# Machine-Learning with Multi-Seismic Attributes in Cambro-Ordovician Carbonates of Southwestern Pennsylvania*

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## Abstract

The prolific Pt Pleasant dry-gas play immediately overlies the legacy Trenton-Black River (TBR) play, which is known to be extensively affected by hydrothermal alteration. Machine-learning analysis of multi-seismic attributes, integrated with drilling and geological data, suggests that hydrothermal alteration in the TBR and deeper Cambro-Ordovician carbonates significantly impacts production and geohazard distribution in the Pt Pleasant.

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# Machine-learning with multi-seismic attributes in Cambro-Ordovician carbonates of SW PA

MAY 10, 2019

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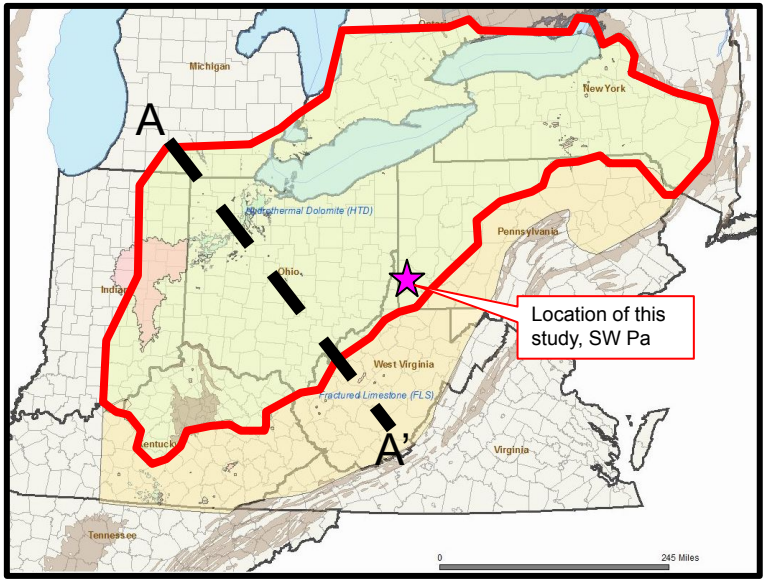
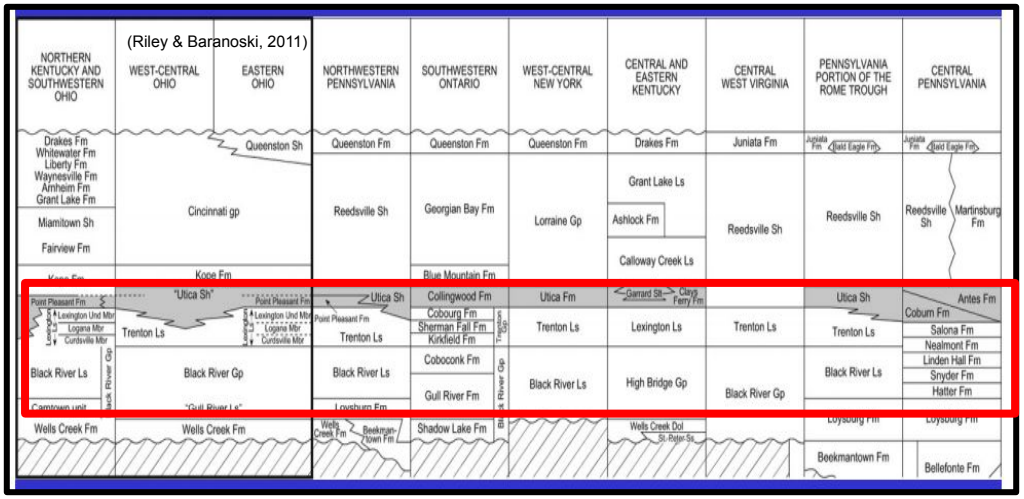
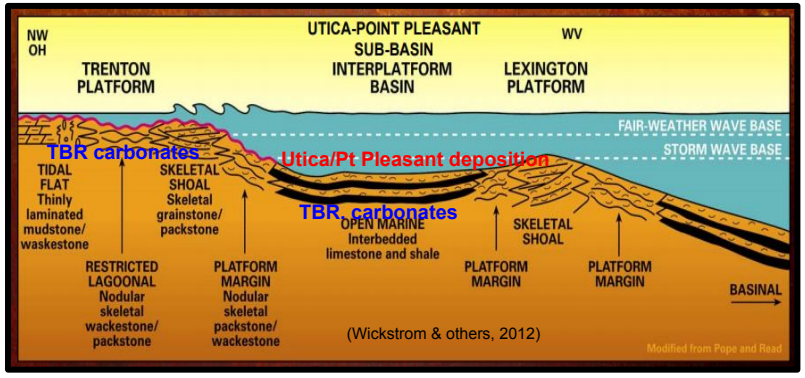
SR STAFF GEOPHYSICIST

# Utica/Pt Pleasant: a hot unconventional play, influenced by a legacy play

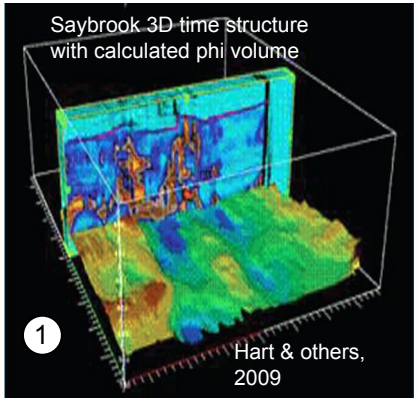
- Utica/Pt Pleasant play sits directly above the legacy Trenton/Black River play, a play historically associated with hydrothermal alteration and deep karsting
- Vertical zones of enhanced porosity, either deep “karsting” or hydrothermal dolomitization, are known to occur in the Trenton/Black River
- Via 3D seismic attributes integrated with well observations, we see evidence that the Pt Pleasant is impacted by some of the same phenomena as the TBR
- Underlying TBR alteration appears to affect production and drilling hazards in the Pt Pleasant

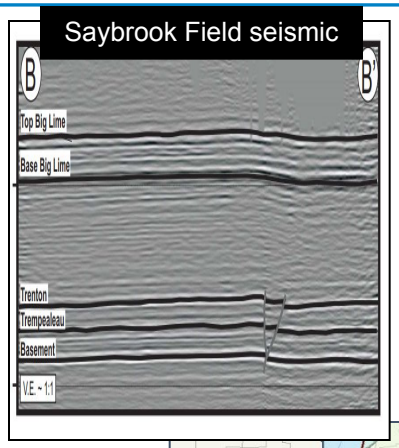


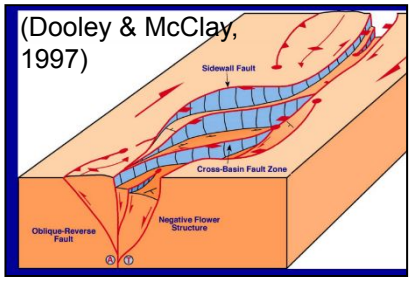



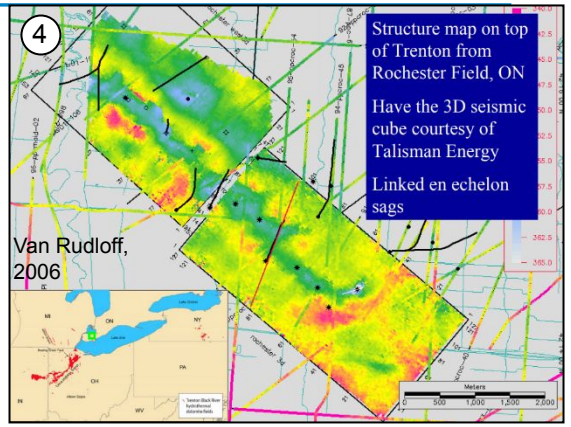



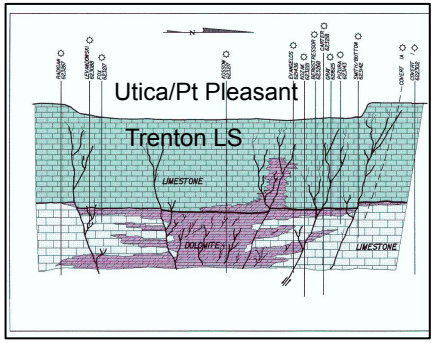
# Trenton/Black River hydrothermal/karsting examples around Appalachia

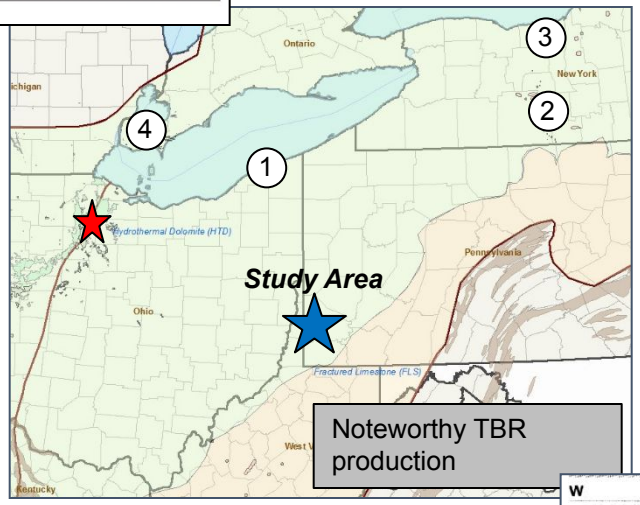


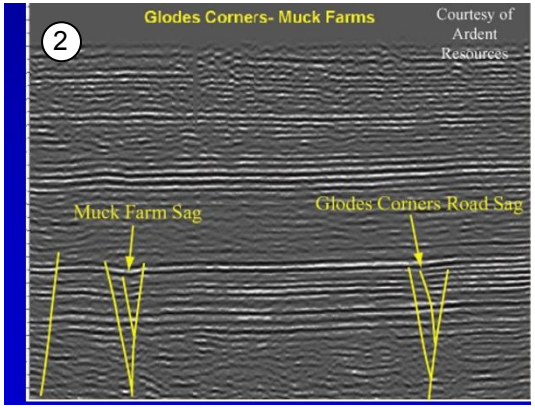



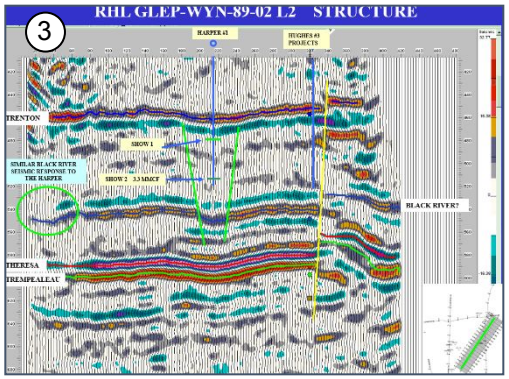



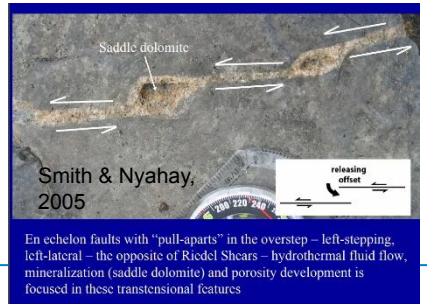



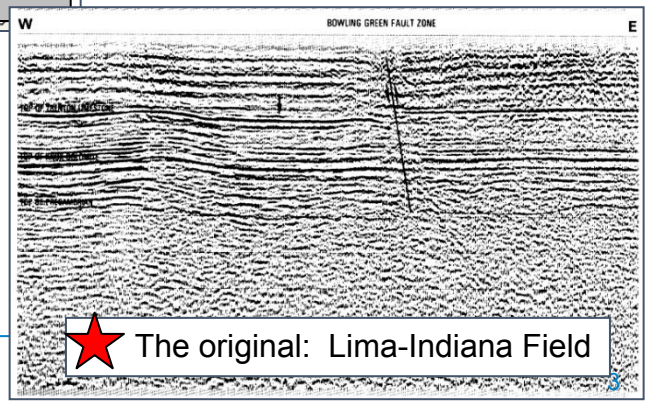



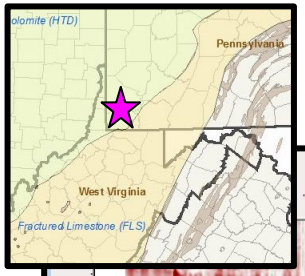



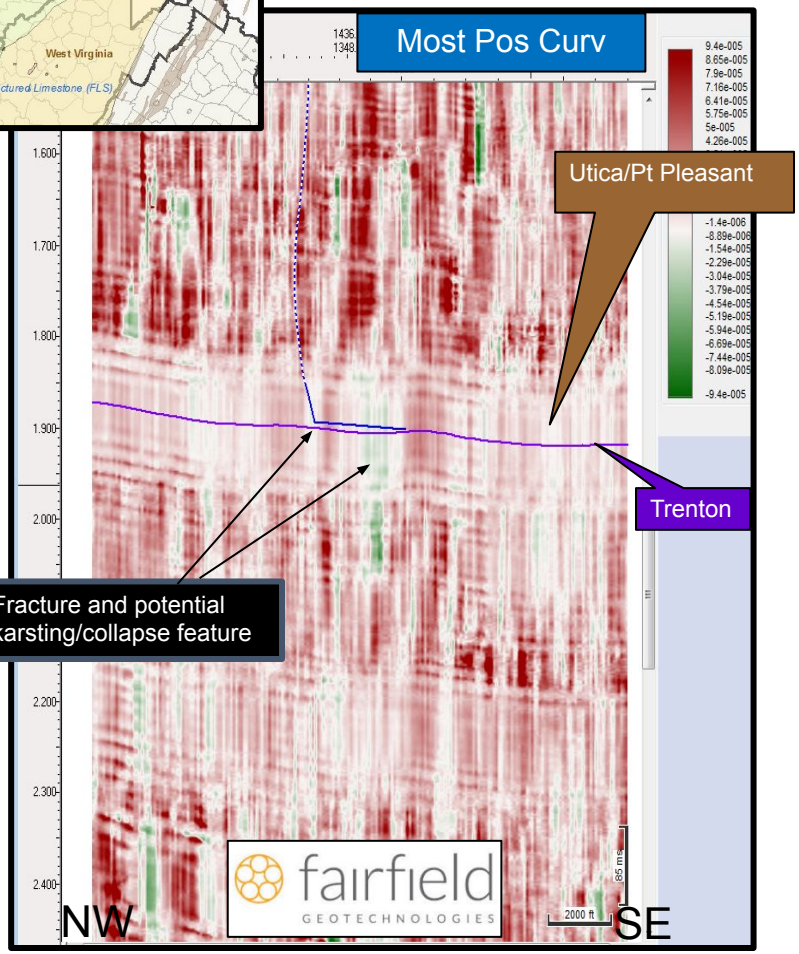



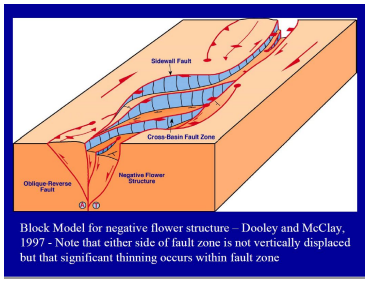



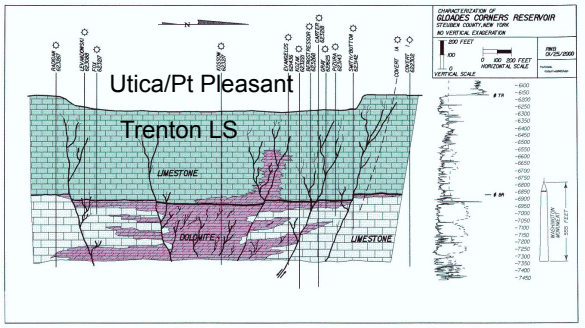
# Hydrothermal alteration or deep karsting in a big Pt Pleasant well?

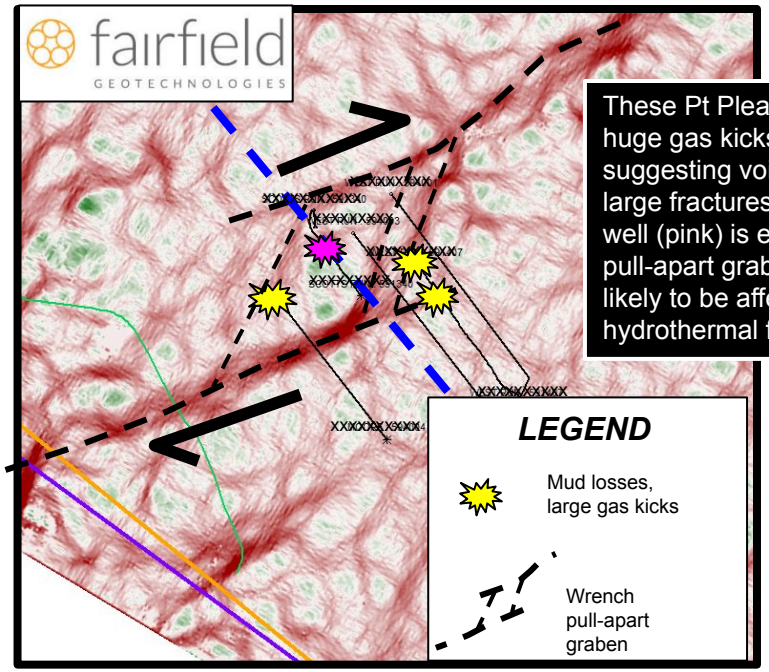



Block Model for negative flower structure – Dooley and McClay, 1997 - Note that either side of fault zone is not vertically displaced but that significant thinning occurs within fault zone

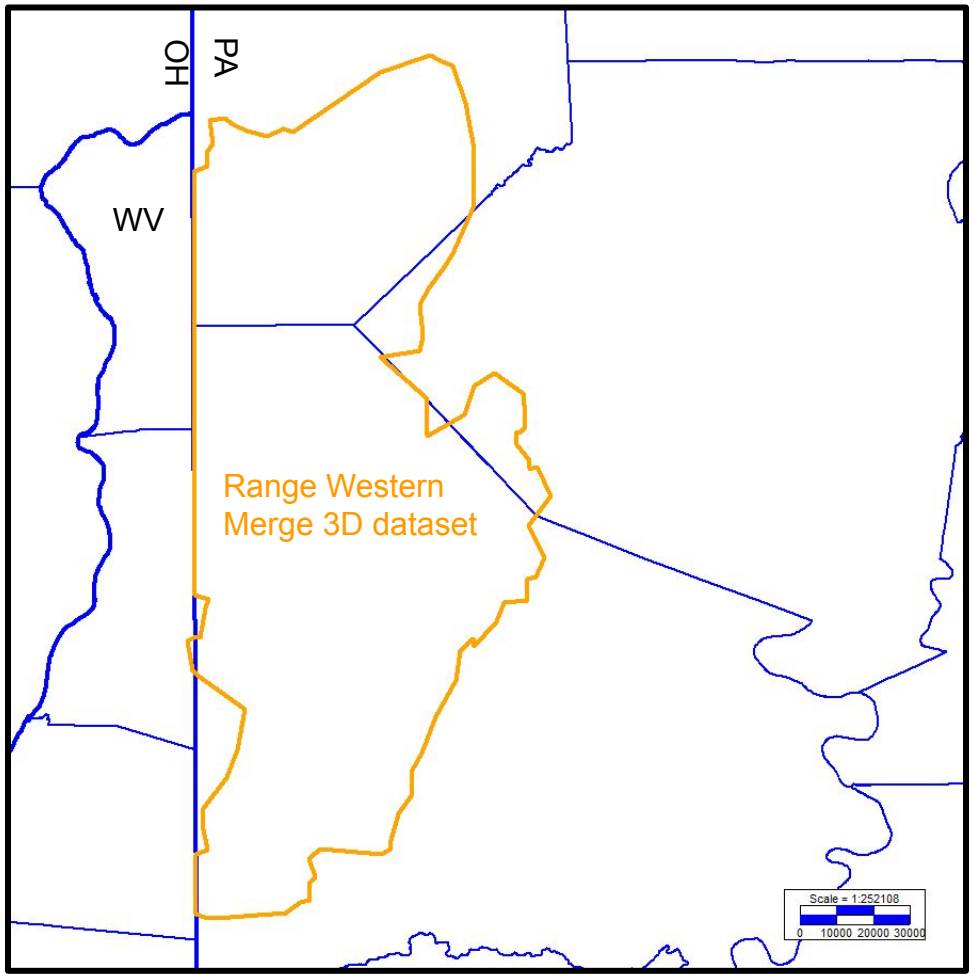



These Pt Pleasant wells had huge gas kicks and mud losses, suggesting void space and/or large fractures. The most prolific well (pink) is entirely within the pull-apart graben, an area more likely to be affected by potential hydrothermal fluids

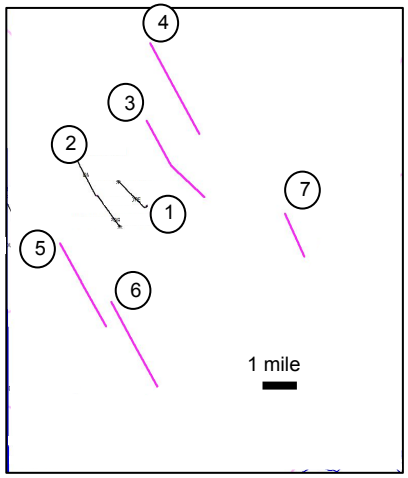
***Seismic provided by Fairfield Geotechnologies***

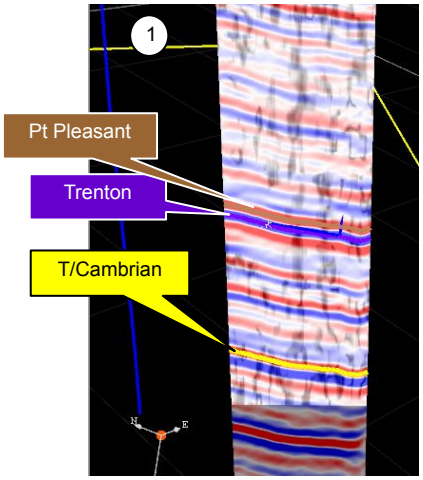
# 3D seismic datasets for “Paradise” machine-learning input

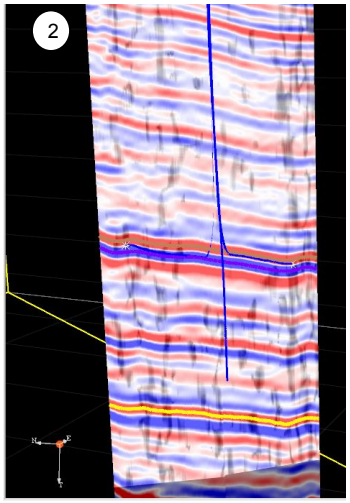


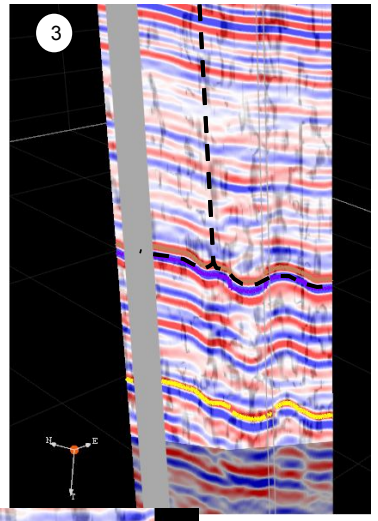

- 550 $mi^2$
- Several merged legacy 3Ds
- Merge reprocessing by Sterling Seismic Services, 2017
- OVT PSTM with 5D interpolation
- P/S inversion done by Rock Solid Images, 2017
- Resampled to 1 msec
- Analyzed using Geophysical Insight’s “Paradise” machine-learning software

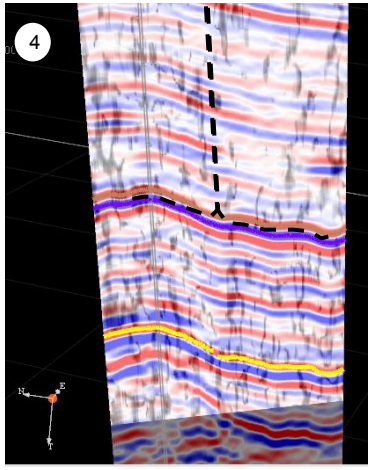
# Example of the wrench-type structural style in study area

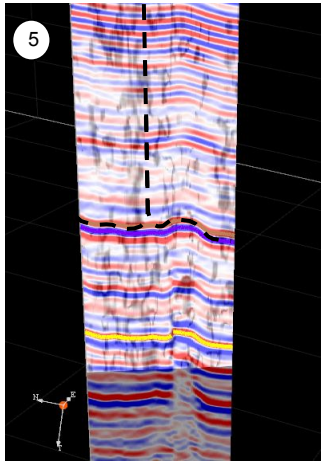


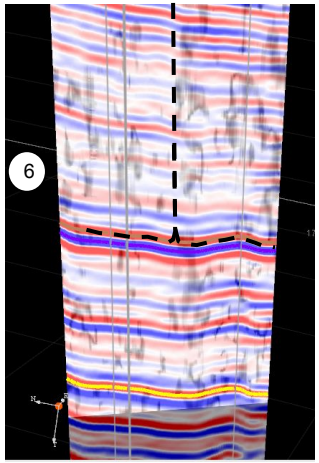



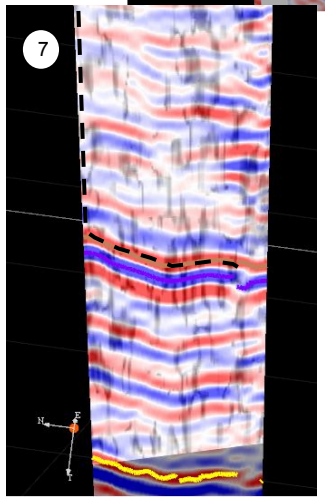



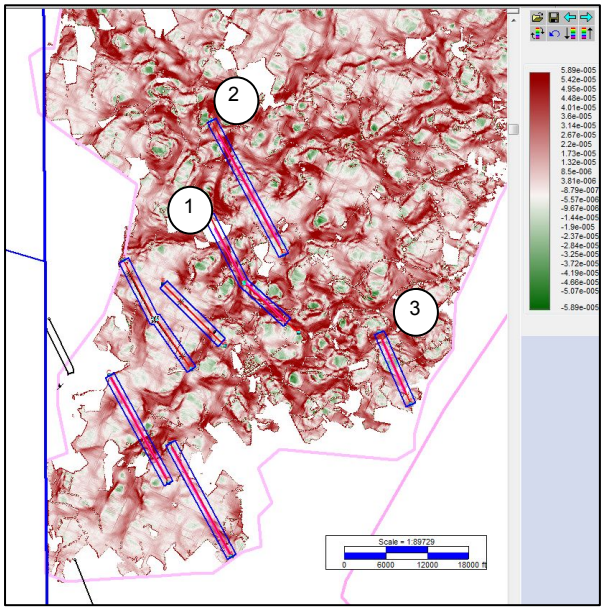



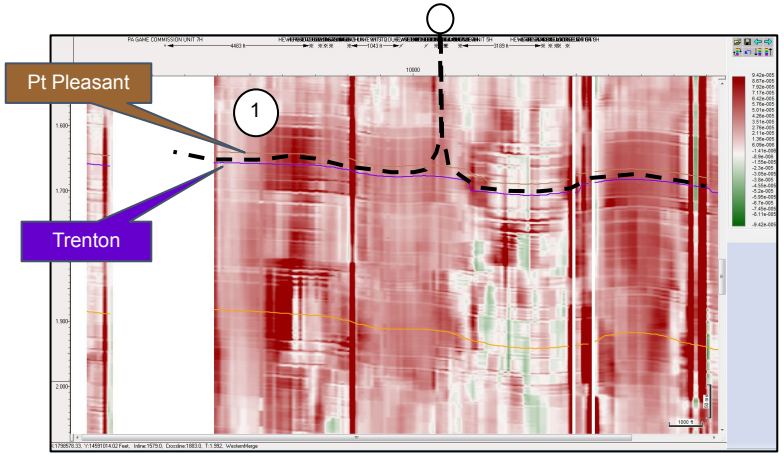



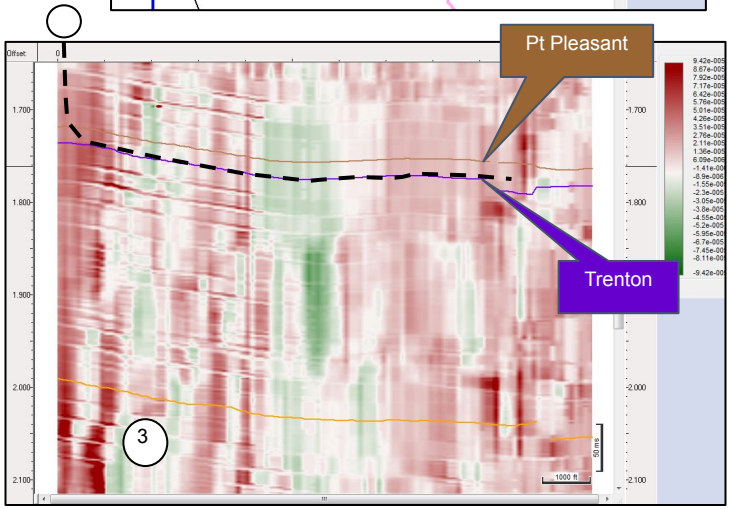
# Most Positive Curvature highlights “sags”, but are they altered?

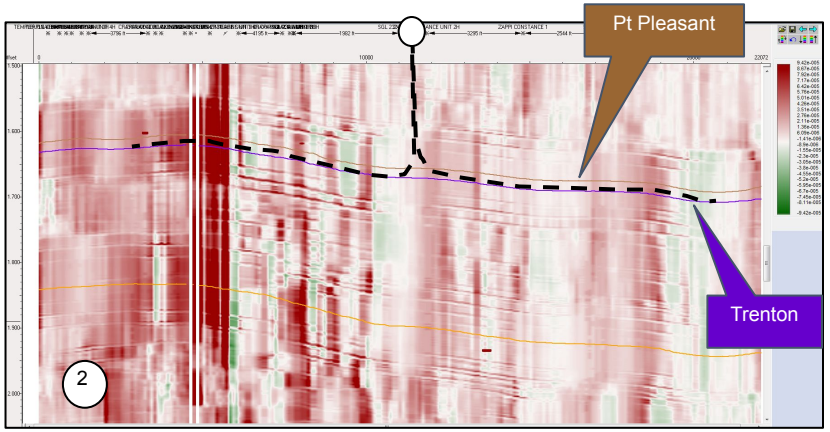



*East/South is to right on all profiles*

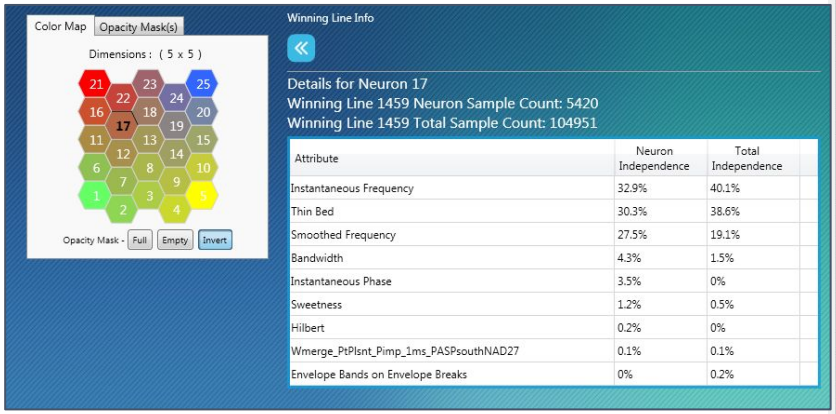


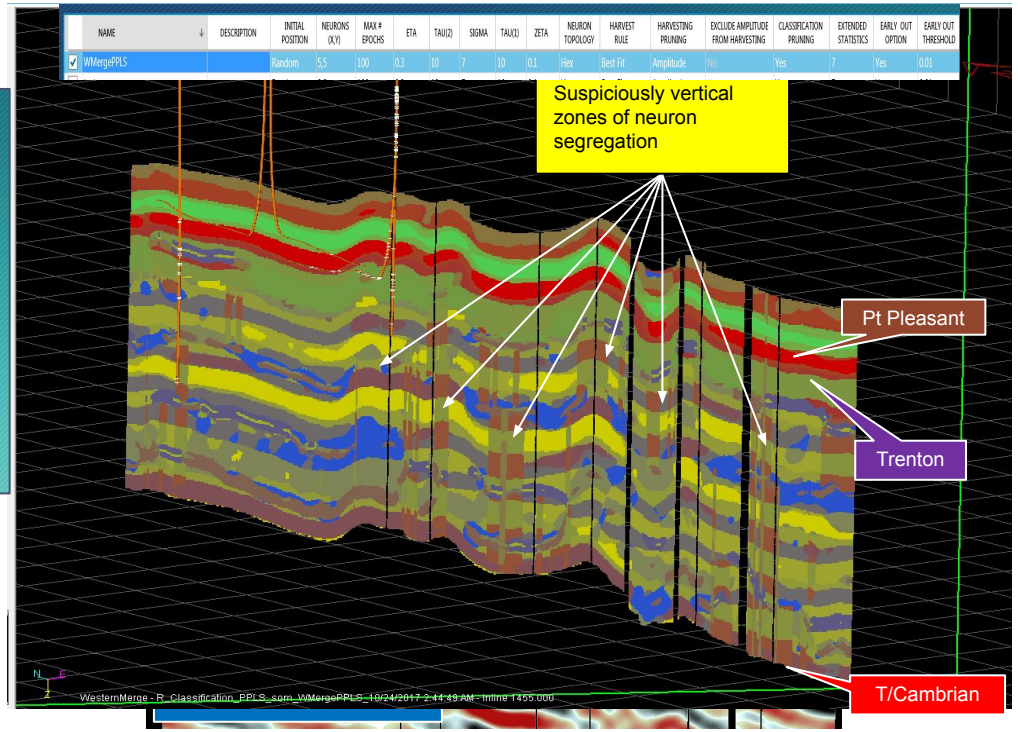

***Structural sags (green) may point to karsting/collapse, but not necessarily. Can Paradise discriminate the altered sags vs the non-altered ones?***

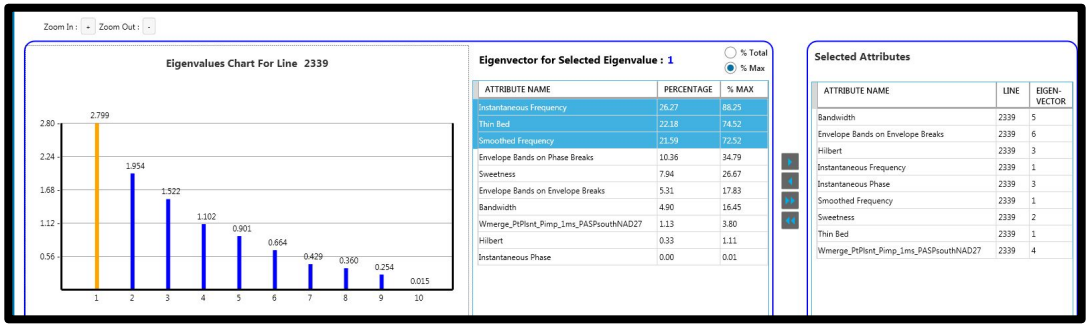


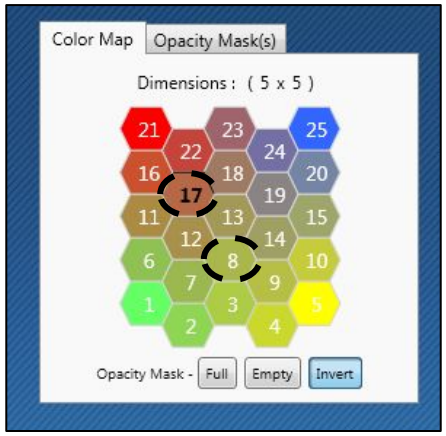
# SOM result: goal to detect zones of hydrothermal/karsting alteration

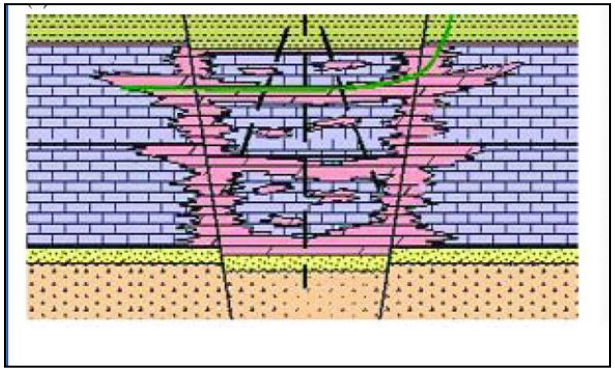




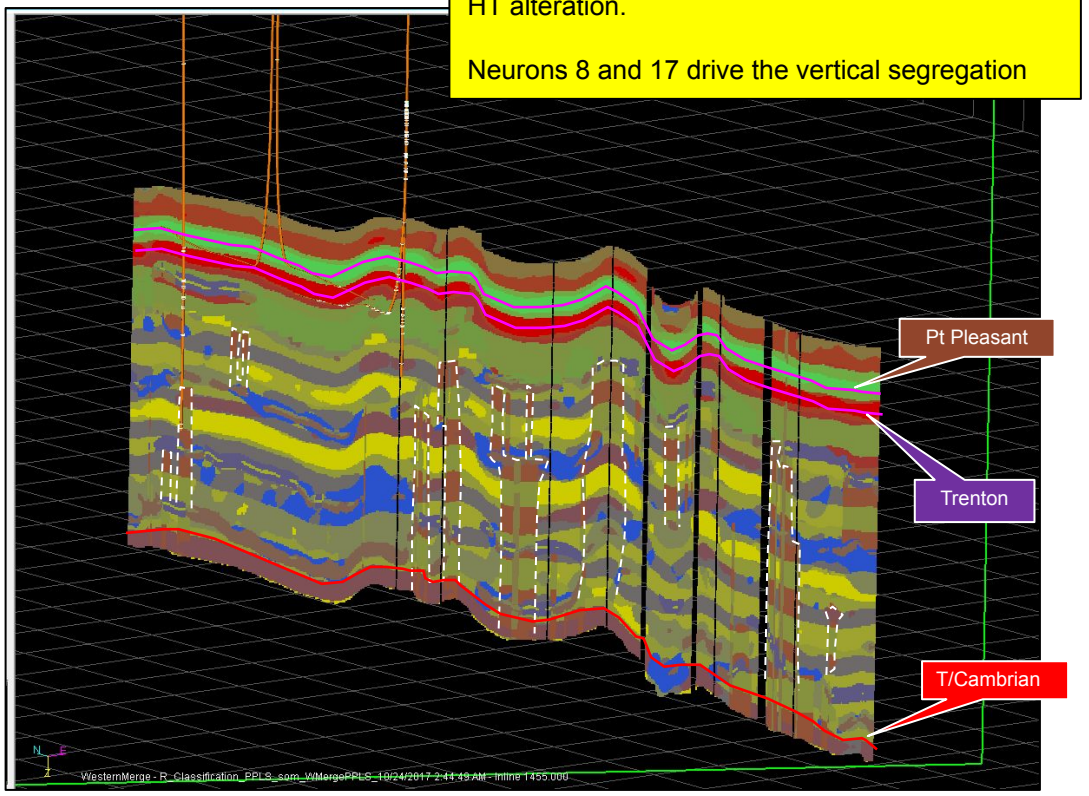
# SOM results fit a model of deep hydrothermal/karsting alteration



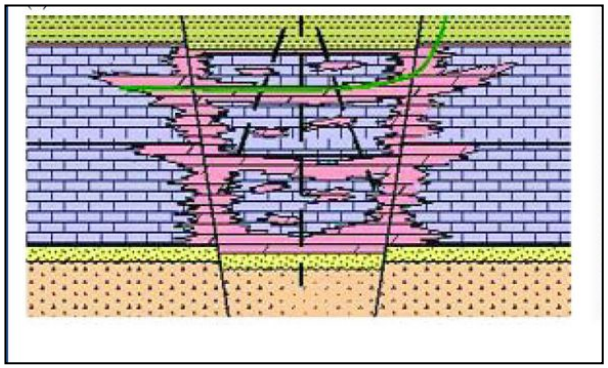
Vertical zones of neuron segregation in the SOM output, without any structural attribute as input, suggest vertically-oriented compositional changes in the rocks. This is what we would expect from HT alteration.

Neurons 8 and 17 drive the vertical segregation

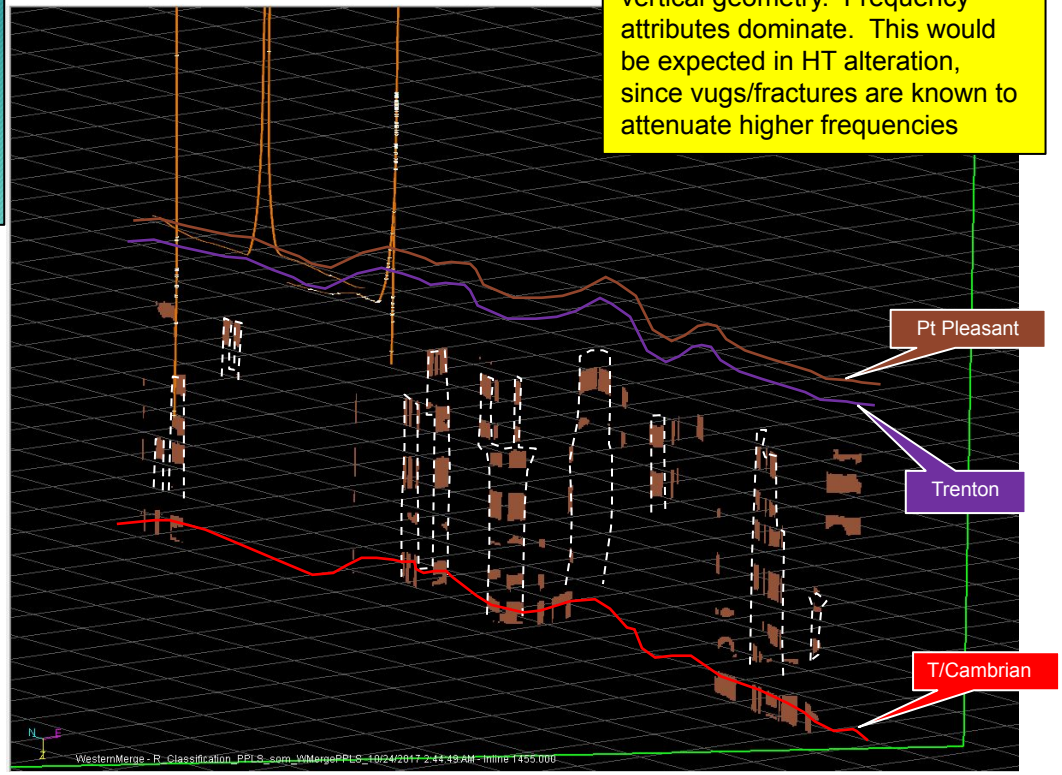


# SOM results: neuron 17

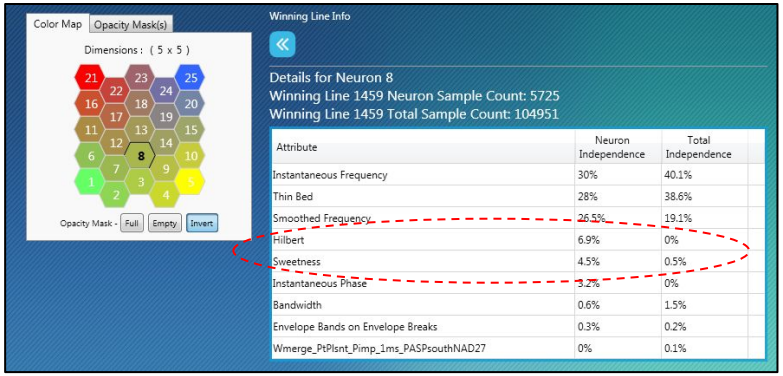
| Attribute | Neuron Independence | Total Independence |
|---|---|---|
| Instantaneous Frequency | 32.9% | 40.1% |
| Thin Bed | 30.3% | 38.6% |
| Smoothed Frequency | 27.5% | 19.1% |
| Bandwidth | 4.3% | 1.5% |
| Instantaneous Phase | 3.5% | 0% |
| Sweetness | 1.2% | 0.5% |
| Hilbert | 0.2% | 0% |
| Wmerge_PtPlsnt_Pimp_1ms_PASPsouthNAD27 | 0.1% | 0.1% |
| Envelope Bands on Envelope Breaks | 0% | 0.2% |



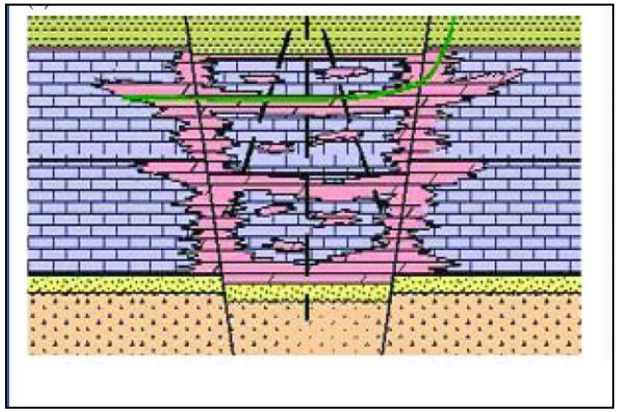
Neuron 17 captures a lot of the vertical geometry. Frequency attributes dominate. This would be expected in HT alteration, since vugs/fractures are known to attenuate higher frequencies



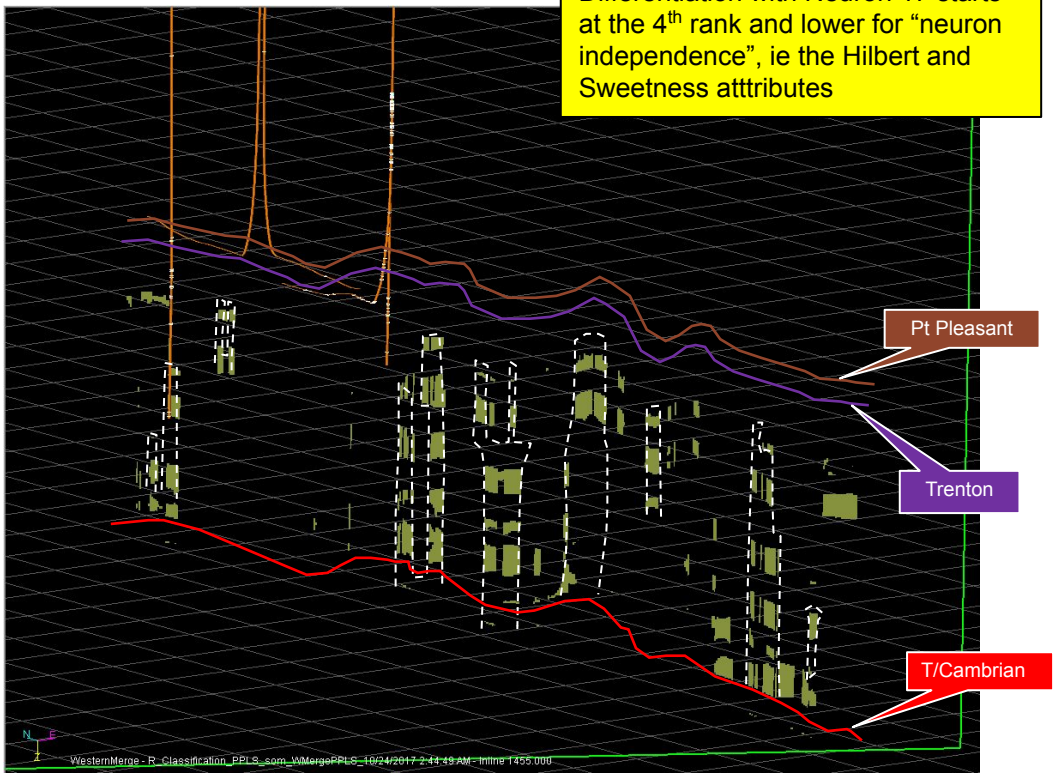
# SOM results: neuron 8



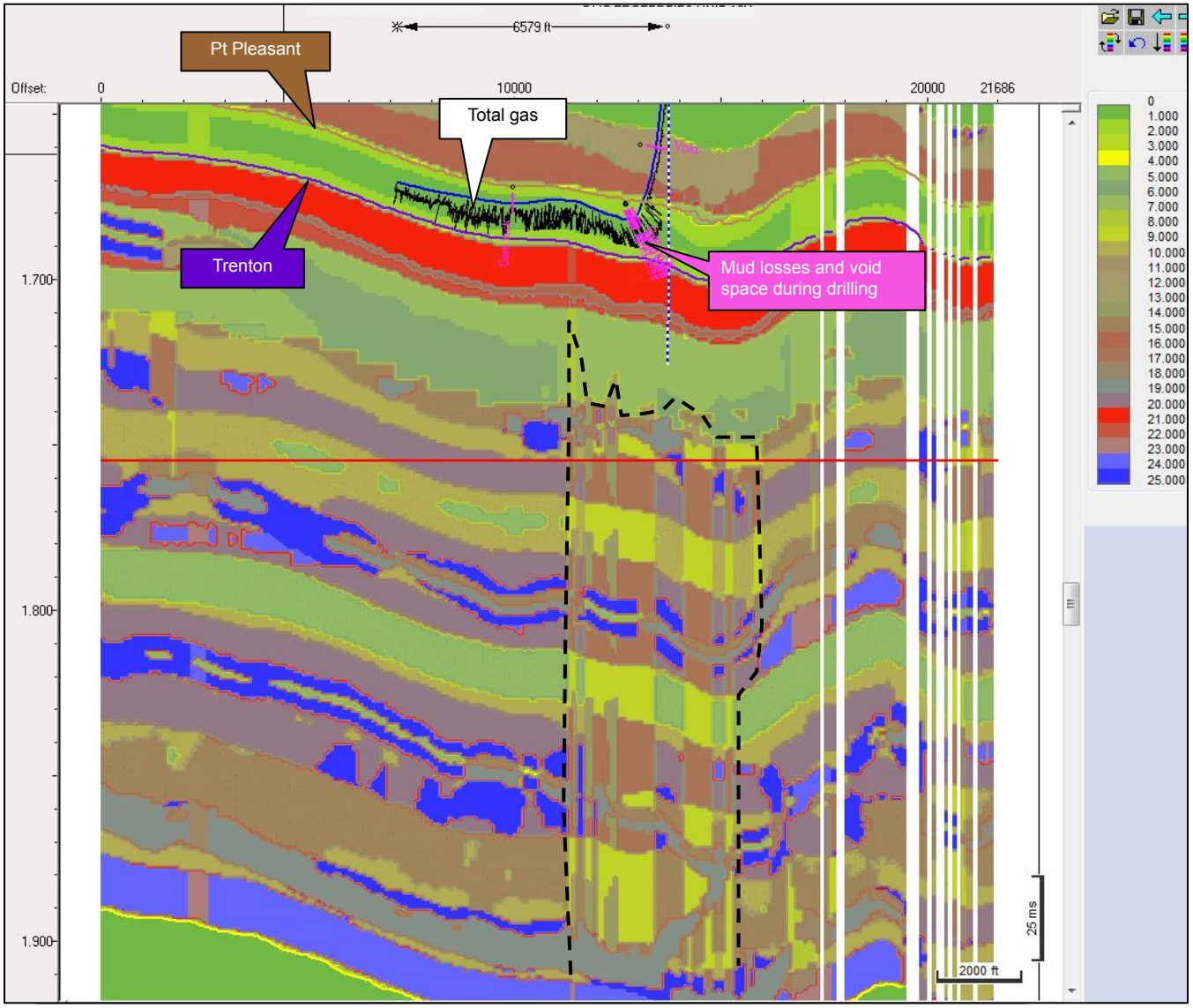

| Attribute | Neuron Independence | Total Independence |
|---|---|---|
| Instantaneous Frequency | 30% | 40.1% |
| Thin Bed | 28% | 38.6% |
| Smoothed Frequency | 26.5% | 19.1% |
| Hilbert | 6.9% | 0% |
| Sweetness | 4.5% | 0.5% |
| Instantaneous Phase | 3.2% | 0% |
| Bandwidth | 0.6% | 1.5% |
| Envelope Bands on Envelope Breaks | 0.3% | 0.2% |
| Wmerge_PtPlsnt_Pimp_1ms_PASPsouthNAD27 | 0% | 0.1% |



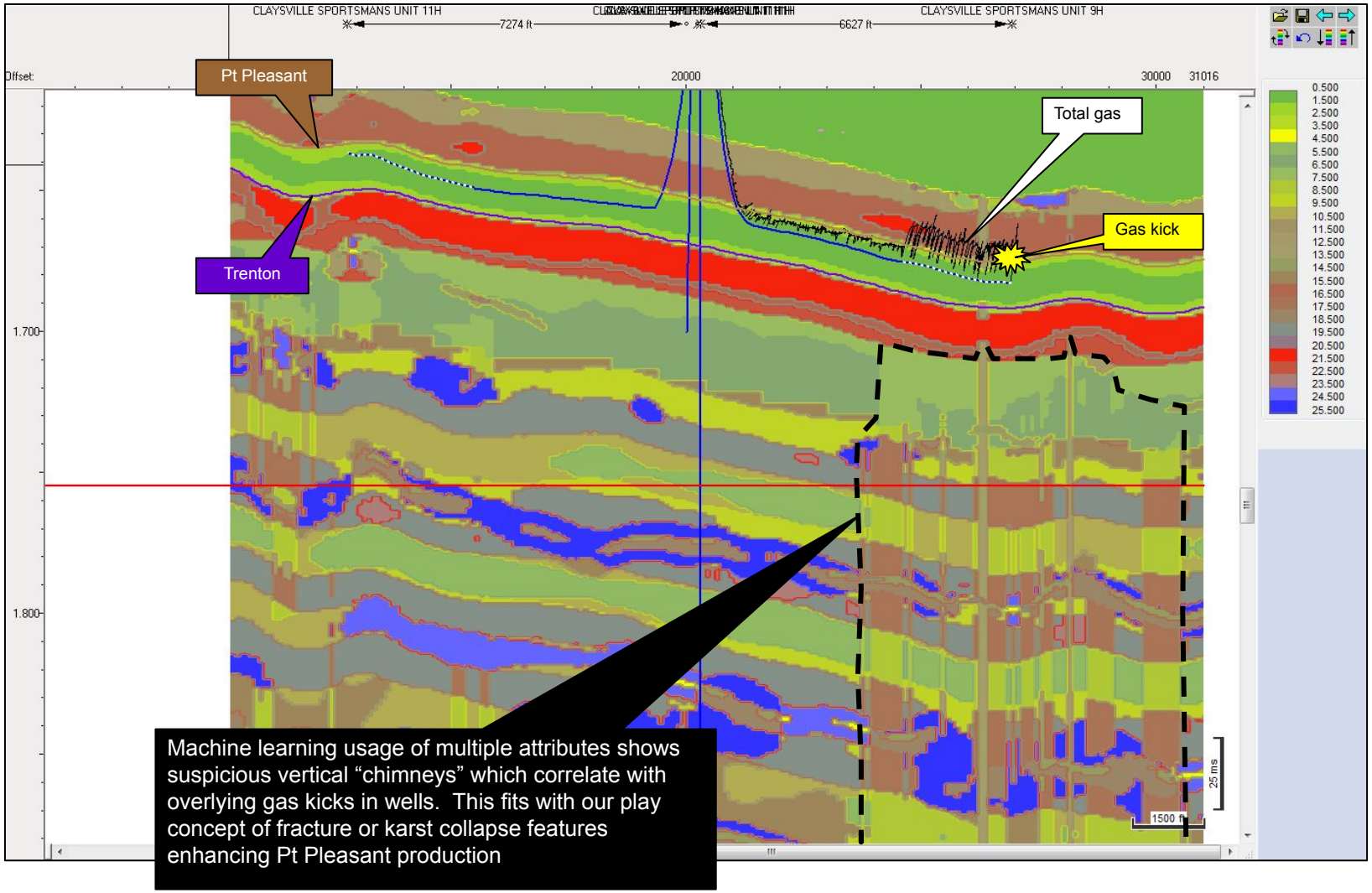
Neuron 8 captures the remaining vertical character. The same top 3 attributes as seen with Neuron 17. Differentiation with Neuron 17 starts at the 4th rank and lower for "neuron independence", ie the Hilbert and Sweetness atttributes



# Groundtruthing：well-control events directly above vertical SOM zone



# Groundtruthing: gas kicks directly above vertical SOM zone



# Conclusions

- The Utica/Pt Pleasant play is directly above the TBR, a play historically associated with hydrothermal alteration, deep karsting, & fracturing
- ML interpretation of multi-attributes combined w/drilling observations suggests underlying TBR alteration can significantly impact the production and drilling hazards of the overlying Pt Pleasant play
- This type of analysis permits more informed mapping of geohazards, and potential high-production areas,  than “typical” seismic attributes (Acoustic impedance, curvature, etc.)
- The resulting insights show that what seemed like an unconventional play may actually be a “hybrid” play, ie a mixture of unconventional production and gas-filled fractures/karst production