AI and Machine Learning in the Identification of Geochemical Variability and Geogenic Carbon: A Case Study of the Barnett Shale Formation

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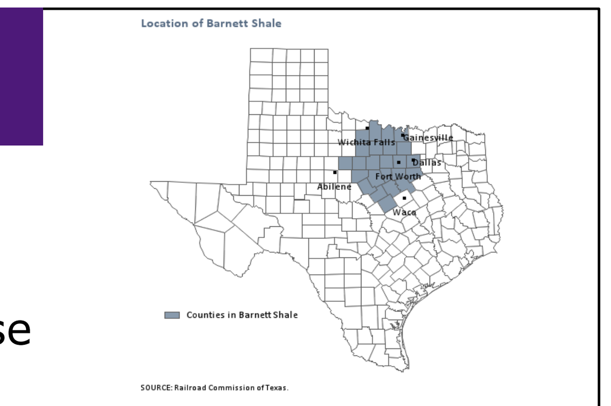
Introduction

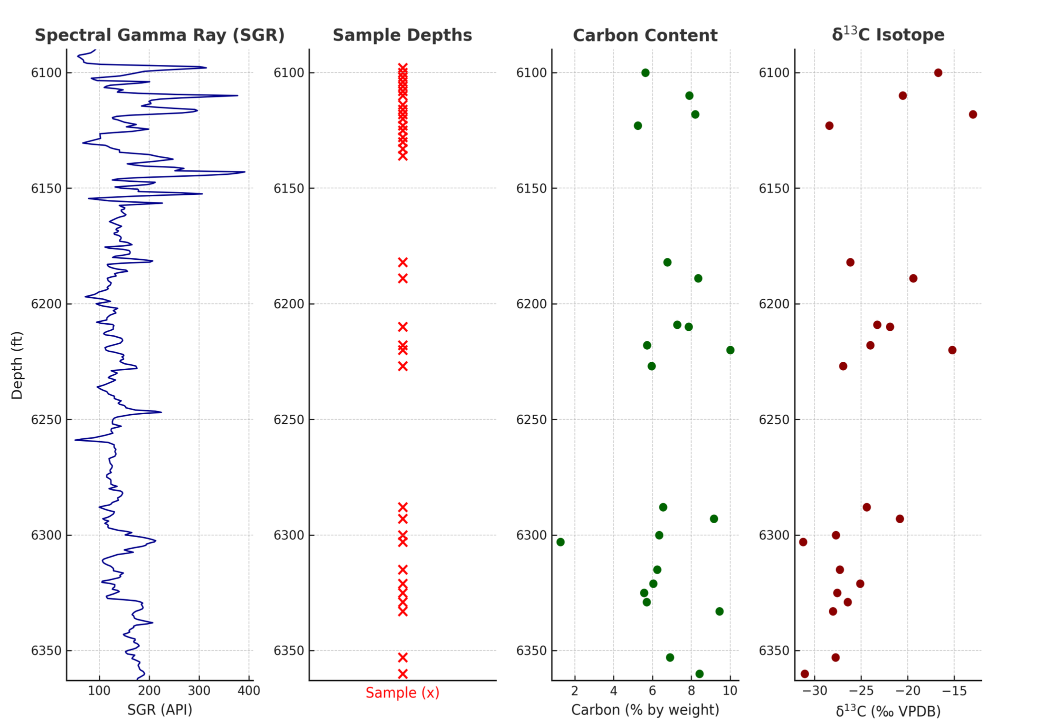
The Barnett Shale formation in the Fort Worth Basin has been a substantial producer of oil and gas energy resources. The Barnett Shale serves as an ideal testing ground for innovative approaches to subsurface analysis, offering both abundant production history and a wealth of existing data. This study integrates experimental thermal analysis methods with AI-driven workflows to rapidly process and interpret large volumes of geochemical data. We aim to identify and evaluate geochemical variability and the distribution, content, and quality of geogenic carbon with depth across key stratigraphic intervals. Expanding subsurface applications of AI-machine learning and developing refined geochemical methodology are central to understanding the scalability of resource assessments and underscores the broader potential of these emerging analytical tools in energy exploration.



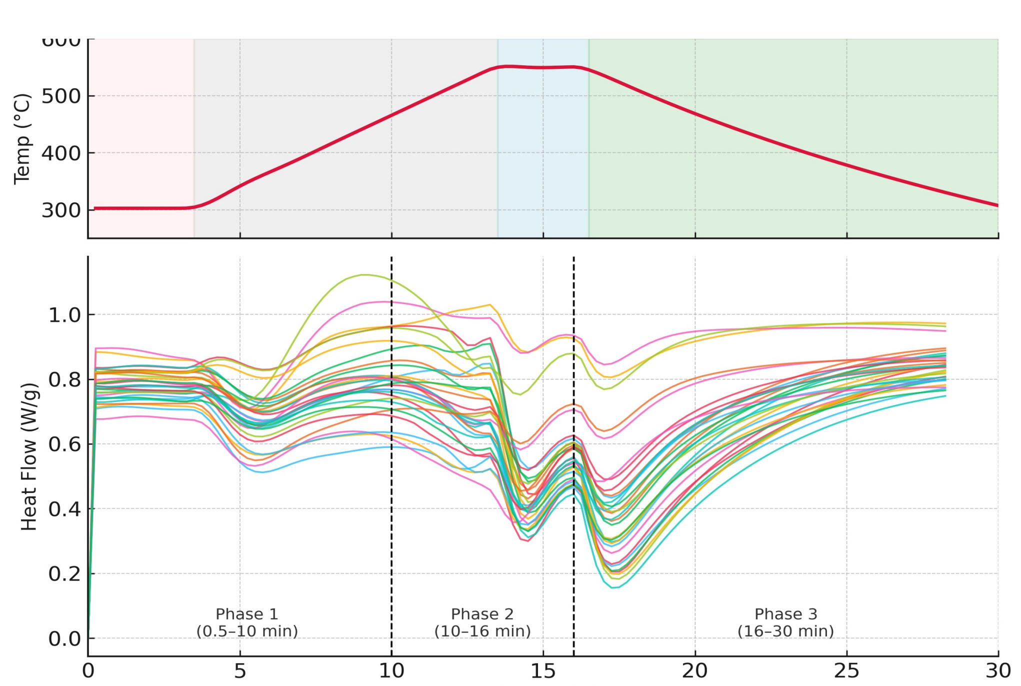
Methods And Data Analysis

- AI-assisted analysis was used to identify ideal sampling depths from coarse core data (6098–6363 ft)
- Elemental combustion analysis and stable carbon isotope ratio ($\delta^{13}C$) measurements were performed on selected samples to evaluate variations in organic carbon content and quality
- High-resolution sampling was conducted every 0.5 ft within the high-variability interval (6098–6130 ft)
- A novel, rapid thermogravimetric analysis–differential scanning calorimetry (TGA-DSC) method in a RockEval environment was used to simulate the thermal cracking of organic matter
- Derivative weight loss and heat flow data were combined with AI workflows to perform 2D correlation analysis, highlighting depth-dependent geochemical trends

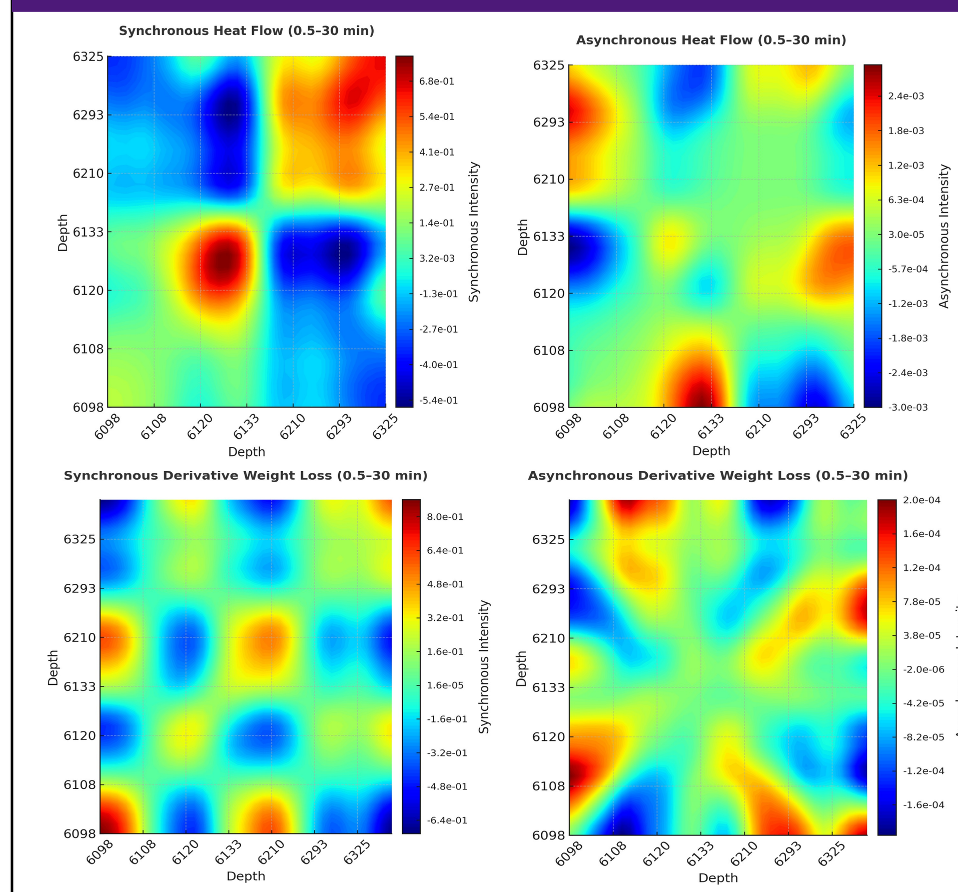
Graphs display Barnett Shale well log data, AI-selected depths for sample collection, carbon weight %, and carbon isotope ratios pictured left to right. High variability zone at the top of the well log was selected for high-resolution sampling



The TGA-DSC temperature protocol is illustrated to the right, with the corresponding heat flow data presented below. The AI-2D correlation analysis was segmented into three distinct time phases to isolate and characterize changes associated with individual thermal events observed in the heat flow profile. Variations in thermal responses across different depths provide insight into heterogeneity within the sample, particularly regarding differences in organic matter content and composition.

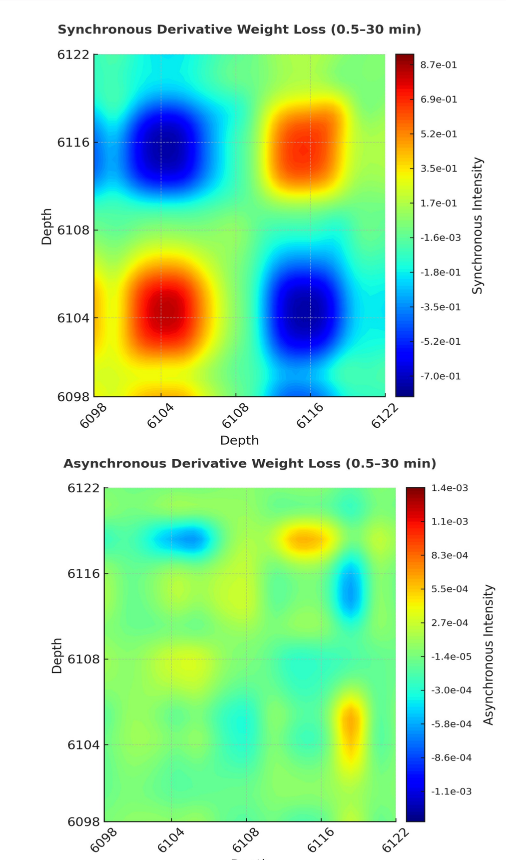


Results



Global Analysis

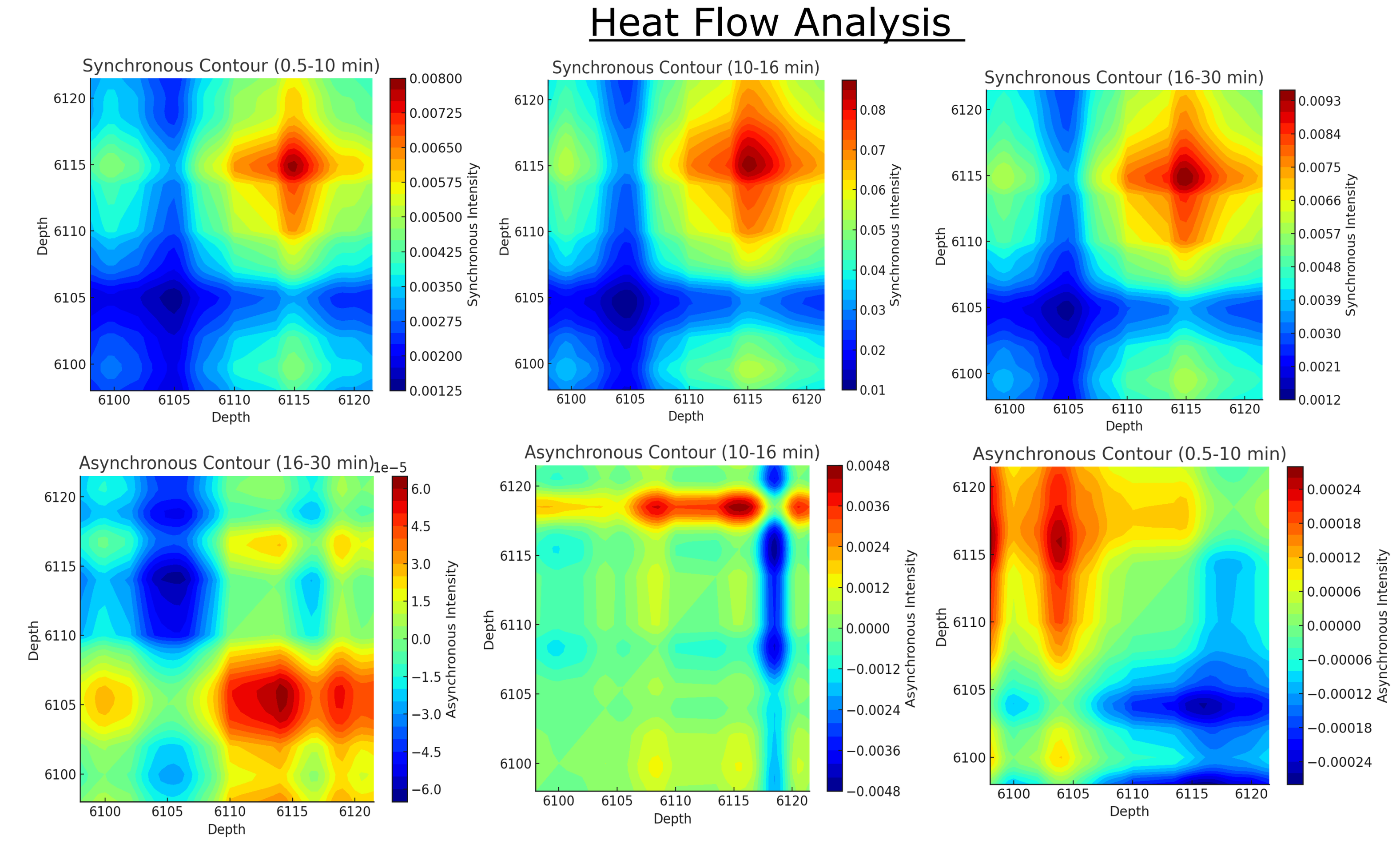
- Global heat flow shows strong synchronous zones of opposing intensity (6120 ft and 6293 ft) followed by transitional intervals of asynchronous thermal responses (6133 ft and 6300 ft)
- Derivative weight loss shows alternating intervals of in-phase thermal events and out-of-phase shifts (6108 vs. 6120 ft and 6293 ft)
- AI 2D analysis displays great variability in thermal behavior throughout the depth range



Weight Loss Analysis

- Strong synchronous correlation zones at 6104 and 6116 ft suggest concentrated organic matter layers
- Differences in synchronous intensity likely result from differing organic matter content or quality
- Dispersion of weak asynchronous signals could indicate small-scale differences in mineralogy, porosity, or organic matter content, as well as support the idea of transitional layering with rapid shifts in thermal characteristics

Heat Flow Analysis



- Synchronous heat flow contours reveal concentrated thermal activity near 6105 and 6115 ft, with opposing intensity signatures suggesting compositional differences between these intervals
- Phase-specific differences in asynchronous thermal behavior suggest stratigraphic variability in the composition and abundance of geogenic carbon

Heat Flow Cross-Sections

- 2D heat flow cross sections capture thermal behavior ranging from endothermic to exothermic processes, with distinct variations in reaction intensity across depths
- Consistent synchronous variations among the selected depths may reflect mineralogical heterogeneity within the core
- Asynchronous differences between thermal phases likely reflect variations in carbon content and quality with depth

Acknowledgements

Thanks to Dr. Xiangyang Xie, Bo Henk, Simoon Nice, Elvis Owusu, Josh Benford, Tabby Pyle, Portia Twumsi, and the TCU SERC Grant for their support.

Conclusion

This study demonstrates the effectiveness of AI-driven methods for analyzing large Barnett Shale datasets. By integrating rapid thermal analysis techniques, we can efficiently capture and assess geochemical variability, providing insights into geogenic carbon content and quality. These advanced approaches offer a powerful tool for enhancing our understanding of subsurface characteristics and optimizing resource evaluation.