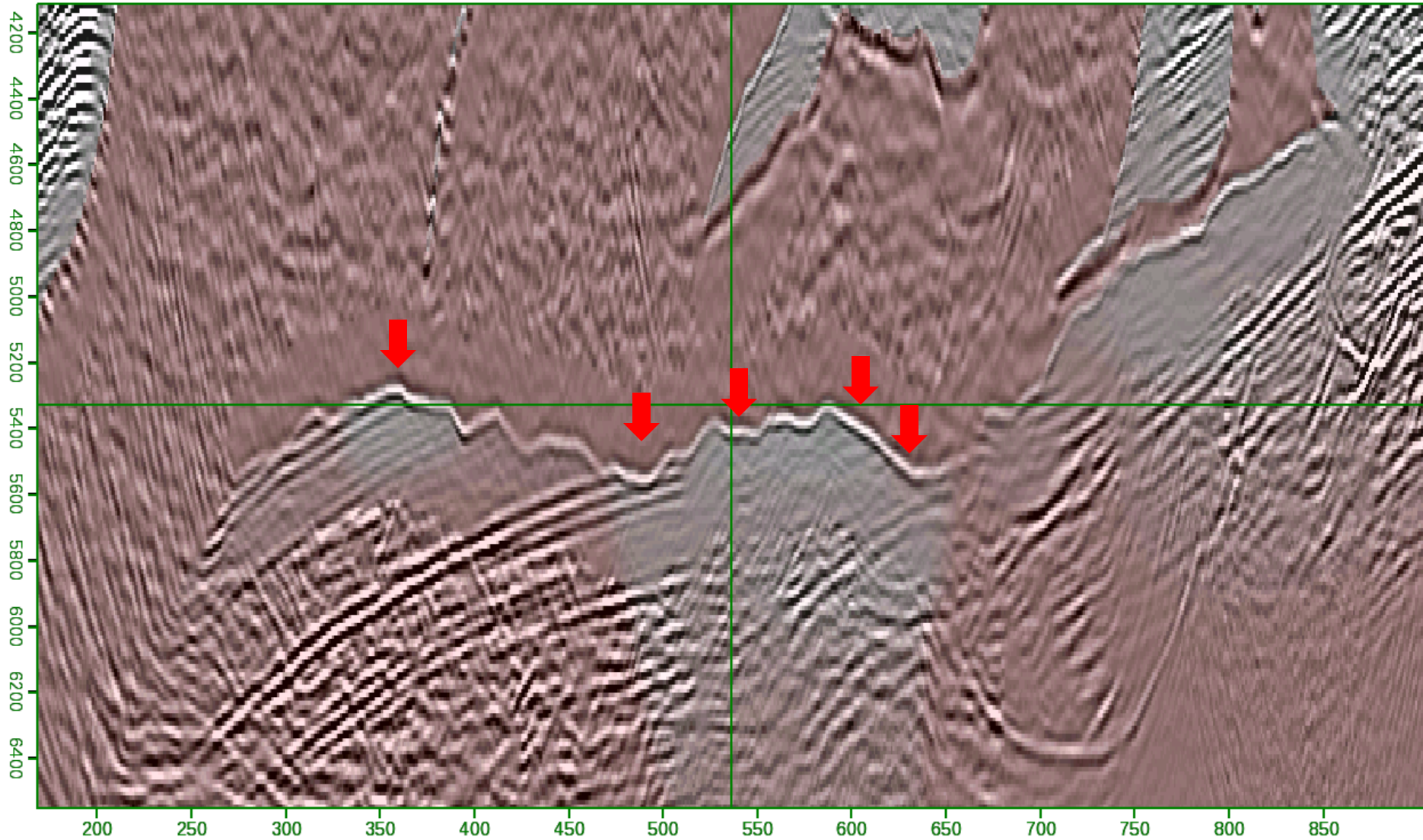


Phase 1: Raw WEM Image





Phase 1: Normalized WEM Image



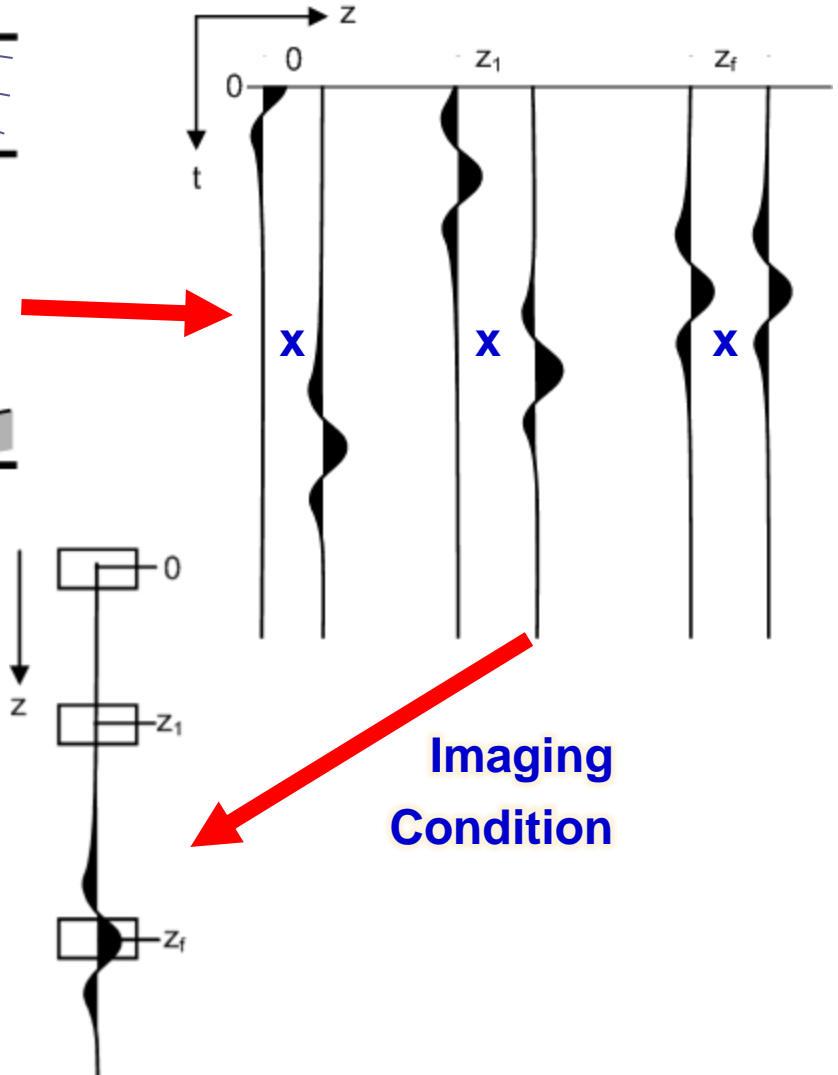
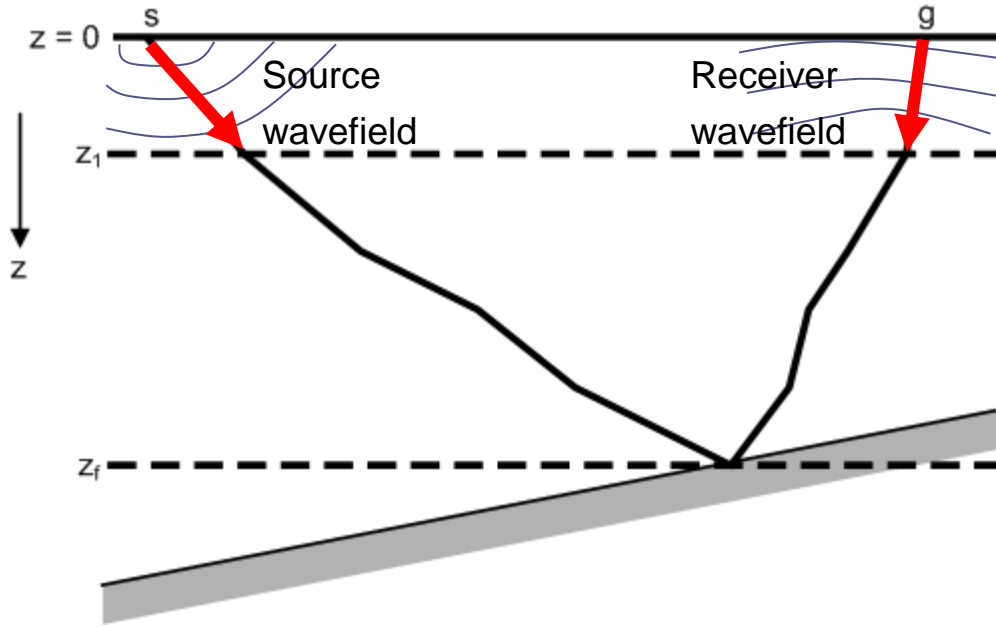


Phase 2: Measure Sub-salt Velocity

- Migration Velocity Focusing Analysis (MVFA)
 - Time-shift imaging condition for WEM
 - Relate time shift to ΔV_{rms}
- Sub-salt Overpressure:
 - Use “best” velocity to BoS, “trend” below salt
 - Below-trend deviations = overpressure potential
 - Perfect velocity below salt not required



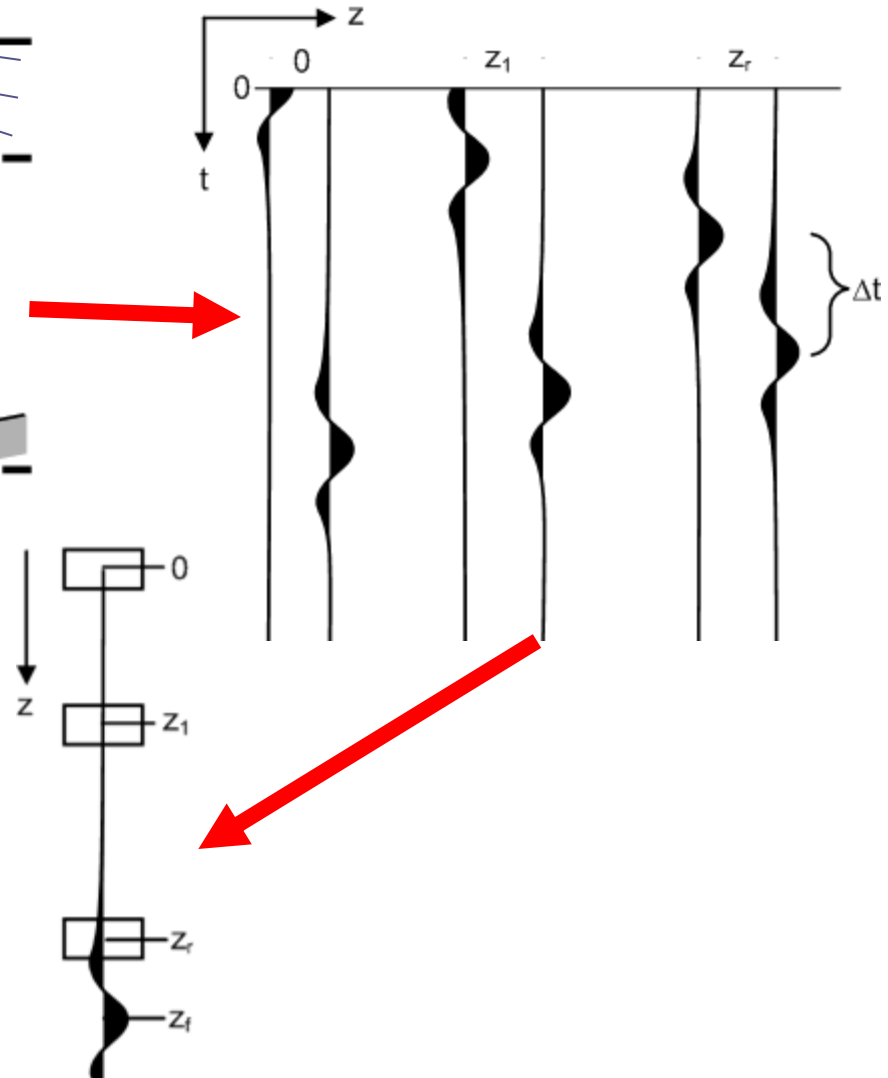
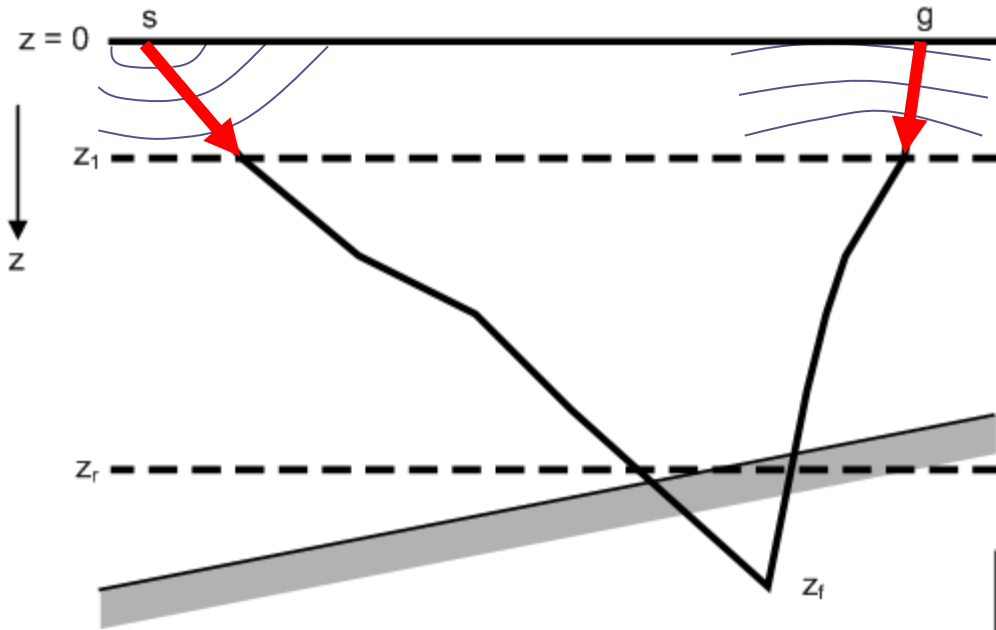
Shot Record Migration with Correct Velocity



Imaging Condition



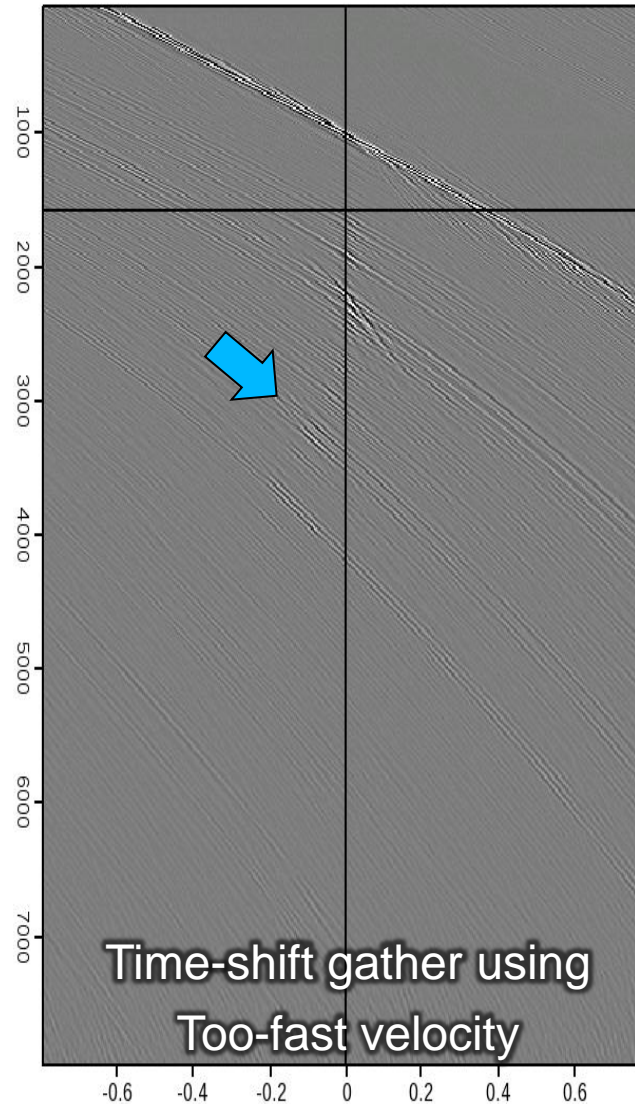
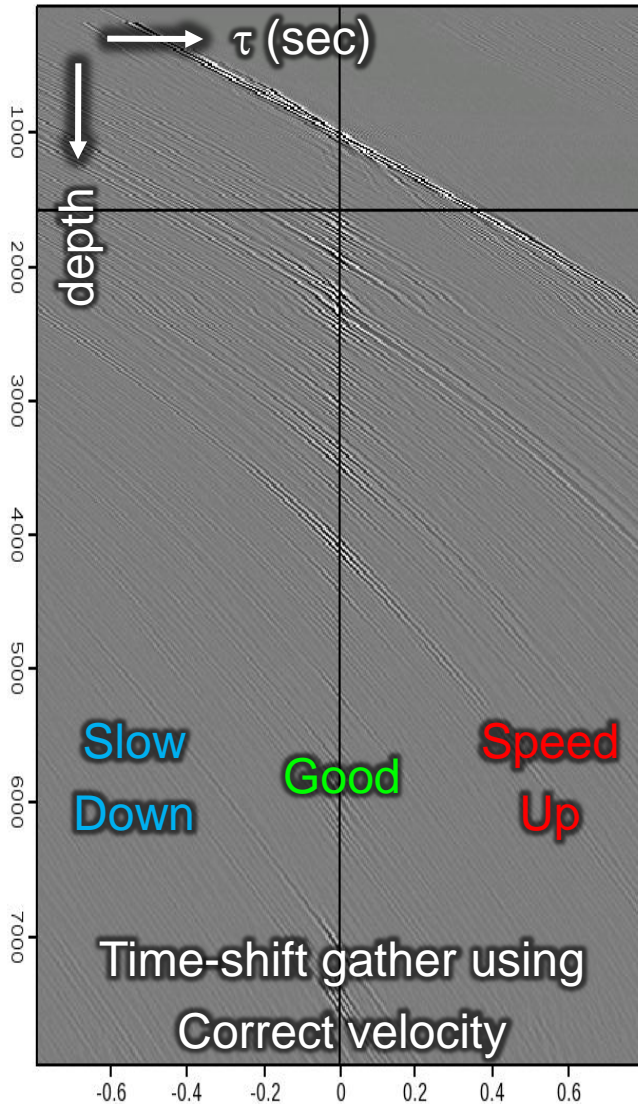
Shot Record Migration with Too-fast Velocity



Measure Δt , relate to ΔV



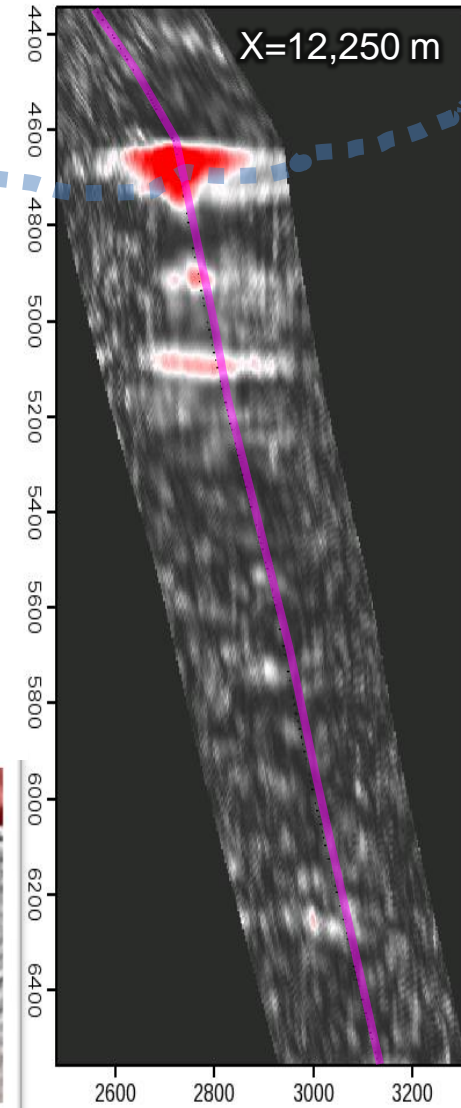
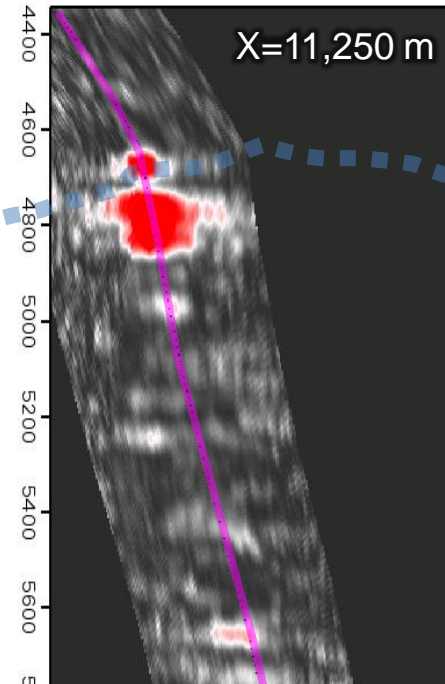
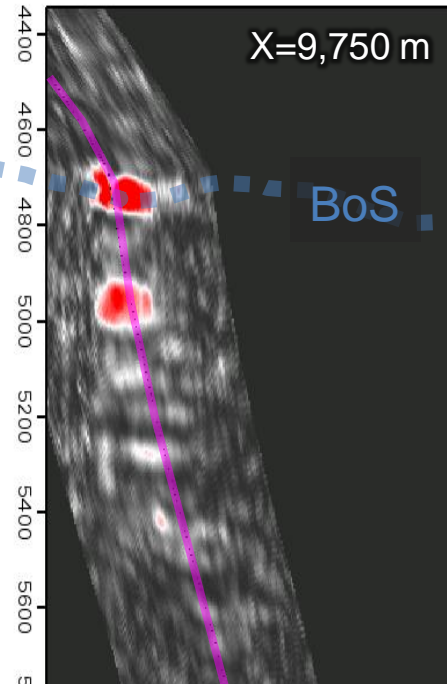
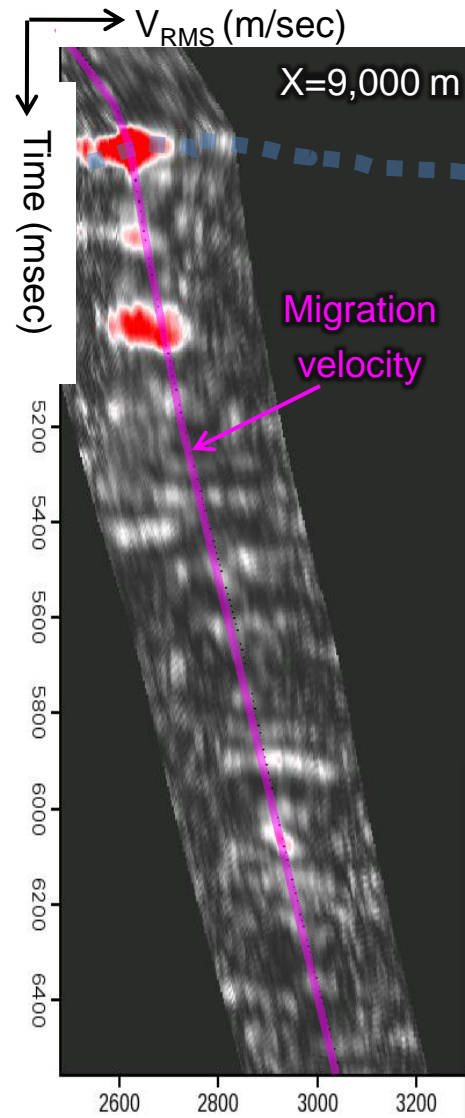
Migration Velocity Focusing Analysis (MVFA)



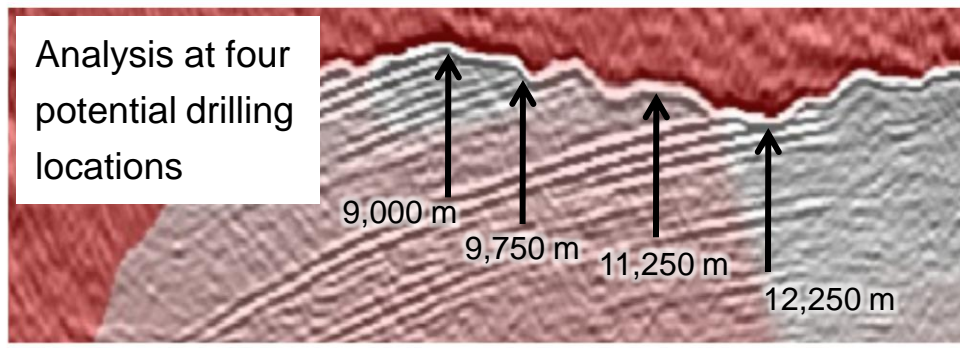
- Time shift before correlation
- Relate best-focusing τ to Δv
- Robust when gathers are "ugly"



Phase 2: MVFA Under Salt

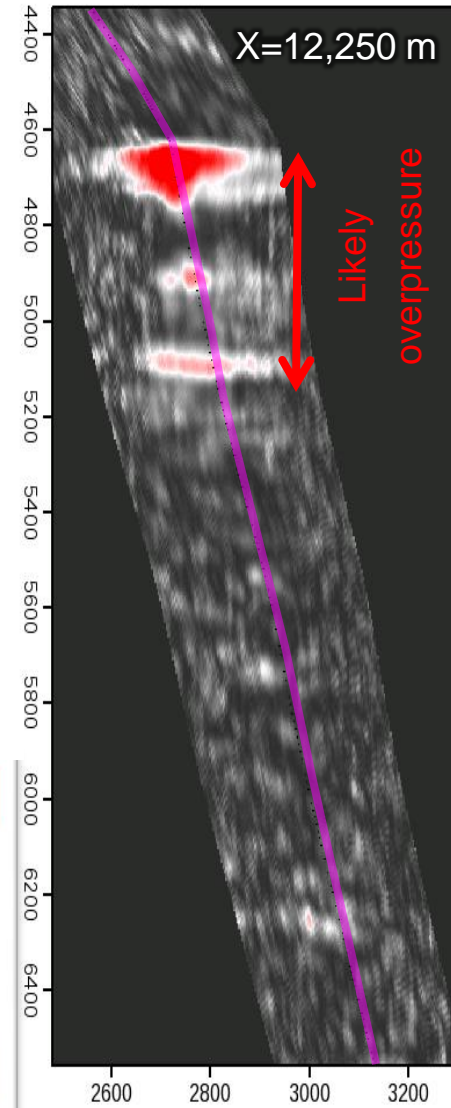
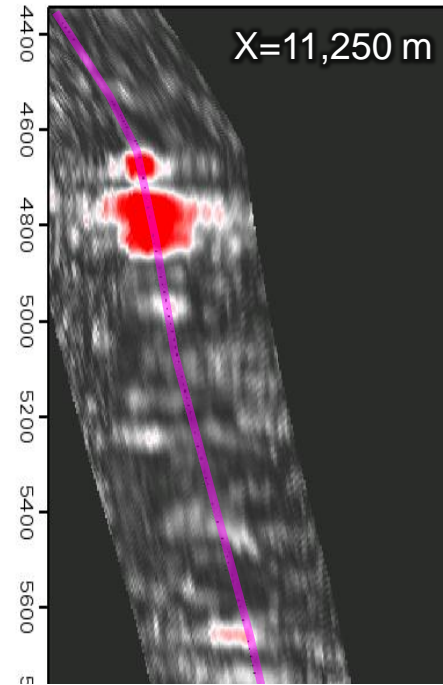
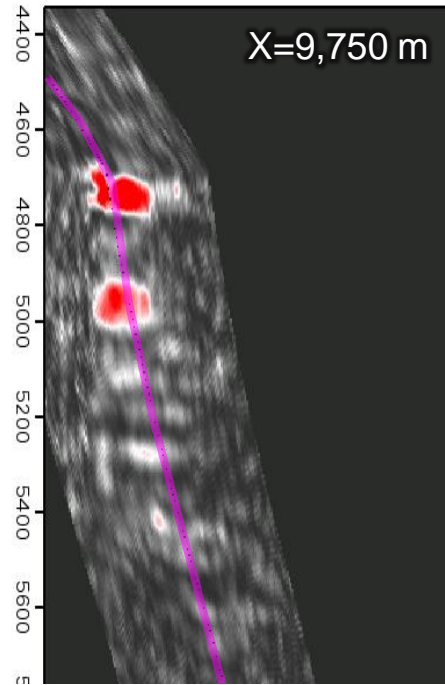
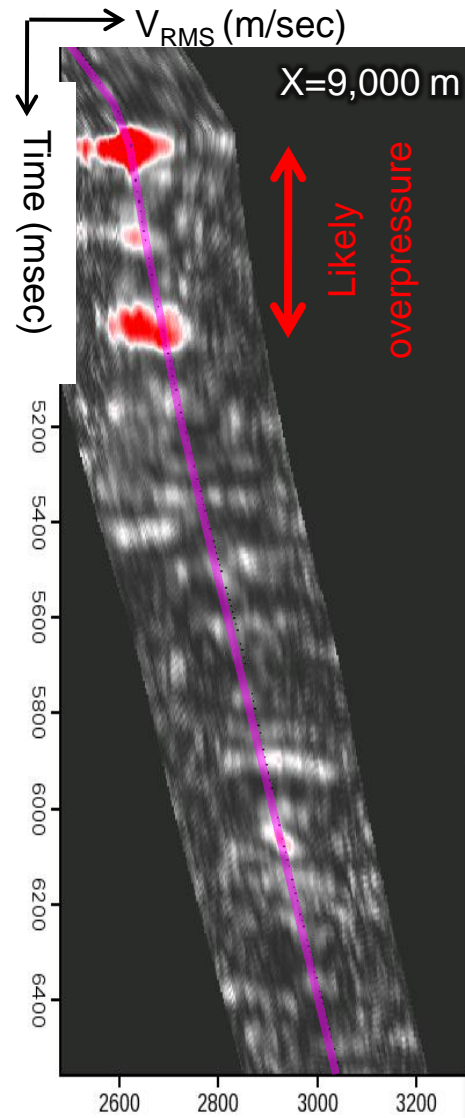


Migration velocity = perfect to BoS, $v(z)$ trend below salt

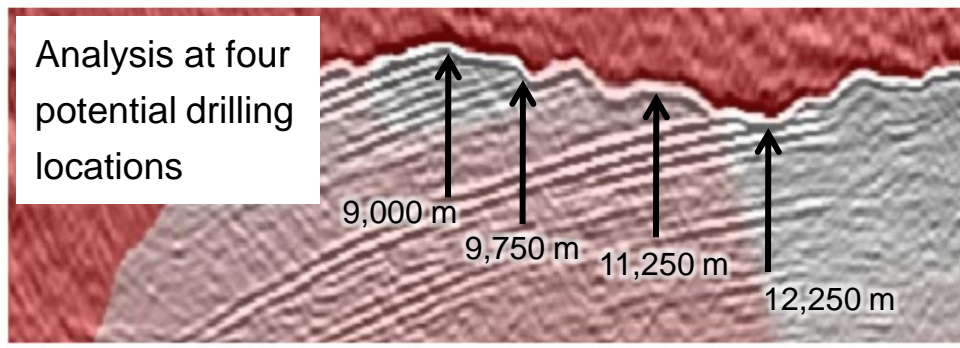




Phase 2: MVFA Under Salt

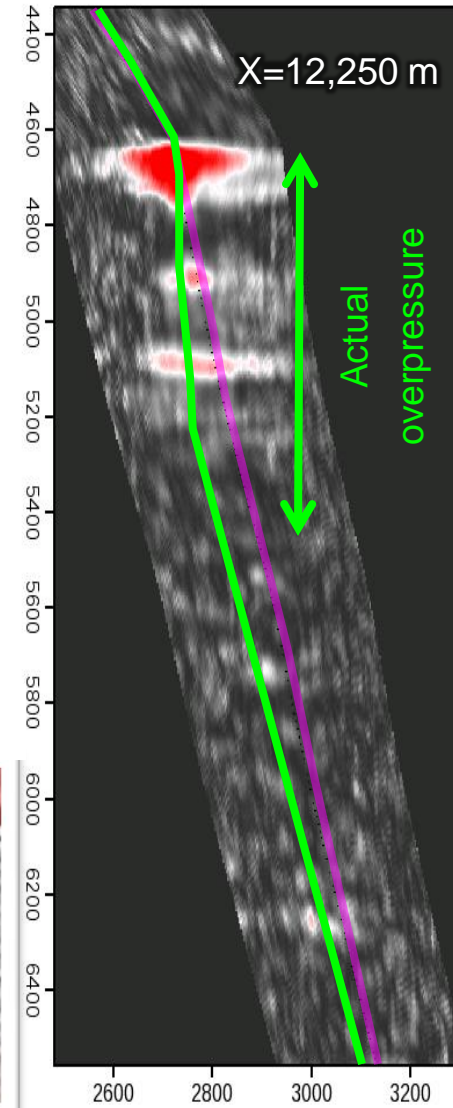
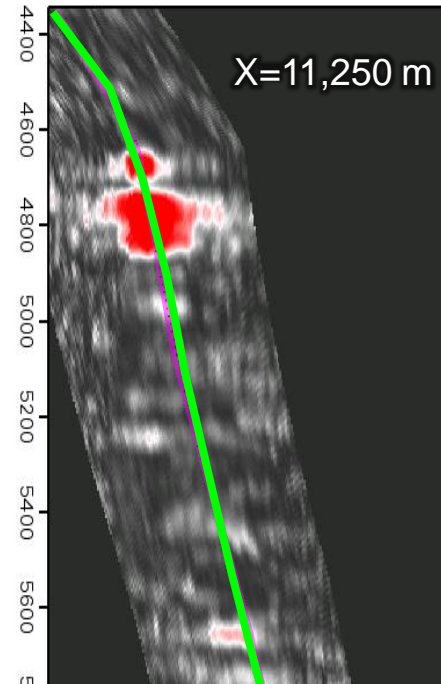
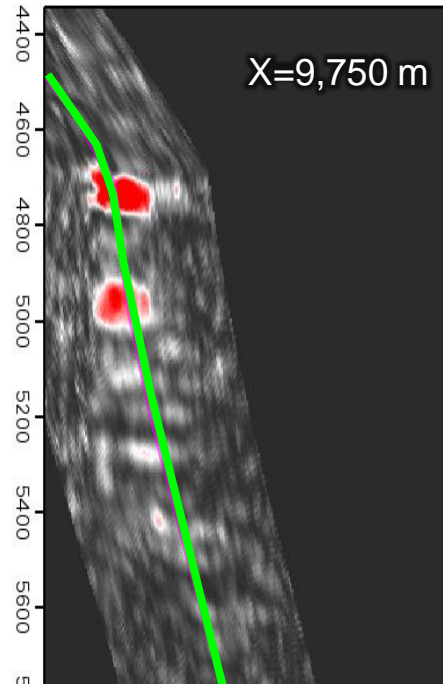
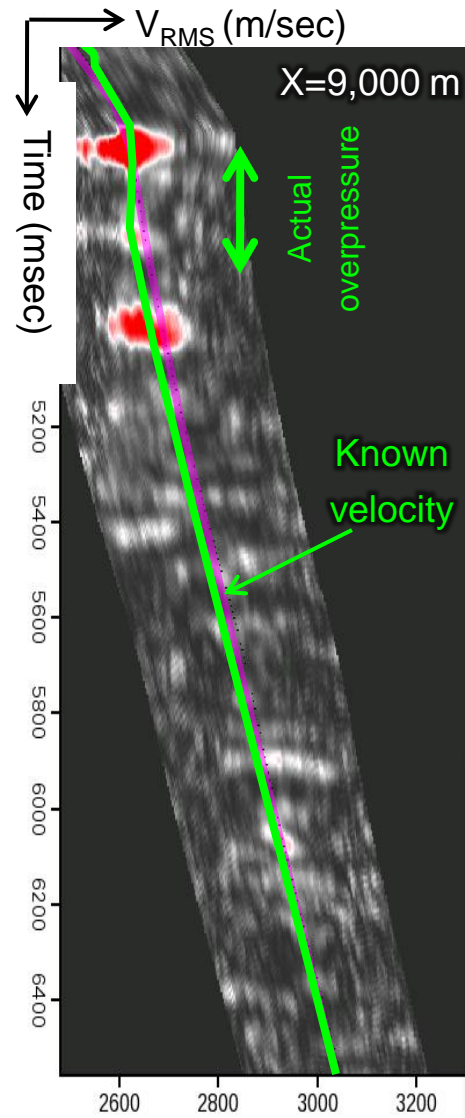


Migration velocity = perfect to BoS, $v(z)$ trend below salt

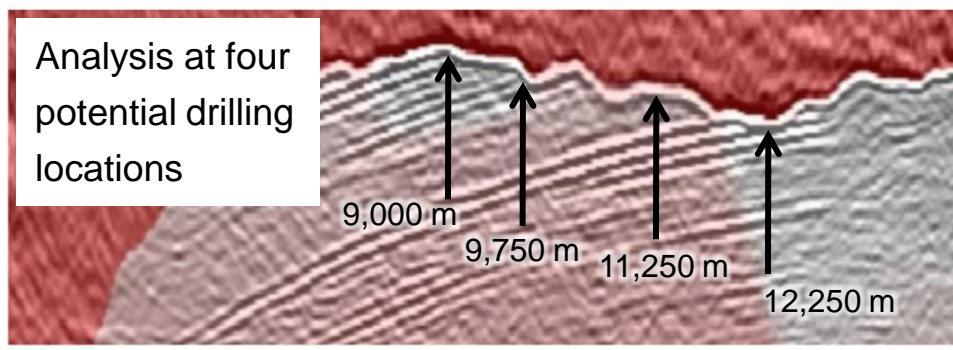




Phase 2: MVFA Under Salt



Migration velocity = perfect to BoS, $v(z)$ trend below salt



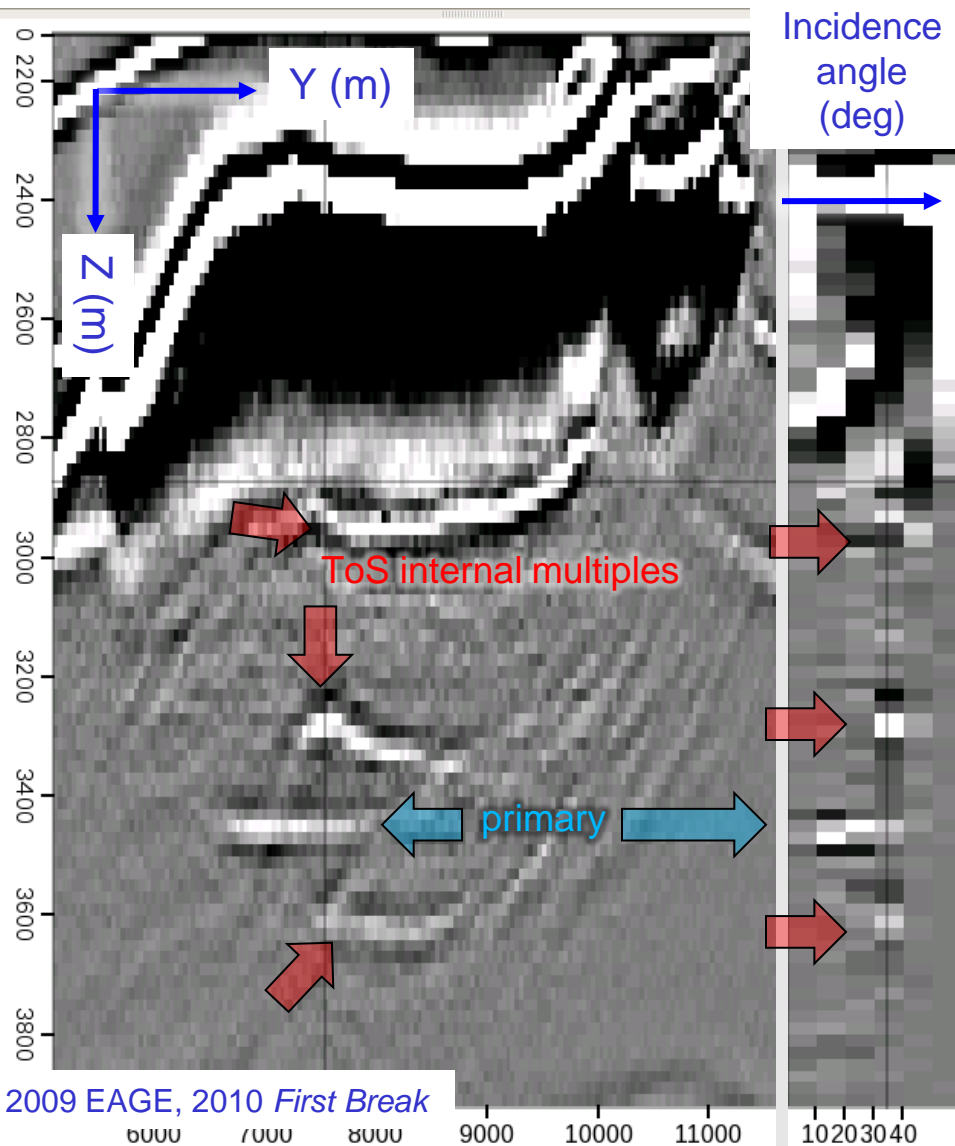
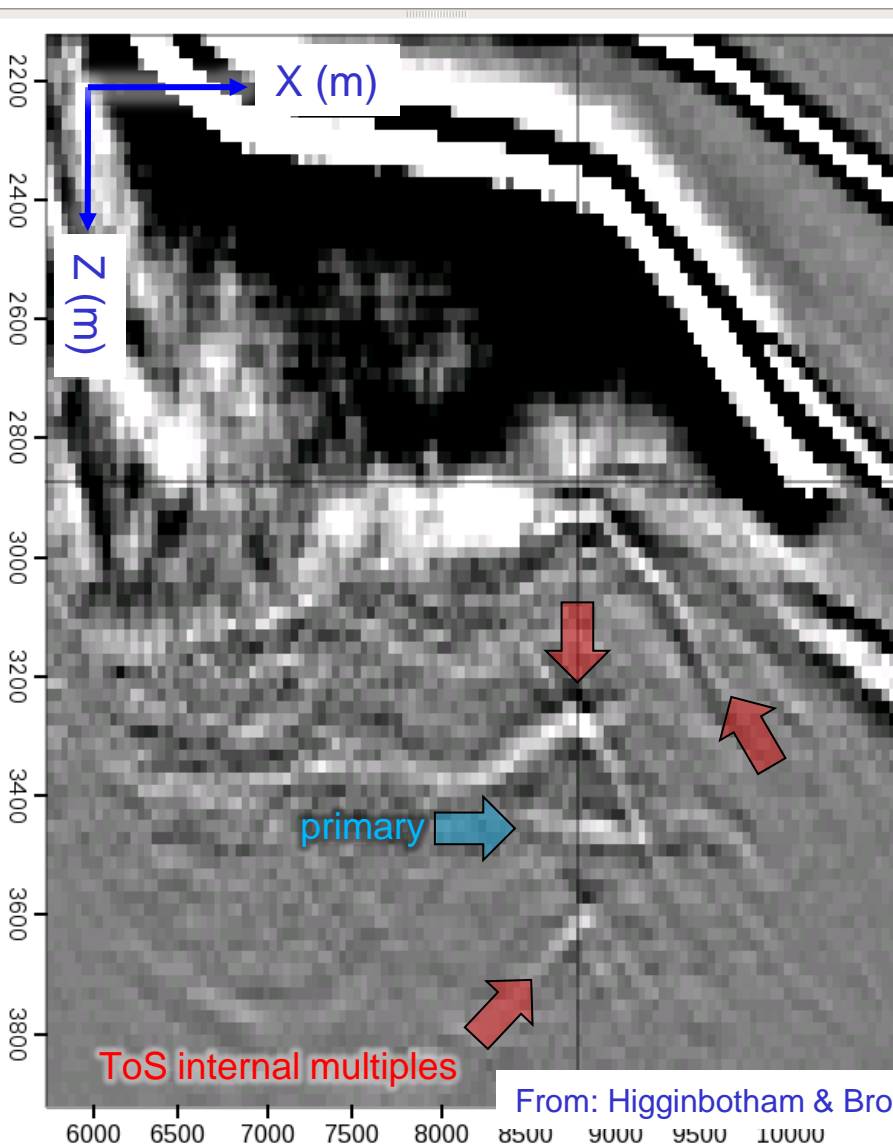


Phase 1 Enhances Phase 2

- Phase 2 big question: reliability of focusing?
- Overburden complexity degrades focusing
- Answer: MVFA using modeled data
 - Sub-salt test reflectors
 - Migrate with trial velocity
 - Diagnostics: focusing width, skew



WEM Angles...Converted Waves?



From: Higginbotham & Brown, 2009 EAGE, 2010 *First Break*



Conclusions and Discussion

- Pre-drill sub-salt overpressure attributes
 - VP-based
 - From surface seismic
 - Efficacy on BP Salt Model
- Phase 1: Normalized BoS amplitude
- Phase 2: Sub-salt velocity with MVFA
- Complements VSP technologies...much cheaper than doing nothing



Thank you...

- Cosmin Macesanu and Bob Clapp
- BP
- Bob Shank/Gordon Smith (Chevron)

...for your attention!

(More information at SEG booth #215)