Using basis pursuit in seismic data

CRESWES Tech Talk

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Outline

- Basis pursuit
- Results
- AVO and frequency-dependent AVO
- Results
- Conclusion
- Future Work

Time-frequency analysis methods

- Short-Time Fourier Transform (STFT)
- Continuous Wavelet Transform (CWT)
- Synchro-squeezing Transform (SST)
- **Basis Pursuit (BP)**

Basis pursuit (BP) method

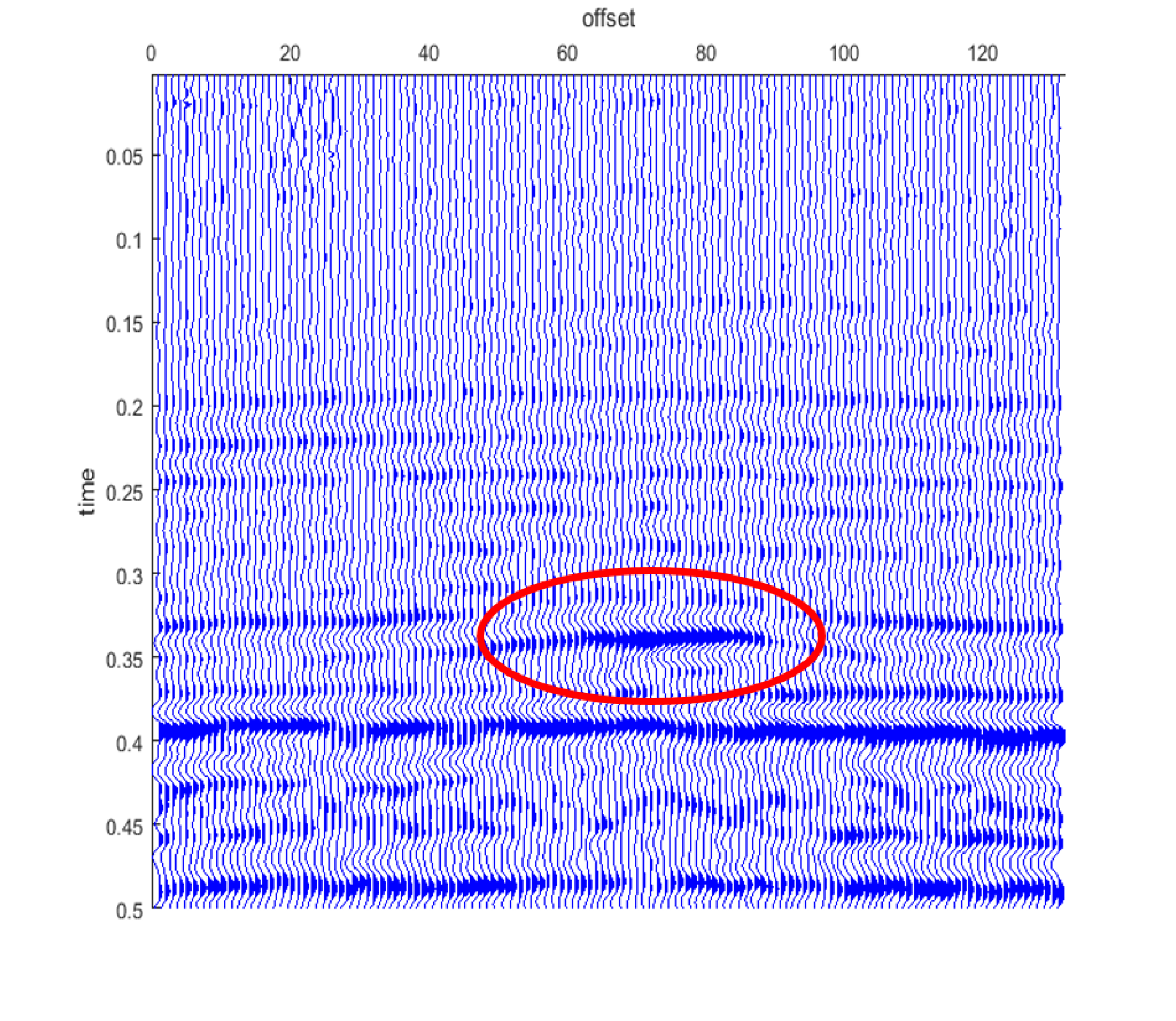
The signal

$$s(t) = \sum_{k=1}^{N} [\psi(t,n) * a(t,n)]$$

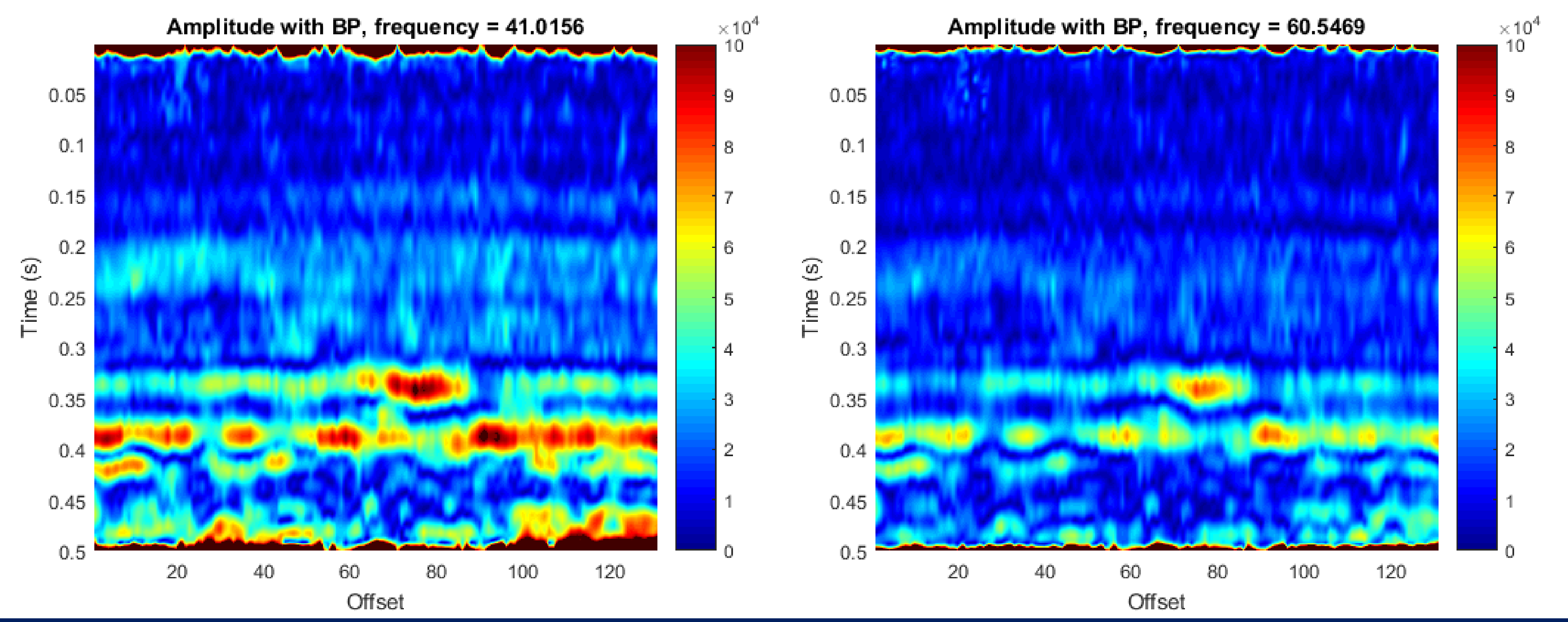
The cost function

$$J = \frac{1}{2} \|\vec{s} - D\vec{a}\|_2^2 + \lambda \|\vec{a}\|_1$$

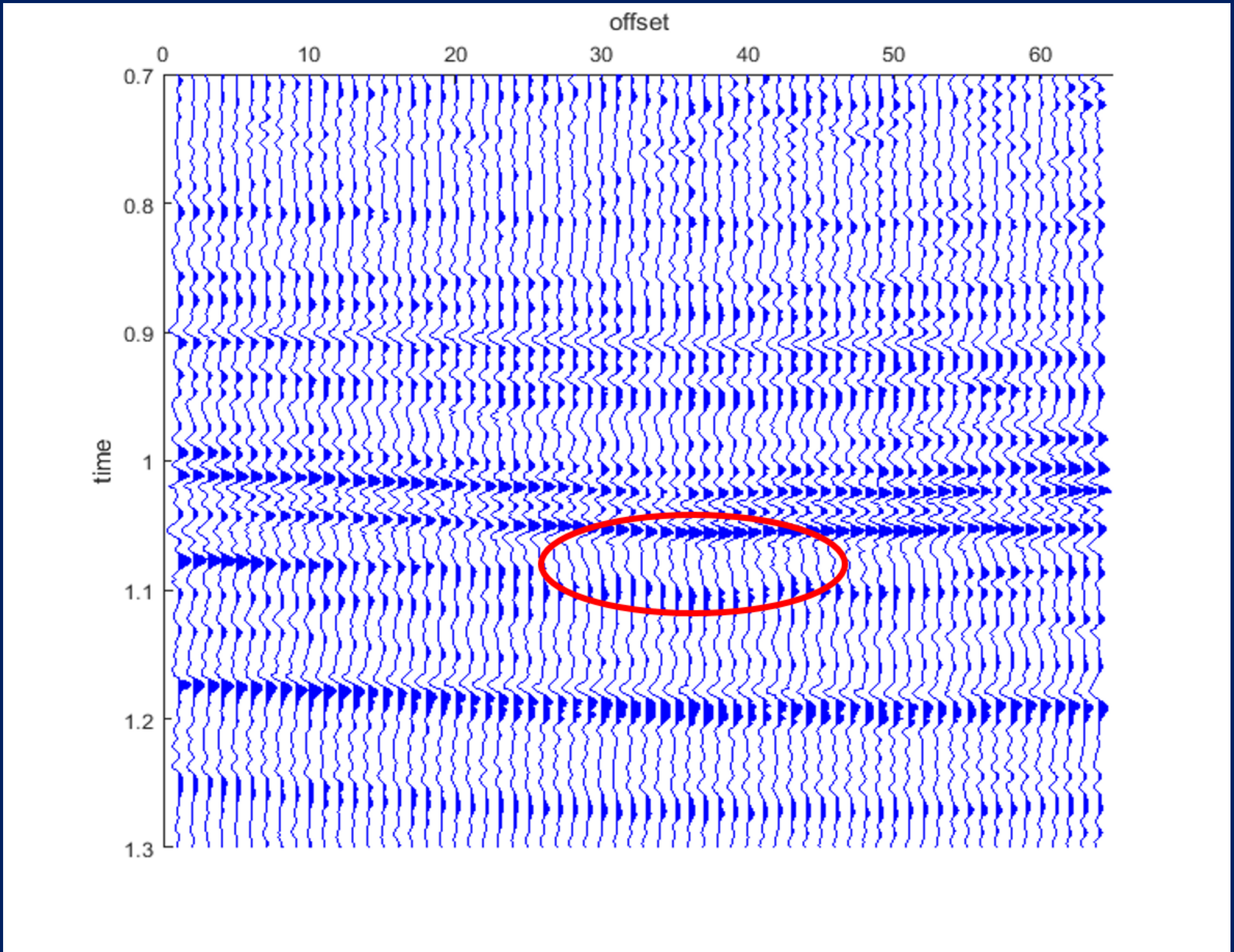
Reservoir data set



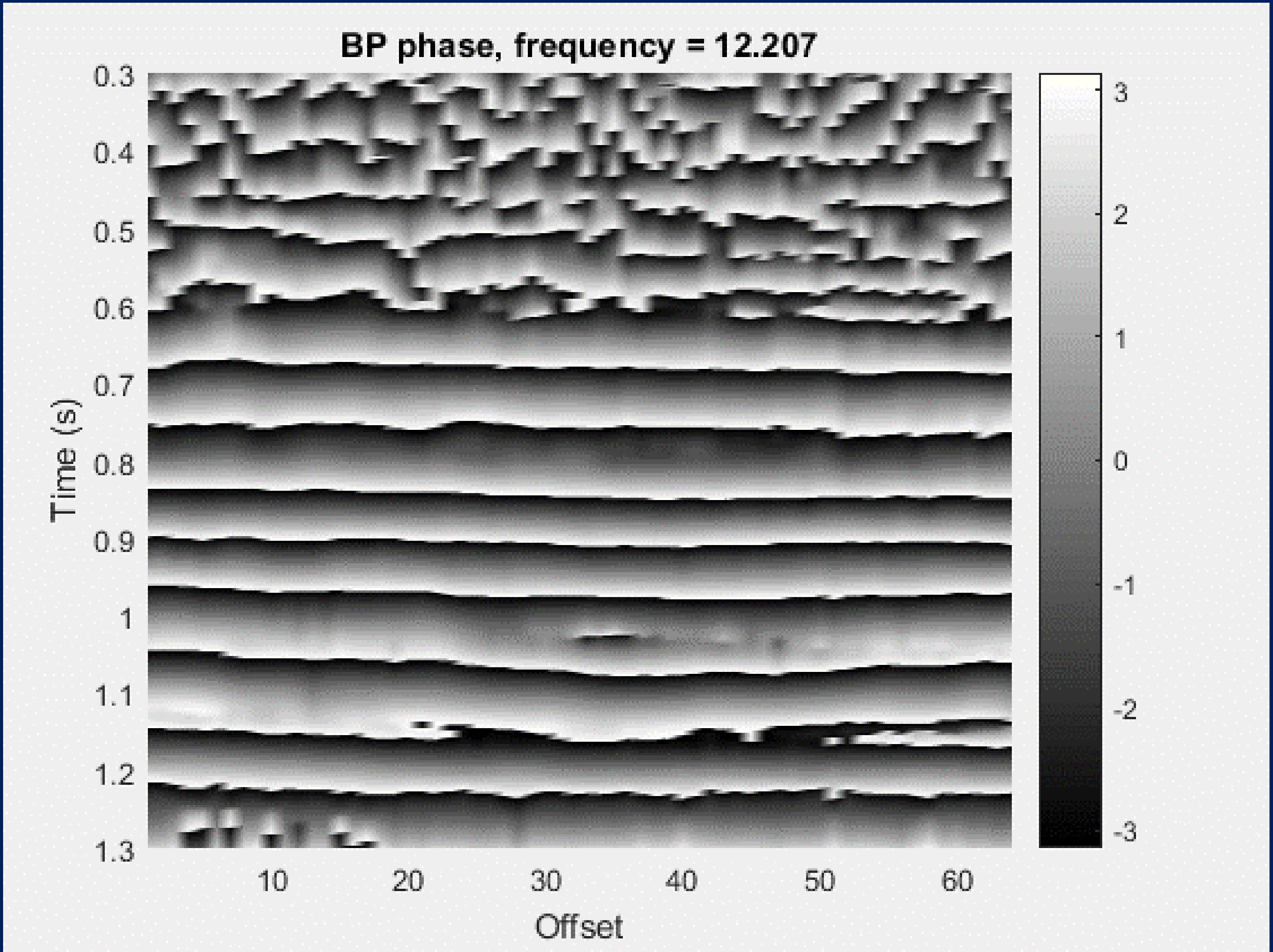
Amplitude attribute



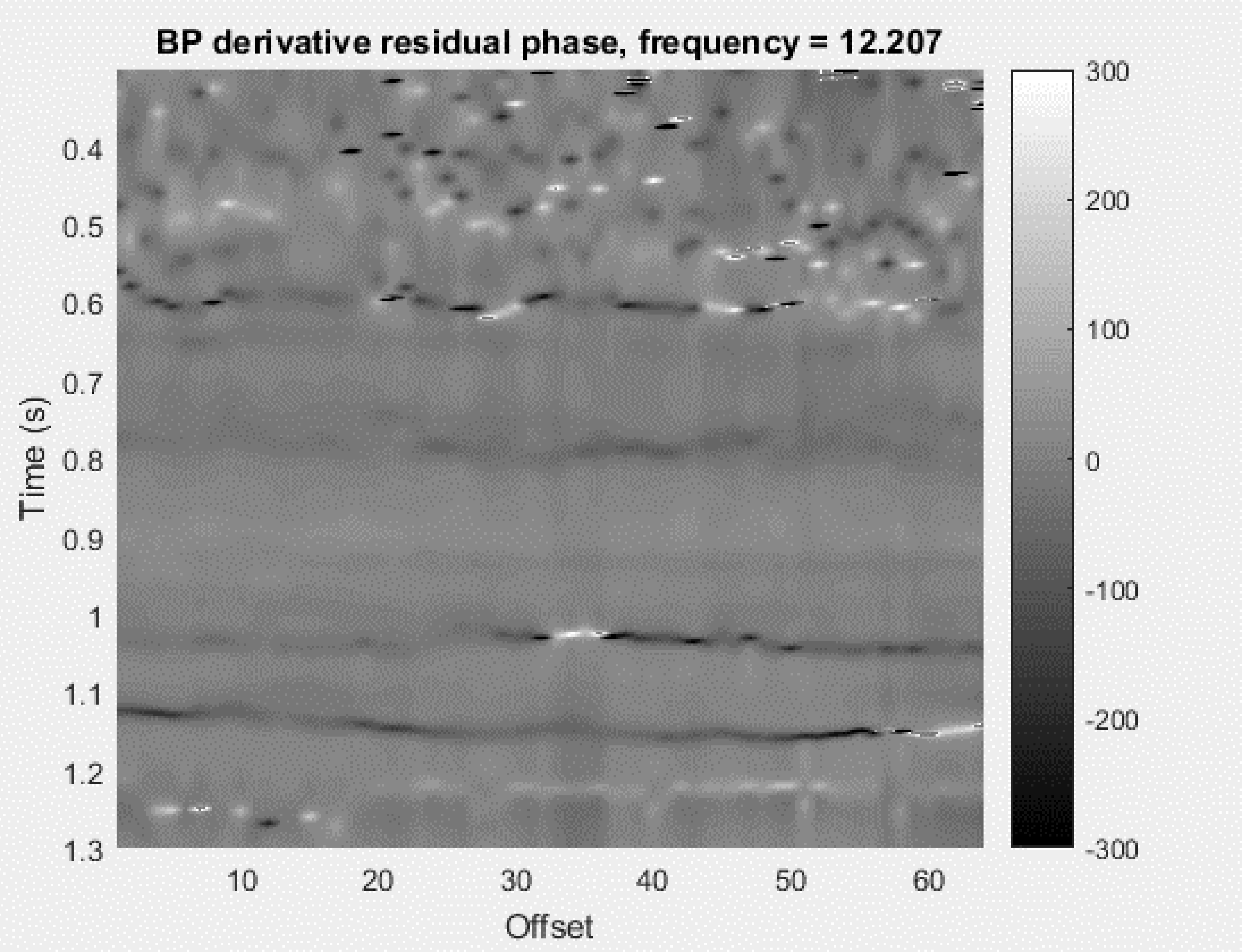
Valley data set



Phase attribute



Corrected phase attribute

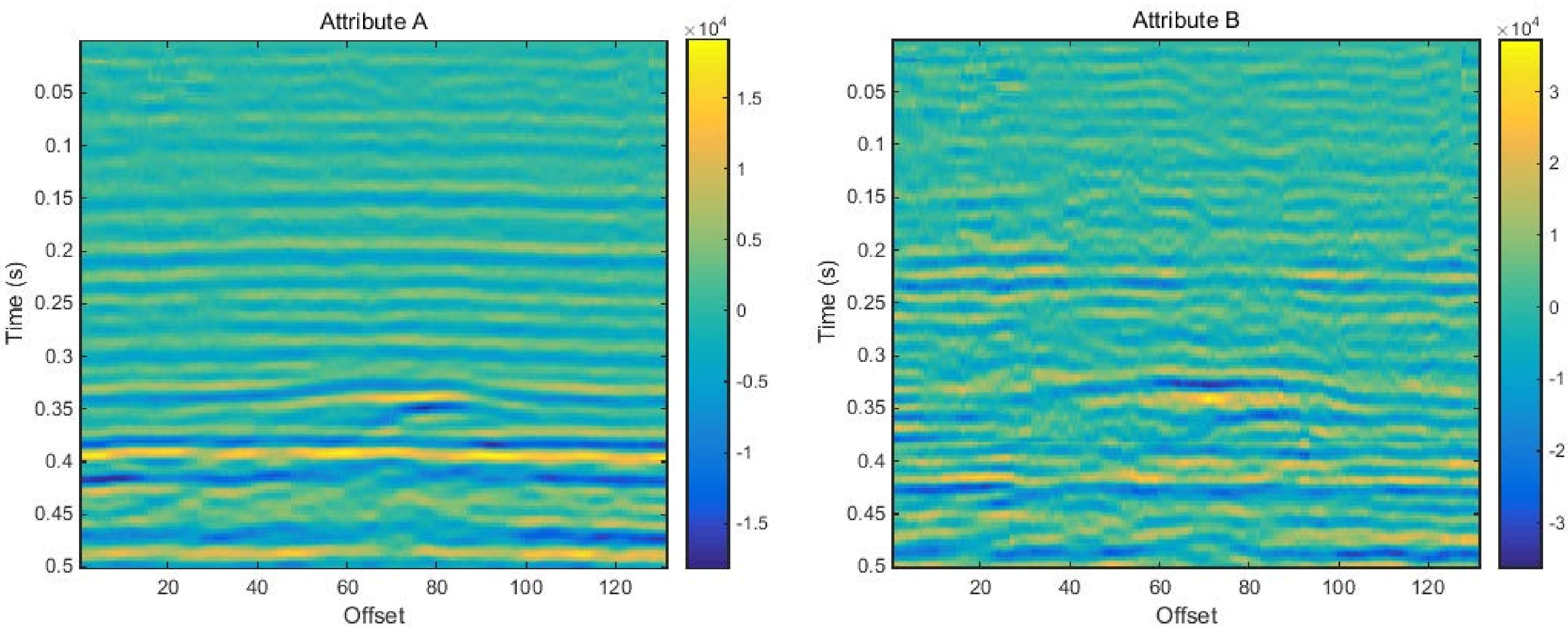


Traditional AVO

- AVO (Amplitude versus Offset) method - Interpret the amplitudes of the P-waves as a function of offset, or angle, which contain implied information about the S-waves.
- Converting from offset to angle domain
- To extract S-wave type information from P-wave reflections at different offsets - (Wiggins' Form of the Aki-Richards Equation)

$$R(\theta) = A + Bsin^2(\theta) + Csin^2(\theta)\tan^2(\theta)$$

Attributes A and B



Aki-Richards based FAVO

Assuming that the approximation given by the Wiggins' form of the Aki-Richards equation holds, we have that

$$s_\theta(t) = A(t) + B(t)\sin^2(\theta) \qquad (1)$$

Plugging equation (1) into the STFT equation yields

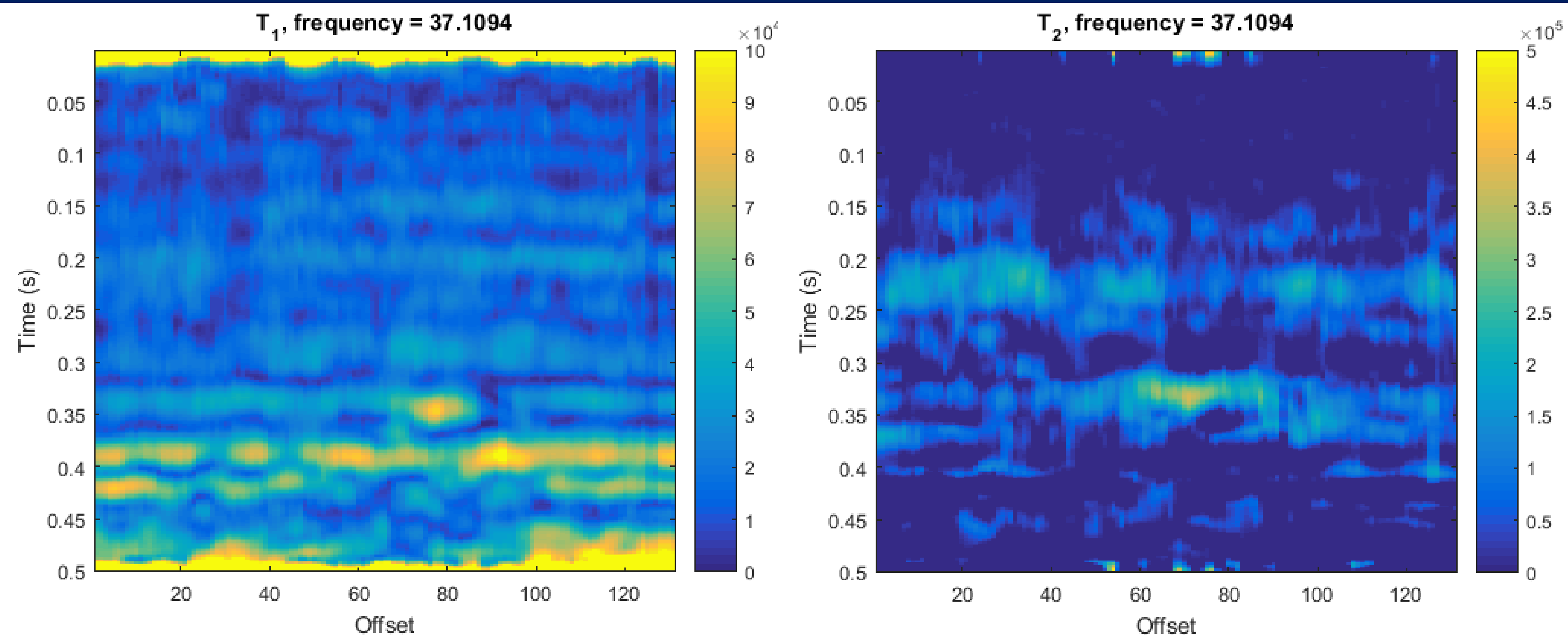
$$S_s(\tau, f) = T_1(\tau, f) + T_2(\tau, f)\sin^2(\theta) \qquad (2)$$

where

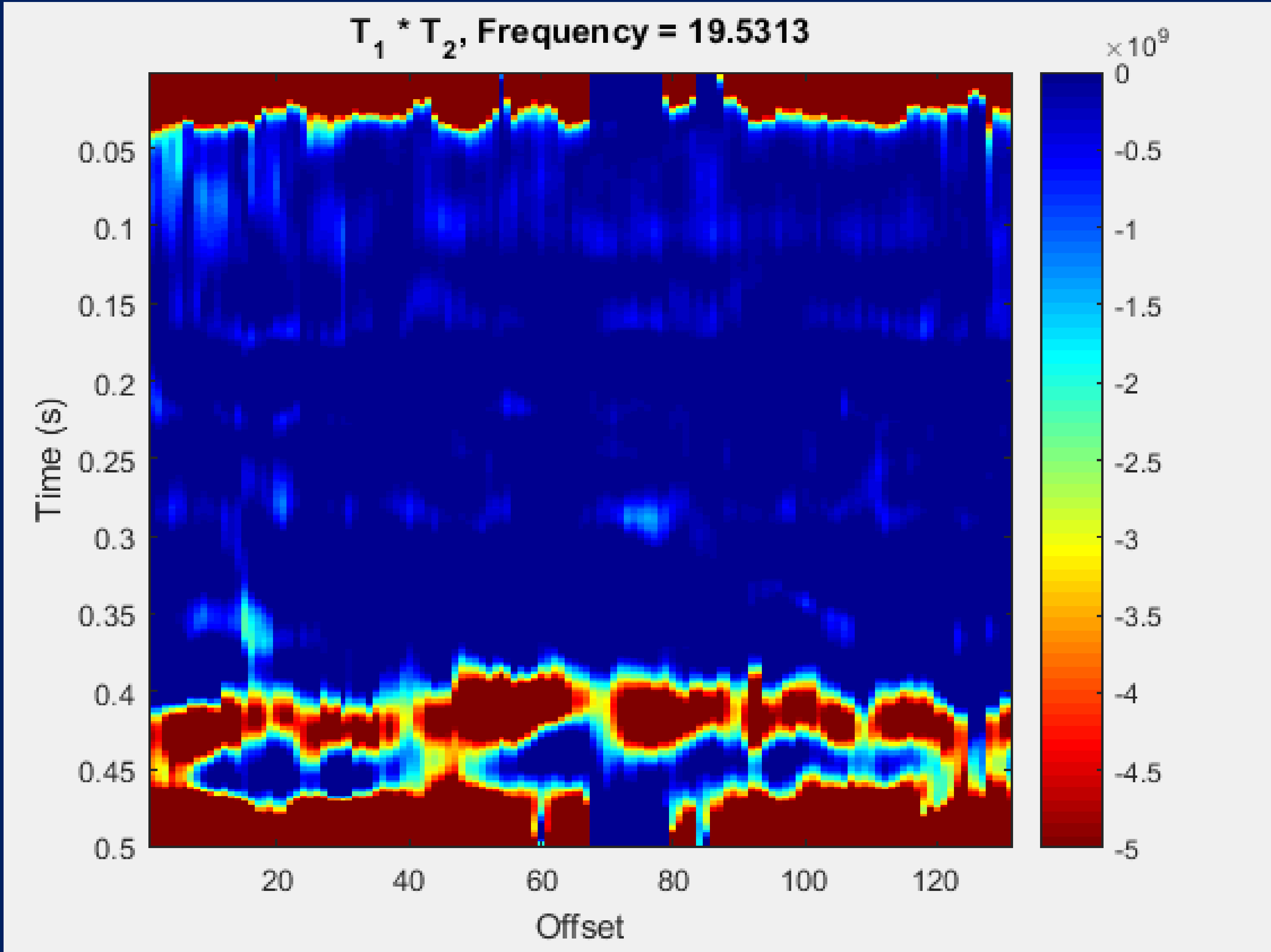
$$T_1(\tau, f) = \int_{-\infty}^{\infty} A(t)w(t-\tau)e^{-2i\pi f t}\,dt, \text{ and}$$

$$T_2(\tau, f) = \int_{-\infty}^{\infty} B(t)w(t-\tau)e^{-2i\pi f t}\,dt$$

Attributes T_1 and T_2



Attribute $T_1 * T_2$



Smith-Gidlow FAVO

The two-term Smith-Gidlow AVO approximation assumes:

$$R(\theta) = \mathrm{P}(\theta)\frac{\Delta \mathrm{V_p}}{\mathrm{V_p}} + \mathrm{Q}(\theta)\frac{\Delta \mathrm{V_s}}{Vs}$$

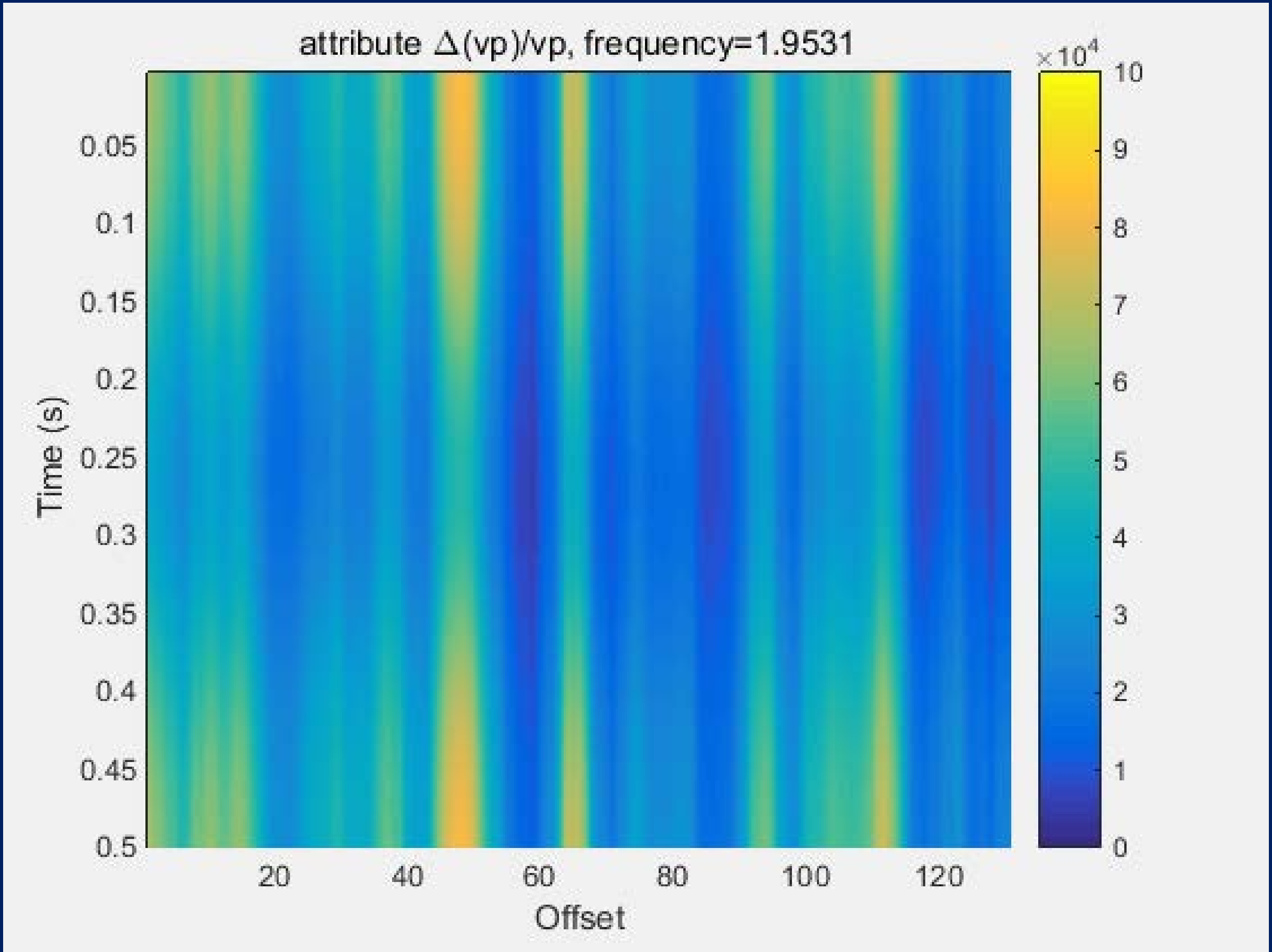
Extend Smith-Gidlow AVO approximation to a frequency-dependent equation,

$$R(\theta, f) = \mathrm{P}(\theta)\frac{\Delta \mathrm{V_p}}{\mathrm{V_p}}(f) + \mathrm{Q}(\theta)\frac{\Delta \mathrm{V_s}}{\mathrm{V_s}}(f)$$

The forward scheme of finite difference is used in the evaluation of attributes:

$$I_a(f) = \frac{\partial}{\partial f}\frac{\Delta V_p}{V_p} \quad \text{and} \quad I_b(f) = \frac{\partial}{\partial f}\frac{\Delta V_s}{V_s}.$$

Attribute $\Delta V_p/V_p$



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Attribute $I_a(f)$

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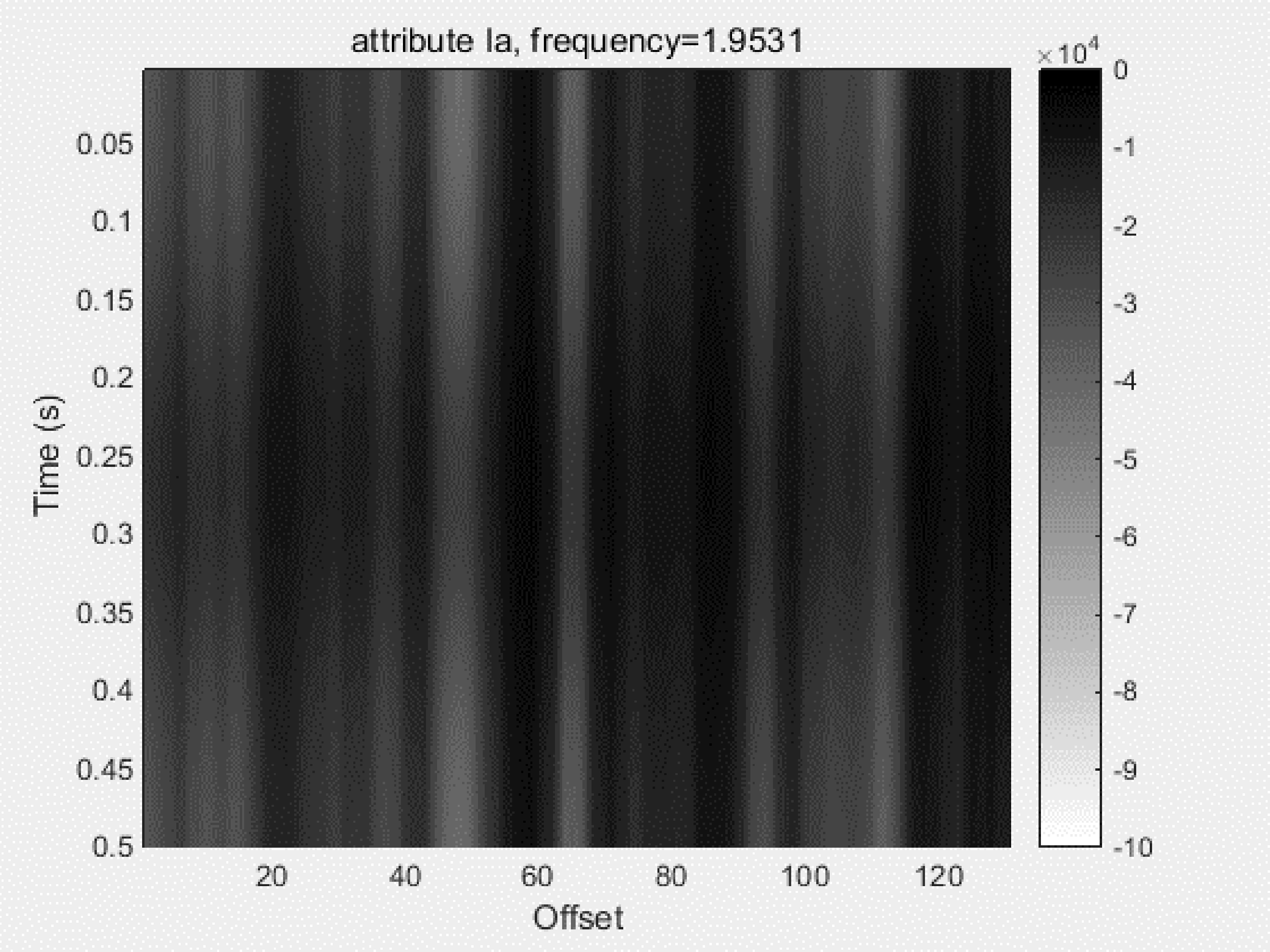

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Conclusions

- **Amplitude and derivative of residual phase** are **promising attributes** for interpretation of post-stack data.
- FAVO methods proposed are **similar** to traditional AVO, **provide** better resolution, and **contain** frequency information.

Future work

- Use other Time-Frequency methods when applying the corrected phase method.
- Apply the corrected phase method to more complicated data sets.
- Apply both FAVO methods to a more complicated data sets.

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Questions or comments?

AVO vs FAVO

- The methods give **similar** localization results for the reservoir pre-stack data set.

- **FAVO** has the following advantages:
  - It provides **better resolution** results with Basis Pursuit time-frequency analysis.
  - It **encodes** frequency-dependent information.