Hydraulic Fracturing Induced Geochemical Evolution of Caney Shale

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Introduction

Research Problem

- Unconventional shale reservoirs hold substantial quantities of hydrocarbons in the US (~6 trillion barrels of oil), but ultra low permeability creates the need for hydraulic fracturing to access these hydrocarbons.
- Permeability created from hydraulic fractures are short-lived due to adverse geochemical reactions which cause fracture closure.
- Significant productivity declines are thus witnessed in hydraulically fractured shales after two (2) to five (5) years.
- This research investigates the geochemical reactions in the subsurface using the Caney Shale in South-Central Oklahoma Oil Province (SCOOP) as case study.

Objectives

- To evaluate chemical and mineralogical composition of Caney Formation.
- To investigate geochemical response of the formation during and after hydraulic fracturing – mineral transformation and clay mineral responses.
- To evaluate the impact of geochemical changes on permeability of reservoir

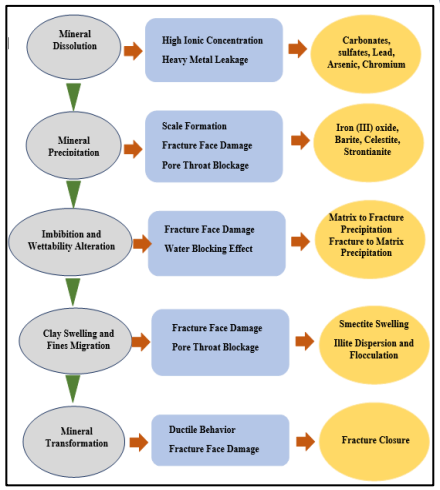
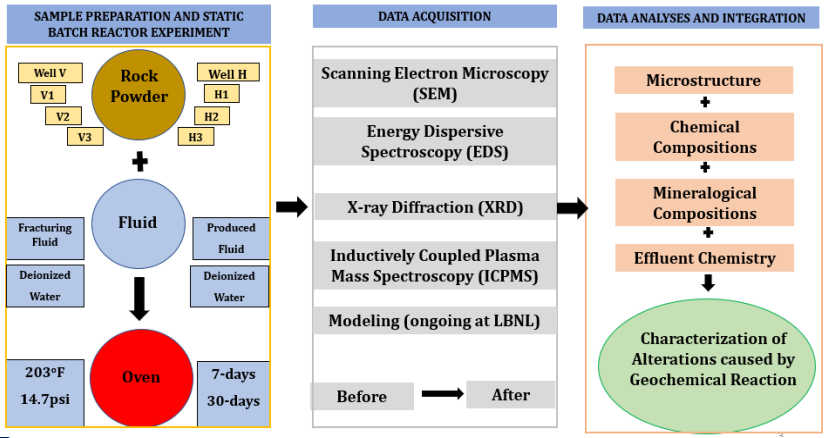


Figure 1: Schematic of geochemical reactions during and after hydraulic fracturing and their impacts on subsurface formation

Materials and Methodology



Results

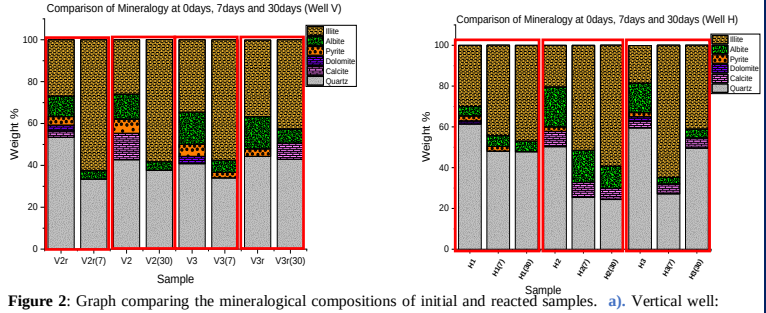


Figure 2: Graph comparing the mineralogical compositions of initial and reacted samples. **a).** Vertical well: Pyrite totally breaks down by day 7; Feldspar (Albite) composition shows a general decline with number of days of reaction; Illite composition increases with reaction time whiles quartz composition remains relatively constant. Repeat samples taken in proximity show different mineralogical compositions thus highlighting the heterogeneity of the reservoir **b).** Horizontal well: Pyrite breaks down completely by the 7th day; Feldspar (Albite) composition shows a general decline with number of days of reaction; Illite composition increases with reaction time whiles quartz composition declines after 7 days and remains relatively constant.

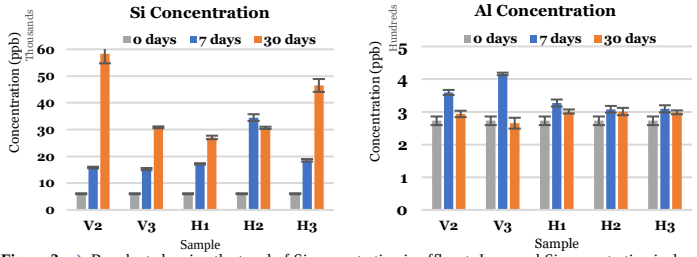


Figure 3: a). Bar chart showing the trend of Si concentration in effluent. Increased Si concentration is due to breakdown of feldspar, quartz and clay exchange sites **b).** Bar chart showing the trend of Al concentration in effluent. Increased Al concentration from feldspar dissolution and decreased concentrations from mineral precipitation (principally clay minerals).

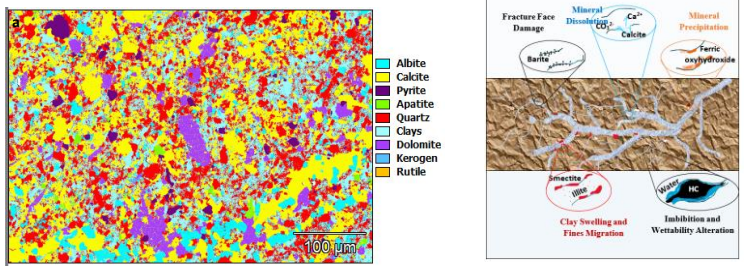


Figure 4: a. EDS map showing microstructural configuration of Caney Shale surface. Arrangement of mineral crystals within the general microstructure highlights the heterogeneity of the samples which is confirmed by repeat sampling during mineralogical composition measurements. **b.** Schematic of geochemical rock-fluid interaction within complex fracture system in the subsurface.

Discussions

- Changes to mineralogical compositions of rocks have been observed following reaction with fluids.
- Mineralogical changes are the result of changing conditions due to the introduction of fluids which creates a disequilibrium to the original stability zone of minerals
- In this study, starting fluid pH is circumneutral thus reactions are moderate relative to reactions in which fluids are acidized.
- Pyrite breakdown and oxidation of iron (II) and sulfide to iron (III) and sulfate respectively was triggered by presence of dissolved oxygen in reaction fluid.
- Random breakdown of pyrite in rock samples create localized and transient pH drops that cause dissolution of carbonates and accelerate dissolution of feldspars and other minerals
- Dissolution of minerals increase ionic concentrations in fluids, thus precipitation of new minerals or transformation of unstable minerals

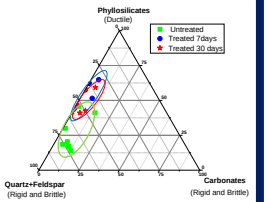


Figure 5: Ternary plot showing comparison of mineralogy of unreacted samples to samples reacted with hydraulic fracturing fluid for 7-days and 30-days respectively

Conclusions

- Breakdown of minerals in formation is a continuous process in which the product of the breakdown of one mineral causes changes to other neighboring minerals
- Increasing illite compositions in sample with corresponding decrease in feldspar compositions signifies the transformation of feldspar to illite or the breakdown of feldspar and formation of illite
- High silica concentrations cannot be explained by dissolution from feldspar, clays and quartz, therefore presence of biogenic silica is postulated
- Aluminum, Magnesium and Iron elemental concentrations follow similar trends. They are taken out of solution at a fast rate. These ions are components of illite and may thus be used in the formation of clay minerals
- Formation of illite can introduce ductile characteristics on fracture walls and near fracture matrix that makes fractures more susceptible to closures.

Acknowledgements

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