# Midland Basin's Wolfcamp A and B – Carbonate Gravity Flows and Rock Characterization through Machine Learning

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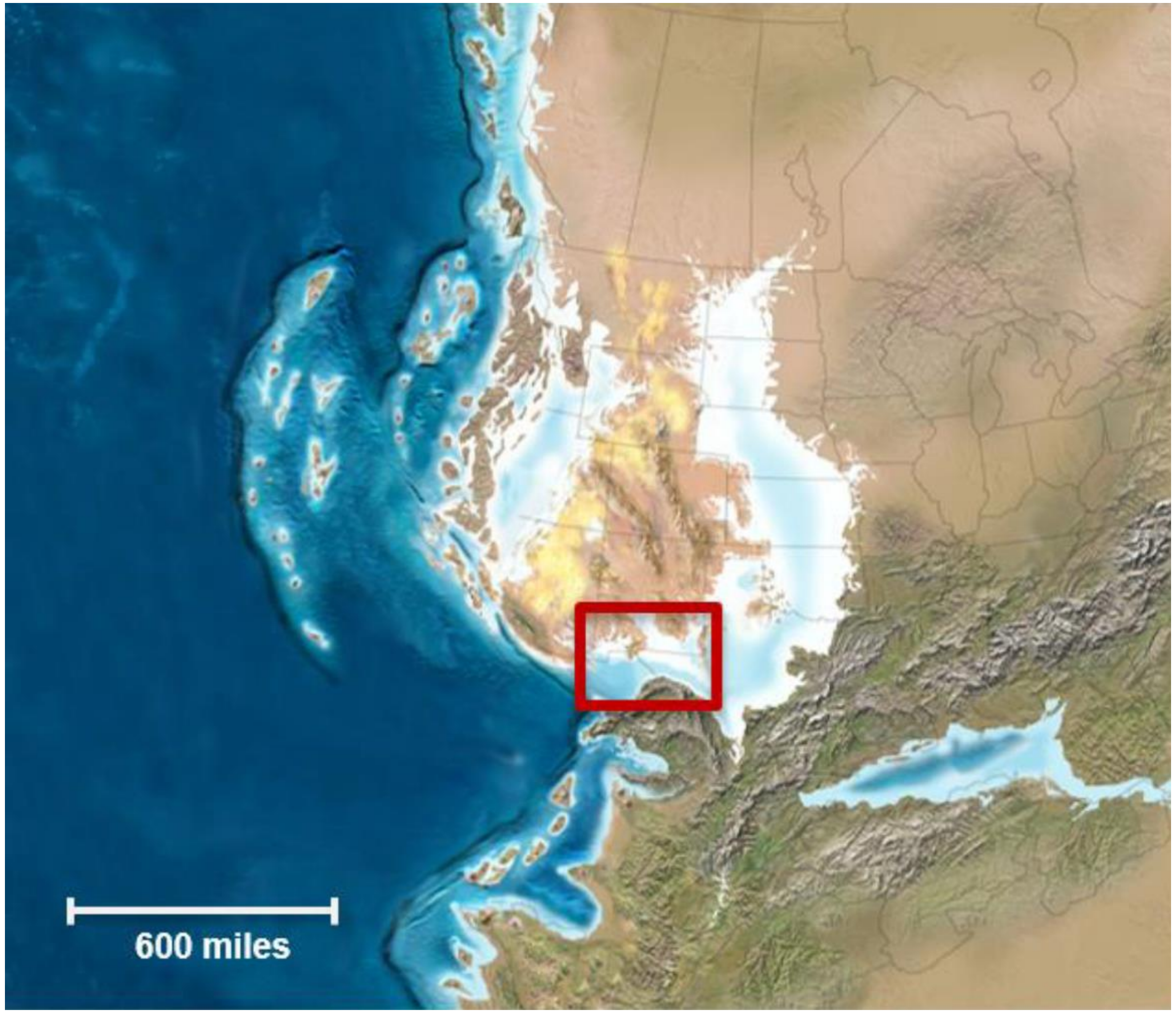
May 2022 (Expected)

# Presentation Outline

- Geologic History of the Permian Basin
- Wolfcamp Depositional Environment
- Sediment Gravity Flows
- Midland’s Upper Wolfcamp Unconventional Play
- Rock Characterization using ML
- Future work

# Geologic History of the Permian Basin

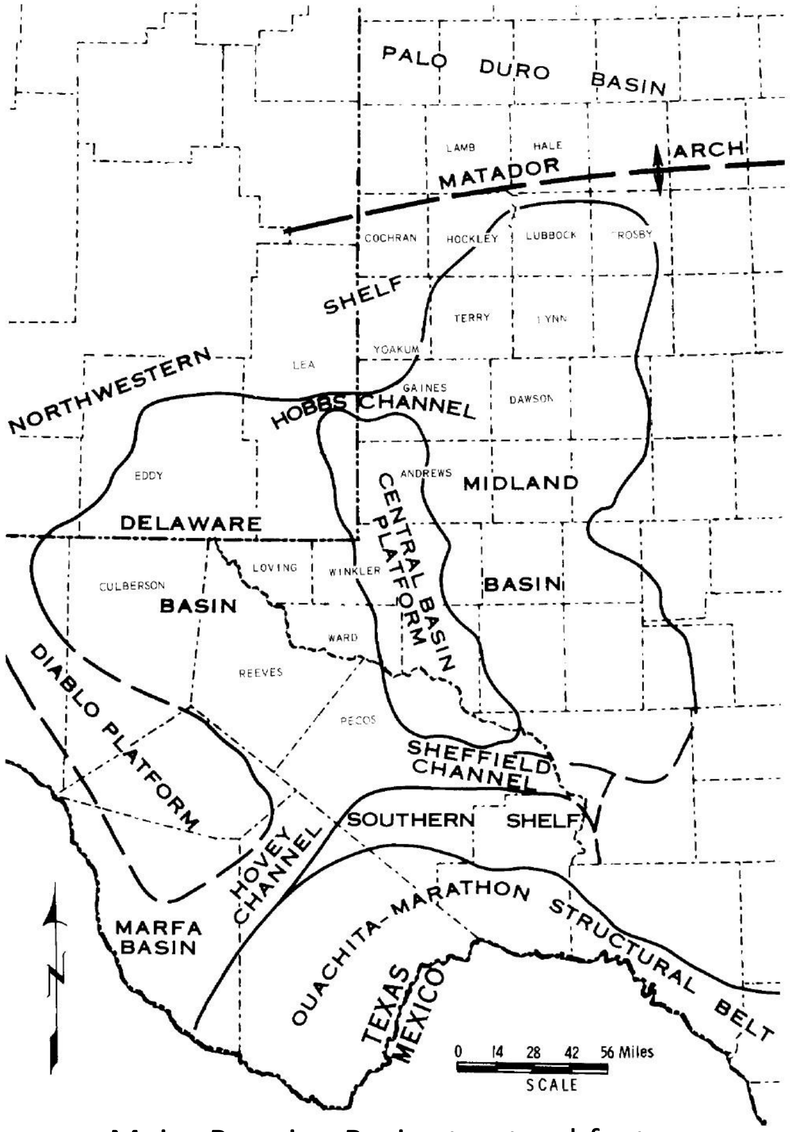
- The development of the Permian Basin can be split into three stages:
  - Cambrian to Mississippian:
    - Tobosa Basin
  - Early Pennsylvanian to Early Permian:
    - Tectonic events and climate fluctuations from glacial eustasy
  - Middle to Late Permian:
    - Infilling and decrease in subsidence




Map of Permian Basin during early-Permian time. Permian Basin denoted by red square. Modified by Lopez-Gamundi, 2019; Blakey, 2003.

# Geologic History of the Permian Basin

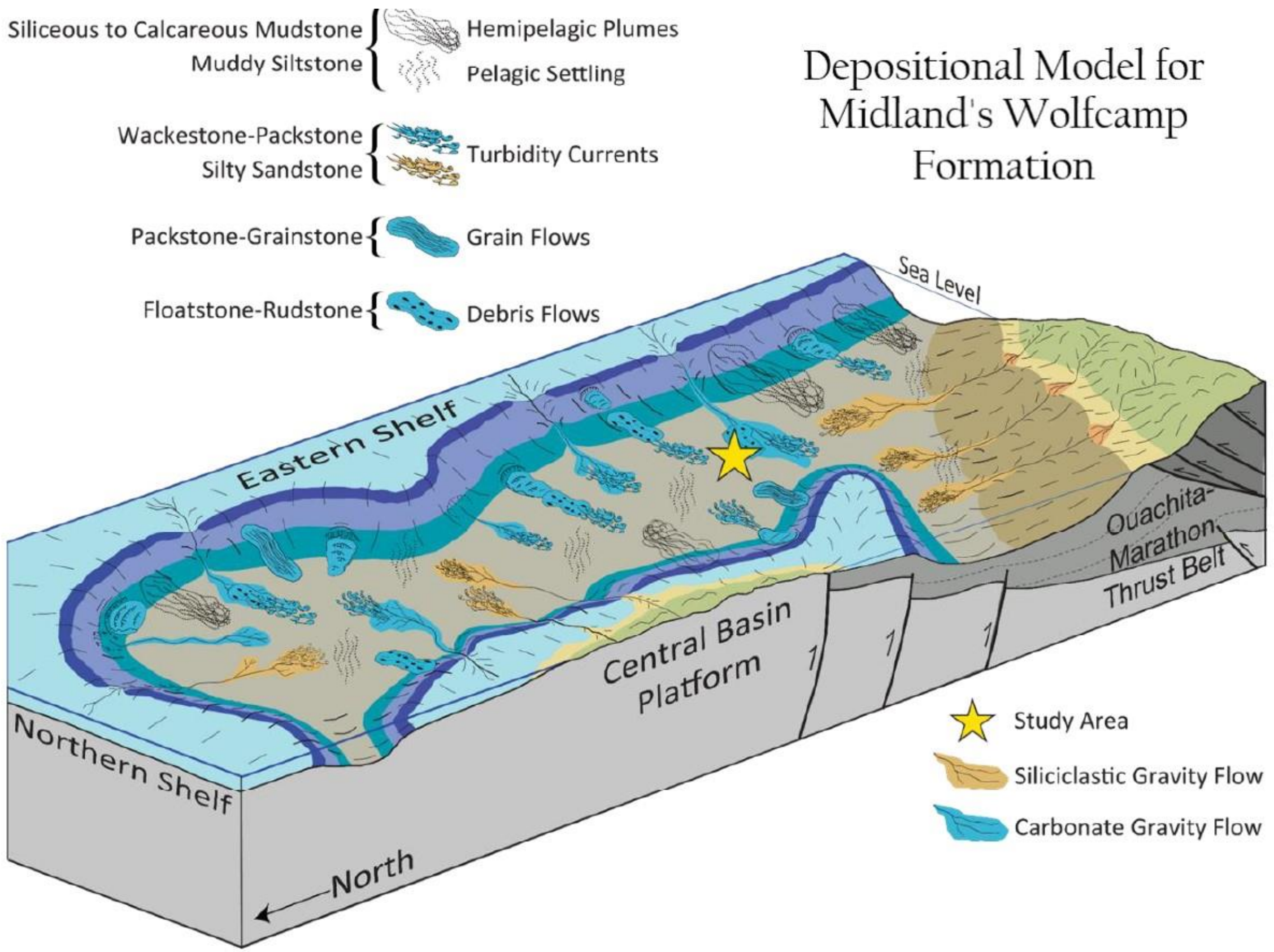
- Permian Basin covers area of 65,000 $mi^2$ or 168,000$km^2$ across west Texas and southeastern New Mexico
- Major structural elements of basin:
  - Midland and Delaware Sub-Basins
  - Central Basin Platform
  - Matador Arch




Major Permian Basin structural features.
Modified from Silver & Todd, 1969.

# Midland Basin – Wolfcamp Depositional History

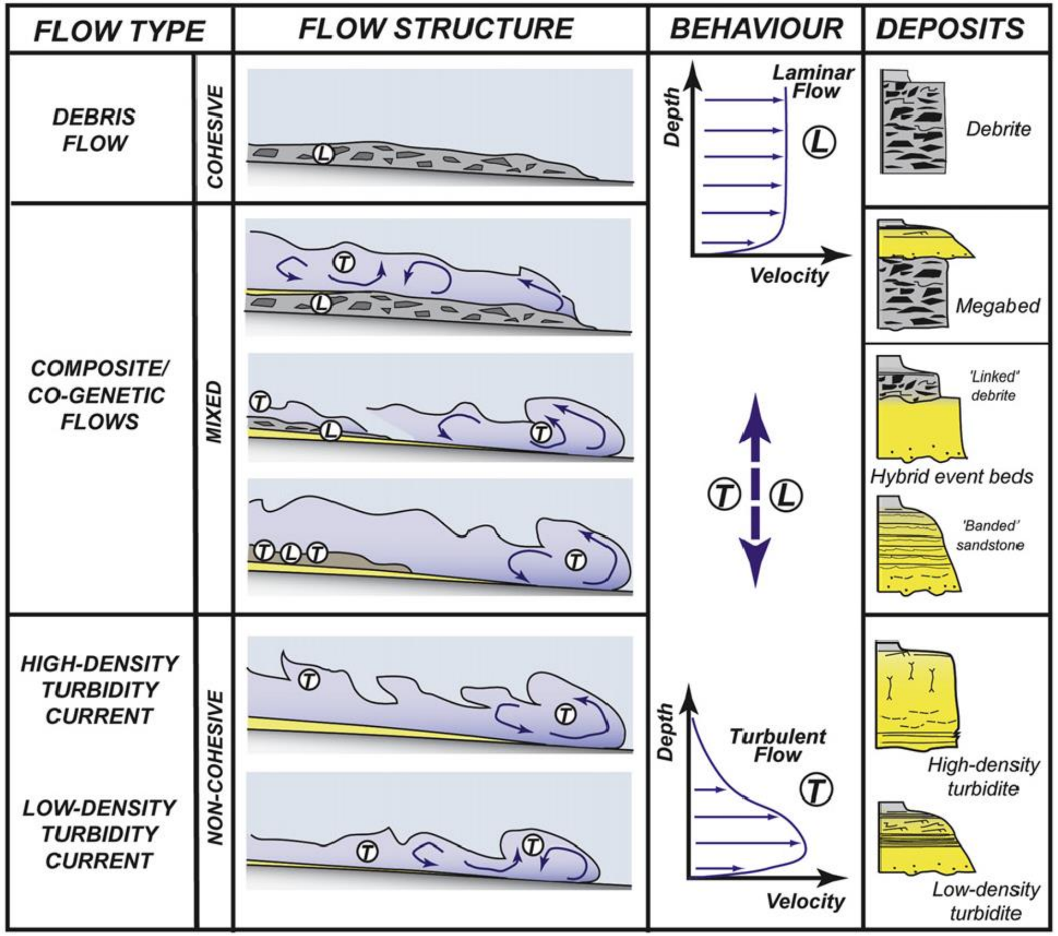
- The Wolfcamp, particularly the upper A and B sections, is dominated by hemipelagic to pelagic deposits and sediment gravity flows
- Sea levels rose and fell during Wolfcampian deposition, leading to the interlayering of siliciclastics and carbonate seen in Midland's Wolfcamp Formation




Depositional model of Midland's Wolfcamp Formation. Modified from Ward, 2013; Pioneer Natural Resources, 2013.

# Sediment Gravity Flows

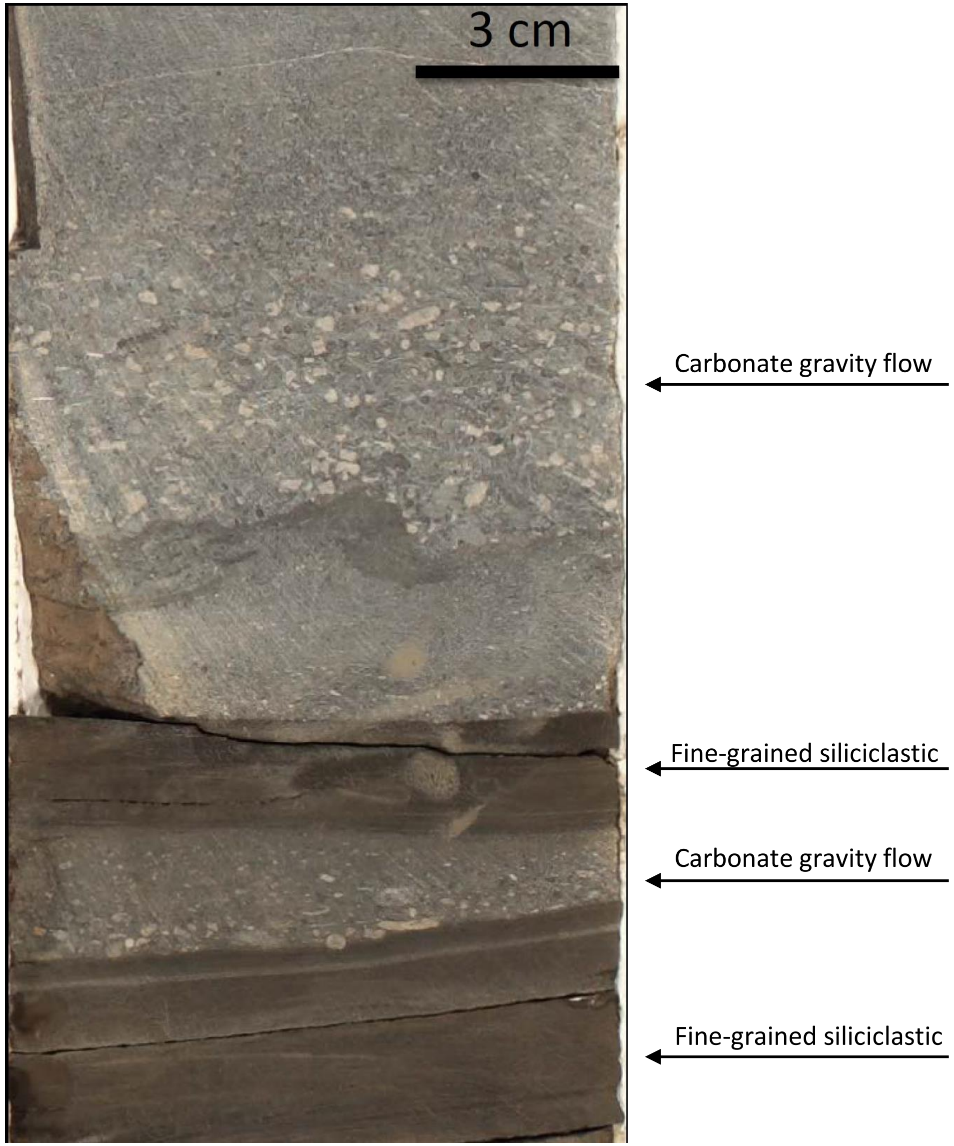
- Sediment gravity flows are mixtures of water and sediment particles where gravity acting on the sediment particles moves the fluid
- Sediment gravity flows can be divided into two end members:
  - Turbidity currents
  - Debris flows
- Figure shows three end member behaviors which govern sediment gravity flows




Classification scheme for sediment gravity flow event beds. Image from Haughton et al., (2009)

# Carbonate Gravity Flows in Midland Upper Wolfcamp

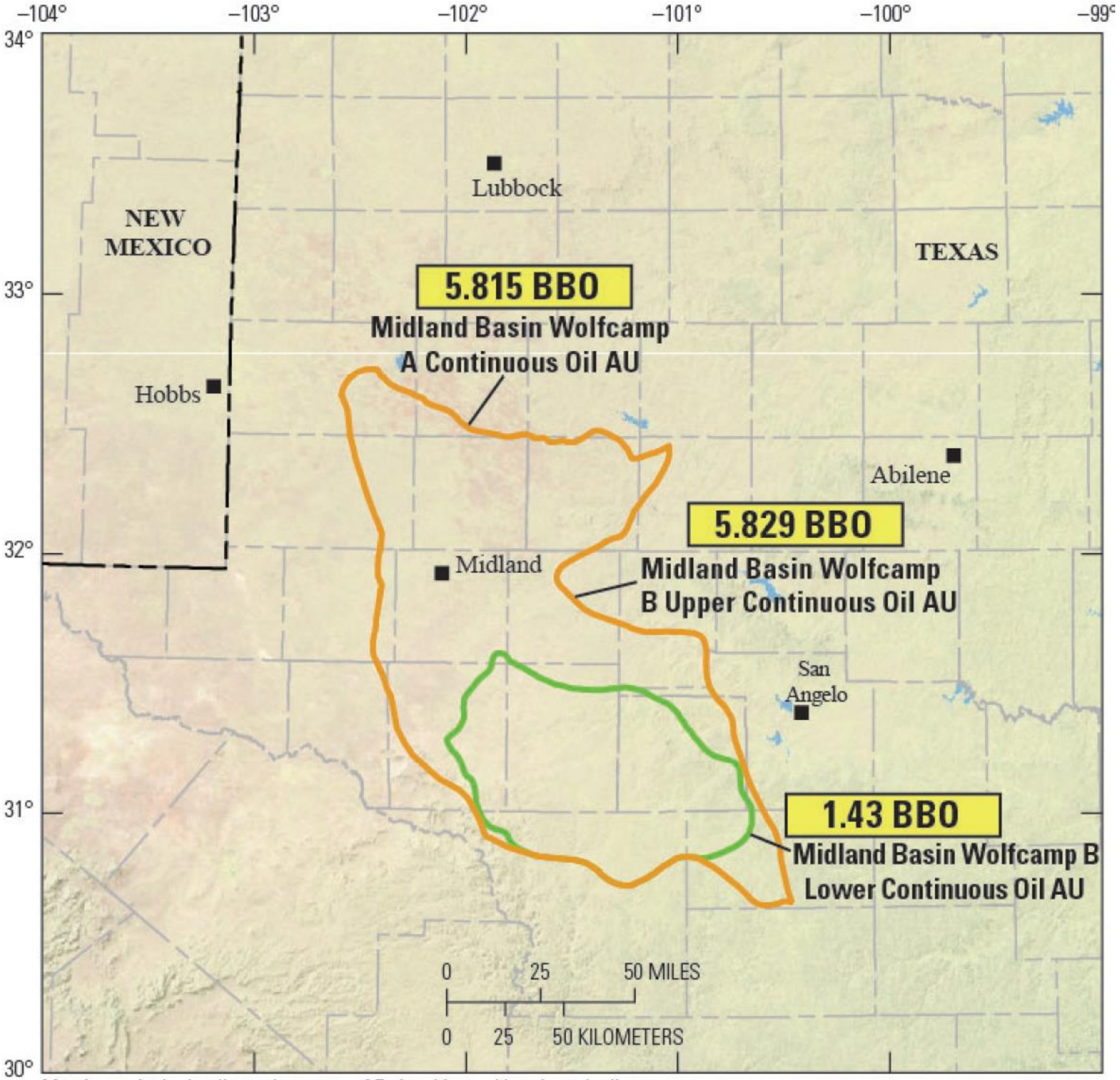
- Core photo from a Midland Wolfcamp A well demonstrates how fine-grained siliciclastics and carbonate gravity flows interlayer in the upper sections of the Wolfcamp
    - The upper carbonate gravity flow likely a packstone deposited by a high-density turbidite or hybrid event
    - The lower carbonate gravity flow likely a wackestone deposited by low density turbidite




Core from a Midland Wolfcamp A well showing carbonate sediment gravity flows and fine-grained siliciclastic deposits. Image from Zoeten & Goldstein, (2017).

# Midland Basin Upper Wolfcamp Unconventional Play

- Between 2010 and 2020, 875 vertical, 12 directional, and 2,190 horizontal wells were drilled in Midland's Wolfcamp Formations
- The Wolfcamp is a world class unconventional play because:
  - Wolfcamp A:
    - Thickness is more than 300ft
    - Porosity ranges from 7% to 22%
    - Estimated TOC ranges from 2.0% to 8.0%
  - Wolfcamp B
    - Thickness is more than 150ft
    - NPHI ranges from 6.0% to 20.0%
    - Estimated TOC ranges from 1.2% to 7.0%

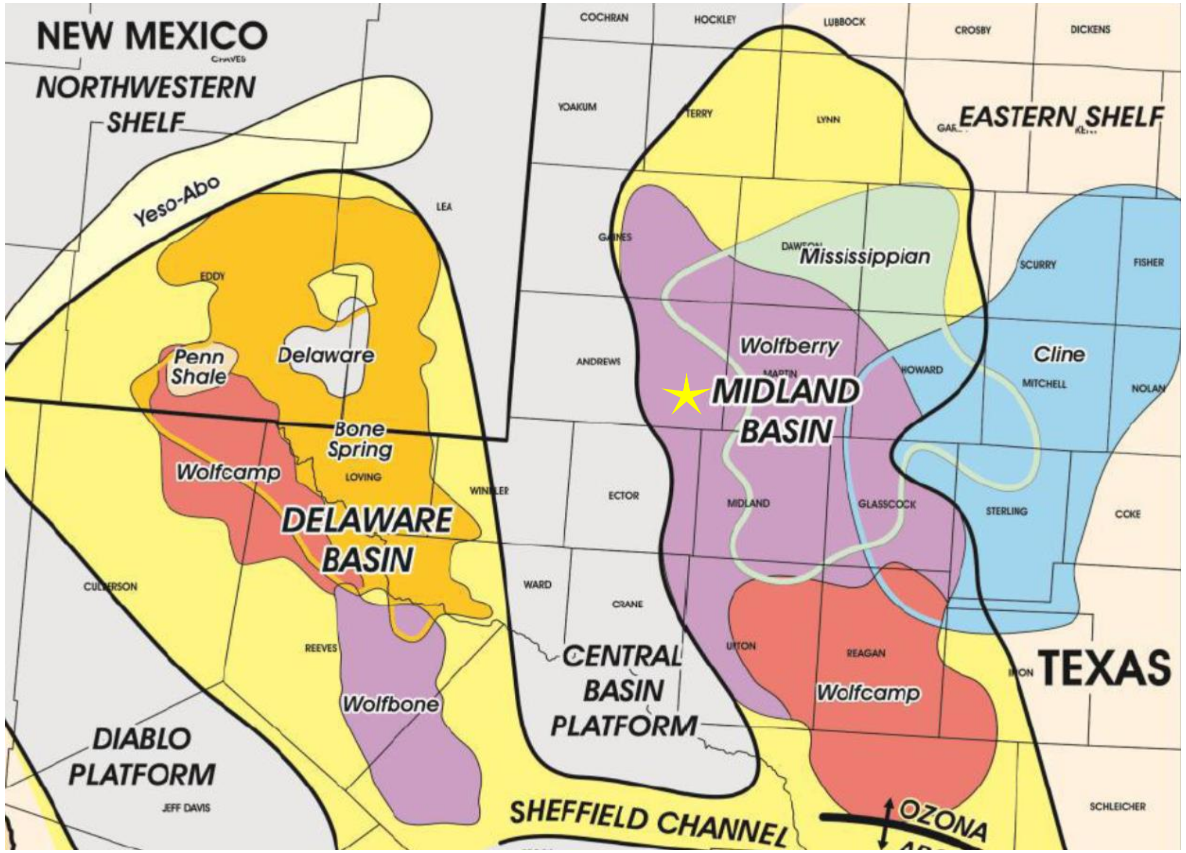





Map of USGS Wolfcamp A and B Continuous Oil Assessment. Image from USGS.

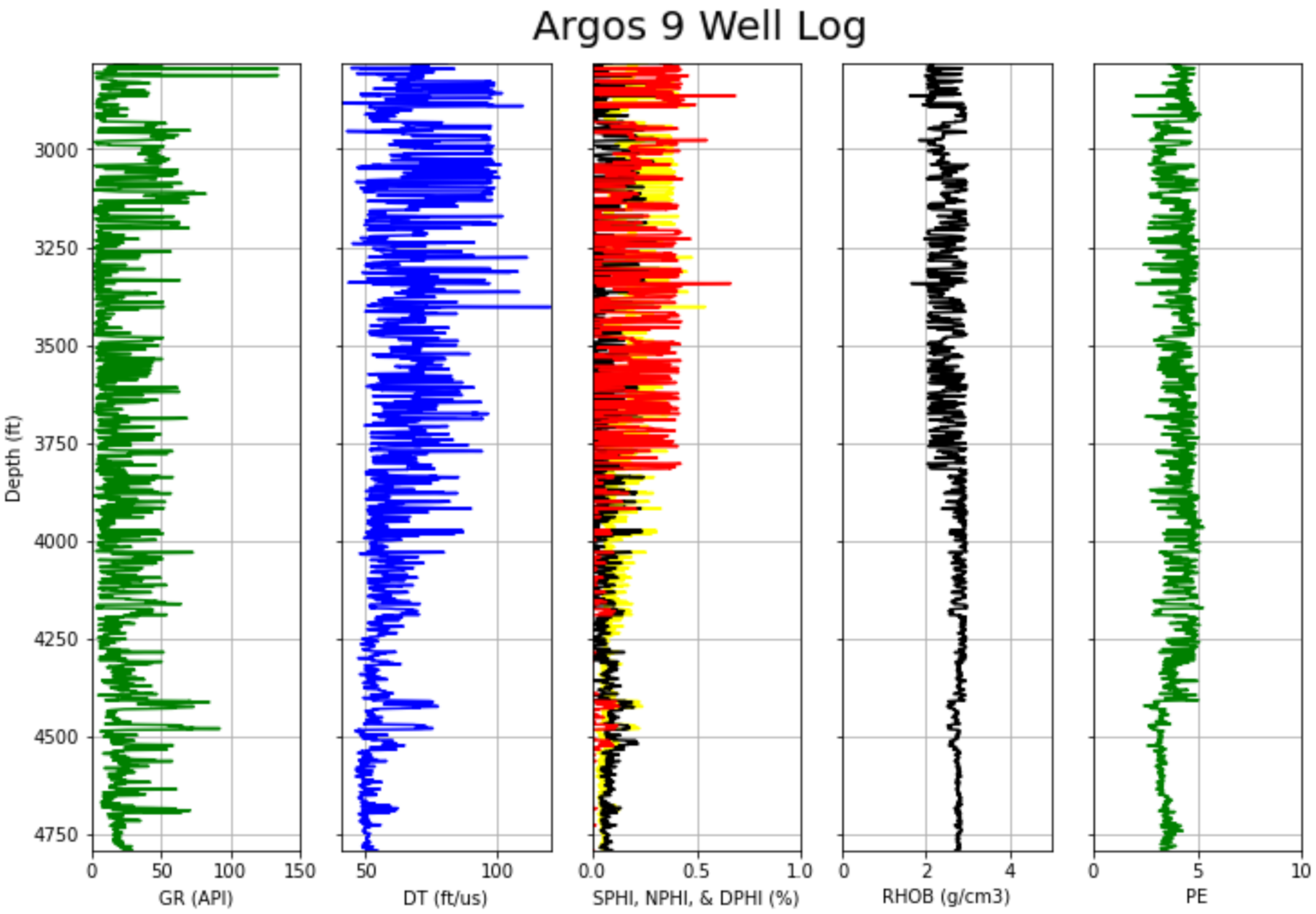
# Rock Characterization through ML – Data Acquisition

- Argos 9 well log acquired from Texas Railroad Commission website
- Located in Andrews County in Midland Basin
- Vertical well with ~2000ft of data at 0.5ft step
- Data acquired by Halliburton for OK Arena Operating Company



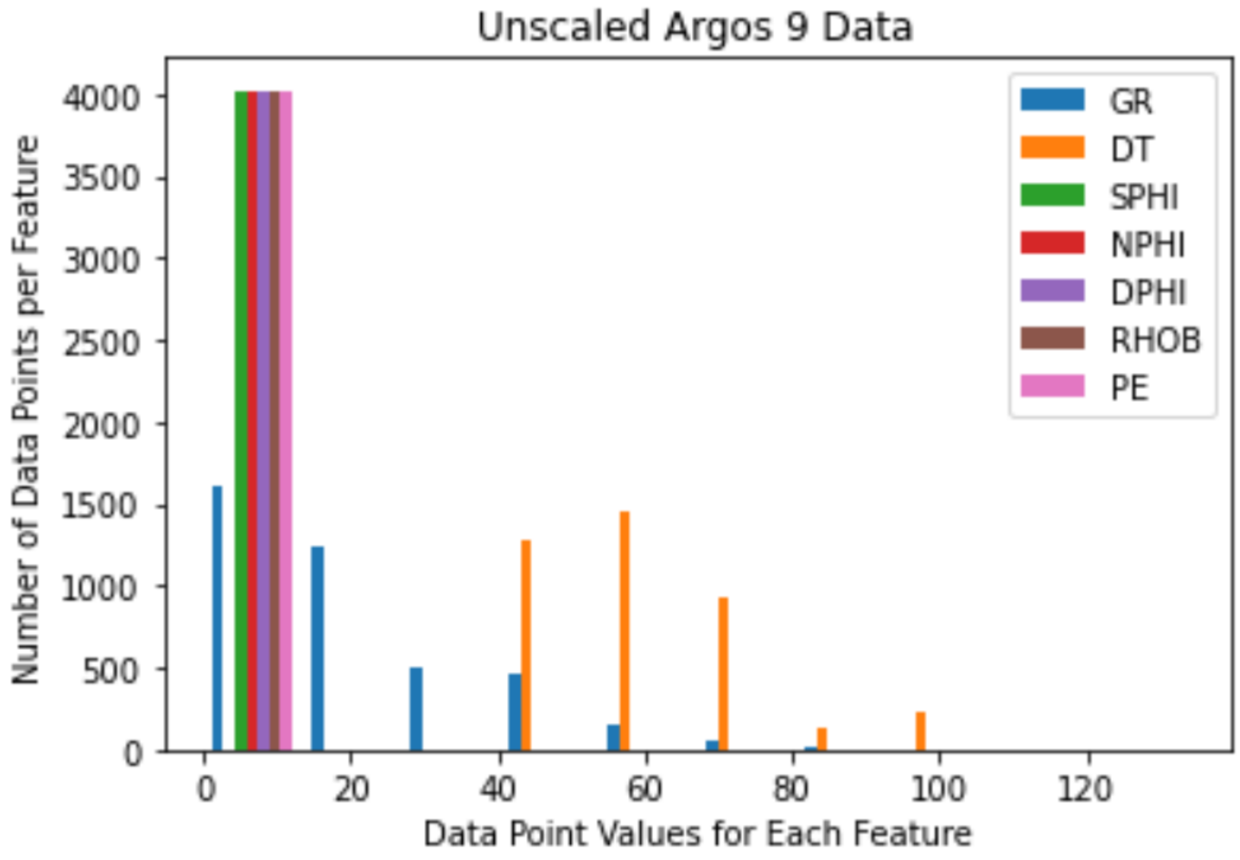

Map of Permian Basin with a star marking the location of Andrews Unit 732 Well. Modified from Shale Experts.

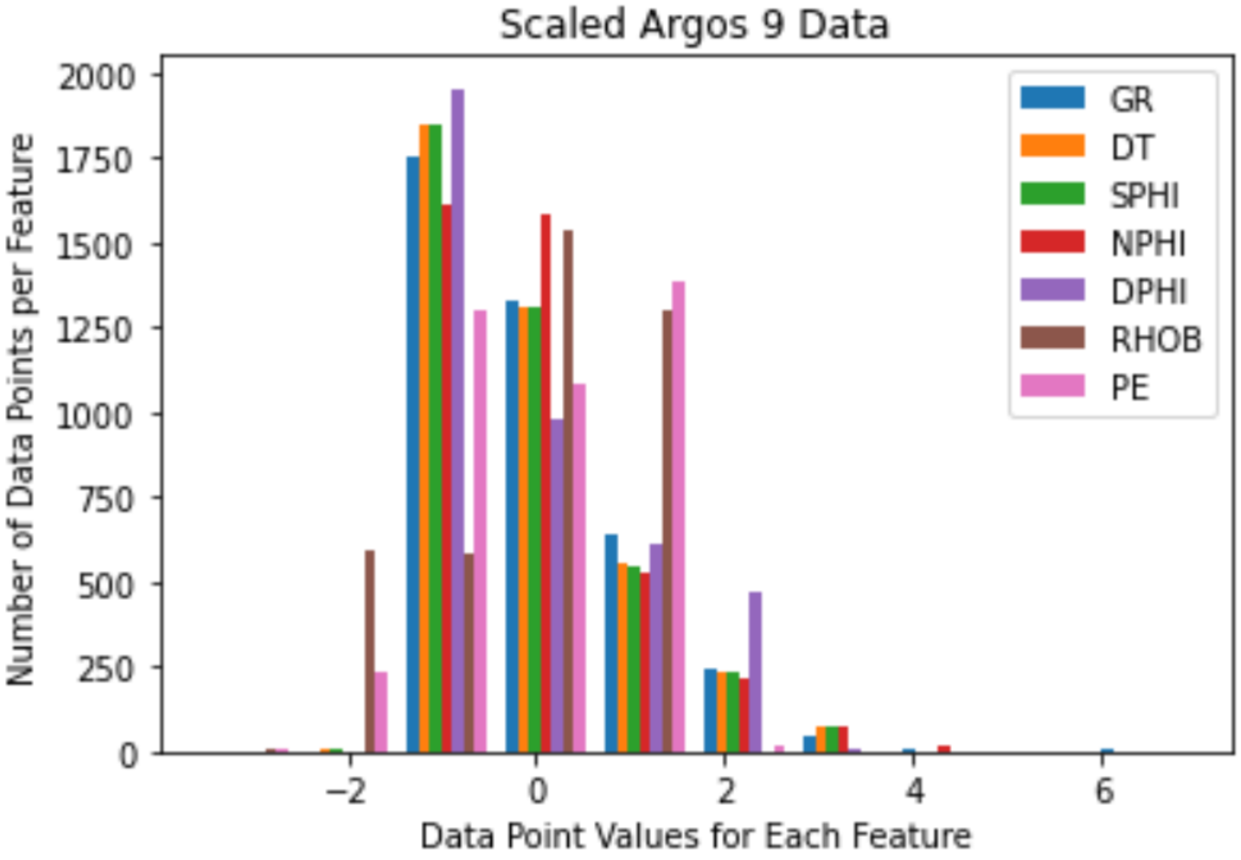
# Rock Characterization through ML – Preprocessing




Argos 9 well log created using Python. Image by Selena Neale.

# Rock Characterization through ML – Scaling Data

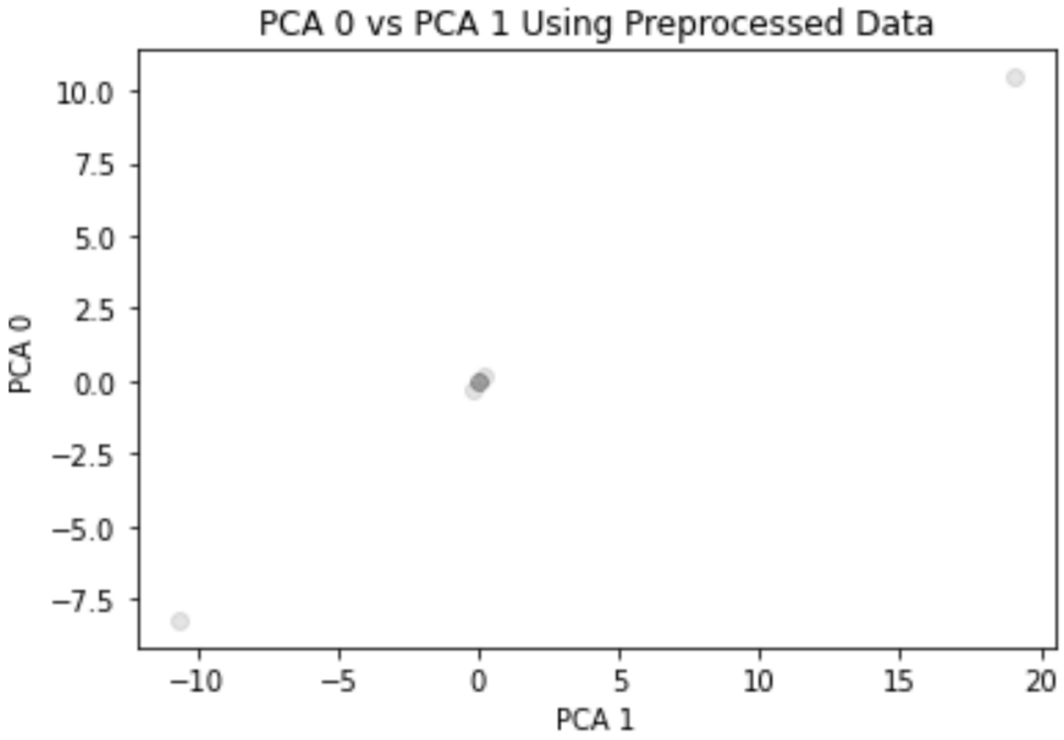


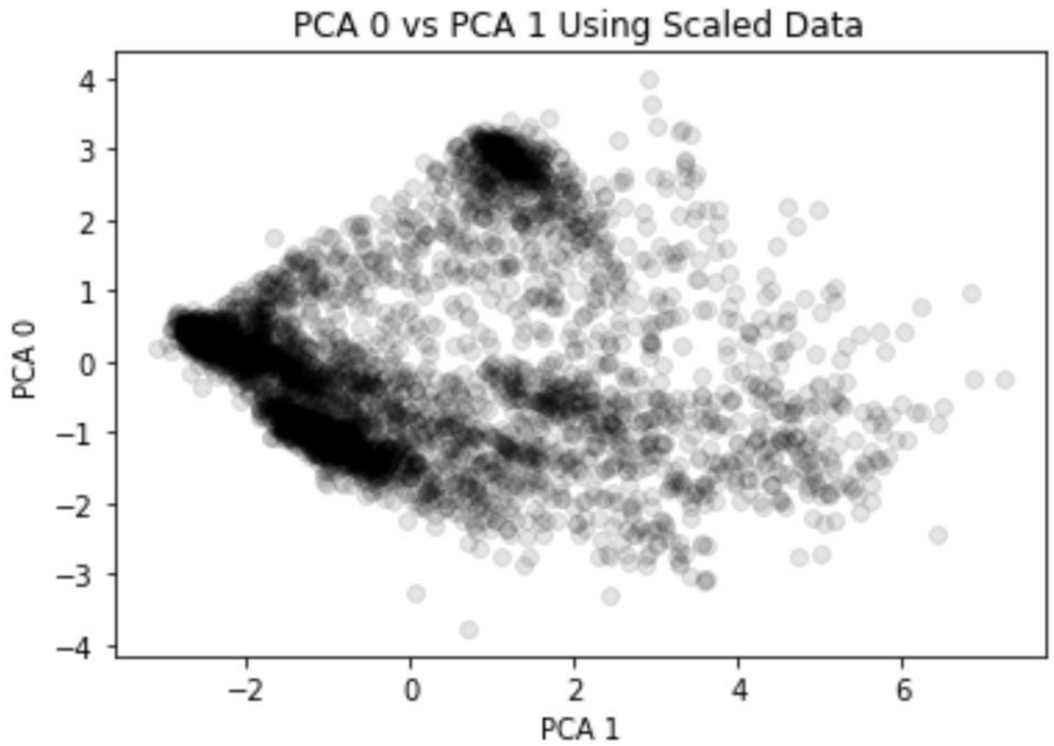



Images created by Selena Neale.

# Rock Characterization through ML – Principle Component Analysis




| | GR | DT | SPHI | NPHI | DPHI | RHOB | PE |
|---|---|---|---|---|---|---|---|
| **0** | 8.723680e-01 | 0.488316 | 3.450996e-03 | 0.002650 | 0.003317 | -0.005341 | -2.152616e-02 |
| **1** | 4.880576e-01 | -0.872392 | -6.165381e-03 | 0.000475 | -0.010321 | 0.016616 | -1.764517e-02 |
| **2** | 2.572711e-02 | 0.000063 | -5.308322e-07 | -0.034725 | -0.125160 | 0.201509 | 9.704954e-01 |
| **3** | 1.054917e-02 | -0.020592 | -1.446620e-04 | -0.078031 | 0.511211 | -0.823043 | 2.337510e-01 |
| **4** | -8.301406e-04 | -0.002493 | -6.815883e-06 | 0.996342 | 0.035670 | -0.057429 | 5.219663e-02 |
| **5** | 3.636651e-08 | -0.006748 | 9.548552e-01 | -0.000010 | 0.252289 | 0.156704 | -1.696182e-07 |
| **6** | -7.396177e-08 | 0.002099 | -2.969875e-01 | 0.000003 | 0.811147 | 0.503821 | -1.162507e-06 |

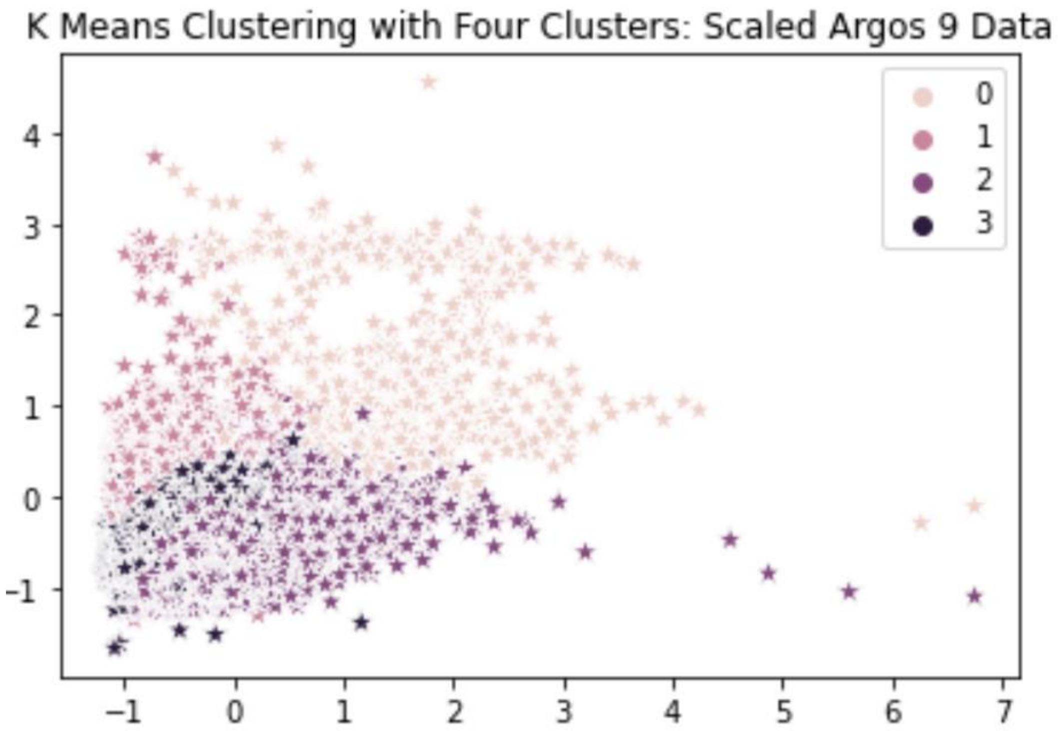



| | GR | DT | SPHI | NPHI | DPHI | RHOB | PE |
|---|---|---|---|---|---|---|---|
| **0** | 0.325027 | 0.450845 | 0.450845 | 3.326089e-01 | 0.385184 | -0.385184 | -2.836779e-01 |
| **1** | -0.465453 | 0.144457 | 0.144460 | -4.740533e-01 | 0.397205 | -0.397205 | 4.487177e-01 |
| **2** | -0.075156 | -0.434271 | -0.434266 | -1.036159e-01 | 0.374527 | -0.374526 | -5.708736e-01 |
| **3** | 0.800115 | -0.076198 | -0.076211 | -5.524032e-01 | 0.059878 | -0.059870 | 1.894278e-01 |
| **4** | 0.178547 | -0.285439 | -0.285434 | 5.905584e-01 | 0.223626 | -0.223619 | 5.969922e-01 |
| **5** | -0.000007 | 0.707054 | -0.707056 | 5.254584e-06 | -0.008537 | -0.008542 | -9.423194e-07 |
| **6** | -0.000005 | 0.008542 | -0.008538 | 1.294527e-07 | 0.707054 | 0.707057 | -3.492852e-06 |

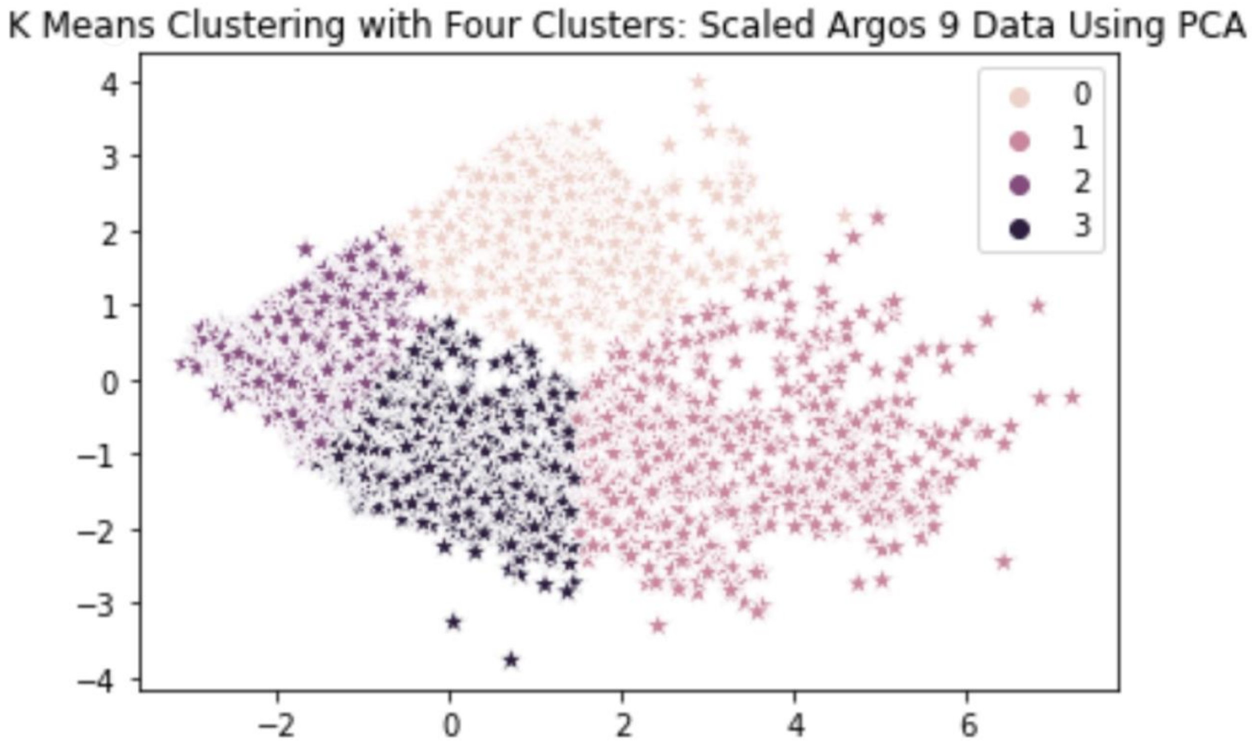


Images created by Selena Neale.

# Rock Characterization through ML – K Means with Four Clusters




With four K Means clusters and scaled data, the average silhouette score is 0. 4503.

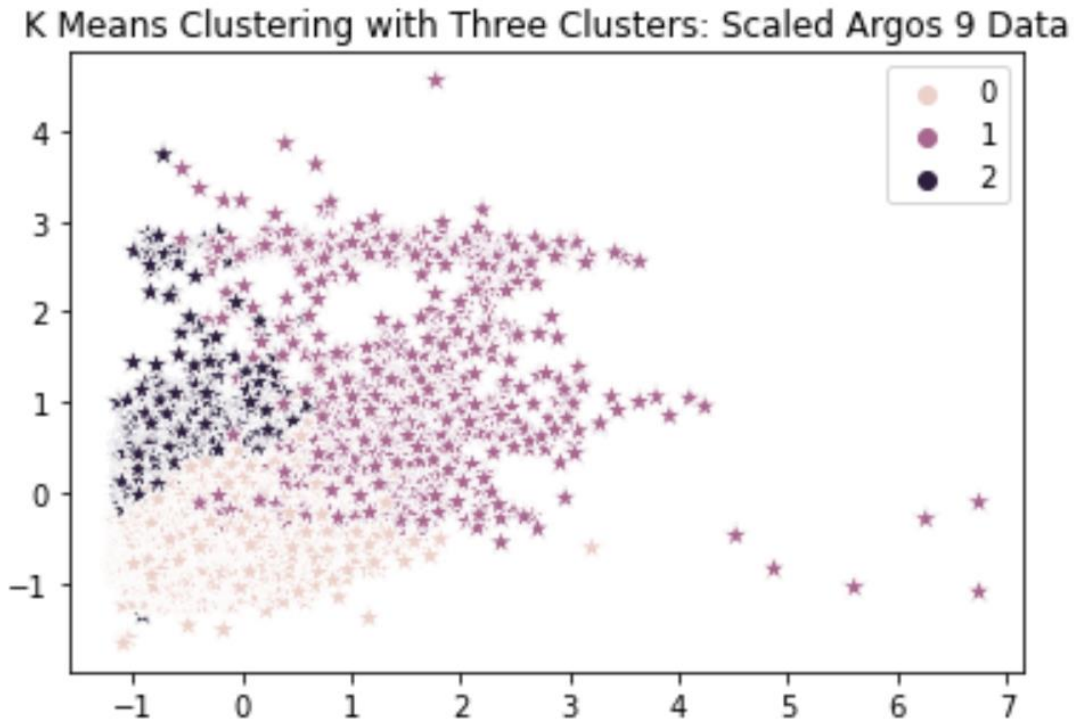



With four K Means clusters and scaled PCA data, the average silhouette score is 0.5012.

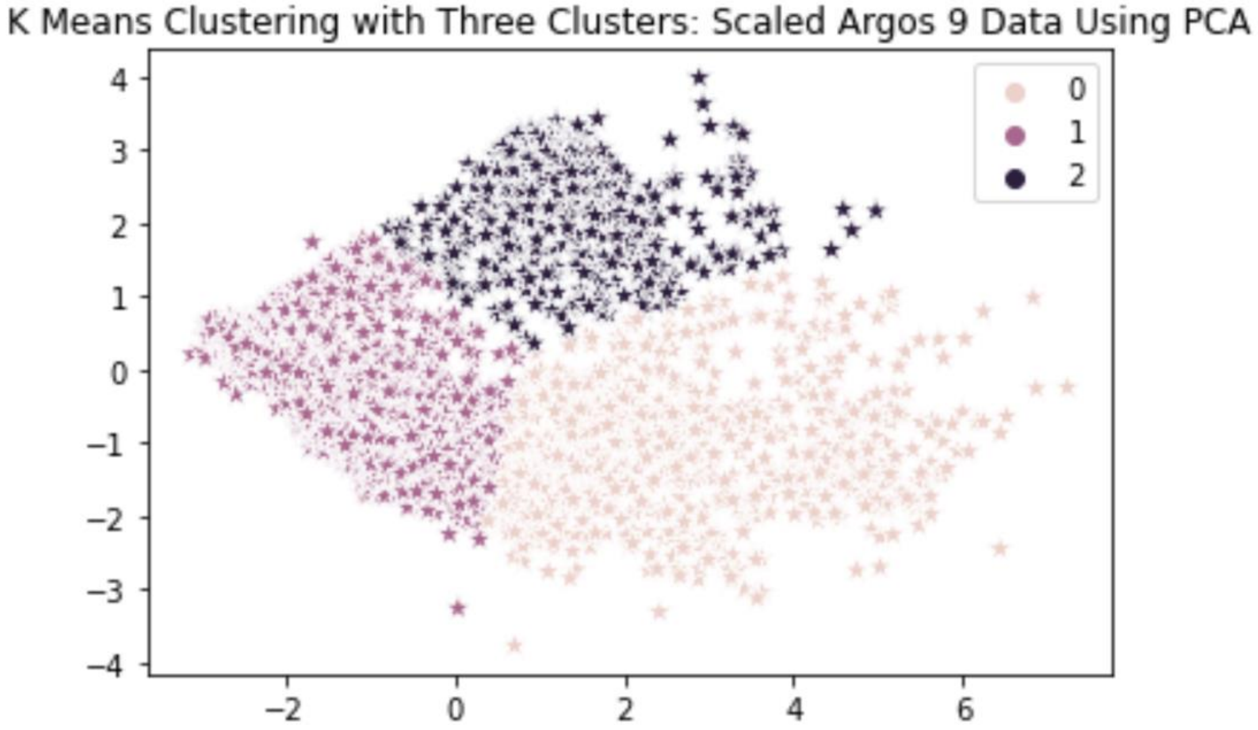


Images created by Selena Neale.

# Rock Characterization through ML – K Means with Three Clusters




With three K Means clusters and scaled data, the average silhouette score is 0.4865.




With three K Means clusters and scaled PCA data, the average silhouette score is 0.5677.



Images created by Selena Neale.

# Rock Characterization through ML – Future Work

- Using other well data from Midland Basin wells and the Argos 9, work with more complex machine learning algorithms, particularly neural nets, that are capable of more in-depth, accurate lithology characterization than K means clustering
- Definitively characterize lithology in well logs using a more accurate, more complex algorithm, like neural networks
- Extract sections of well logs the more advanced algorithm correctly picks as carbonate in close proximity wells
- Using this carbonate data, model possible carbonate gravity flow geometries that could connect or isolate the wells

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