Mineralogy and Diagenetic History of the Temblor Formation Sandstones, McKittrick Oil Field, California*

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Abstract

The McKittrick oil field is located near the western edge of the San Joaquin basin approximately 60 km west of Bakersfield and just northeast of the McKittrick thrust fault. The oil field is currently producing from the Tulare, San Joaquin, Reef Ridge, Monterey, Temblor, Tumey, and Kreyenhagen Formations. Within the Temblor Formation, production is mainly from the Carneros and the Phacoides sands. Samples were obtained from the California Well Sample Repository. Depths range between 2400 and 2650 meters. These were studied using petrography and with a scanning electron microscope equipped with an energy dispersive x-ray spectrometer (SEM-EDS) and a cathodo-luminescence system (SEM-CL). The Temblor Sandstones consist of fine to very coarse poorly to well-sorted arkosic arenites. Detrital framework grains include sub-angular quartz, K-feldspar (microcline and orthoclase), plagioclase, and rock fragments. Three chemically distinct types of K-feldspars have been identified: Ba-free, Ba-rich, and perthite. Accessory minerals include glauconite, biotite, muscovite, magnetite, titanomagnetite, sphene, zircon, phosphate, corundum, and rutile. Diagenetic alteration includes compaction, dissolution of detrital minerals, albitization of feldspars, cementation by kaolinite, calcite and dolomite, precipitation of K-feldspar and quartz overgrowths, replacement of framework grains by calcite, alteration of volcanic rock fragments, and the alteration of biotite to pyrite and chlorite. Long, sutured, and interpenetrating grain-to-grain contacts, squashing of labiles to create pseudomatrix, and fracturing of brittle grains (quartz and feldspar) indicate significant compaction. Early formed fractures were healed by authigenic quartz, albite, and K-feldspars. Precipitation of carbonates and clays, rearranging of broken grains, and formation of pseudomatrix subsequently reduced porosity. Secondary porosity is common and formed initially by the dissolution of plagioclase (excluding albite) and volcanic fragments and later by dissolution of calcite, dolomite, and detrital K-feldspars. Oil emplacement was followed by precipitation of late pyrite framboids in pores containing both oil and clays. This suggests that continuing maturation of the hydrocarbons supplied sulfur that reacted with ferrous ions in pore fluids trapped within the clays' microporosity.

Selected References

Dickinson, W.R., 1985, Interpreting detrital modes of greywacke and arkose: Journal Sedimentary Petrology, V. 40, p. 695-707.

Pettijohn, F.J., P.E. Potter, and R. Siever, 1987, Sand and Sandstones: Springer, New York, 553 p.

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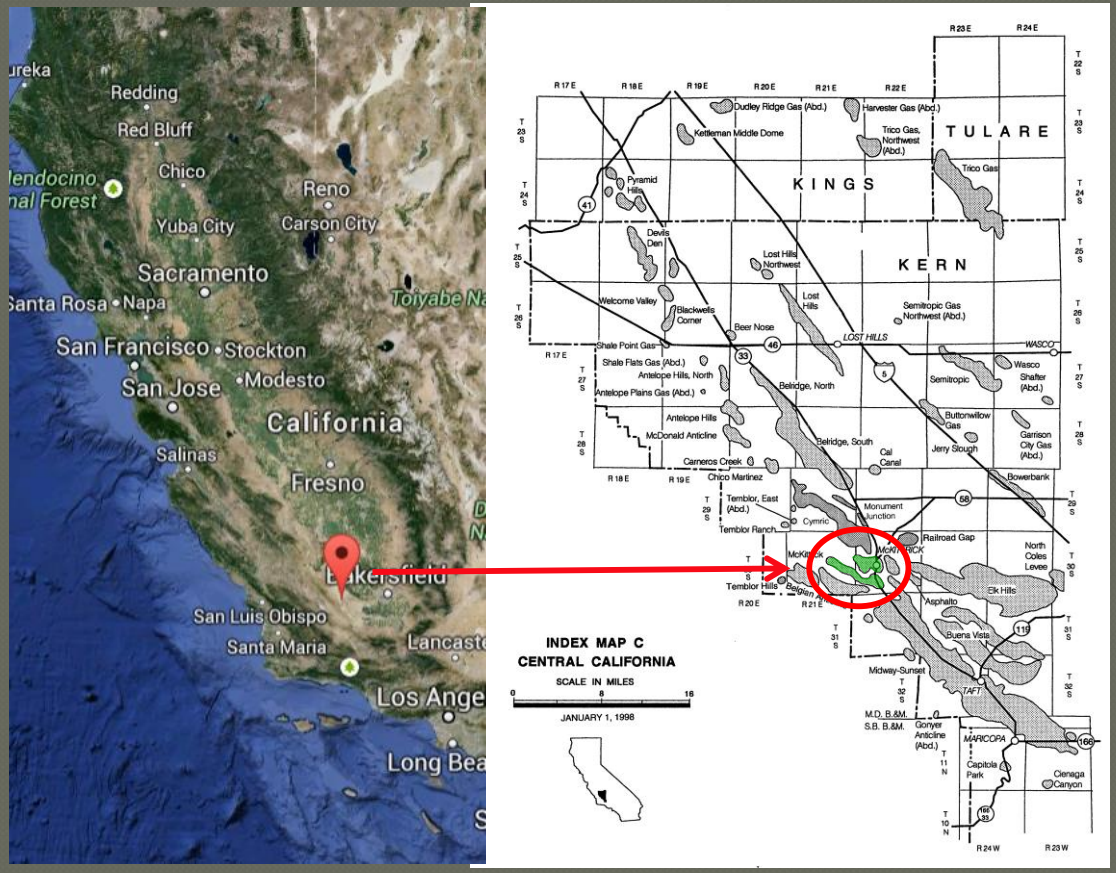
Introduction

- **The Oligocene to Miocene Temblor Formation sandstones have been identified as a candidate for carbon capture and sequestration (CCS).**
- **The goal of this project is to provide baseline data on the mineralogy and reservoir quality, including diagenesis, for future geochemical analysis for CCS.**
- **By obtaining and interpreting the changes of porosity and permeability affected by diagenetic processes at this location, the quality of the reservoir can be determined for long term, and safe, CO_2 storage.**

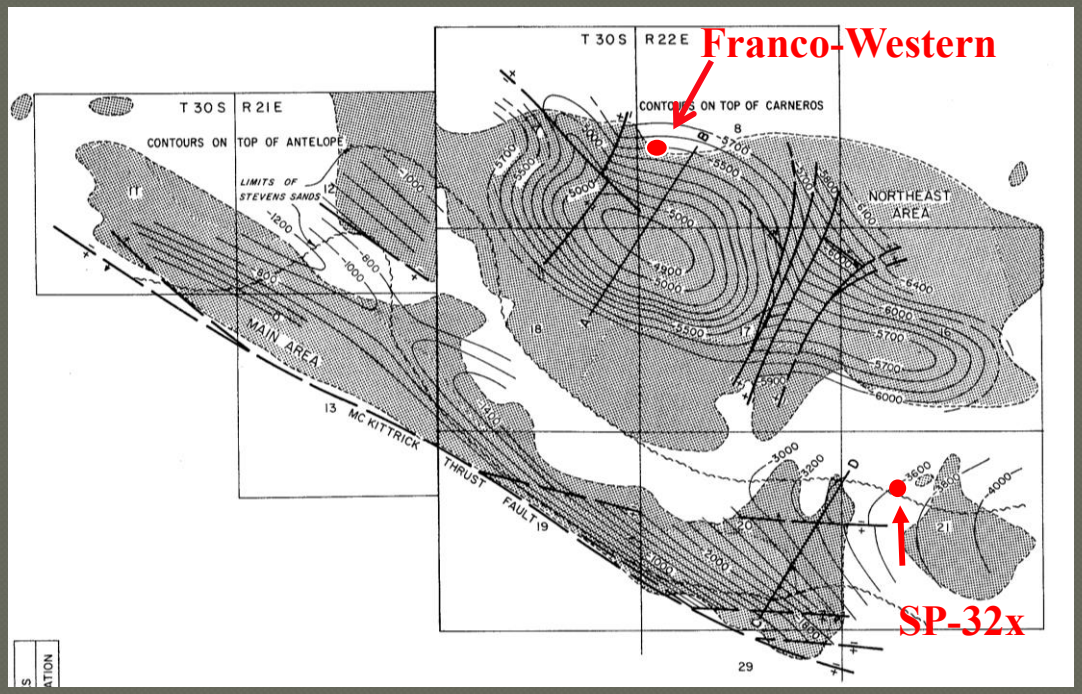
Geologic Setting



Modified from CA DOGGR, 1998 and Map of California, Google Maps.

- Approximately 60 kilometers (40 miles) west of Bakersfield, CA and 200 meters east of the California State Routes 33 and 58 intersection.
- Just north-east of the McKittrick Thrust Fault.
- The oil field is currently in production with 480 producing wells.

Geologic Setting



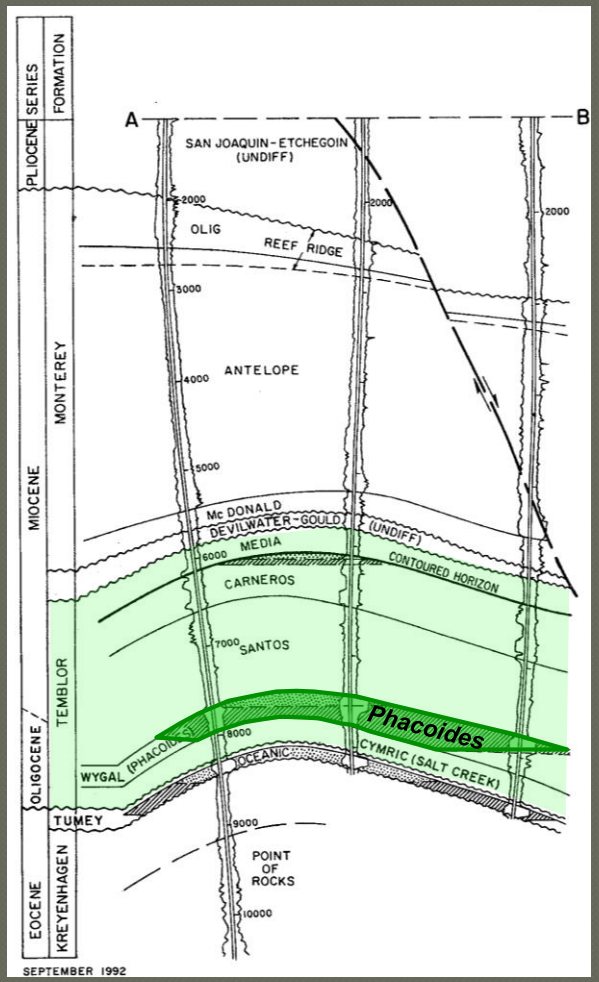


Figure 2 and 3. Structure map and stratigraphic cross section of the McKittrick Oil Field (California Department of Conservation, 1998).

Methods

- Thin sections were prepared from core samples obtained from the California Well Sample Repository at CSUB.
- Sample depths range from 7890 to 8560 feet from the Franco-Western well (516-8) and from 9938 to 9990 feet from well SP-32X.

Methods

- All samples were impregnated with blue epoxy to show porosity, and some were stained for potassium and calcium.
- Quantitative data was obtained using petrography, scanning electron microscopy-energy dispersive spectrography (SEM-EDS), and cathodo-luminescence for 64 thin sections.

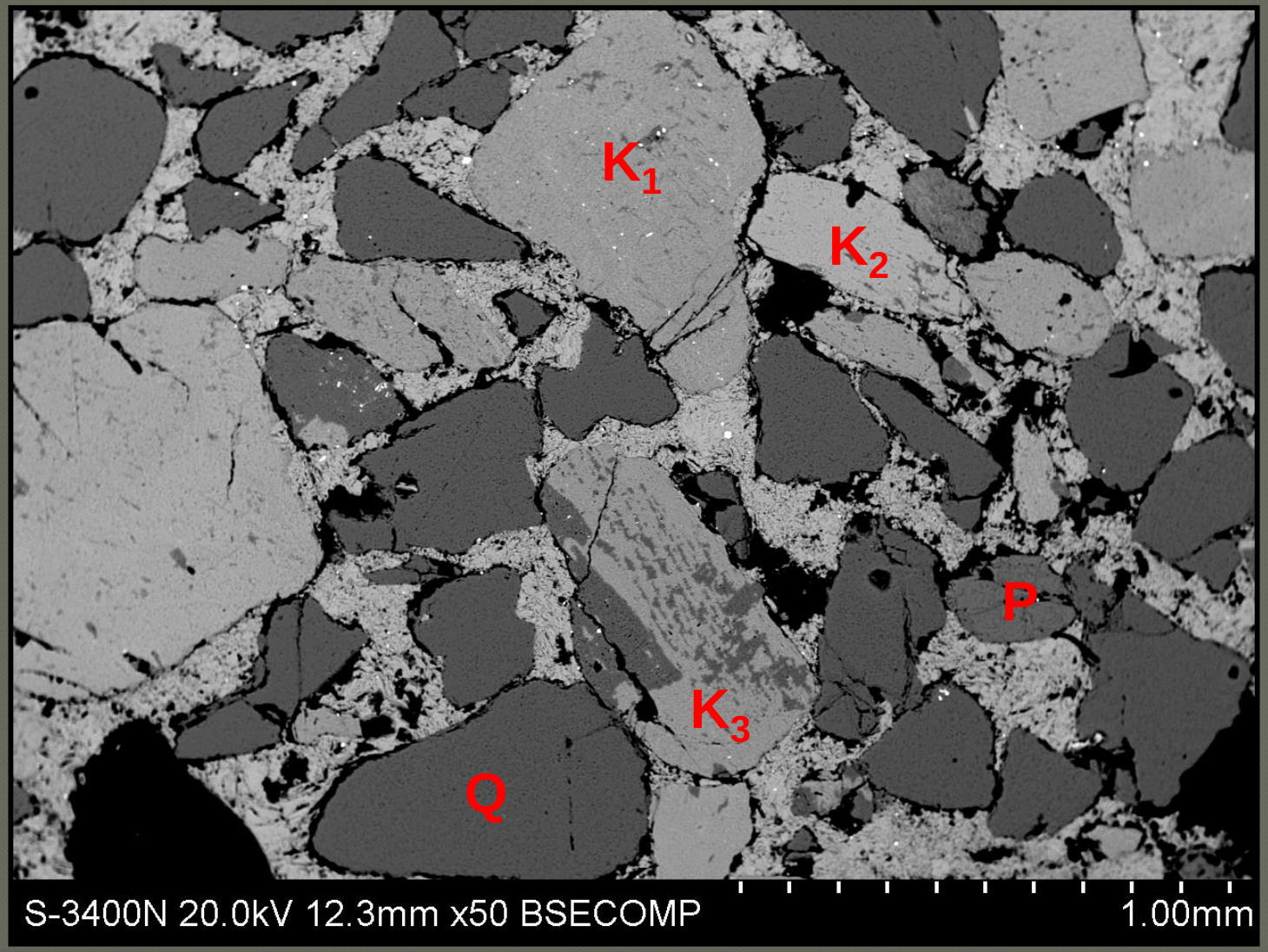
Results: Detrital Components

- Medium to very coarse arkosic arenites and some arkosic wackes.
- Angular to sub-round.
- Poorly to well sorted.
- The detrital framework grains include quartz, K-feldspar (microcline and orthoclase), plagioclase, and rock fragments.

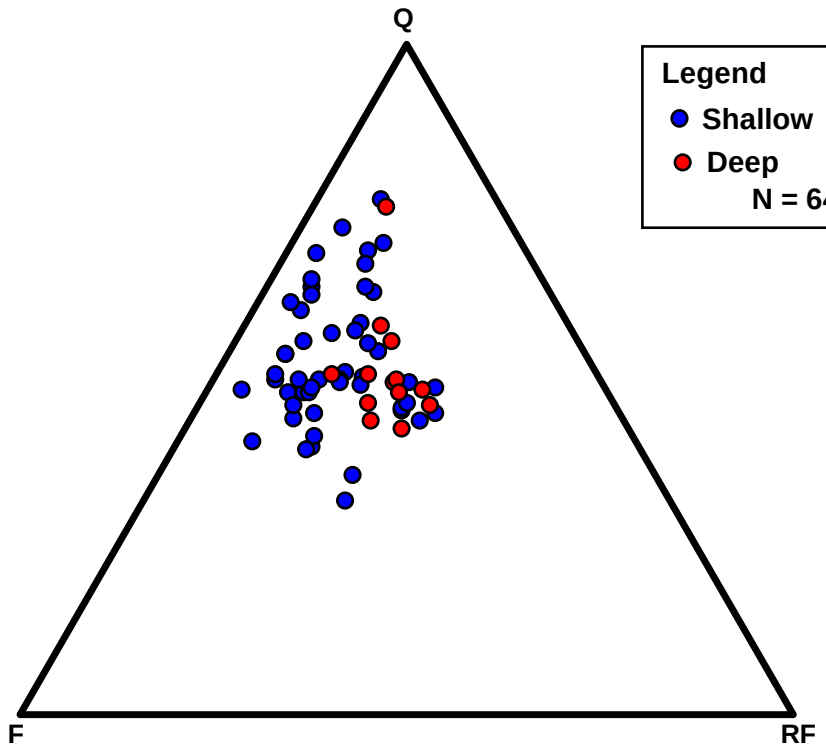
Results: Detrital Components

- Rock fragments include volcanics, microphanerites, shale clasts, chert, and carbonates.
- Accessory minerals include glauconite, biotite, muscovite, magnetite, pyrite, titanomagnetite, sphene, zircon, apatite, rutile, hornblende and phosphate.
- Three chemically distinct types of K-feldspars have been identified, Ba-free, Ba-rich, and perthite.

Detrital Components



Results: Detrital Components

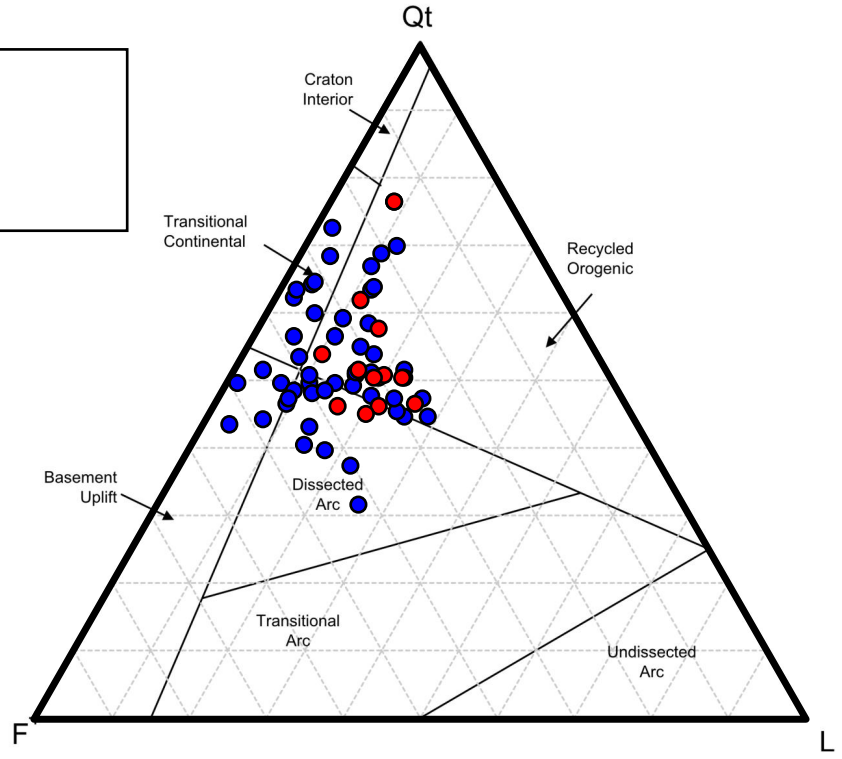


QFRf Composition Plot (Pettijohn et al., 1987)

Legend

- Shallow
- Deep

N = 64

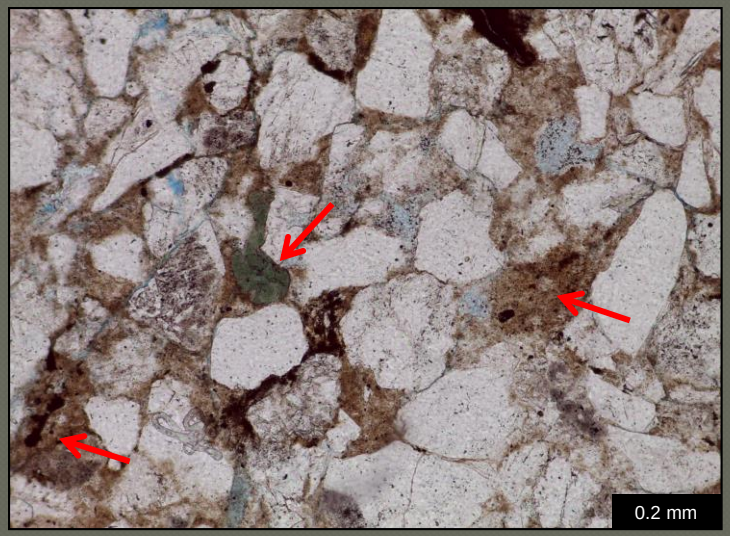


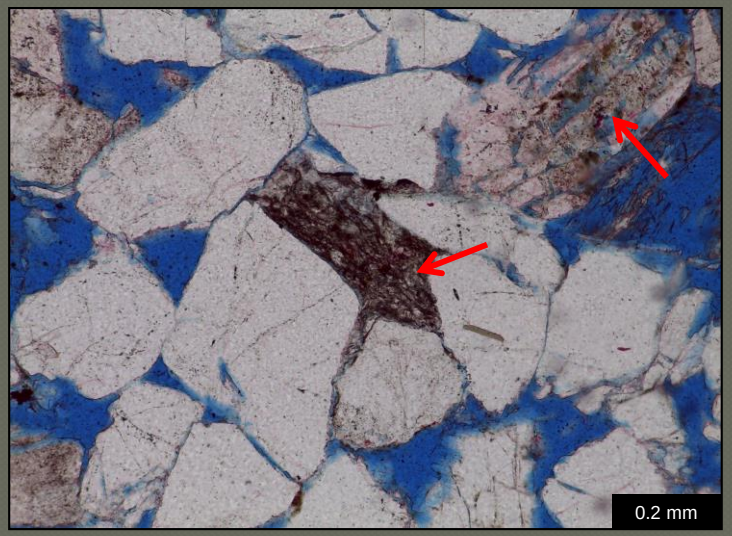
QtFL Provenance Plot (Dickinson, 1985)

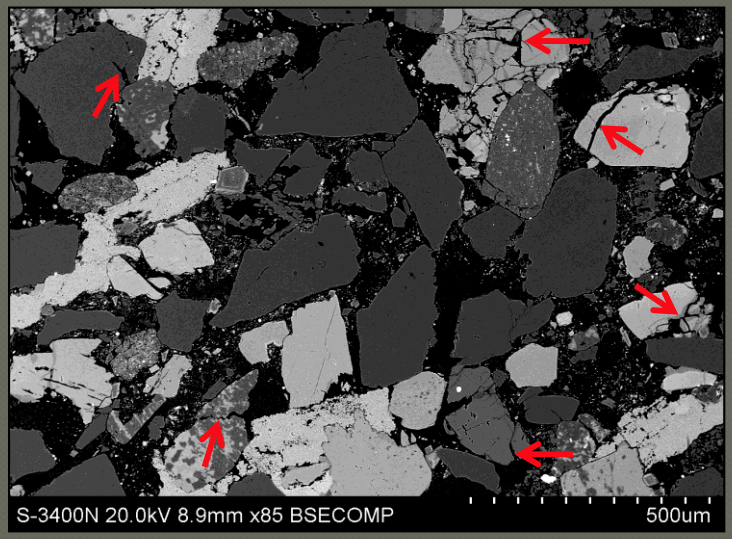
Results: Diagenetic Components

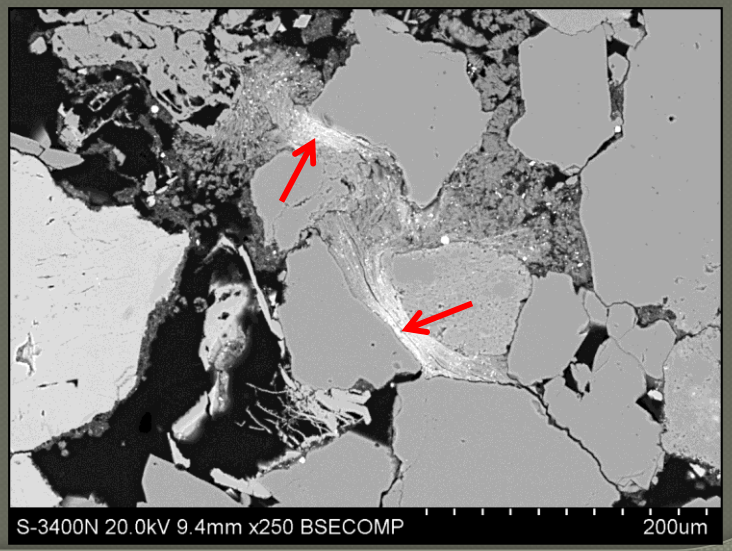
- **Diagenesis -**
  - **Compaction**
    - Labile and brittle deformation
  - **Cementation**
    - Pore-filling cements: Carbonates and clays
    - Overgrowths: K-feldspar and quartz
  - **Alteration**
    - Alteration of volcanic grains
    - Replacement by carbonates
    - Albitization of feldspars
  - **Dissolution and formation of secondary porosity**
    - Predominately feldspars and some quartz
  - **Mechanical rearrangement of grains**
  - **Hydrocarbon migration and pyrite precipitation**

Labile and Brittle Deformation

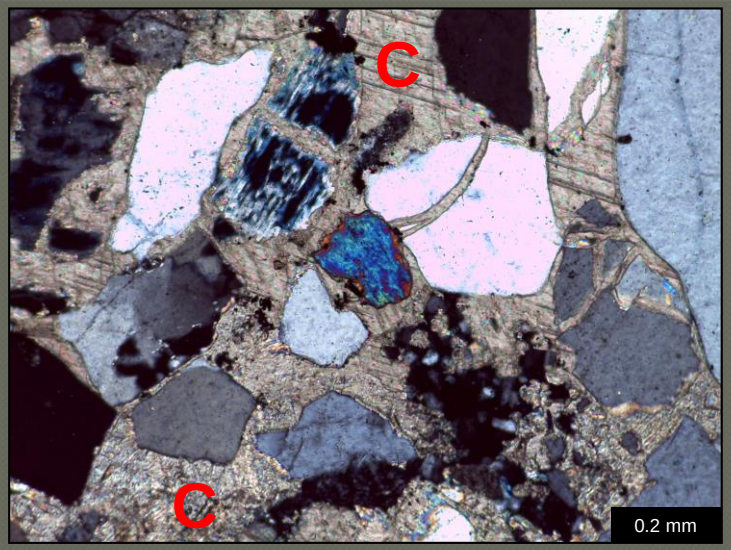


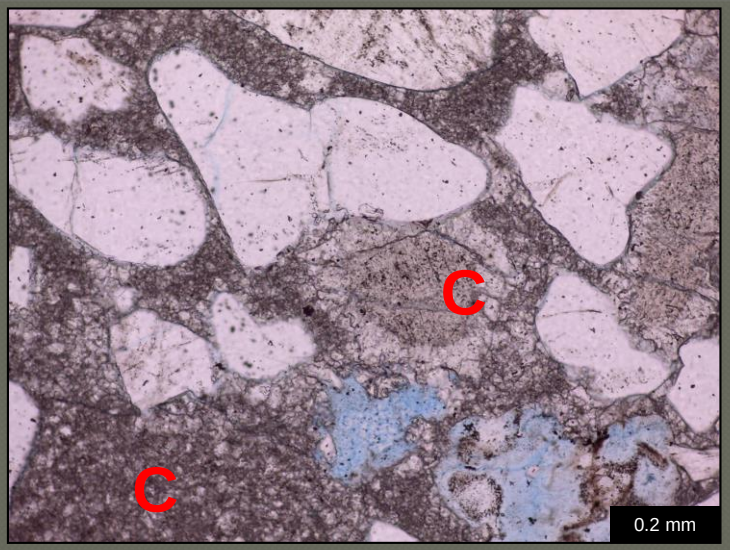


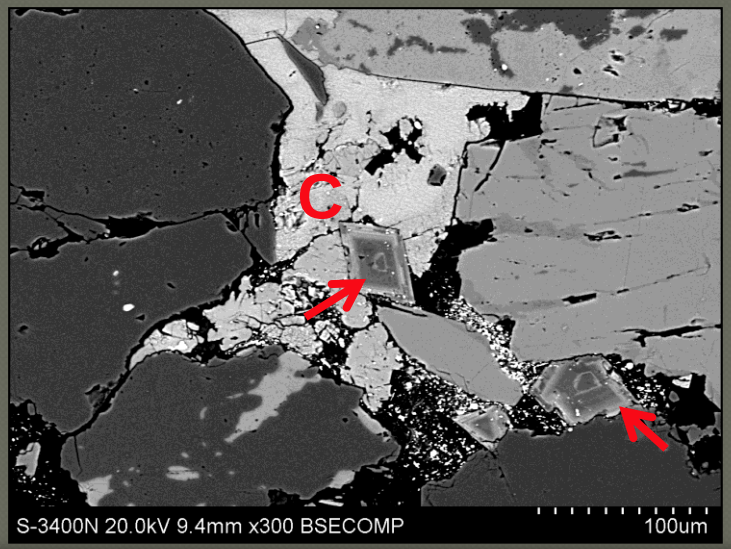


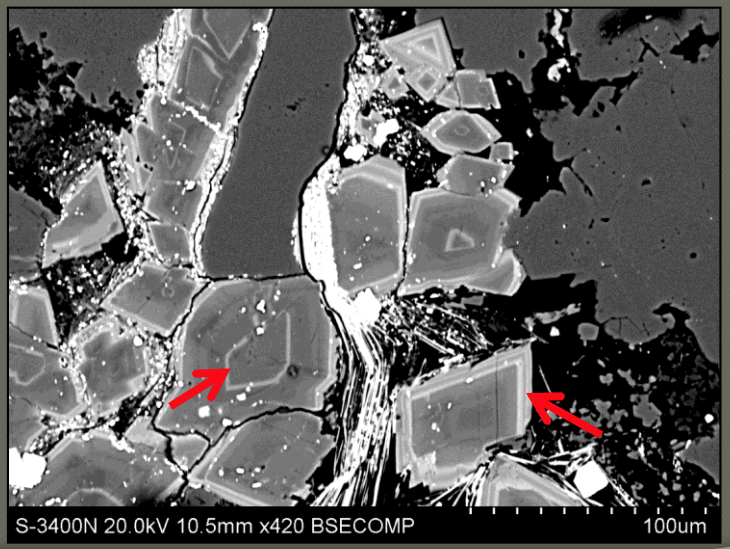


Cementation – Carbonates

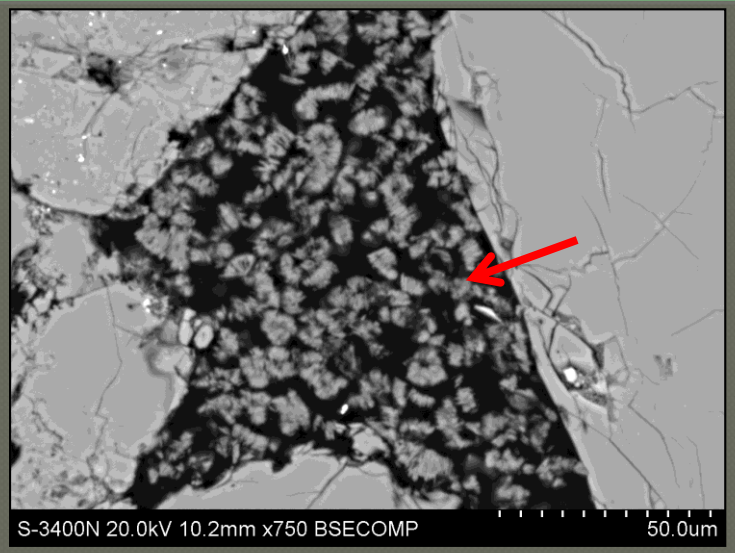


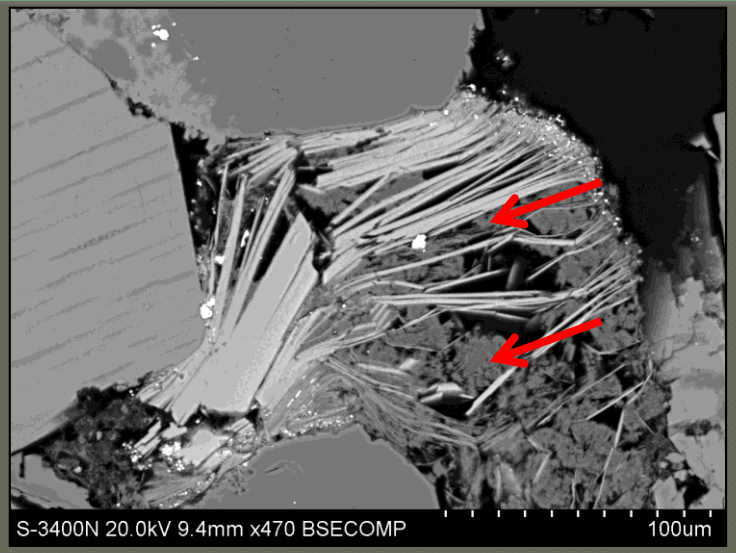


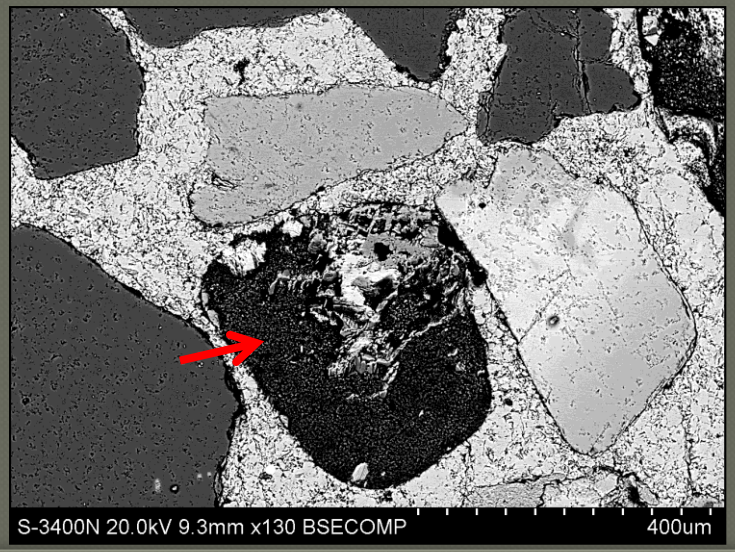


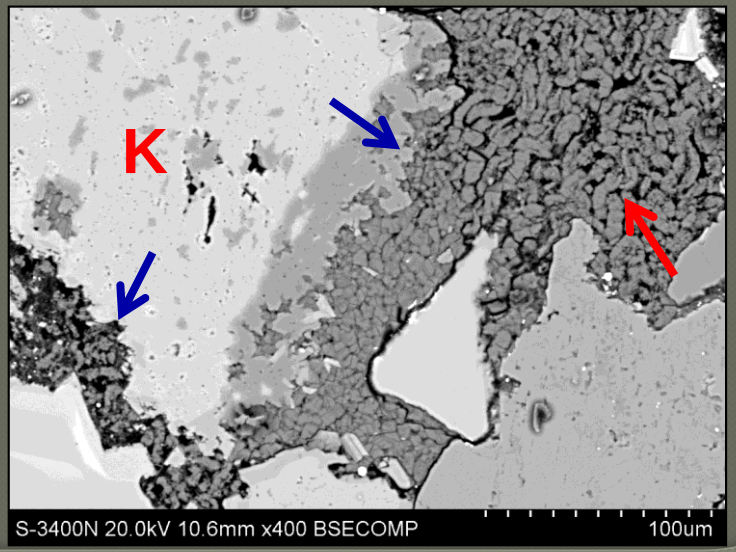


Cementation – Kaolinite

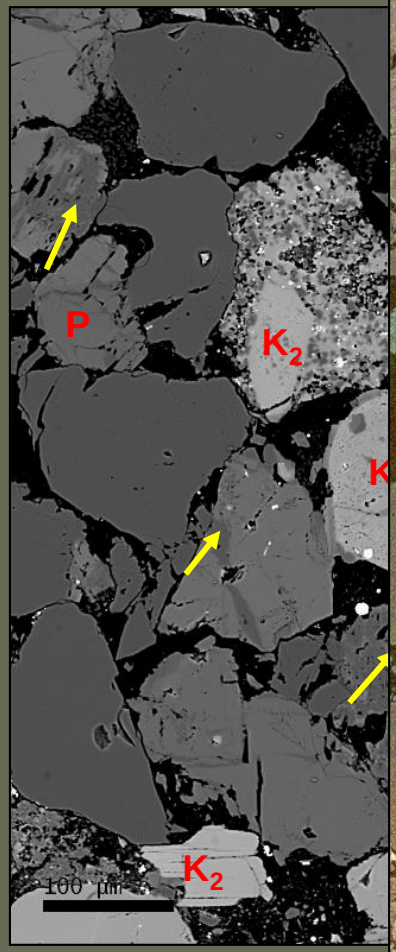


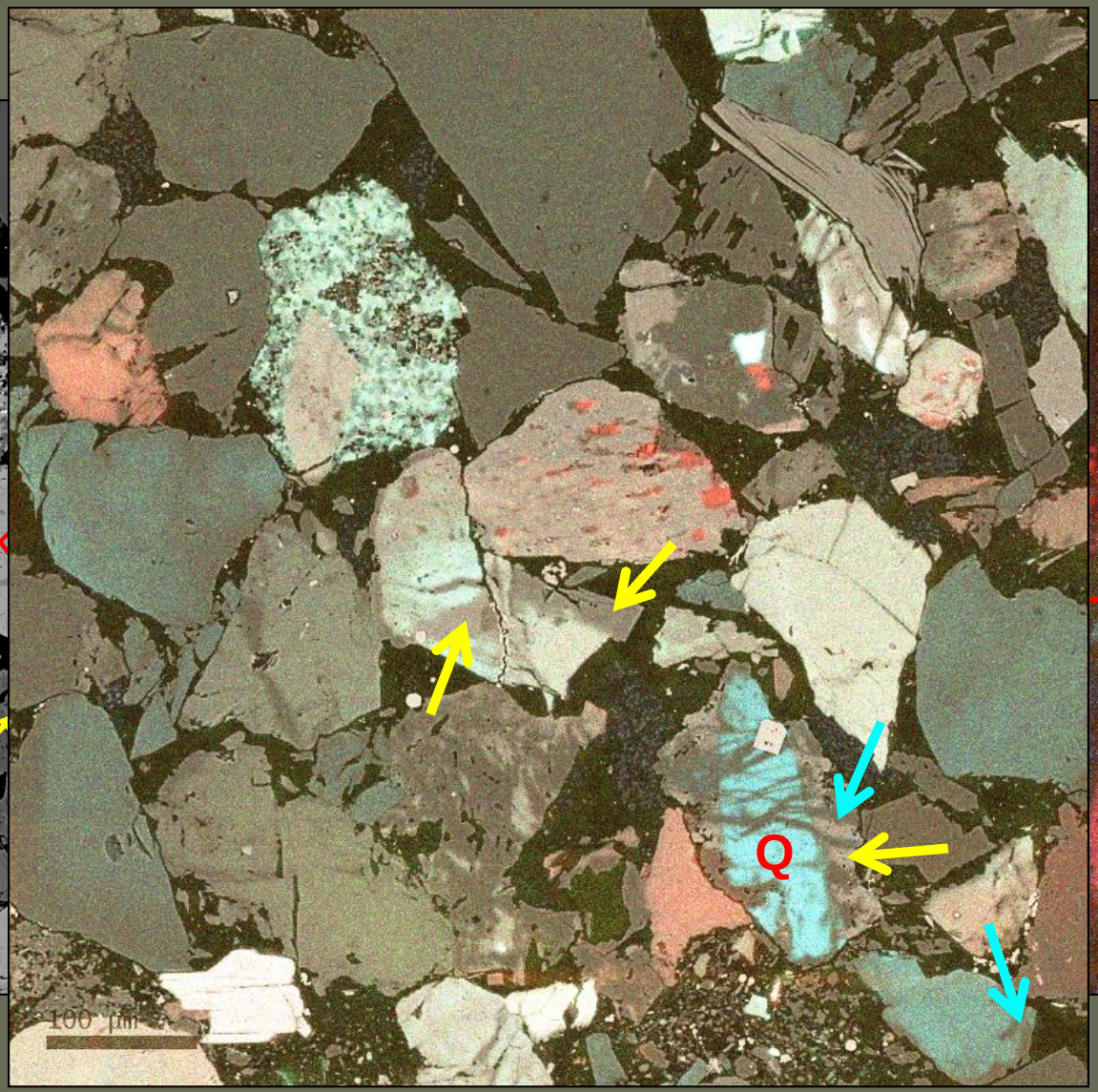






Cementation – Overgrowths and Healed Fractures





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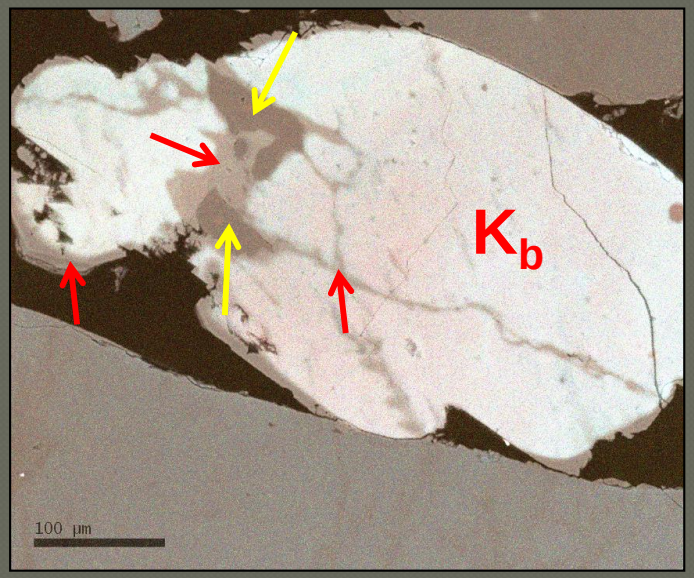

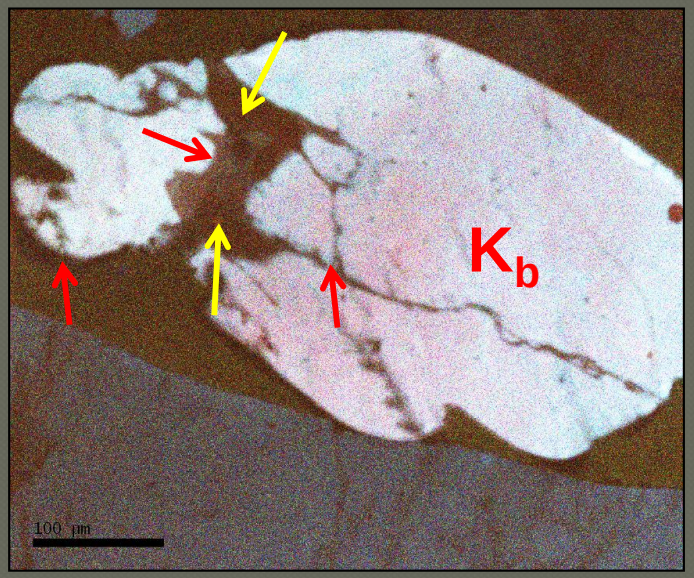

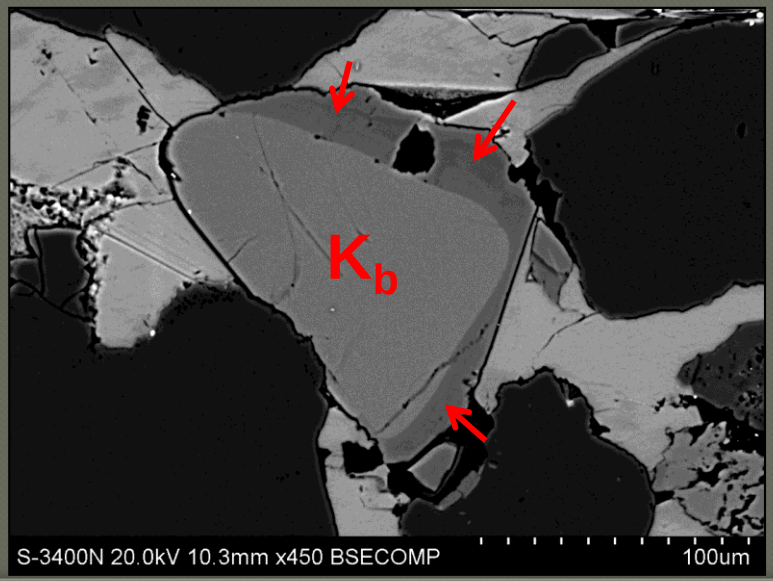

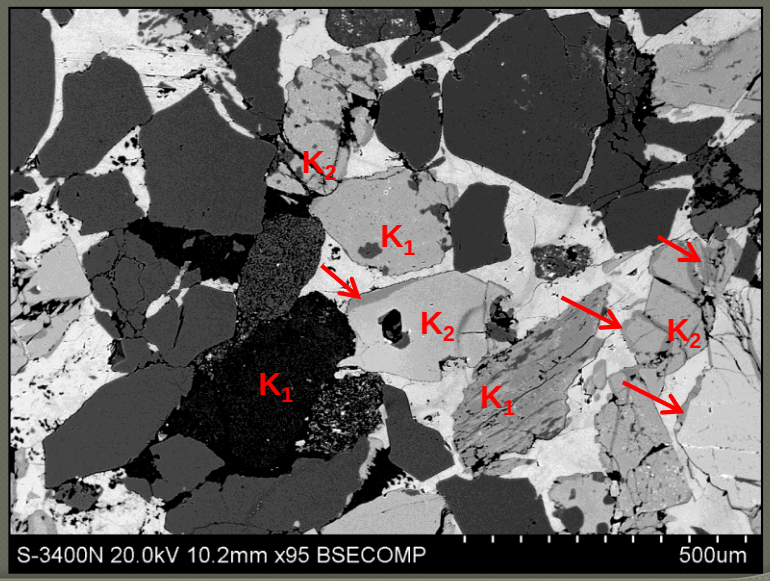

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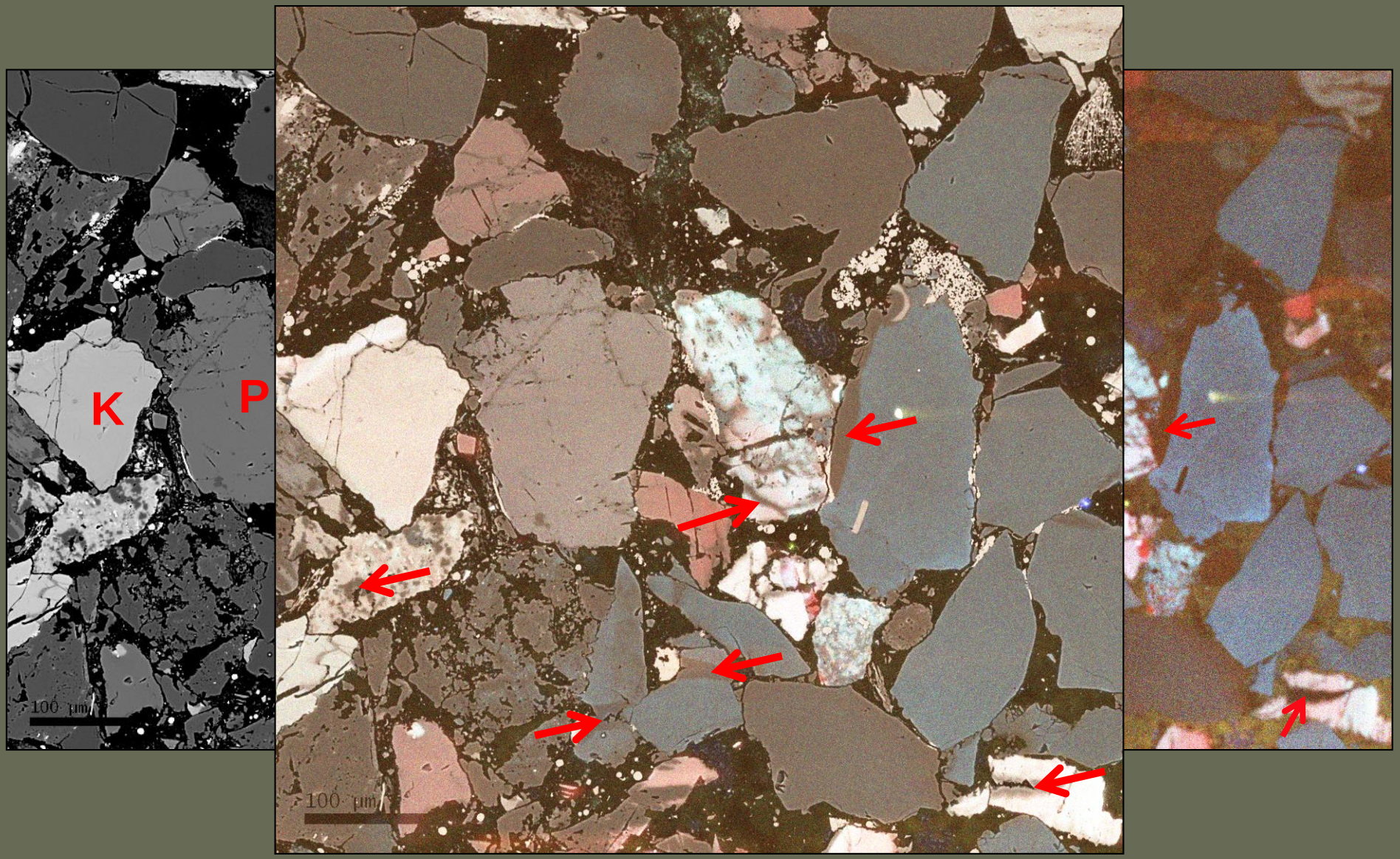
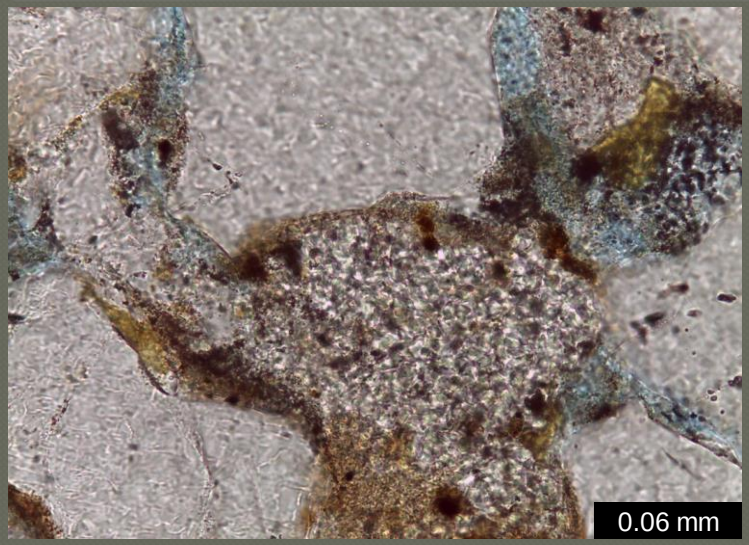
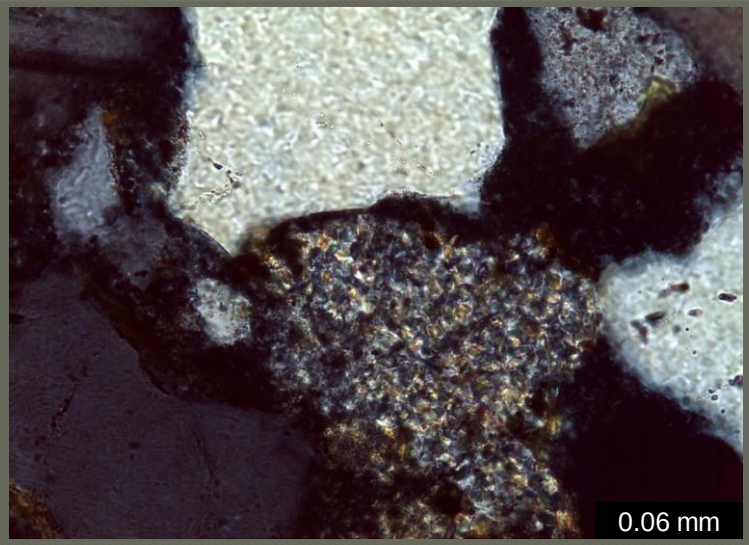
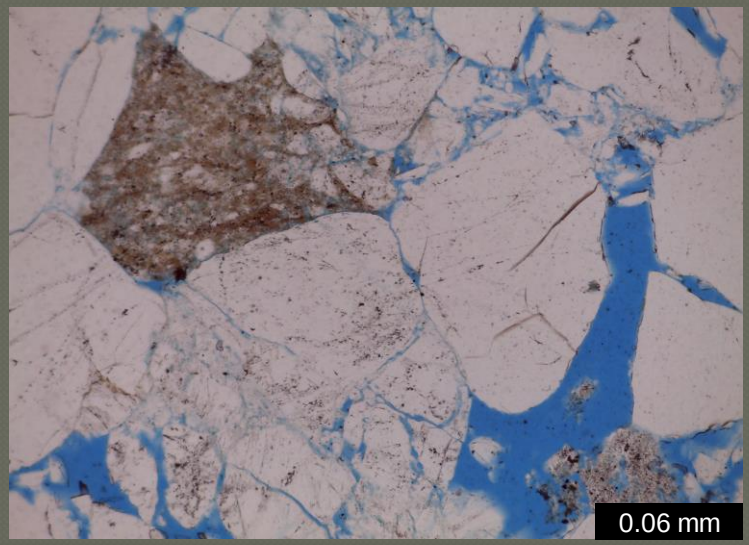
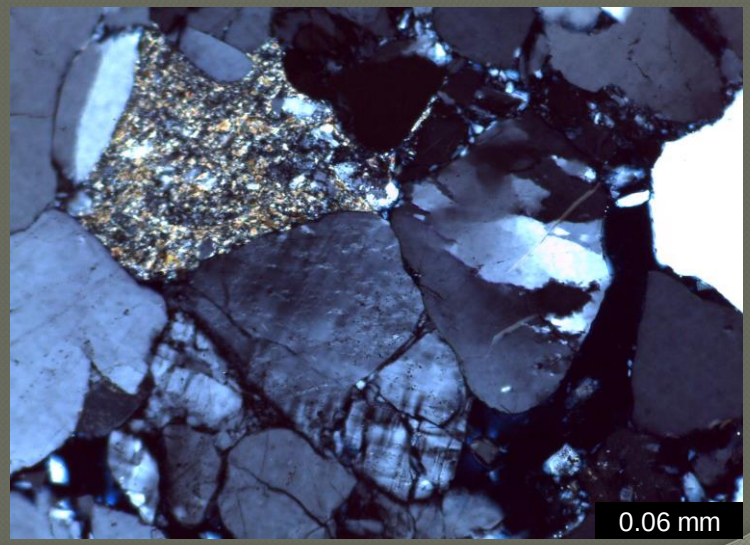


Alteration of Volcanics

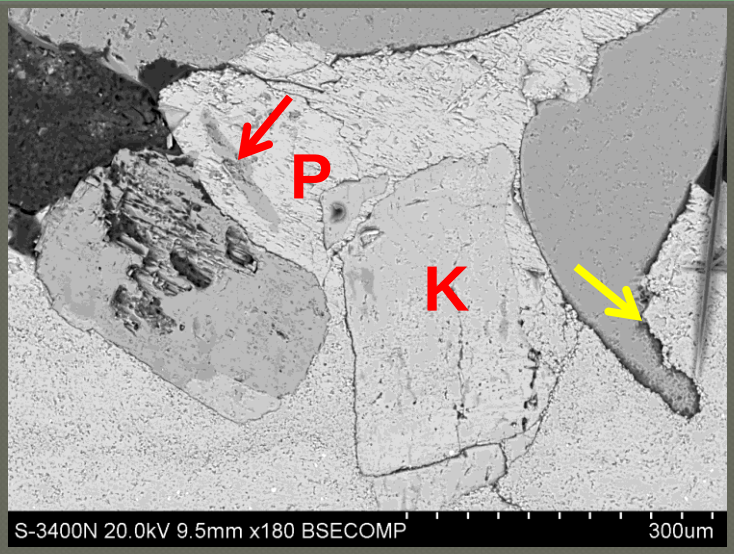


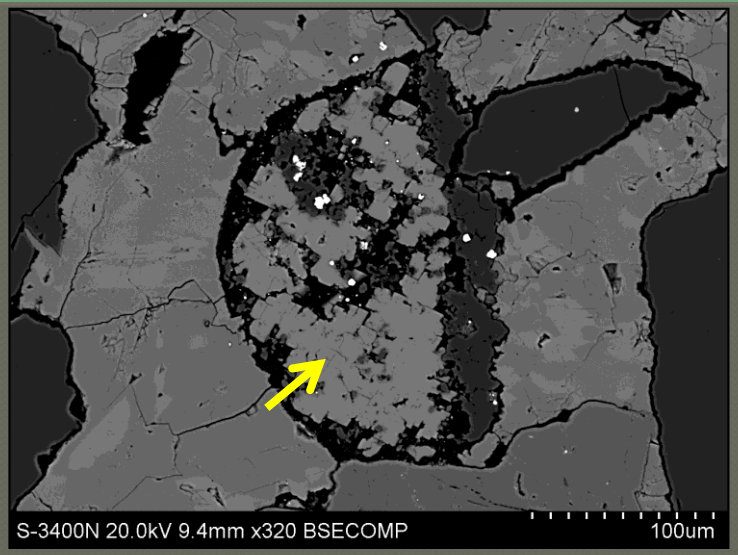


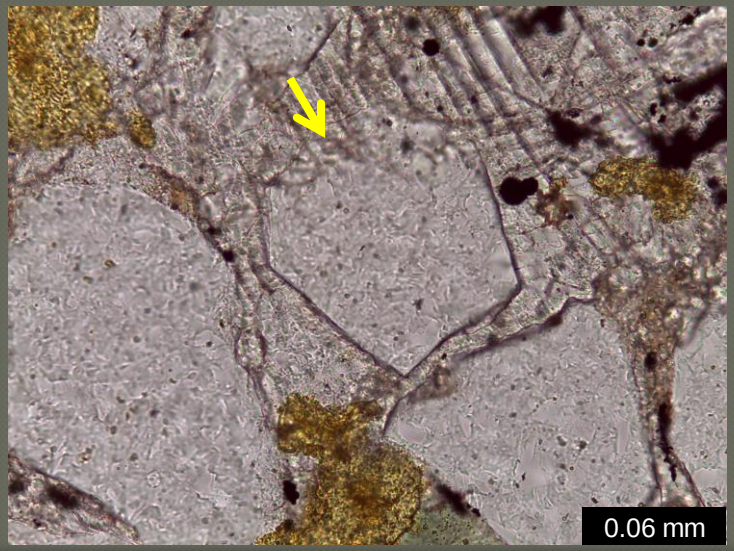


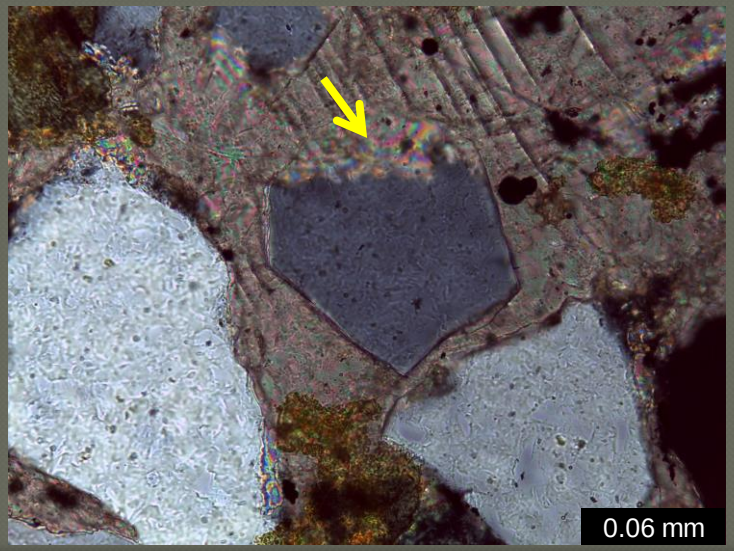


Replacement by Carbonates

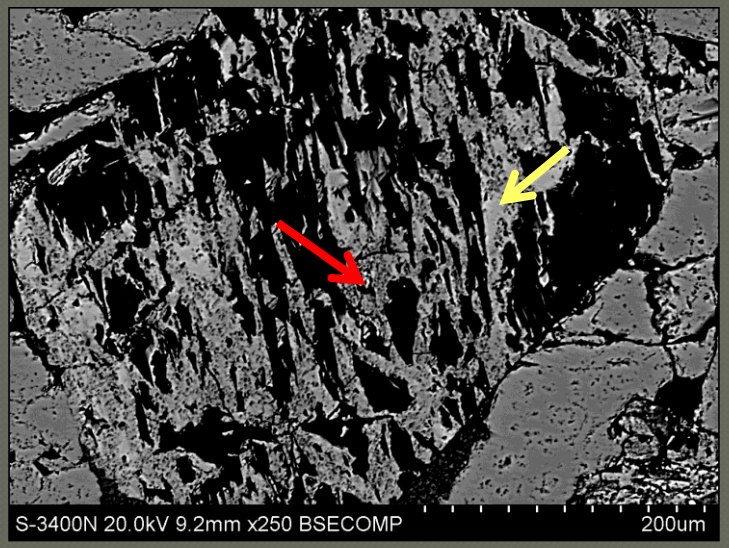


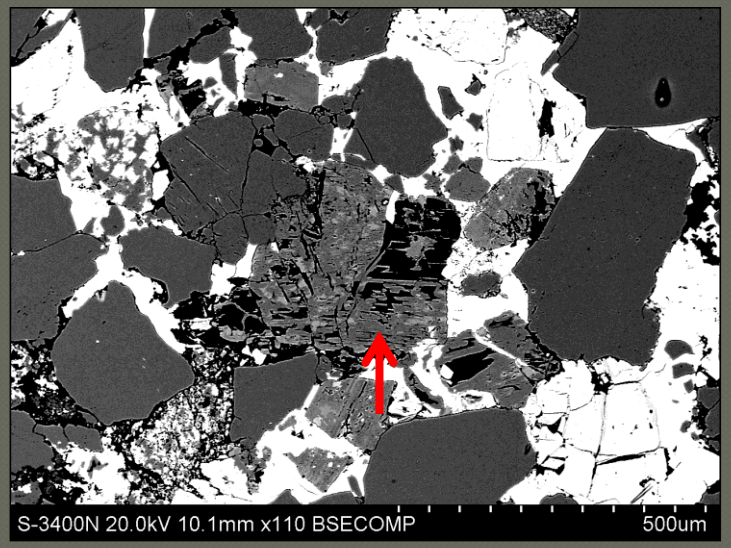


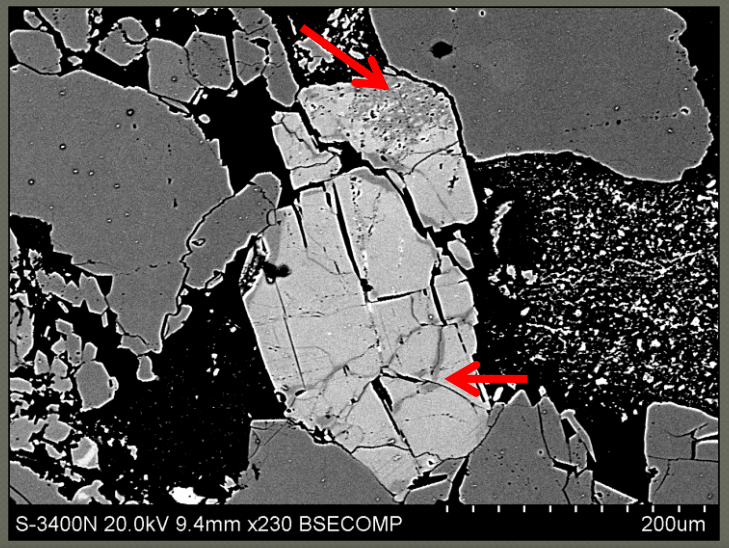


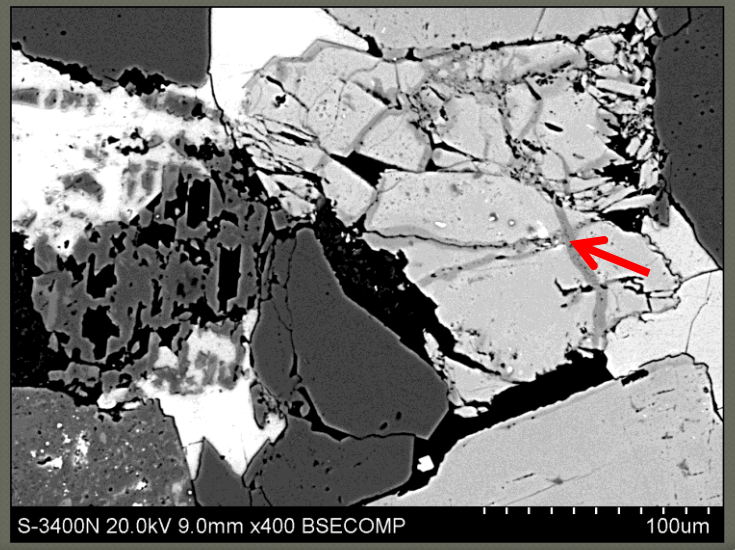


Albitization of Feldspars

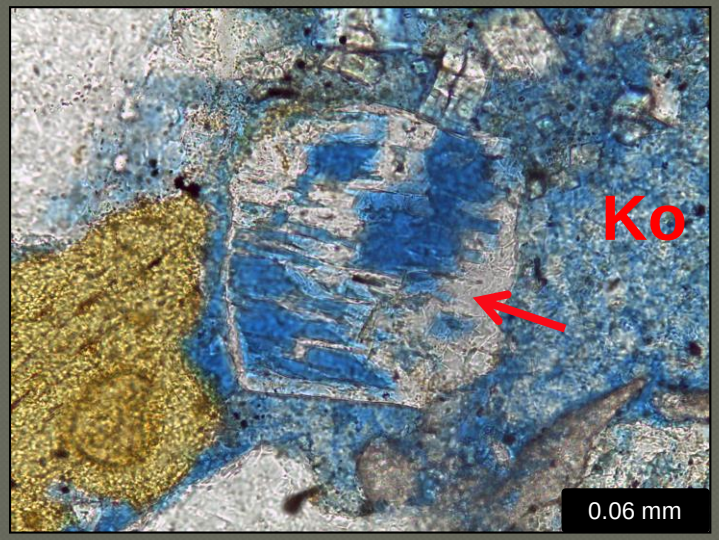


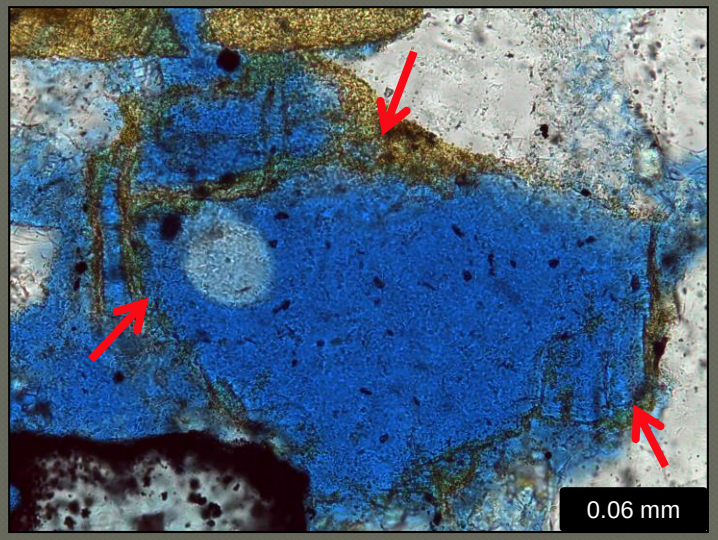


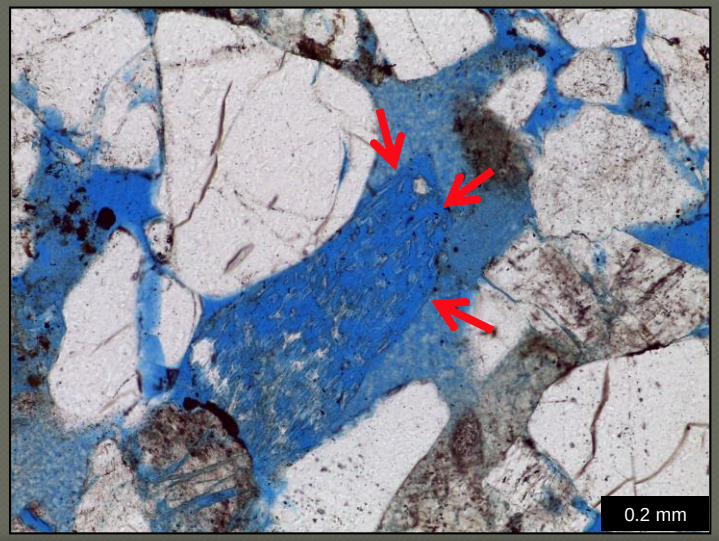


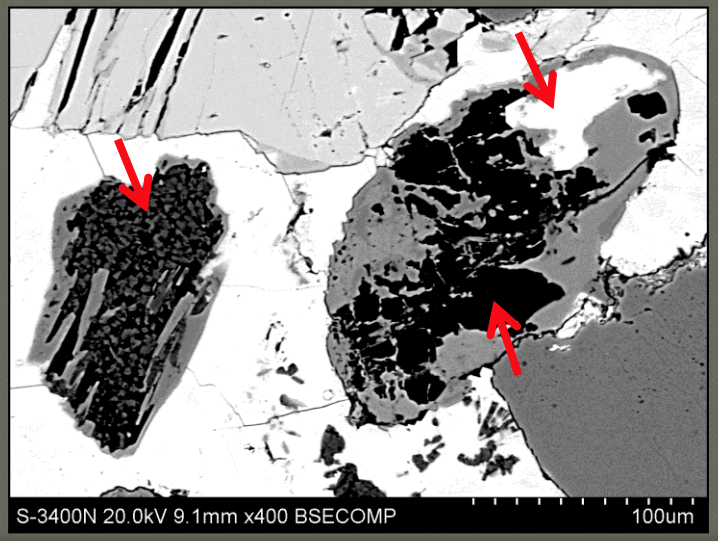


Dissolution and Secondary Porosity

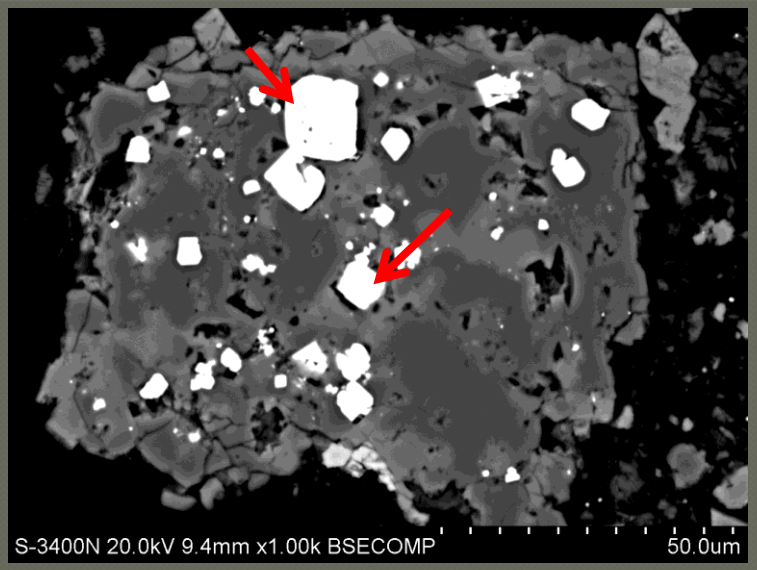


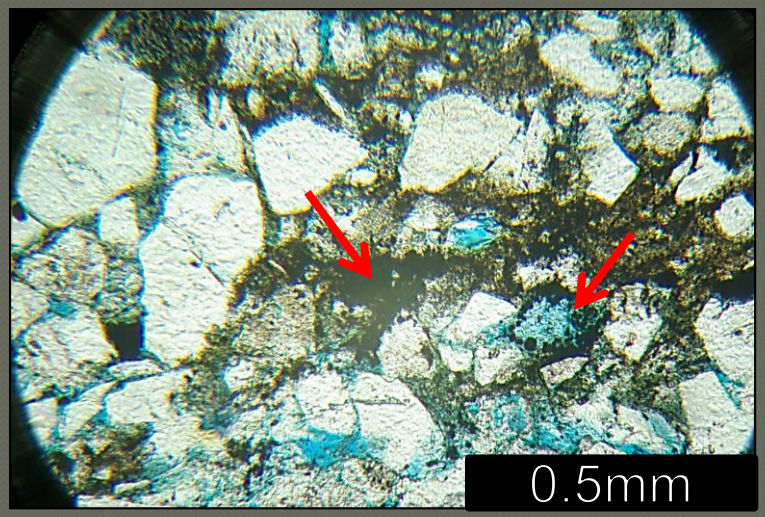


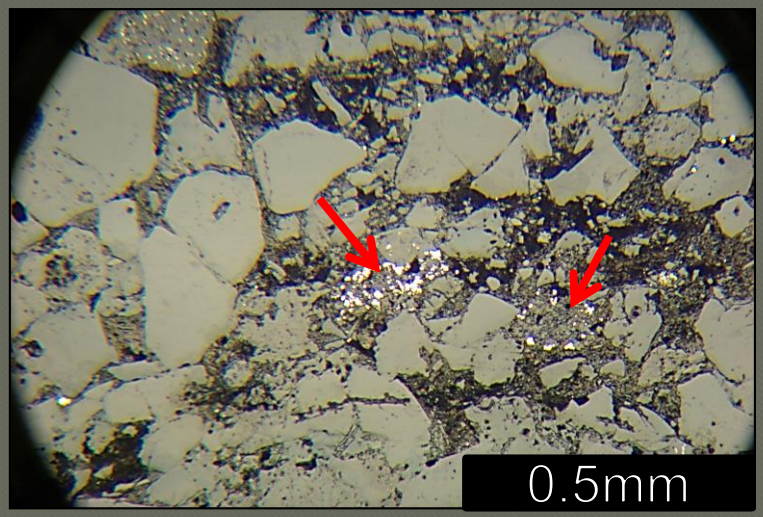




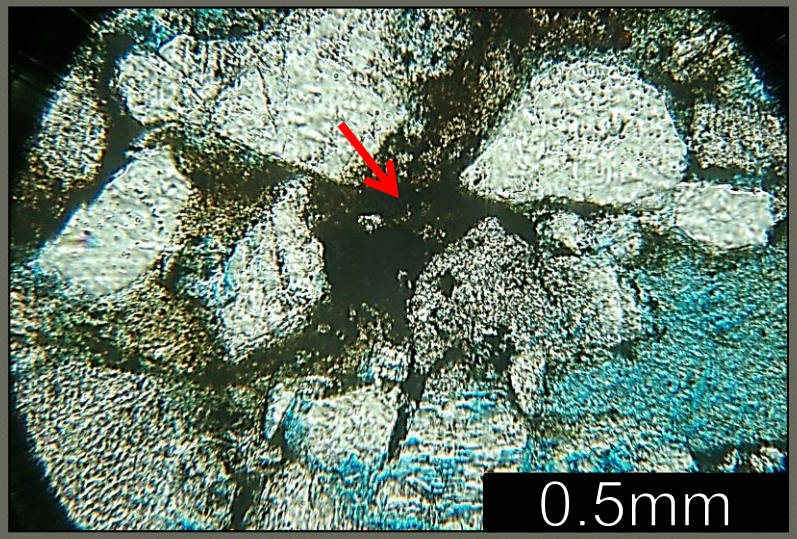
Hydrocarbon Migration and Pyrite Precipitation

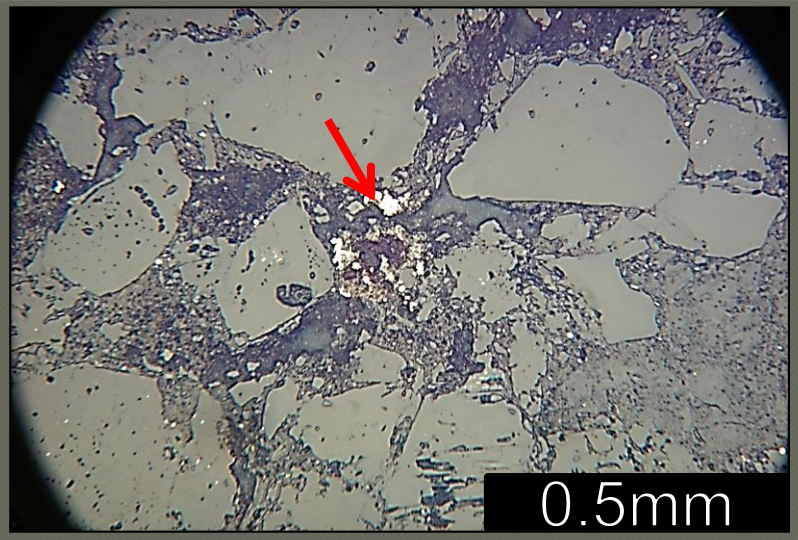


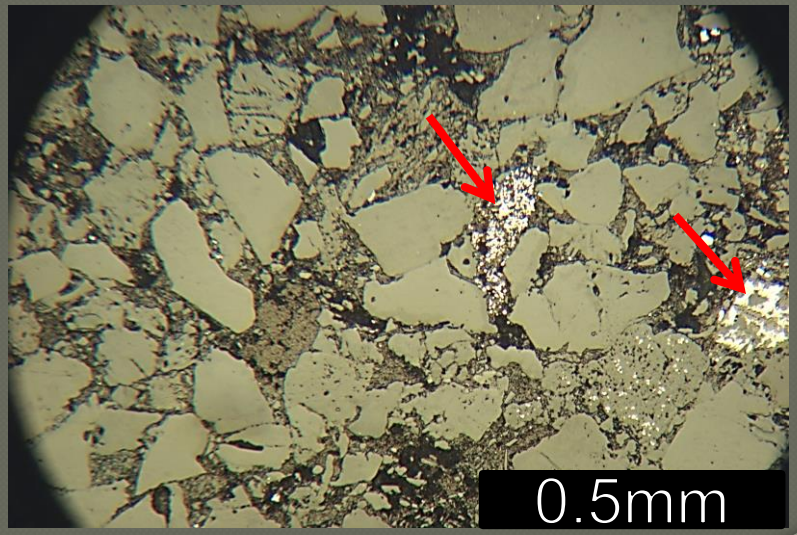




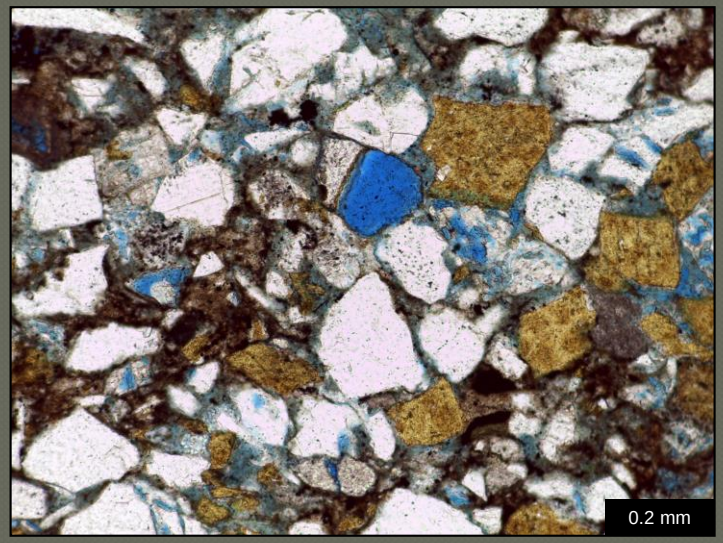
Hydrocarbon Migration and Pyrite Precipitation

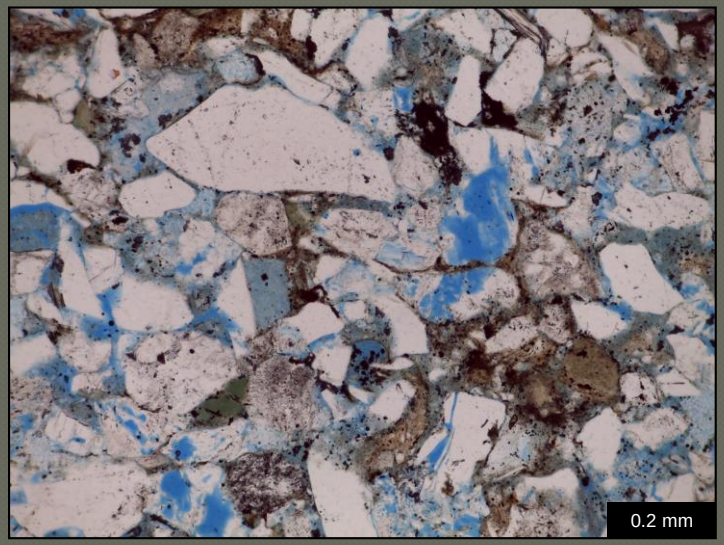


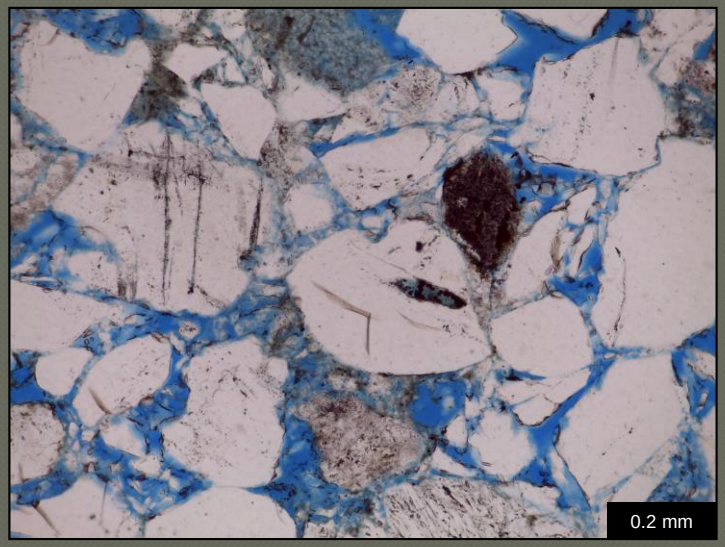


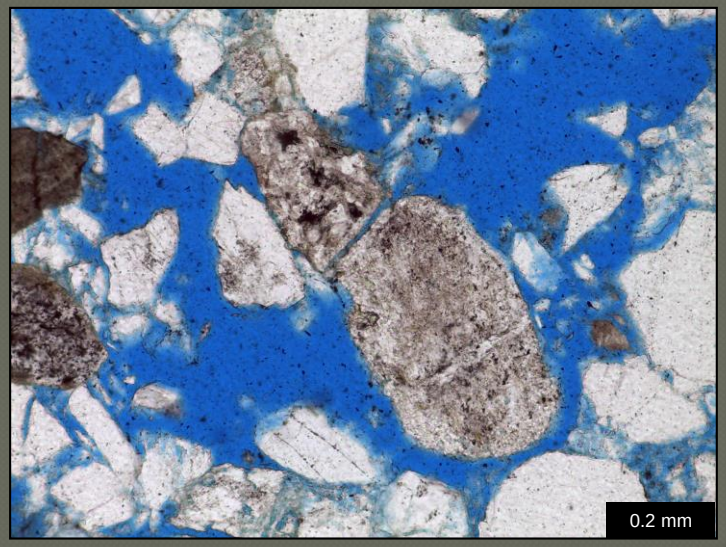


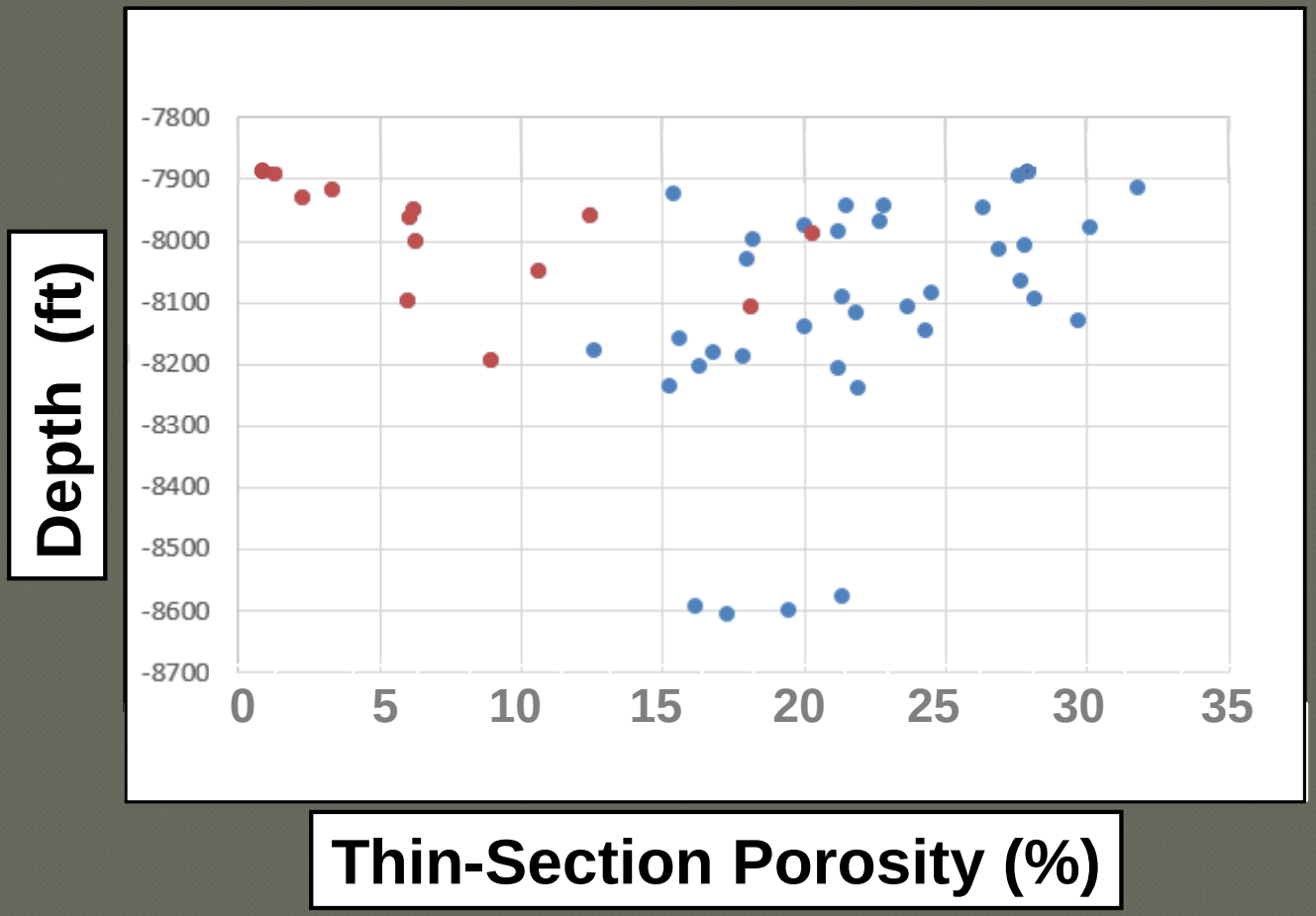
Reservoir Quality





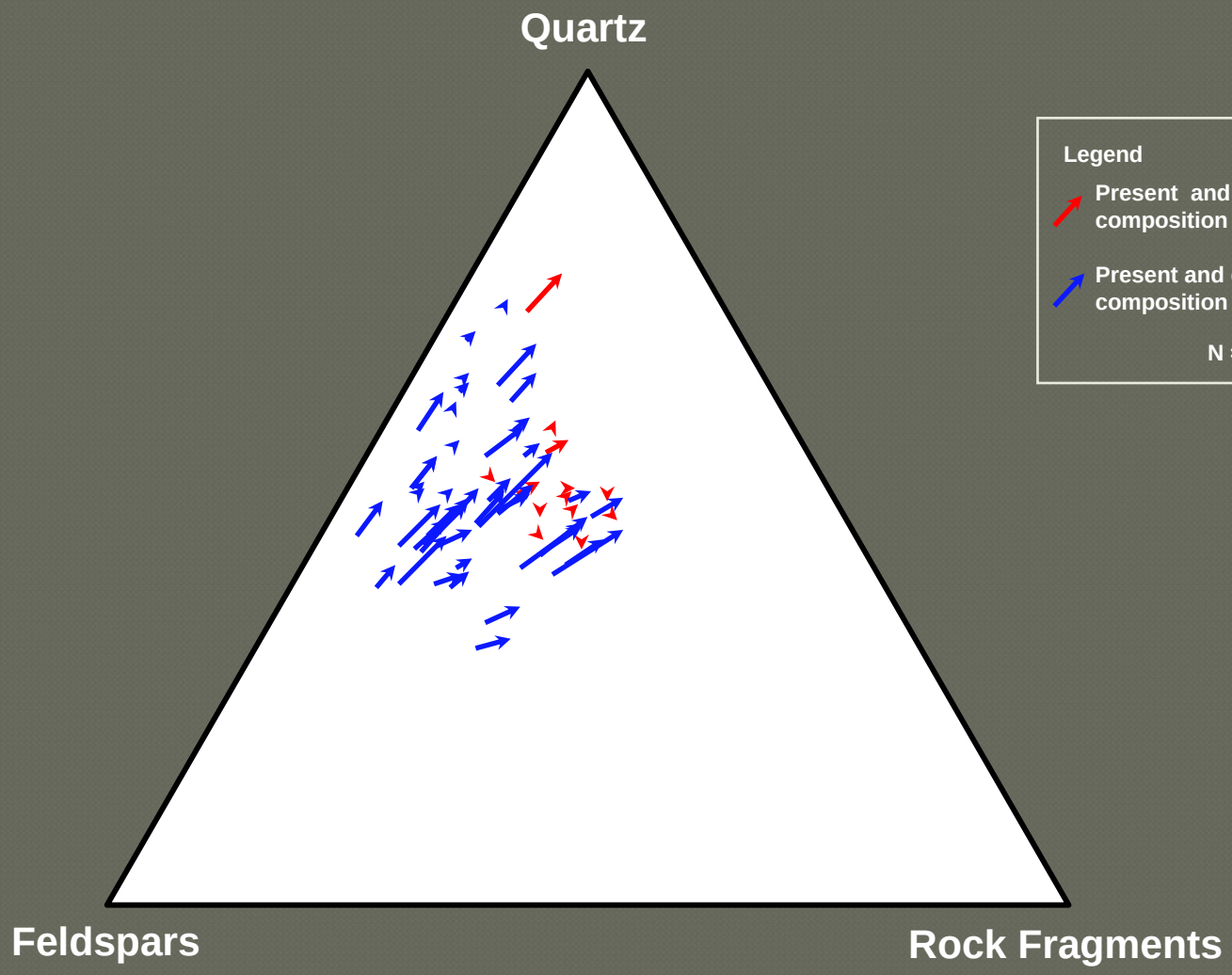






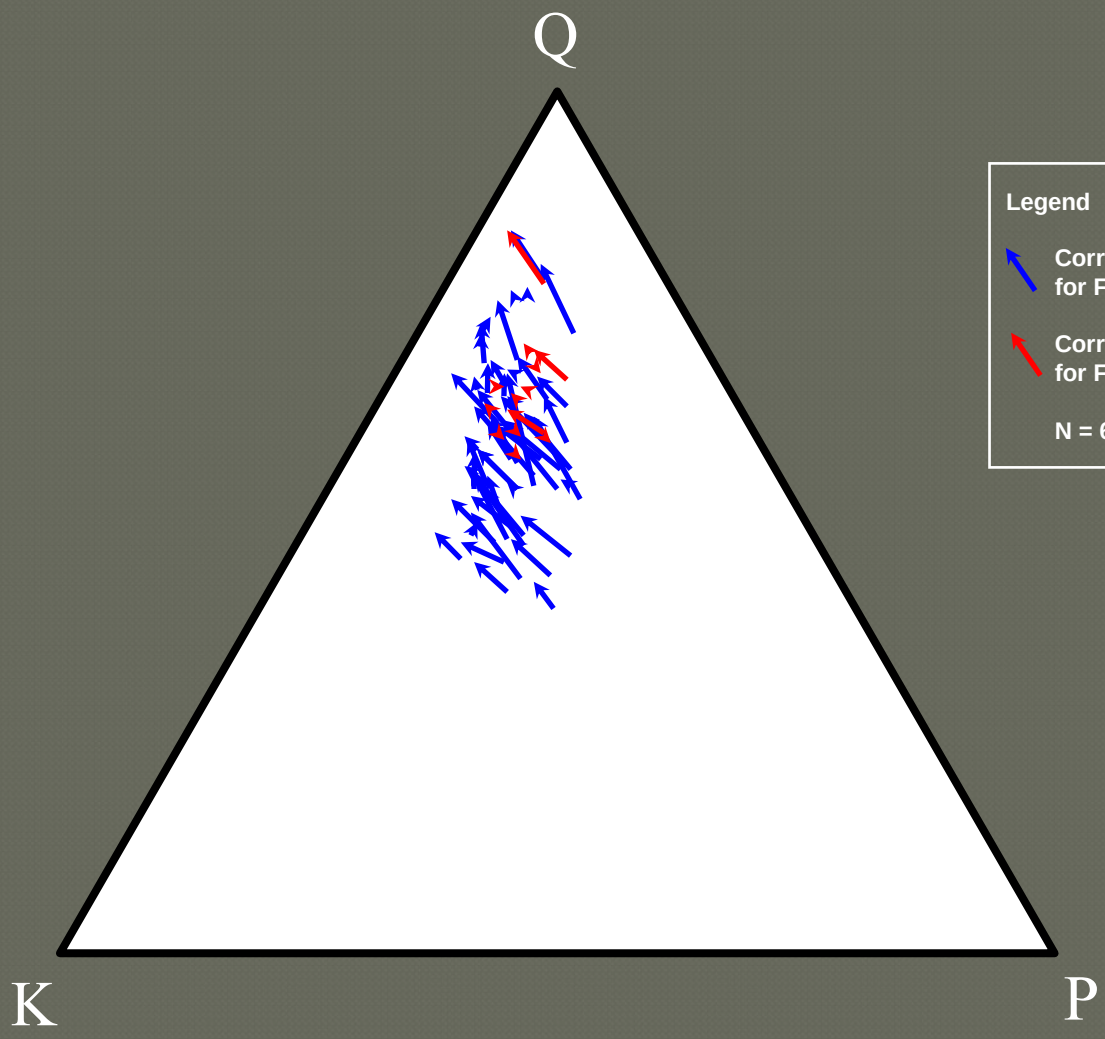
Legend

- = Uncemented Sandstone
- = Calcite-cemented sandstone



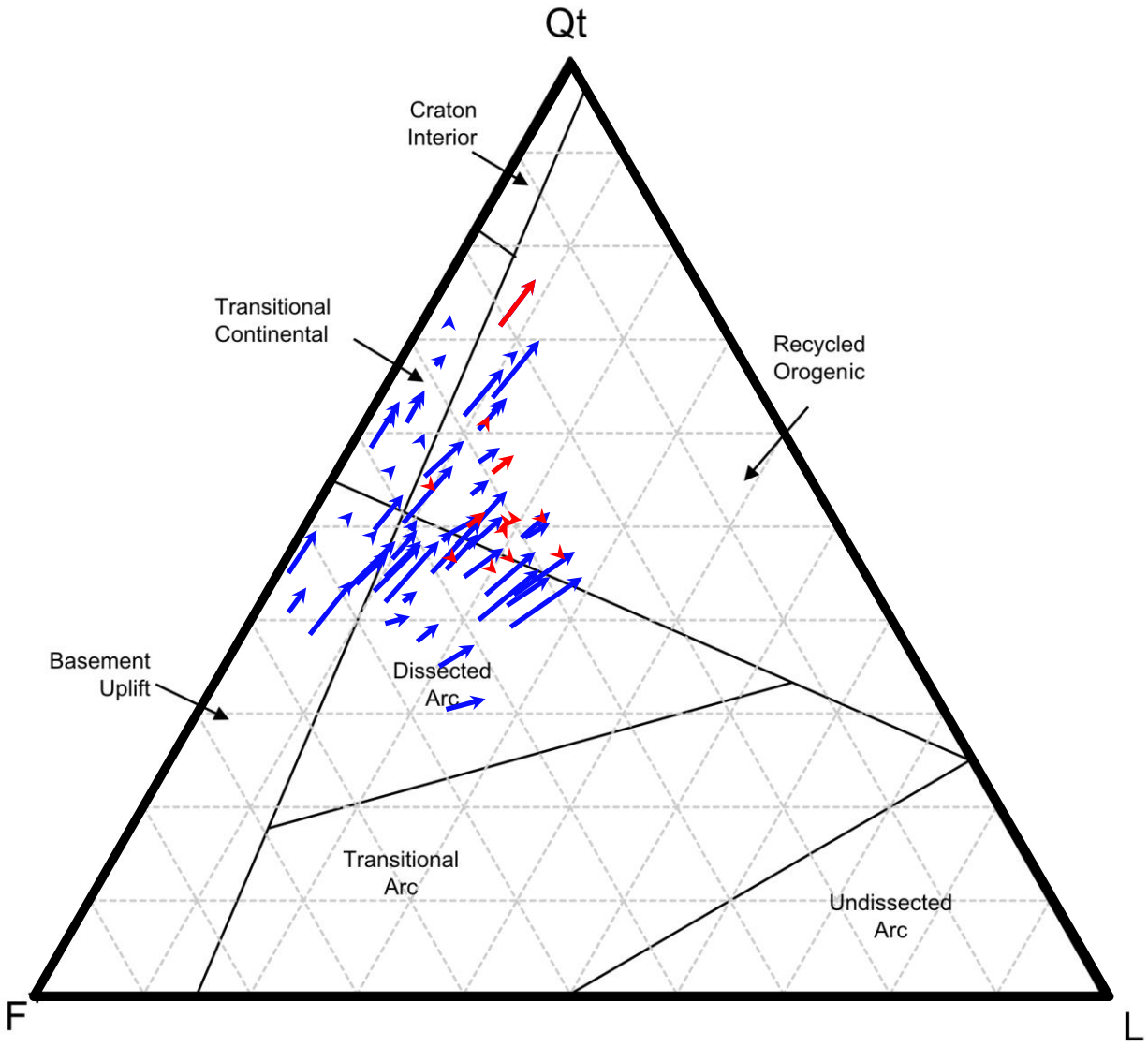
TEMBLOR FORMATION

(Following Pettijohn et al., 1987 and Harris, 1989).



TEMBLOR FORMATION

(Following Harris, 1989).



QtFL Provenance Plot (Dickinson, 1985)

Summary

- **Complicated detrital mineralogy suggests multiple source rocks.**
- **Complicated diagenetic history produced changes in mineralogy.**
- **Selective dissolution of feldspars resulted in improved reservoir quality.**

Summary

- **Feldspar dissolution caused shifts in the detrital grain ratios, diminishing their use for determining provenance accurately.**

- **Quantitative mineralogical and chemical compositions of the sediments may provide a useful base for future modeling of the effects of CO_2 sequestration in this reservoir.**

Acknowledgments

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