Advanced self-organizing map facies analysis with stratigraphic constraint

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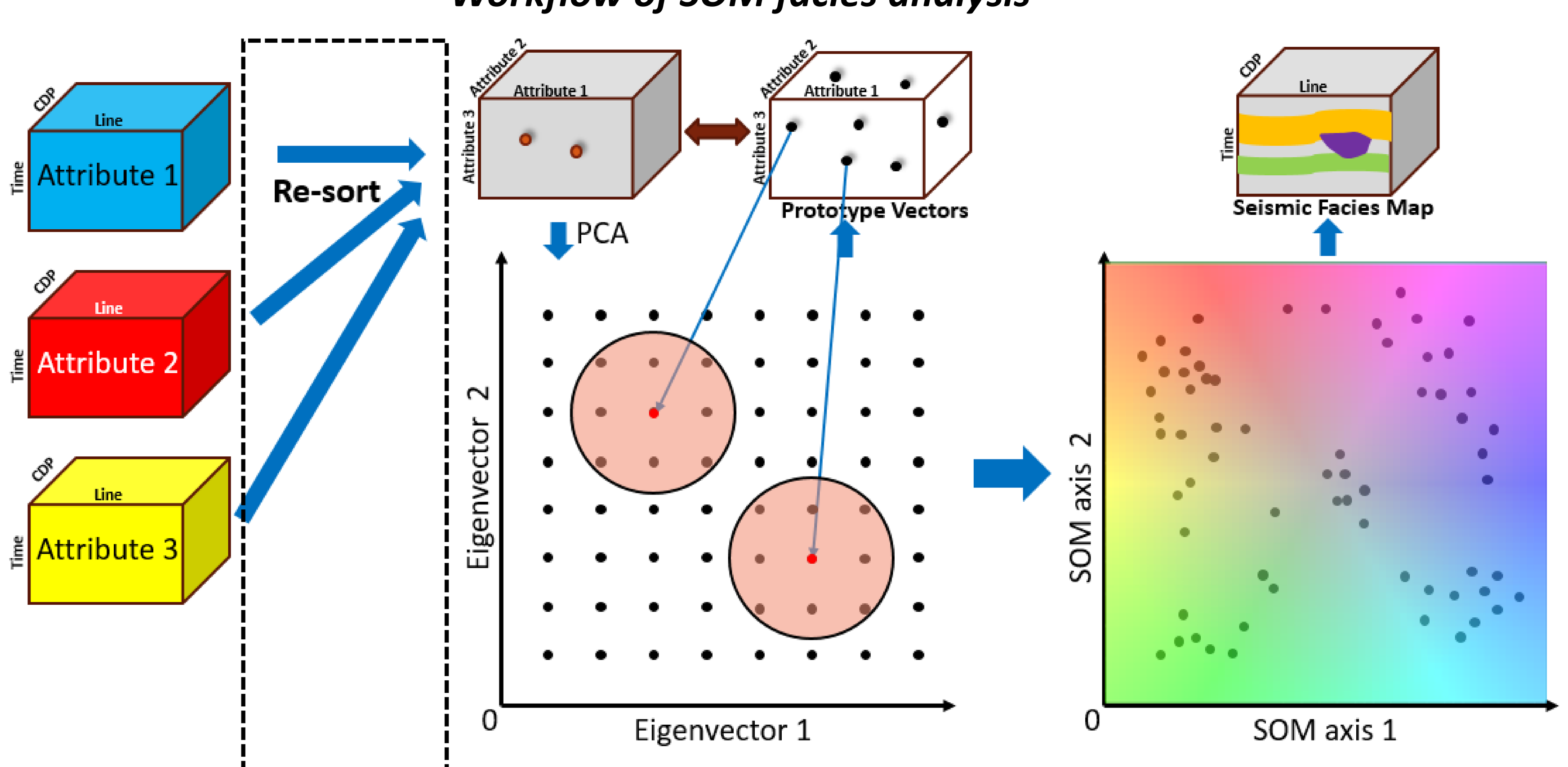
Summary

In this study, we briefly introduce a stratigraphic constraint derived from seismic decomposition method into self-organizing map (SOM) facies analysis. After describing the methodology, we show an improved SOM workflow using information of sedimentary cycle, which is derived from variational mode decomposition (VMD) on seismic amplitude data. On an unconventional shale application, we observe that the constrained SOM facies map shows layers that are easily overlooked on traditional unconstrained SOM facies map.

Introduction

Workflow of SOM facies analysis



Spatial/temporal information is lost when data are re-sorted from physical space into attribute space

Adding a background model of **sedimentary cycle** may help define layers that are otherwise not well defined on seismic attributes

Mode decomposition methods are able to approximately recover sedimentary cycle information from seismic amplitude data

SOM is an excellent seismic facies analysis/classification tool that captures the information residing in (multiple) input seismic attributes by reorganizing data samples based on their topological relation. Examples of the very first applications of SOM on seismic facies analysis include Strecker and Uden (2002), in which the authors used multiattribute input and performed SOM classification volumetrically using a 2D SOM latent space, and Coleou et al. (2003) used both seismic amplitudes (waveform classification) and seismic attributes as inputs for SOM. To overcome the issue that the distance information in the input attribute space is lost once projected into the 2D SOM latent space, Zhao et al. (2016) adopted a distance-preserving step in SOM, constraining the SOM facies to better reflect the degree of diversity in input attribute space. However, till now all the SOM applications are spatially (and temporally, for time domain seismic data) unaware, because seismic data are sorted into "attribute space" (each dimension is one seismic attribute) before feeding into a classification technique like SOM.

In this study we follow the workflow described in Li et al. (2016), adopting the VMD method to decompose the seismic amplitude signal into a user-defined number of modes, and select one of the modes as an indicator of the sedimentary cycle by calibrating with well logs. By adding such sedimentary cycle constraint in SOM facies analysis, we identify some layers are better represented comparing to the traditional unconstrained SOM facies analysis.

Methodology

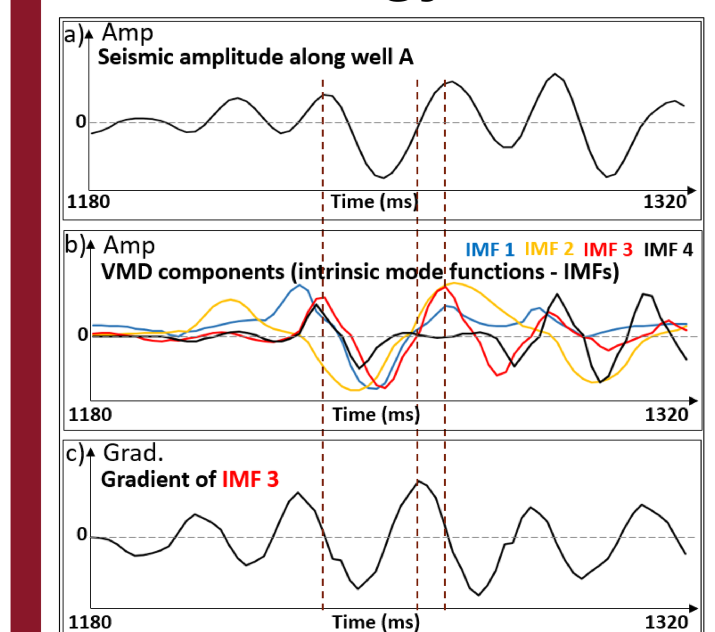


Figure 1. (a) Seismic amplitude from a trace along well A (location shown later). **(b)** VMD components (IMFs) of the trace above. Four components are used to represent sedimentary cycles. **(c)** The gradient of IMF 3. Dashed lines show the correspondence among seismic amplitude, IMF 3, and IMF 3 gradient.

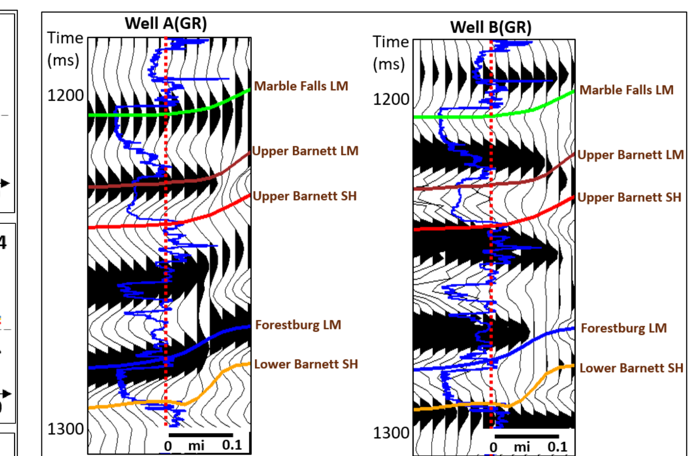


Figure 2. Vertical section along the IMF 3 gradient plotted with Gamma ray log (blue curve) at well A and well B (location shown later). The well trajectory is marked by the red dash line. Formation tops are marked as colored curves. Note the good match in pattern between Gamma ray log and IMF 3 gradient.

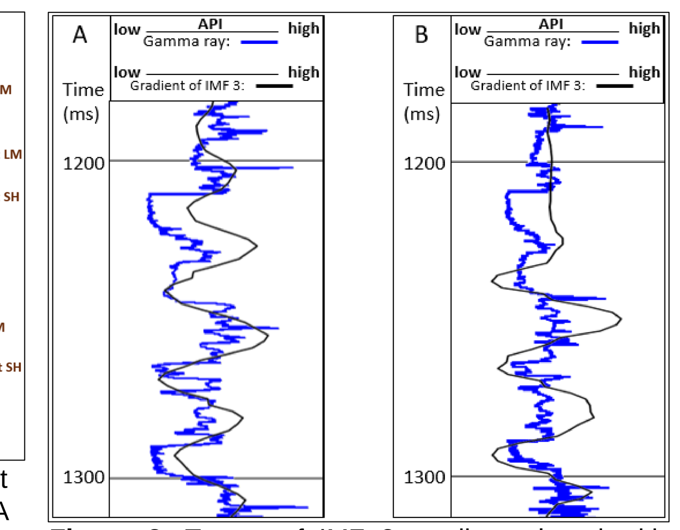


Figure 3. Traces of IMF 3 gradient plotted with Gamma ray logs (blue curve) at well A (left) and well B (right) (location shown later). Well A is a vertical well, and the corresponding IMF 3 gradient trace is the most adjacent trace of well A. Well B is a deviated well, and the corresponding IMF 3 gradient trace is a composite trace along the well trajectory.

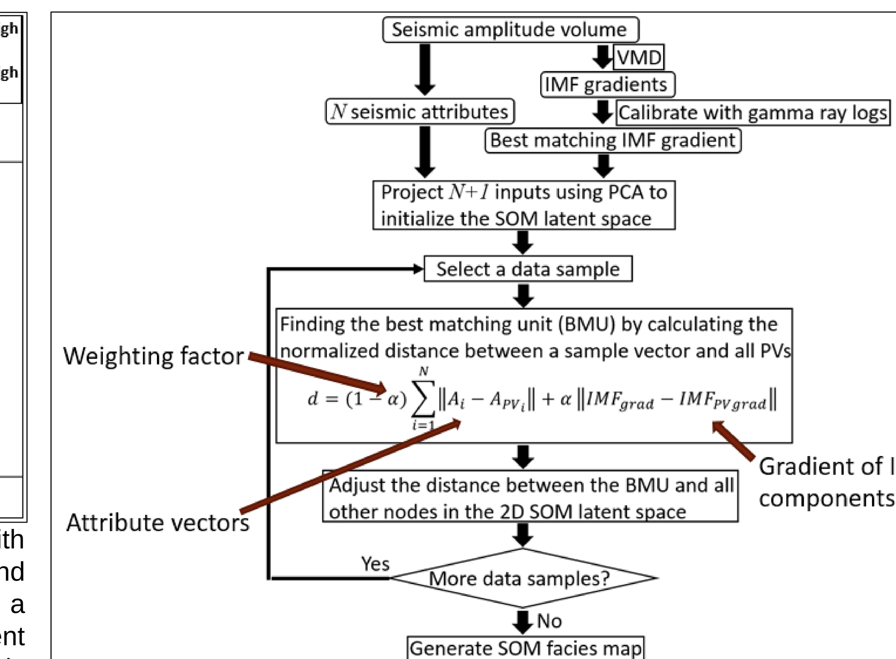


Figure 4. Workflow of the stratigraphically constrained SOM facies analysis.

Data Description

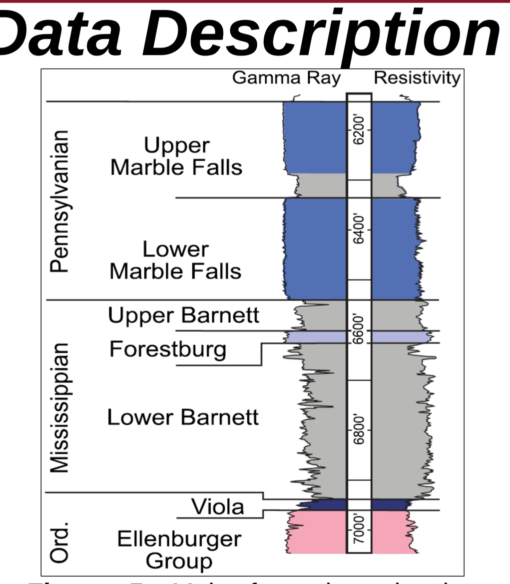


Figure 5. Main formations in the Barnett Shale study area (After Loucks and Ruppel, 2007).

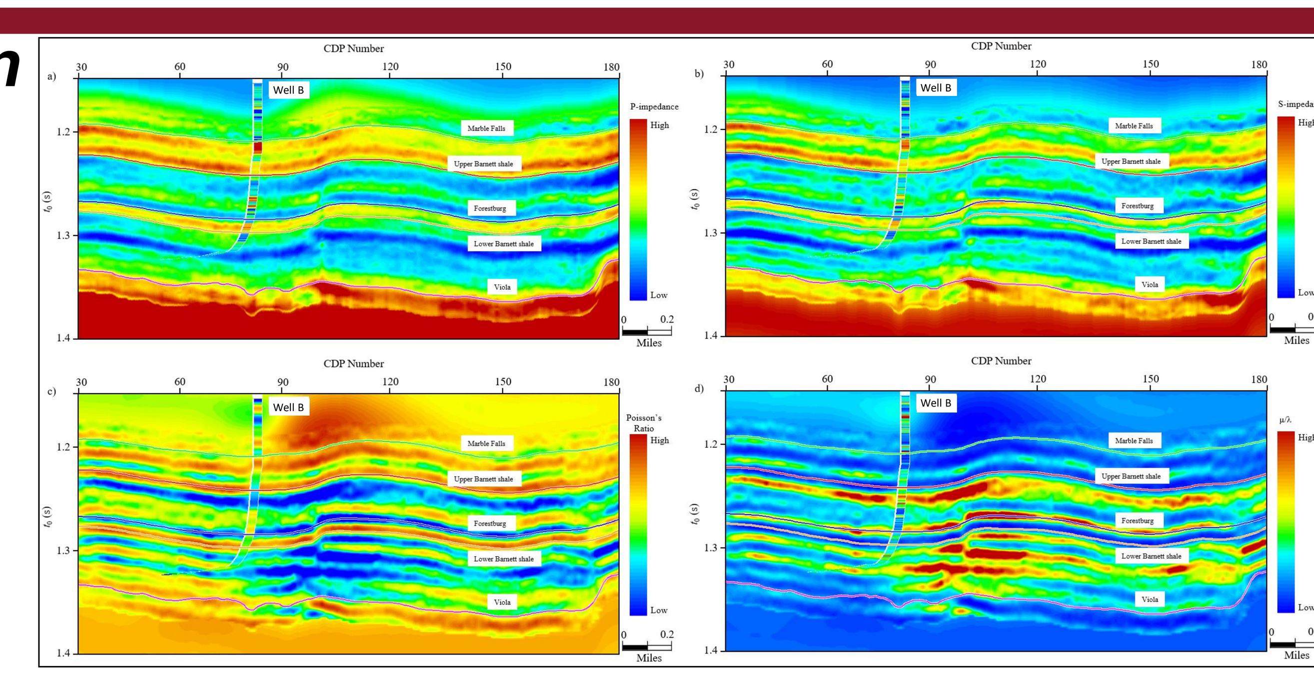


Figure 6. Input prestack inversion seismic attributes for SOM facies analysis.

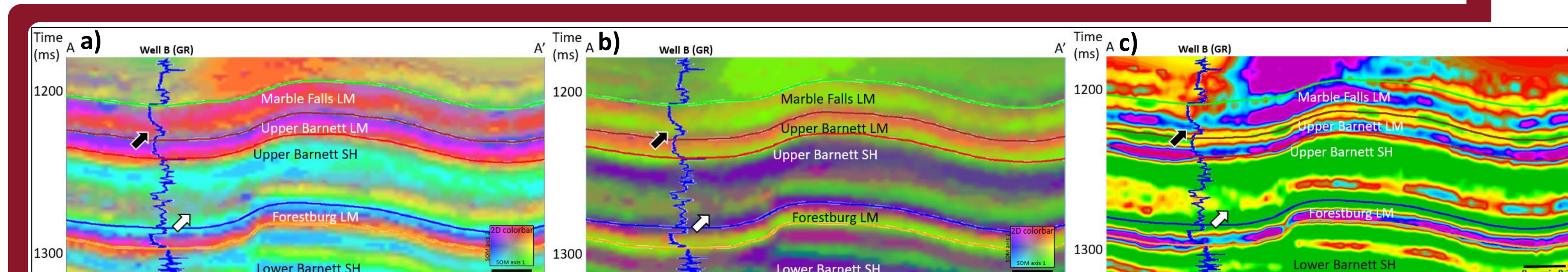


Figure 8. Vertical section along line AA' through **a)** unconstrained SOM facies map; **b)** VMD constrained SOM facies map; and **c)** V_p/V_s ratio.

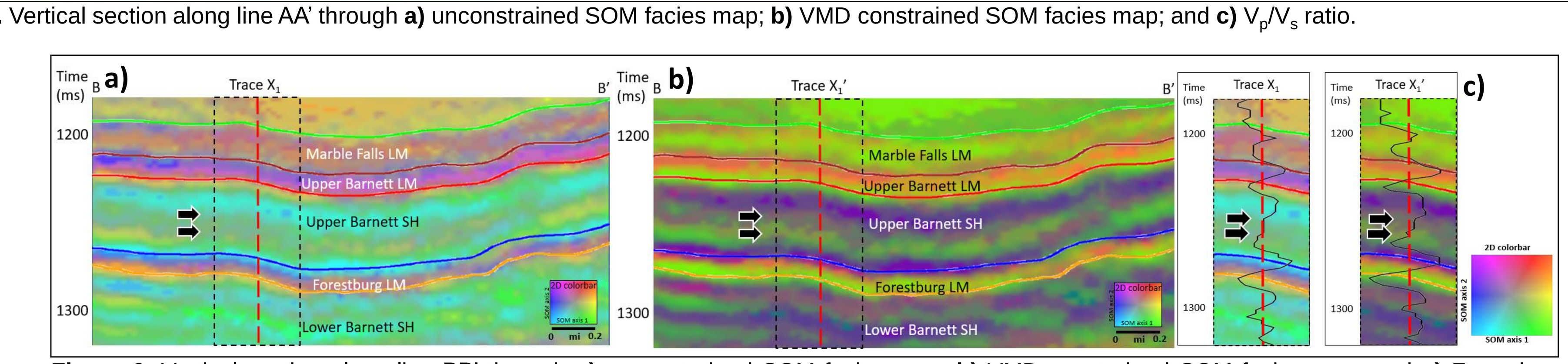


Figure 9. Vertical section along line BB' through **a)** unconstrained SOM facies map; **b)** VMD constrained SOM facies map; and **c)** Zoom-ins around traces X_1 and X_1' extracted from the unconstrained and constrained SOM facies volumes.

Result

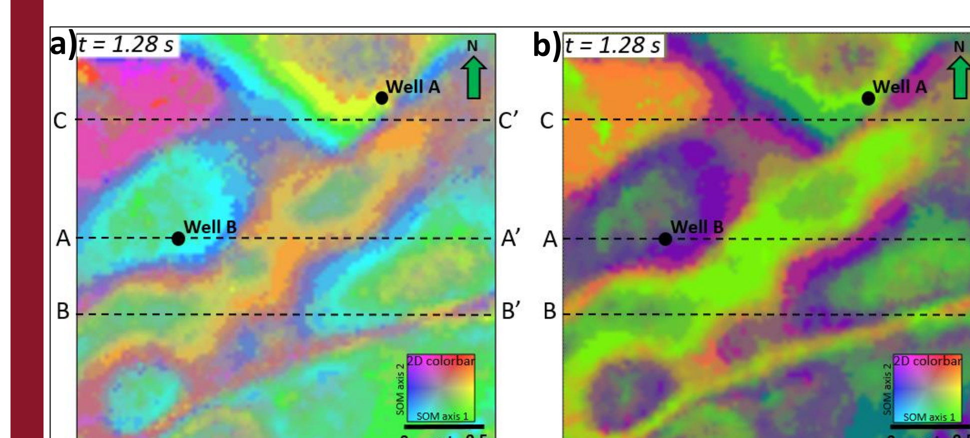


Figure 7. a) SOM on Zp, Zs, Mu/Lambda, and Poisson's Ratio, without VMD constraint. **b)** SOM on Zp, Zs, Mu/Lambda, and Poisson's Ratio, with VMD constraint.

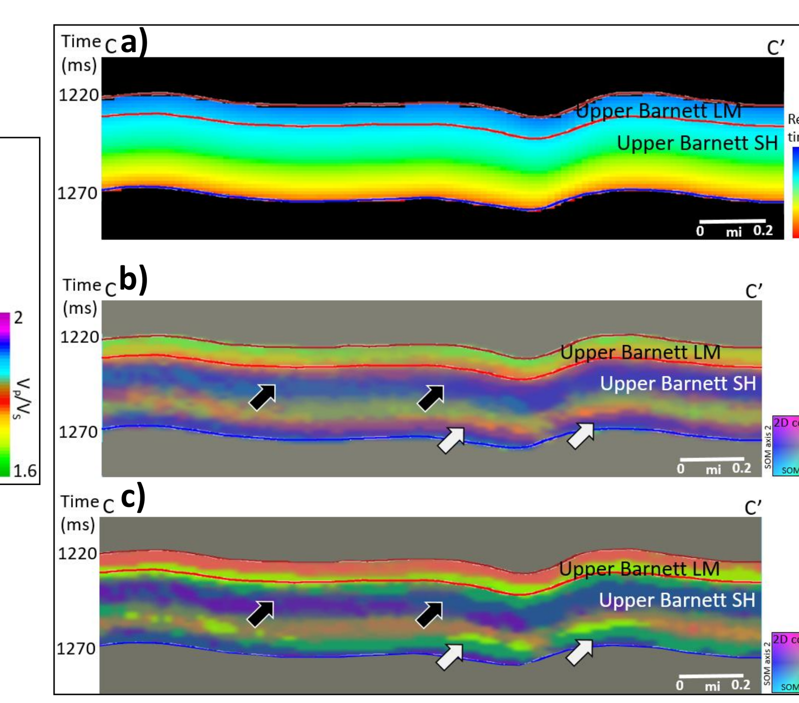


Figure 10. Vertical section along line CC' through **a)** proportional slice model representing relative time in the Upper Barnett formation; **b)** proportional slice model constrained SOM facies map in the Upper Barnett formation; and **c)** VMD constrained SOM facies map in the Upper Barnett formation. The proportional slice model is based on chronostratigraphy and provides monotonic change in the vertical direction. The VMD sedimentary cycle model introduces more contract among stacked layers.

Conclusion

In this study, we explored the feasibility of constraining the SOM facies analysis using sedimentary cycle information. Being an initial attempt to approximate stratigraphy information, the constrained SOM facies map shows layers that are more likely being overlooked on unconstrained SOM facies map. The geological meaning of the VMD derived sedimentary cycle model needs to be carefully calibrated with well logs. A well log constrained chronostratigraphic model may further improve the performance.

Acknowledgement

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References

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