Copyright

By

Diem T. Nguyen

2014

Diagenesis of Oligocene and Eocene Sandstones at the Greeley Oil Field, Southern San Joaquin Basin, California

By

Diem T. Nguyen, B.S.

A Thesis Submitted to the Department of Geological Sciences
California State University Bakersfield
In Partial Fulfillment for the Degree of
Masters of Science

Fall 2014

Diagenesis of Oligocene and Eocene Sandstones at the Greeley Oil Field, Southern San Joaquin Basin, California

By Diem T. Nguyen

This thesis or project has been accepted on behalf of the Department of Geological Sciences by their supervisory committee:

Robert A. Horton, Jr., Ph.D., Chair

Dirk Baron, Ph.D.

Brian L. Taylor, M.S.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

The Vedder Formation (Oligocene) and Eocene sands at the Greeley oil field consist of arkosic to subarkosic arenites and graywackes. Grain size ranges from fine to coarse sand and the sands vary from poorly to well sorted. Burial depths of the Vedder sands exceed 10,350 ft and the reservoir temperature is 255ºF. The Eocene sands are buried at greater than 12,861 ft and the reservoir temperature is estimated to be around 275°F. These sands are currently at or very near their deepest burial depths.

Porosity within the Vedder and Eocene sands is controlled by compaction, dissolution of framework grains, and cementation. Mechanical compaction is evident by long, concavo-convex and sutured grain-to-grain contacts, fractured and broken framework grains and cements, and deformed labile grains. Compaction reduced primary porosity through readjustment of grains, fracturing and subsequent rotation of grain fragments, and deformation of micas and labile grains. Precipitation of cements, including phosphate, clays, calcite, dolomite, K-feldspar, quartz, barite, anhydrite, and pyrite, also reduced porosity at various times during burial. Other diagenetic processes included glauconization of feldspars, quartz, and chert, phosphate replacing feldspars, glauconite, and quartz, replacement of framework silicates by carbonates, alteration of biotite, albitization of feldspars, dissolution of framework grains and carbonates, and dolomite replacing calcite.

Dissolution of feldspars, quartz, volcanics, micas, and carbonates created secondary porosity and altered QFRf and QFL ratios. Deeper samples are quartz-rich relative to shallower samples, suggesting feldspar removal through dissolution. Dissolution affected

plagioclase more than K-feldspar. Continued compaction reduced both primary and secondary porosity and most likely permeability, while continued dissolution of framework grains and cements maintained an open pore network, thus facilitating the migration and accumulation of hydrocarbons. Pyrite formed after emplacement of hydrocarbons suggesting continuing thermal maturation within the reservoir.

Textural relationships of the diagenetic minerals suggest syndepositional formation of glauconite, phosphate, and early pyrite, followed by early precipitation of pore-lining clay coatings and carbonate cements, along with framework-grain fracturing and possibly dissolution. With increasing burial, dissolution of framework grains continued, accompanied by albitization of feldspars, formation of K-feldspar and quartz overgrowths, precipitation of kaolinite and other clays, and possibly precipitation of late carbonate cements. Finally, hydrocarbon migration and formation of late pyrite occurred during late diagenesis.

INTRODUCTION

Predicting reservoir quality in sandstones is a valuable tool for hydrocarbon exploration and production. In the southern San Joaquin basin (Fig. 1), hydrocarbon production mainly comes from sandstone reservoirs. As these sandstones were buried, they underwent diagenesis. Diagenetic processes include compaction, deformation, dissolution, cementation, replacement, and recrystallization of minerals. These processes significantly alter the reservoir quality by reducing or increasing porosity and permeability (Schmidt and McDonald, 1979; Ehrenberg, 1990). Understanding the diagenetic processes of the target reservoir may increase the possibility of exploration and production success (Galloway, 1979; Hayes, 1979).

The Greeley oil field is located 10 miles northwest of Bakersfield, California (Fig. 1). It has been producing hydrocarbons since 1936. Production comes mainly from sandstones in the Vedder Formation and the Stevens sands within the Monterey Formation (California DOGGR, 1998). Burial depths of the Vedder Formation exceed 10,350 ft. The Eocene sands within the Kreyenhagen Formation are buried at depths greater than 12,861 ft. Petrologic aspects of the Vedder Formation along the eastern margin of the basin and of Eocene sands on the western margin of the basin have been well documented (i.e. Clarke, 1973; Olson et al., 1986; Bent, 1988; Hayes and Boles, 1992; Taylor, 2007), however, there have been no detailed published studies of the Vedder and Eocene sands from near the axis of the basin. The purpose of this study is to determine the mineralogy and interpret the diagenetic processes of the Vedder and Kreyenhagen Formations sandstones at the Greeley oil field.

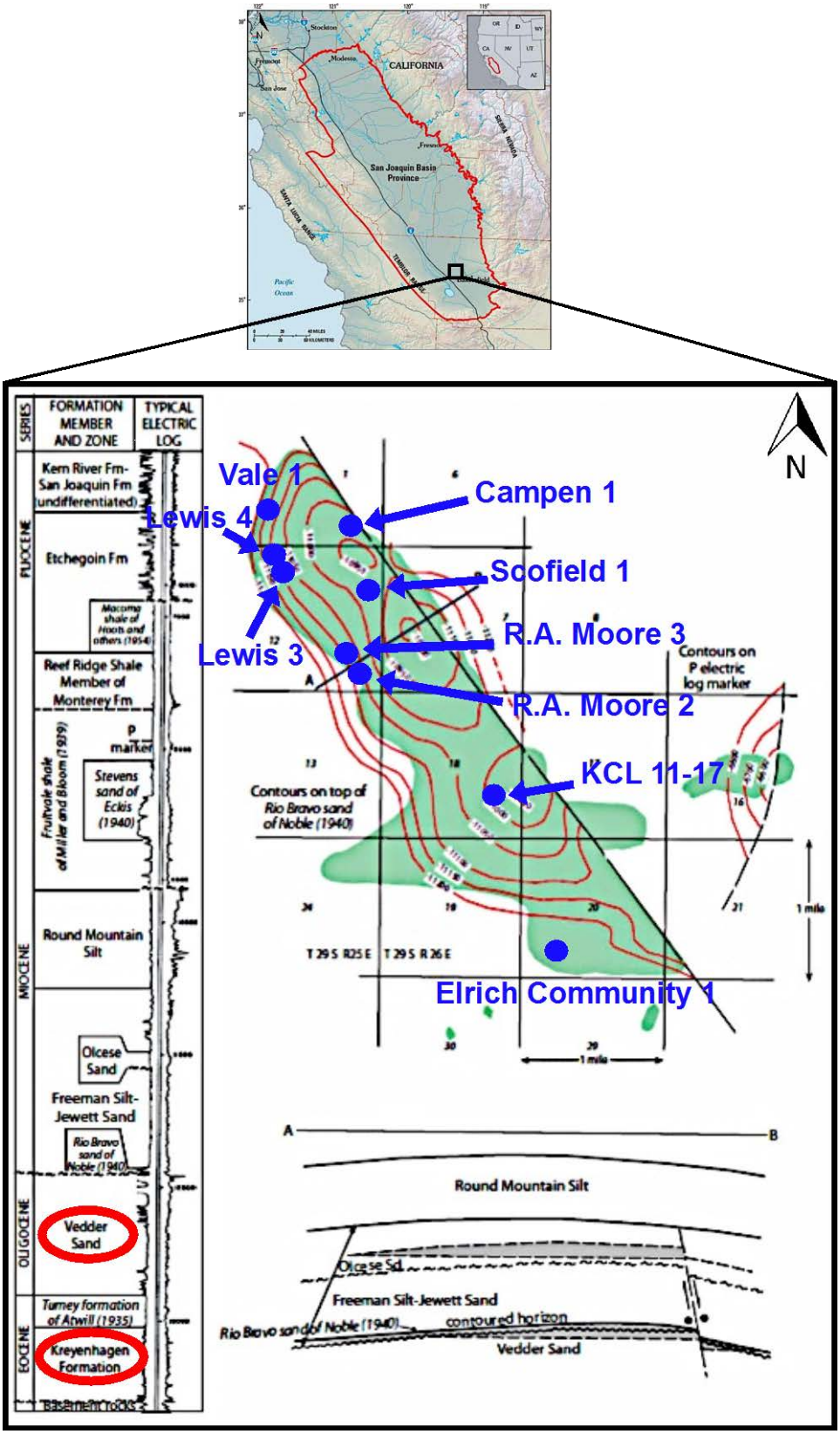


Fig. 1. The location of Campen 1, KCL 11-17, Lewis 3 and 4, R.A. Moore 2 and 3, Scofield and Vale 1, and Elrich Community 1 wells at the Greeley oil field, located in the southern San Joaquin basin, and stratigraphic column of Vedder and Eocene sands. Modified from Gautier and Scheirer (2007).

GEOLOGIC SETTING

The San Joaquin basin is bounded by the Sierra Nevada on the east, Temblor Range on the west, and San Emigdio and Tehachapi Mountains on the south. It is part of the Great Valley forearc basin that formed during Late Jurassic time (Bartow, 1991). The San Joaquin basin contains ~30,000 ft of marine and non-marine sediments, deposited from Late Mesozoic through Cenozoic time (Bandy and Arnal, 1969; Bartow, 1991).

In the southern San Joaquin basin, the stratigraphic sections on the eastern margin consist of continental facies while stratigraphic sections on the western side consist of shallow to deep marine facies (Bartow, 1991; Wagoner, 2009). Structurally, the eastern margin of the basin is little-deformed compared to the western margin of the basin. En-echelon fold sets on the west side are associated with the migration of the Mendocino triple junction and the formation of the San Andreas transform fault in the Oligocene (Bartow, 1991), as well as more recent transpression (Niemi and Hall, 1992; Grove and Niemi, 2005). Active tectonics along the western margin of the North American plate resulted in periods of uplift and subsidence within the basin. The marine Vedder and Kreyenhagen Formations are transgressive units deposited in the Oligocene and Eocene (Bartow and McDougal, 1984; Bloch and Olson, 1990; Bartow, 1991).

The Vedder Formation underlies the Rio Bravo sands of the Freeman-Jewett Formation and is separated from the Kreyenhagen Formation by the Tumey Formation (Fig. 1) (Gautier and Scheirer, 2007). The Vedder Formation covers a large portion of the San Joaquin basin and ranges in thickness from 0 ft on the eastern margin of the basin to 2,000 ft close to the southern basin boundary (Richardson, 1966). It is ~1,250 ft thick at the Greeley oil field (Sullivan and Weddle, 1960; Bloch and Olson, 1990). The upper

portion of the formation consists of well sorted, very fine- to coarse-grained, gray sandstones. The lower portion of the formation consists of dark brown shale; it is separated from the upper portion by thin, tight, gray sands. The Vedder Formation sands are exposed on the eastern margin of the southern San Joaquin basin, where they range from 0 to 262 ft thick, and are composed of light gray, well-sorted, fine to medium sand (Sullivan and Weddle, 1960). These sands were derived from the Sierra Nevada and deposited in a shallow-marine setting (Bent, 1985; Bent, 1988; Olson, 1988; Bloch and Olson, 1990).

The late Middle to Late Eocene Kreyenhagen Formation is composed of mostly deep-marine shales with minor sandstones and siltstones. The formation is thickest to the west and thins out to the north and east (Isaacson and Blueford, 1984). The upper portion of the formation consists of the informal Famoso sand member (Wagoner, 2009) and the lower portion of the formation has not been correlated at the Greeley oil field. The Kreyenhagen Formation covers most of the San Joaquin basin and was derived from source areas to the south, west, and east of the basin (Clarke, 1973). It is one of the basin's major hydrocarbon source rocks (Isaacson and Blueford, 1984; Lillis and Magoon, 2007).

STRUCTURE

The Greeley oil field is located just off the crest on the north flank of the Bakersfield arch, a northeast-southwest trending anticline that separates the Buttonwillow sub-basin to the north from the Maricopa (aka Tejon) sub-basin to the south and along which many important San Joaquin basin oil fields are located. The Greeley oil field is four miles long and ranges from one to two miles wide. The structure of the field is a

northwest-southeast trending anticlinal fold, part of a series of en-echelon fold sets that host oil reservoirs both on and off the Bakersfield arch. On the eastern margin of the field lies the Greeley fault, a normal fault with the downthrown side to the east. The fault has a vertical displacement of ~250 ft (Sullivan and Weddle, 1960).

METHODS

Forty-nine thin sections of Vedder sands from eight wells (Campen 1, KCL 11-17, Lewis 3 and 4, R.A. Moore 2 and 3, Scofield 1, and Vale 1) and fourteen thin sections of Eocene sands from one well (Elrich Community 1) (Fig. 1) were analyzed using a standard transmitted-light petrographic microscope, located in the California State University, Bakersfield Geological Sciences Department. The depths of the samples from Campen 1, KCL 11-17, Lewis 3 and 4, R.A. Moore 2 and 3, Scofield 1, and Vale 1 are between 11,300 to 11,517 ft, and Elrich Community 1 (ELR) well are between 13,446 to 13,512 ft. Each thin section was point-counted (300 points per thin section) using the petrographic microscope. The mineralogy, grain size, roundness, and sorting were recorded for each thin section. Diagenetic features such as cementation, alteration, dissolution, and compaction were also recorded.

The data collected from petrographic analysis are plotted on three ternary diagrams following the methodologies of Dickinson (1970), Dott (1964) as modified by Pettijohn et al. (1987), and Harris (1989). Quantitative analysis of compaction of these sandstones were documented using the contact index (CI) and tight-packing index (TPI) following the methodologies of Wilson and McBride (1998). Selected thin sections were analyzed using a Hitachi scanning electron microscope (SEM) equipped with a back-scattered electron (BSE) imaging and Gatan cathode luminescence (CL) system, and an Oxford

INCA energy-dispersive x-ray spectrometer (EDS). The SEM-EDS analytical system provided the chemical components of the minerals while the SEM-CL system provided the textural relationships between the detrital grains, cements, and fractures.

The point count results were also used to calculate the mass transfer of aluminum by comparing the volumes of authigenic kaolinite and secondary porosity formed by feldspar dissolution (Hayes and Boles, 1992). The calculations assumed dissolved feldspars released aluminum ions that precipitated as kaolinite. The composition of detrital An_{30} was used based on Boles and Ramseyer's (1988) study on albitization in the San Joaquin basin as well as detrital plagioclase compositions determined during this study. For each mole of plagioclase dissolved, 0.65 mole of kaolinite could precipitate:

$$\underset{\text{(Plagioclase)}}{Na_{0.7}Ca_{0.3}Al_{1.3}Si_{2.7}O_8} + H^+ + 3.75H_2O \rightarrow \underset{\text{(Kaolinite)}}{0.65Al_2Si_2O_5(OH)_4} + 1.4H_4SiO_4 + 0.7Na^+ + 0.3Ca^{2+} + 0.3OH^-$$

For each mole of K-feldspar dissolved, 0.5 mole of kaolinite could precipitate:

$$\underset{\text{(K-feldspar)}}{KAlSi_3O_8} + H^+ + 4.5H_2O \rightarrow \underset{\text{(Kaolinite)}}{0.458Al_2Si_2O_5(OH)_4} + 2H_4SiO_4 + K^+$$

The percent imbalance of kaolinite indicates whether aluminum has been exported or imported on the scale of the thin section during diagenesis. This was calculated by comparing the observed kaolinite volume and the expected volume based on observed feldspar dissolution:

$$\text{\% Imbalance} = \frac{\text{Kaolinite Volume Reported} - \text{Expected Volume of Kaolinite}}{\text{Expected Volume of Kaolinite}}$$

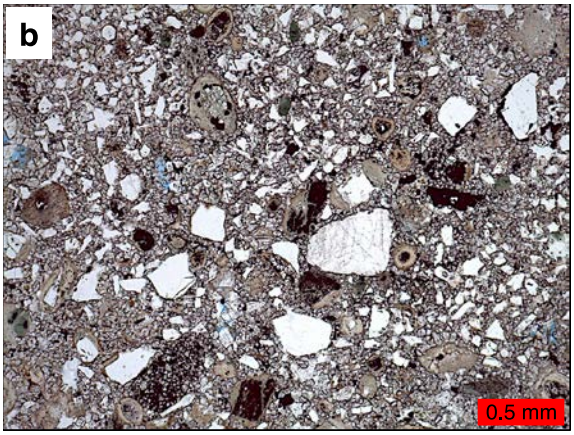
Other sources of aluminum ions are volumetrically minor and have been excluded from the mass-balance calculations. Also, the expected volumes of kaolinite do not take into account secondary porosity for which the dissolved minerals could not be determined and

are, therefore, conservative.

RESULTS

Detrital Composition and Texture

The Vedder sands range in size from fine to medium sand (Figs. 2a, b). The Eocene sands range from fine to coarse sand (Figs. 2c, d). Grain size is typically smaller in graywackes. Framework grains in both sands vary from angular to round and sorting varies from poorly to well sorted. In general, the sands are moderately sorted with subangular grains. Poor sorting in some samples is due to smaller fragments created by fracturing of the framework grains.



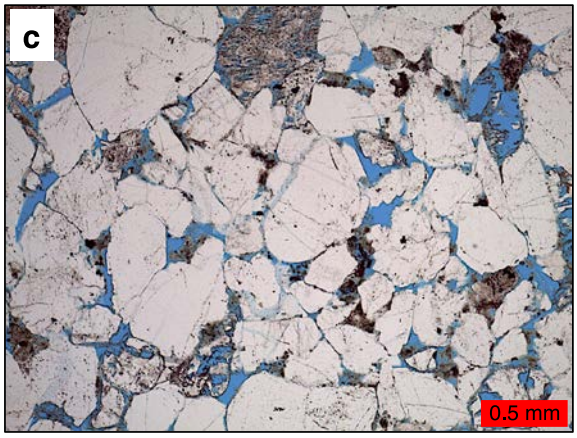


Fig. 2. Porosity is filled with blue epoxy. (**a-b**) Typical and atypical textures of the Vedder sands. (**c-d**) Typical and atypical textures of the Eocene sands.

Compositional data is presented in Table 1. The sandstones are composed of quartz (mainly monocrystalline grains), plagioclase and K-feldspars (microcline and orthoclase), and minor rock fragments. The mean value for the Vedder sands is $Q_{34}F_{52}Rf_{14}$ and Eocene sands is $Q_{69}F_{24}Rf_{7}$. Accessory detrital minerals include biotite, muscovite, chlorite, epidote, hornblende, titanite, and zircon. Fossils occurred in very small amounts in some of the samples, but no attempt was made to identify them. The Vedder Formation sandstones consist of arkosic arenites and graywackes (Fig. 3). The Eocene sandstones consist of arkosic to subarkosic arenites and graywacke (Fig. 3). The Vedder sands plot in the basement uplift field on a QFL diagram (Dickinson, 1970) and Eocene sands plot in the transitional continental field (Fig. 4).

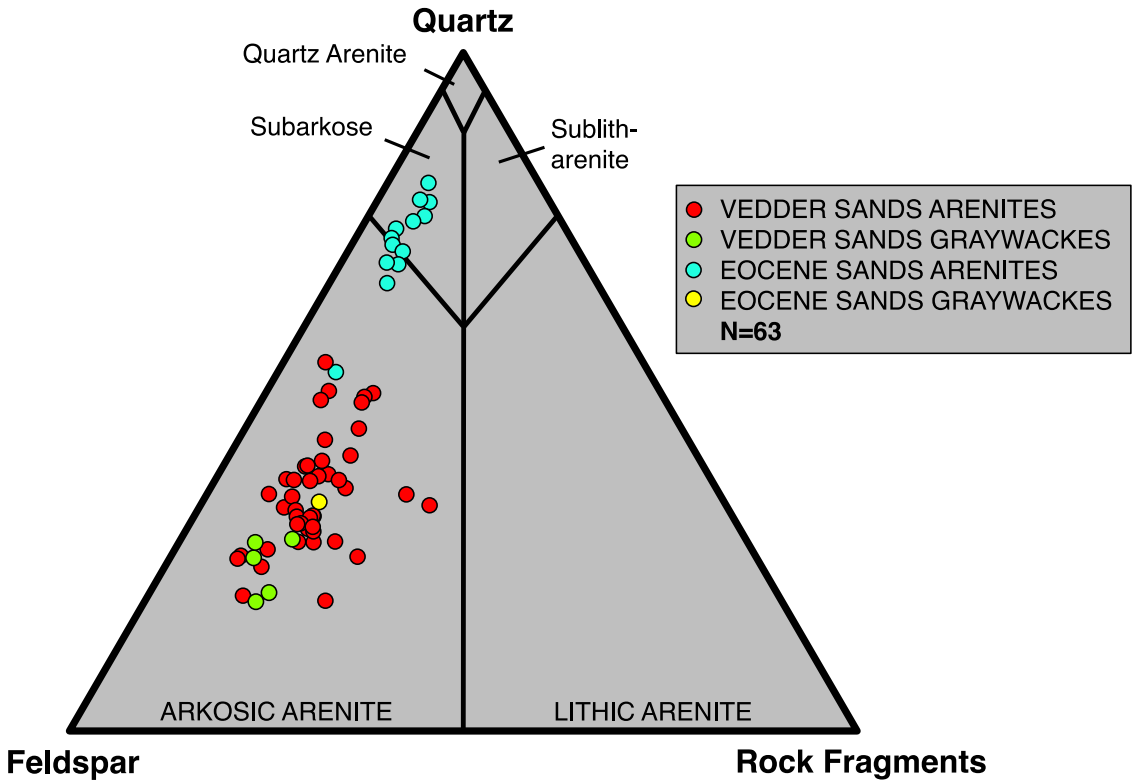


Fig. 3. QFRf ternary diagram (Pettijohn et al., 1987) for Vedder and Eocene sands. The results suggest deeper samples (Eocene sands) are more quartz-rich than shallower samples (Vedder sands).

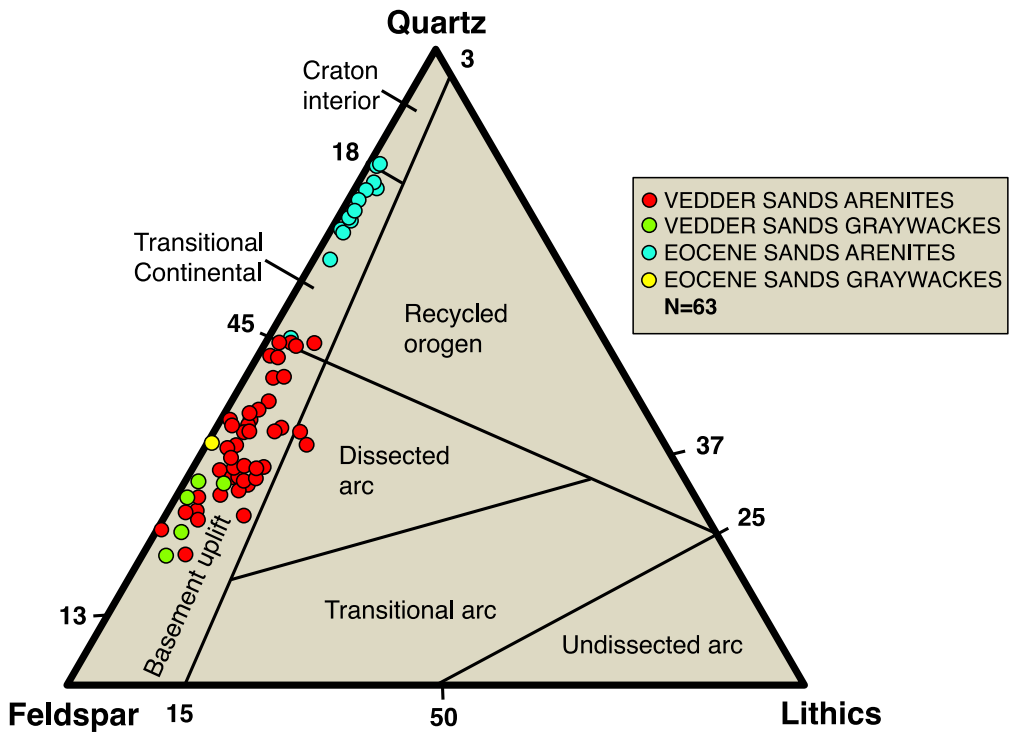


Fig. 4. QFL ternary diagram (Dickinson, 1970) for Vedder and Eocene sands. The results indicate most of the samples are derived from basement uplift and transitional continental.

Quartz is most abundant in the Eocene sands. Quartz generally luminesces blue (Figs. 5, 6, 7, 8) or is non-luminescent (Figs. 5, 6), however, some quartz within the Vedder sands luminesces brownish-red (Fig. 5).

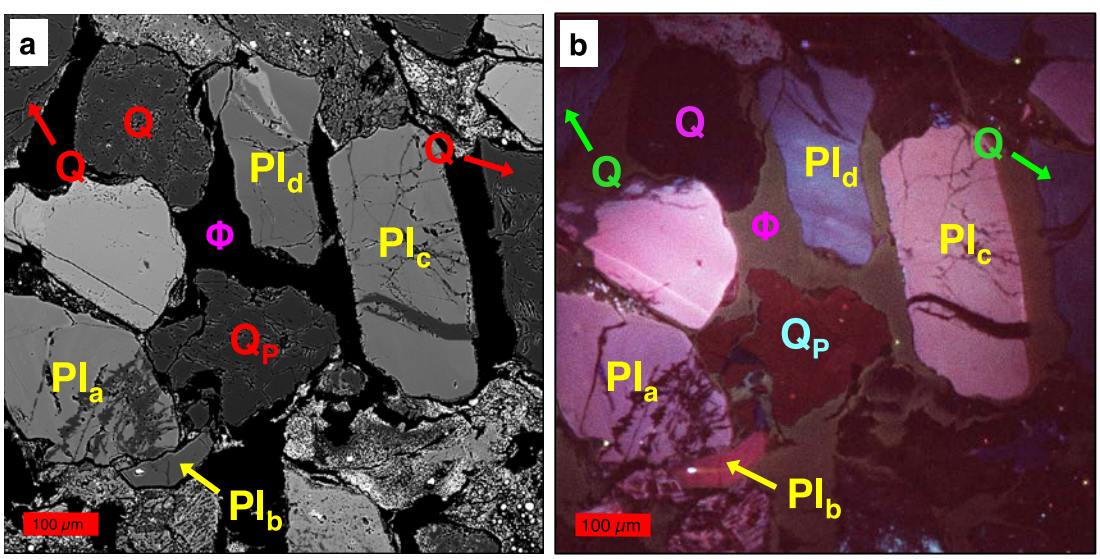


Fig. 5. (**a-b**) SEM-BSE and -CL images of plagioclase (Pl), quartz (Q), polycrystalline quartz (Q_P), and porosity (Φ). Pl_a is Ca-rich, Pl_b is Na-rich, Pl_c is Ba-rich, and Pl_d is under the detection limit. Plagioclase luminesces pinkish-purple (Pl_a), pink (Pl_b and Pl_c), and blue (Pl_d). Quartz luminesces blue (green fonts), brownish-red (blue fonts), and non-luminescent (pink font). Well: KCL 11-17, depth: 11,324 ft.

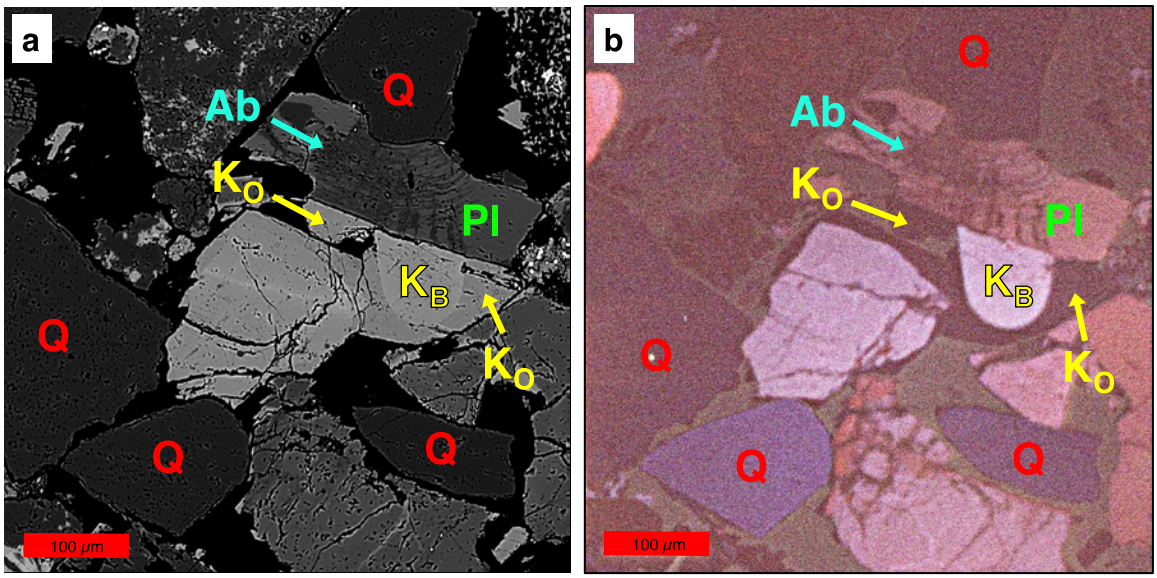


Fig. 6. (**a-b**) SEM-BSE and -CL images of albitized (Ab) plagioclase (Pl), Ba-rich K-feldspar (K_B), K-feldspar overgrowths (K_O), and quartz (Q). Albitization occurs along the radiating fractures in plagioclase. K-feldspar overgrowths formed along plagioclase and Ba-rich K-feldspar grain boundaries. Plagioclase luminesces pink, Ba-rich K-feldspar luminesces bright pink, albite and K-feldspar overgrowths are non-luminescent, and quartz luminesces blue and non-luminescent. Well: R.A. Moore 2, depth: 11,408 ft.

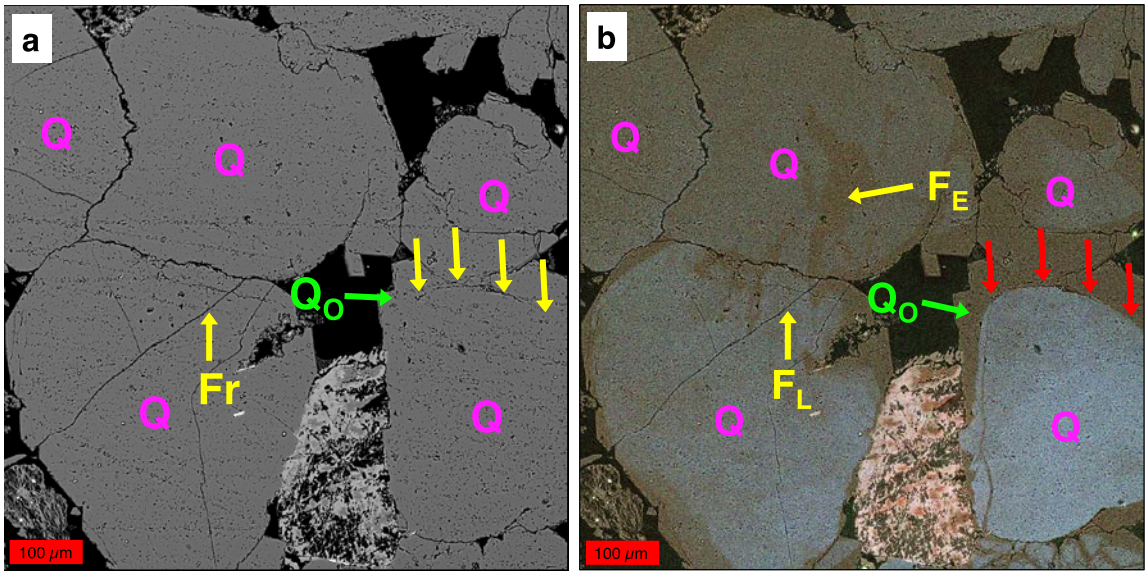


Fig. 7. (**a**) SEM-BSE image of fractured (Fr) quartz (Q) and quartz overgrowth (Q_O) on quartz grain. The yellow arrows point at the possible original grain boundary between detrital and authigenic quartz. (**b**) Composite image of SEM-BSE and -CL images revealing quartz overgrowth (Q_O) on a rounded quartz grain (red arrows) and multiple episodes of fracturing. Early fractures (F_E) in quartz were healed by secondary quartz whereas late fractures (F_L) remain open. Notice quartz luminesces blue. Well: ELR, depth: 13,464 ft.

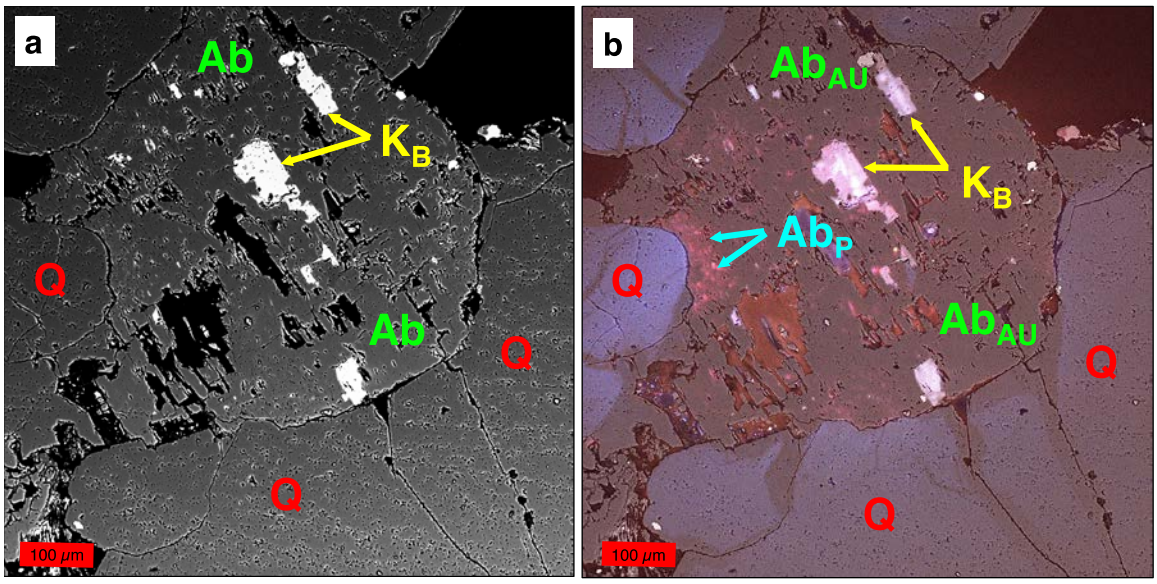


Fig. 8. (**a**) SEM-BSE image of almost completely albitized (Ab) Ba-rich K-feldspar (K_B) surrounded by quartz (Q). (**b**) Composite image of SEM-BSE and -CL images of authigenic albite (Ab_{AU}) replacing Ba-rich K-feldspar, but not albite from perthite (Ab_P). K-feldspar and albite from perthite luminesce pink, quartz luminesces blue, and authigenic albite is non-luminescent. Well: ELR, depth: 13,464 ft.

Feldspars decrease with depth (Figs. 9a, 10). Plagioclase (Fig. 9b) decreases at a faster rate compared to K-feldspars (Fig. 9c). Plagioclase averages 20% in volume in the Vedder sands and 7% in volume in the Eocene sands. SEM-EDS analyses indicate detrital plagioclase compositions in the Vedder Formation range from An_{55} to An_2 (Fig. 11). Detrital plagioclase ranges from An_{38} to An_8 in the Eocene sands, but only two analyses exceeded An_{30}. Some plagioclase grains also contain up to 1.0 wt% of Sr and/or 0.1 wt% of Ba (Fig. 12); there is a significant decrease in the Sr content of plagioclase in the Eocene sands as compared to the Vedder Formation. Detrital plagioclase luminesces pink (Figs. 5, 6), pinkish-purple (Fig. 5), and blue (Fig. 5).

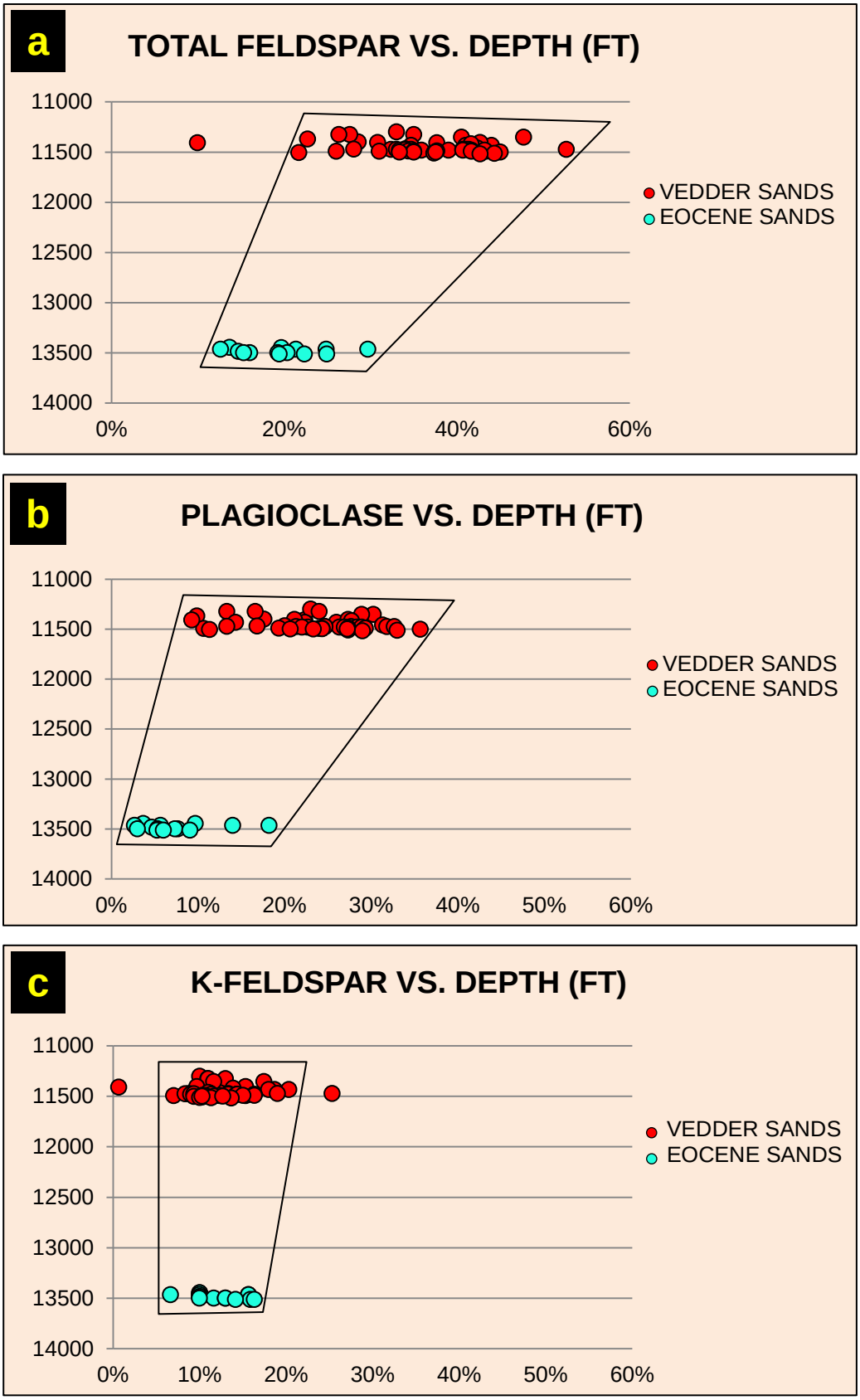


Fig. 9. (**a-c**) Feldspar decreases with increasing depth, N=63.

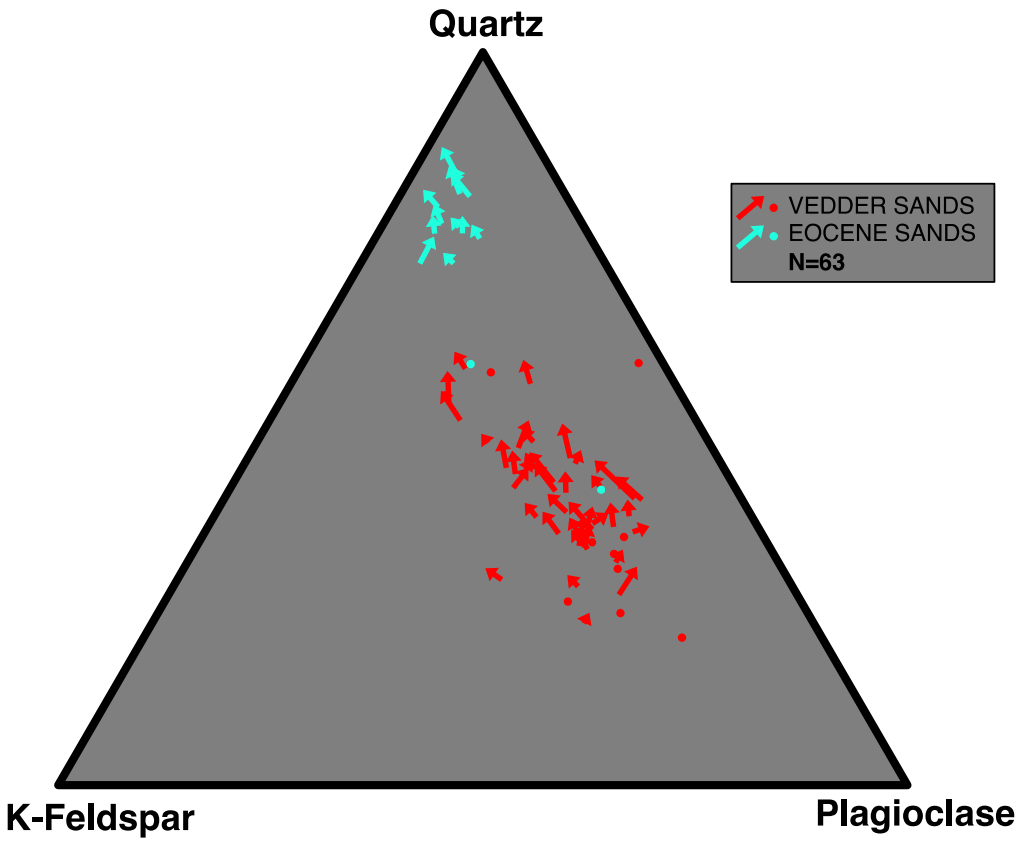


Fig. 10. QKP ternary diagram plotted for the Vedder and Eocene sands following the methodology of Harris (1989). The compositions are adjusted for dissolution. The arrows point to the present composition, they originate at the reconstructed compositions. This suggests significant plagioclase dissolution has occurred as evidenced by the arrows pointing toward the quartz corner. The Dots indicate no change in composition.

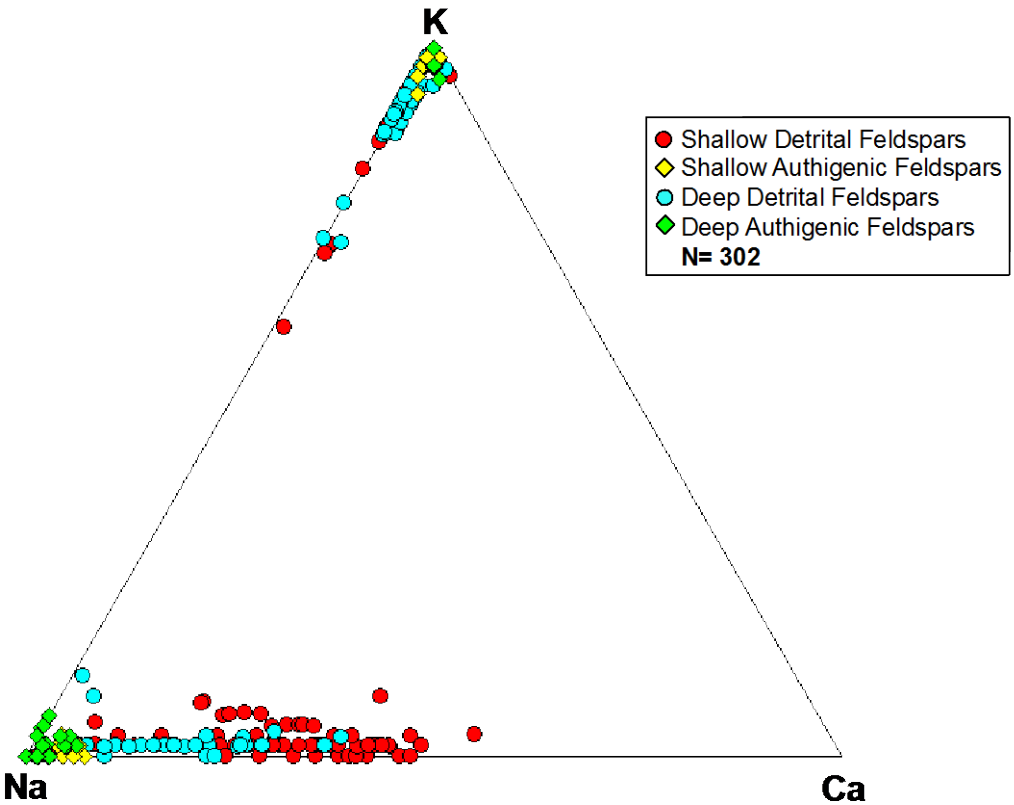


Fig. 11. K,Na,Ca ternary diagram of detrital and authigenic feldspars. Calcic plagioclase was preferentially removed as indicated by a shift towards more sodic compositions in deeper samples. Authigenic K-feldspar and albite are almost pure.

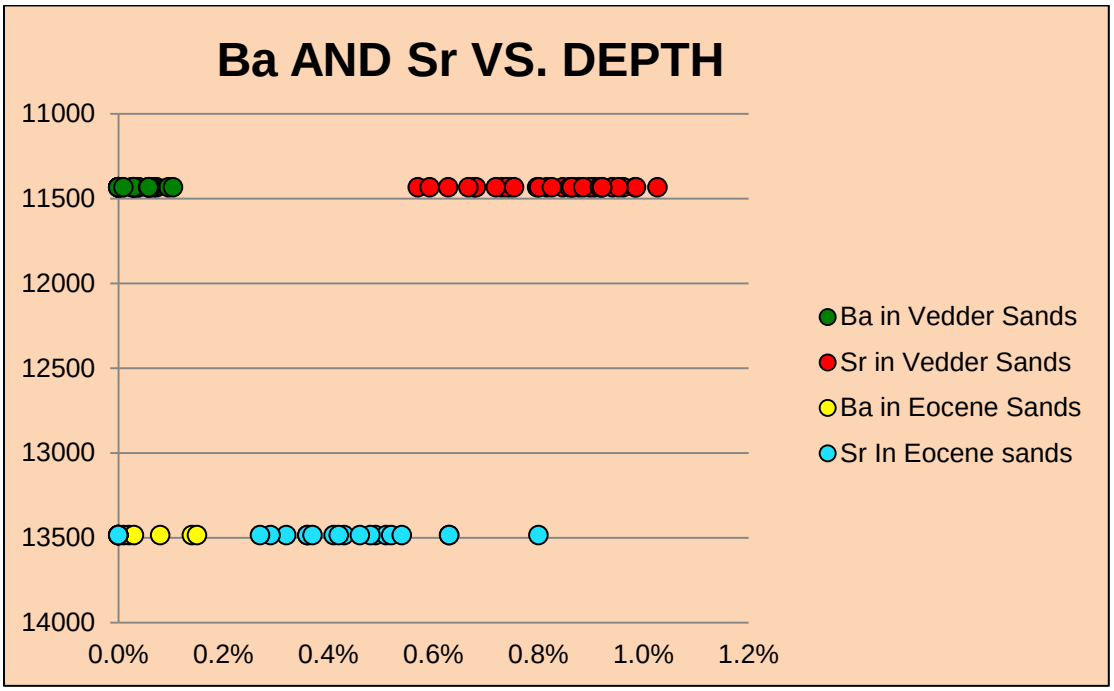


Fig. 12. Depth vs. Ba and Sr (wt%) in plagioclase of the Vedder and Eocene sands. The amounts of Ba remain the same in both sandstones while the amounts of Sr decrease with depth.

Both the Vedder and Eocene sandstones contain an average 12.5% K-feldspars (Fig. 9c). The Vedder sands consist of 7.5% microcline and 5.1% orthoclase. In the Eocene sands, 8.1% is microcline and 4.0% is orthoclase. Most detrital K-feldspars contain some Na (Fig. 11) and some are Ba-rich (Figs. 6, 8). K-feldspars luminesce pink (Figs. 6, 8) and blue.

Rock fragments include metamorphics, volcanics, cherts, and microphanerites. In some instances labile rock fragments were squashed to form pseudomatrix.

Compaction

Quantitative analysis (Table 2) of compaction in arenite samples of the Vedder (N=12) and Eocene sands (N=11) have been investigated following the methodologies of Wilson and McBride (1988). The number of contacts between grains is reported as contact index (CI) and tight-packing index (TPI). The CI for the Vedder sands ranges from 2.9 to 6.1 and TPI ranges from 2.3 to 6.0 (Fig. 13). For the Eocene sands, CI ranges from 4.9 to 7.0 and TPI ranges from 3.5 to 6.8 (Fig. 13). The CI of the Vedder and Eocene sands shows a minor increase with depth, but there is no significant change in the TPI. Floating grains are not common in arenites but are more common in those samples with significant cement (phosphate or carbonate) volumes.

Detrital feldspars, volcanics, glauconite, biotite, and muscovite are commonly deformed. Some volcanics, feldspars, and biotite (Fig. 14) have been altered and squeezed into adjacent pore spaces to form pseudomatrix. Early compaction between the framework grains created point and tangential contacts. Late compaction between the framework grains caused pressured-induced dissolution, forming long, concavo-convex, and sutured contacts.

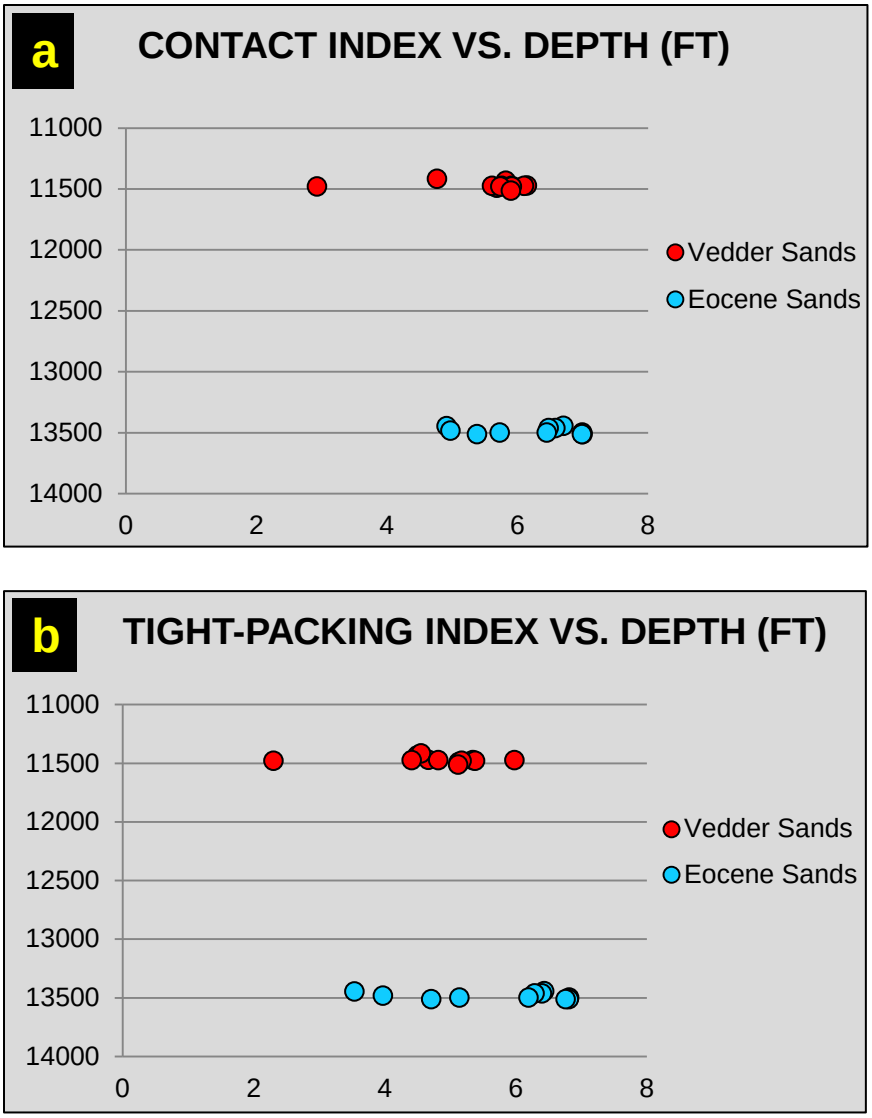


Fig. 13. Contact index (**a**) and tight-packing index (**b**) of the Vedder and Eocene sands.

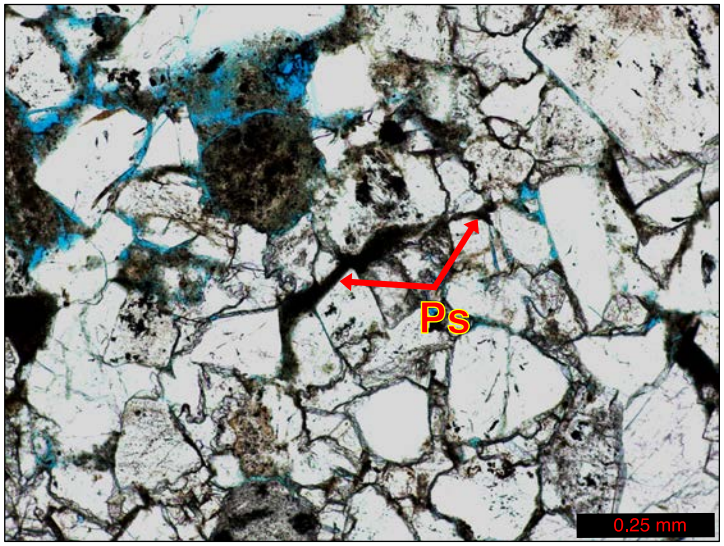


Fig. 14. Deformed and altered biotite forming pseudomatrix (Ps). Well: KCL 11-17, depth: 11,300 ft.

Fractures

Fracturing of the feldspars (Fig. 6), quartz (Figs. 7, 15), and micas is common. Fracture growth occurred along grain boundaries and/or cleavage planes. Fracturing within detrital grains (Fig. 6) and cement crystals (Fig. 16) is common at shallower depths. Through-going fractures are more common in deeper samples (Figs. 7, 15). Fracturing created various sizes of angular fragments, thus increasing the angularity of grains and decreasing the degree of sorting.

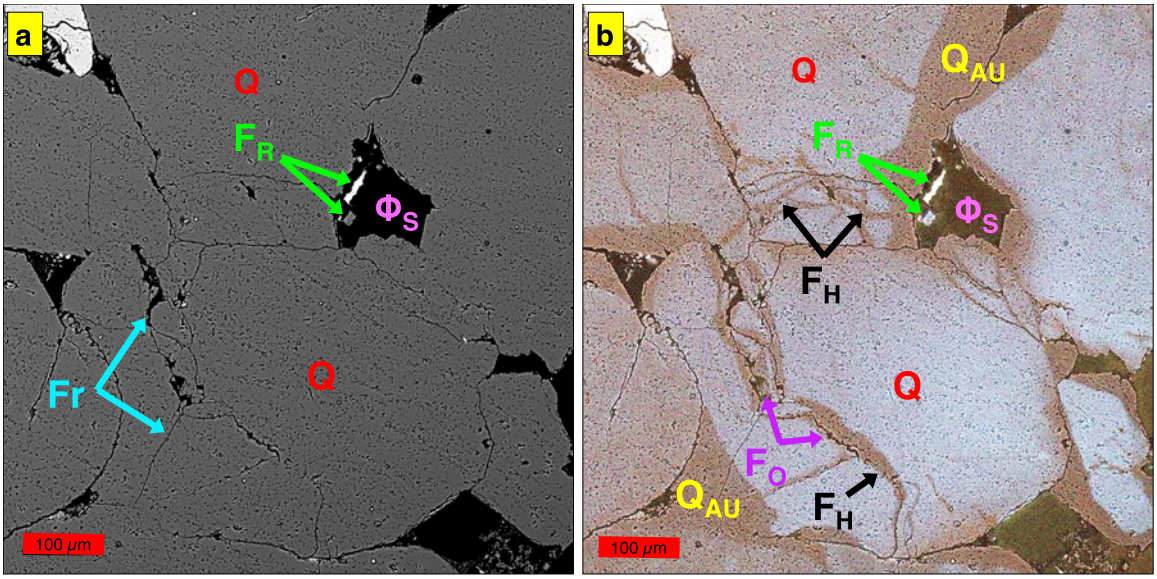


Fig. 15. (**a**) SEM-BSE image shows remnants of feldspars (F_R) and fractured (Fr) quartz (Q). Small remnants of feldspars within porosity (Φ_S) suggests porosity created by dissolved feldspars. (b) Composite image of SEM-BSE and –CL images shows authigenic quartz (Q_{AU}) healed fractures (F_H) within quartz grains. Subsequent compaction reopened (F_O) the healed fractures within quartz and may have collapsed secondary porosity created by feldspar dissolution. Well: ELR, depth: 13,464 ft.

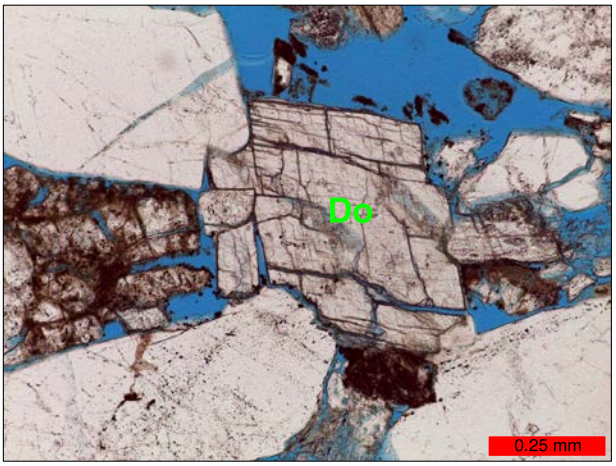


Fig. 16. Fractured dolomite (Do) crystal in pore space. Well: Campen 1, depth: 11,400 ft.

Authigenic Minerals

Glauconite

Glauconite grains range from subround to round (Fig. 17). Glauconite replaced chert, feldspars, and quartz. Replacement by glauconite ranges from partial to complete and occurred along the fractures and grain boundaries. Complete replacement by glauconite often occurred in feldspars. Glauconite is most common in medium sand with abundant matrix.

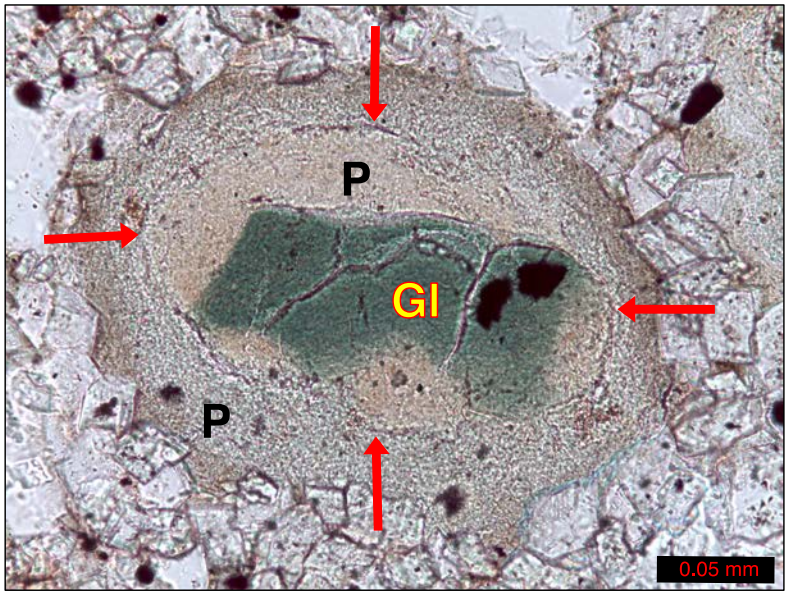


Fig. 17. Zoned phosphate (P) replacing glauconite (Gl). The red arrows point to the original grain boundary. Well: R.A. Moore 2, depth: 11,408 ft.

Phosphate

Phosphate is present in several samples in the Vedder sands. It occurred as individual grains, coatings on framework grains, and cement. The phosphate coatings occur as light, medium, and dark brown zones (Fig. 17). The outer zones are darker than the inner zones. Phosphate replaced feldspars, glauconite (Fig. 17), and quartz. Phosphate replacement often occurred along the grain boundaries and sometimes along fractures. Phosphate cement filled the intergranular pore space. Some phosphate cement contains

fragments of feldspars and quartz. The cement occurred as light and dark brown zones. The outer zones are darker than the inner zones.

Pyrite

Authigenic pyrite crystals occur throughout the sandstones, ranging from 0 to 5% of the rock. Pyrite formed along the biotite cleavage planes, within hydrocarbon-filled pores (Fig. 18), and between feldspar and phosphate coating. The crystal shapes range from subhedral to euhedral, up to 40 µm long. Pyrite occurs as isolated crystals or cement.

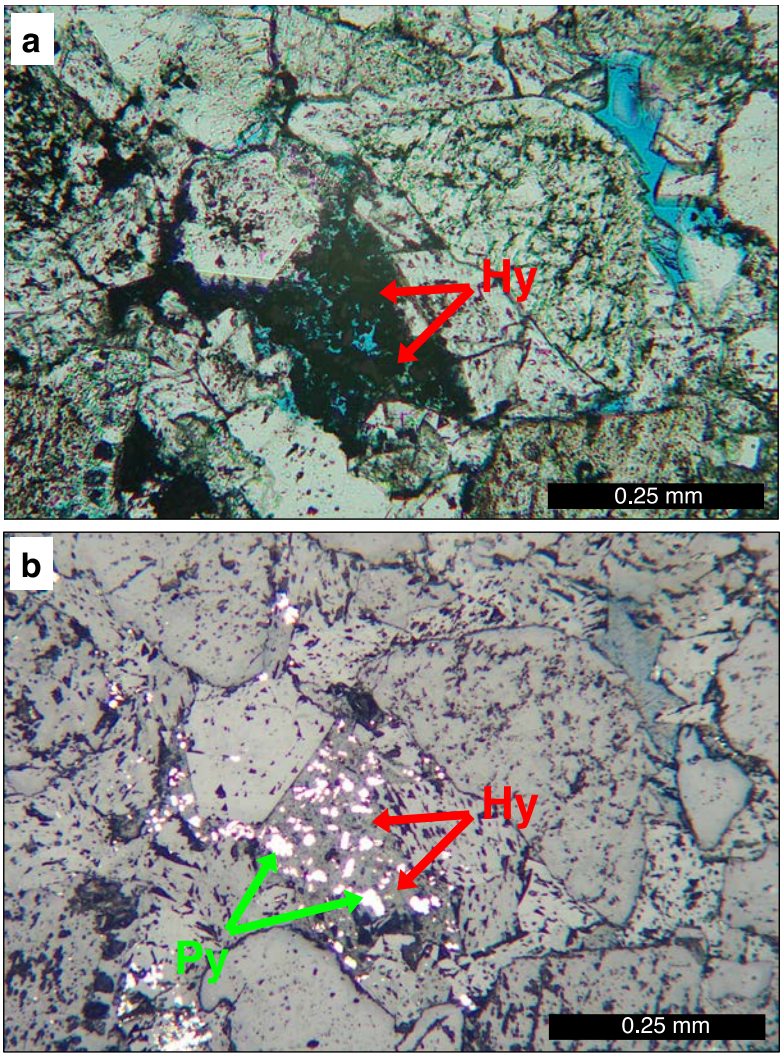


Fig. 18. Pyrite (Py) formed within hydrocarbon (Hy) in secondary pore created by framework-grain dissolution. (**a**) Transmitted light, (**b**) Reflected light. Well KCL 11-17, depth: 11,470 ft.

Clays

Authigenic clays occurred as coatings on detrital grains (Figs. 19, 20) and cement crystals (Fig. 21), and as pore-lining and pore-filling cements (Fig. 22). The authigenic clays have been observed within the petrographic microscope and confirmed using SEM-EDS analyses. They include mixed-layer illite/smectite (I/S) (Fig. 22) and illite/chlorite (I/C), chlorite, and kaolinite (Fig. 19). Most samples contain all four species; they range from 0 to 18% of the rock volume (Table 1). Clays in these sandstones are mostly products of altered feldspars (Fig. 19) and rock fragments.

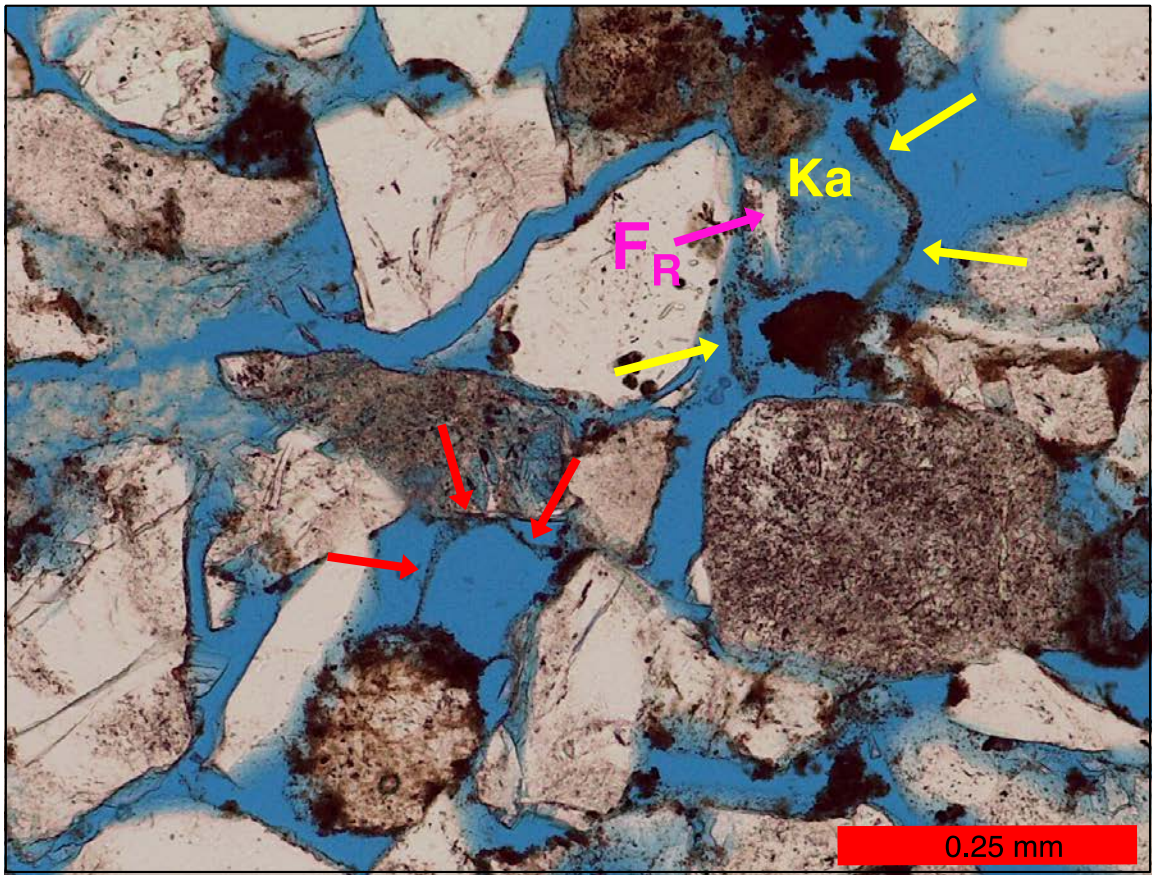


Fig. 19. Kaolinite (Ka) formed adjacent to remnants of feldspar (F_R) within a clay coating (yellow arrows) suggests kaolinite precipitated from dissolved feldspar. Unstable grain completely dissolved and left a clay coating behind (red arrows). Well: R.A. Moore 3, depth: 11,474 ft.

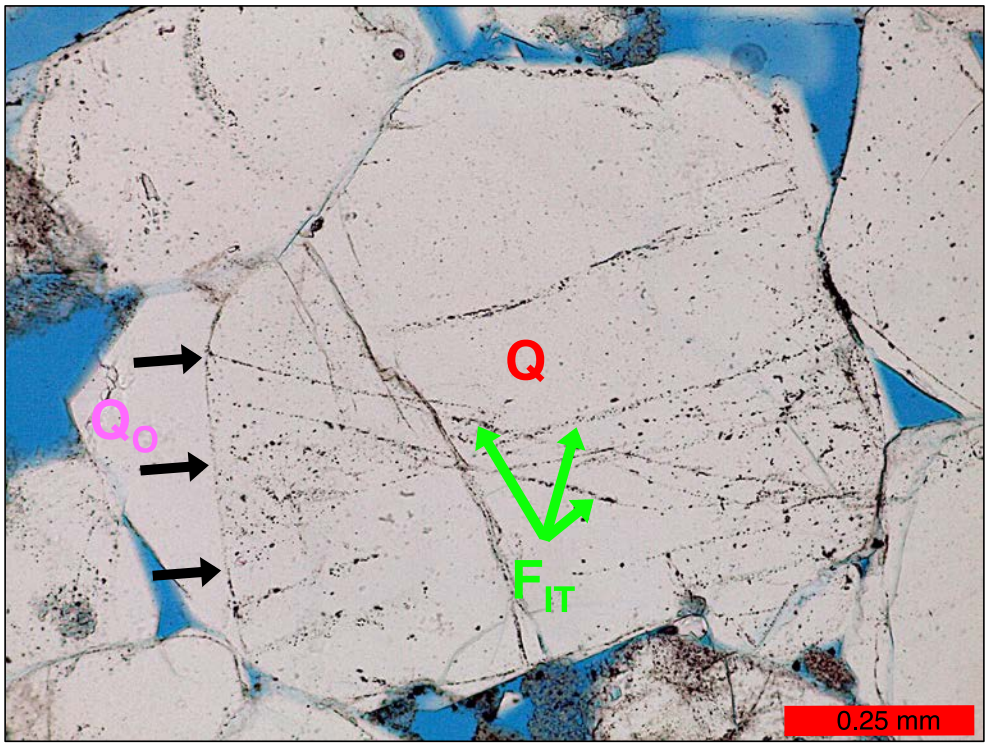


Fig. 20. Quartz (Q) exhibit fluid inclusion trains (F_{IT}) and clay coating (black arrows). Fluid inclusion trains suggest authigenic quartz healed fractures within detrital quartz. The clay coating on quartz separates the detrital grain from overgrowth (Q_O). Well: ELR, depth: 13,464 ft.

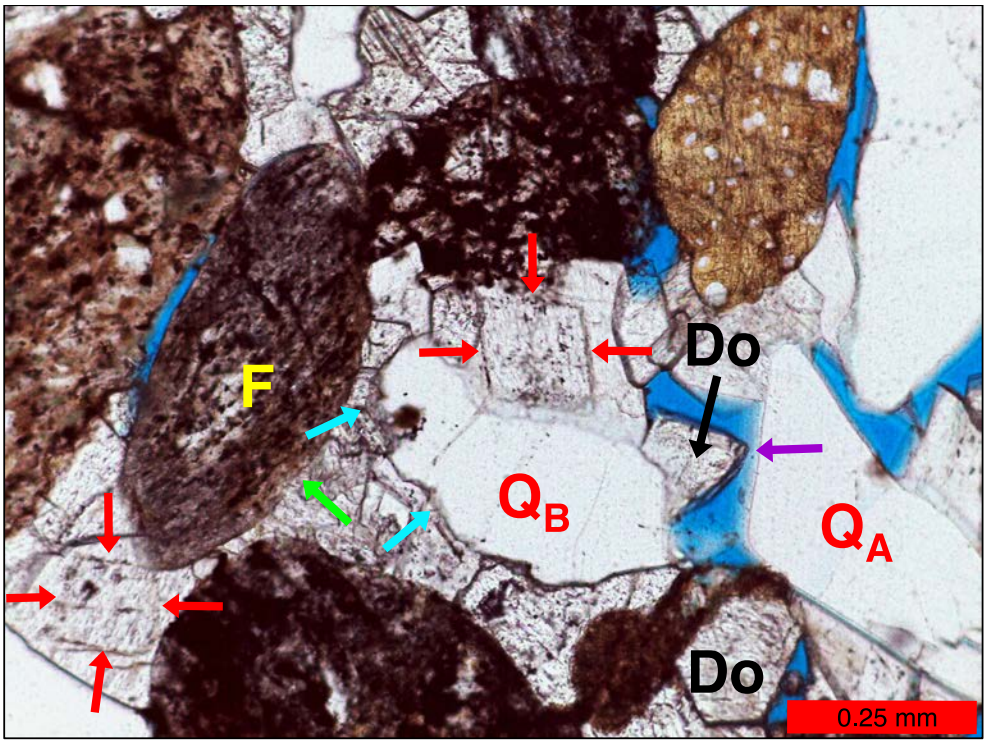


Fig. 21. Dolomite formed in pore space created by quartz (Q_A) dissolution (purple arrow). Dolomite (Do) cement replaced feldspar (F) and quartz (Q_B). The blue and green arrows point to the original grain boundaries of quartz (Q_B) and feldspar. Dolomite exhibiting clay coatings (red arrows) suggest at least two episodes of dolomite precipitation. Well: Campen 1, depth: 11,370 ft.

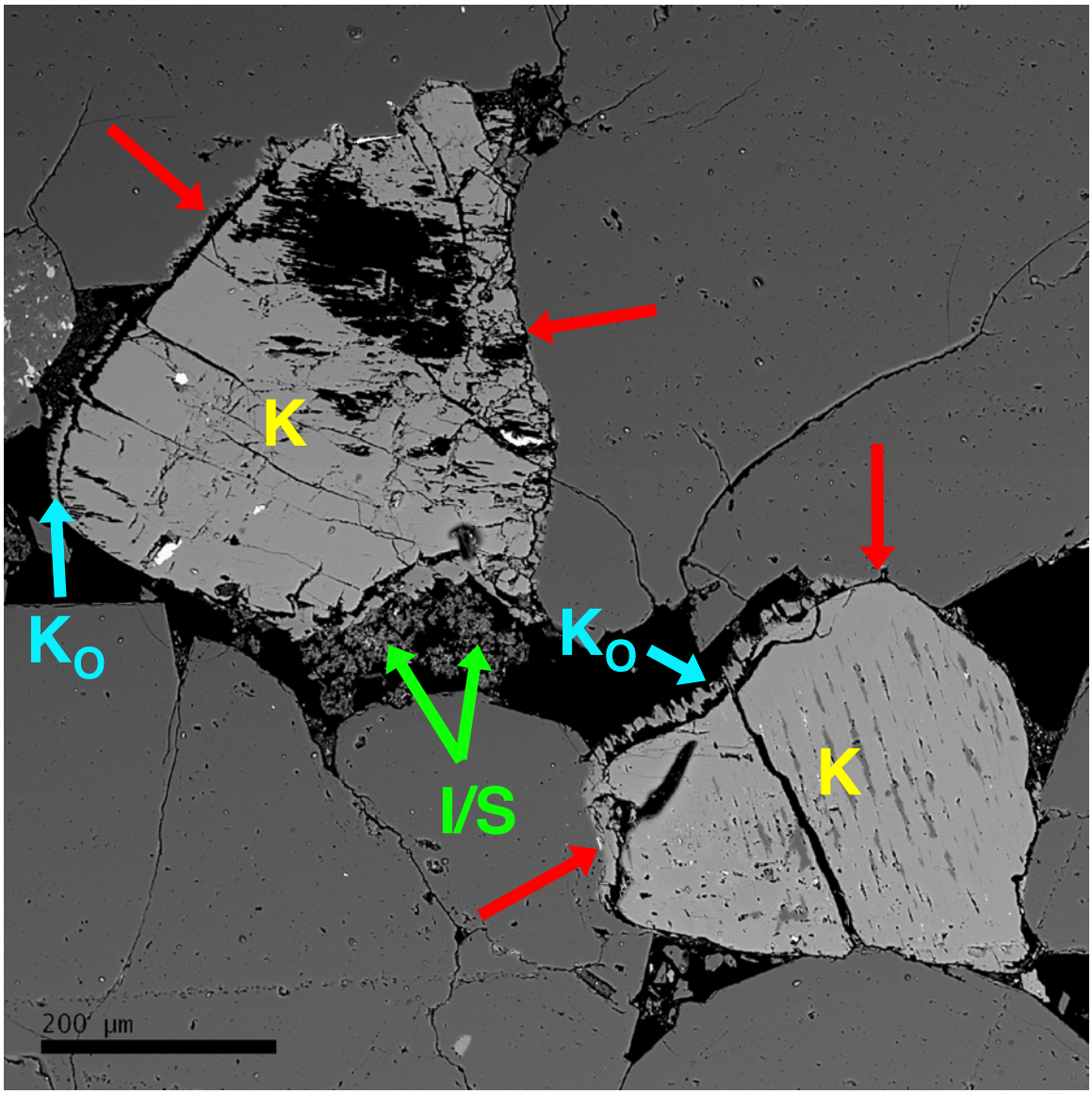


Fig. 22. SEM-BSE image of partially dissolved K-feldspar overgrowths (K_O) on detrital K-feldspar (K) grains. Mixed layer illite/smectite (I/S) formed on the edge of K-feldspar with tightly-packed framework grains (red arrows) suggests the clays formed during late diagenesis. Well: ELR, depth: 13,464 ft.

I/S and I/C often occur as pore linings or coatings and are commonly found near or sometimes intergrown with pore-filling kaolinite. These clays range from 0 to 18% in volume, with the average volume of 2%. In some cases I/S or I/C coatings occur between detrital quartz grains and overgrowths.

Chlorite is present in very small amounts. It commonly occurs as a product of biotite alteration, in which patches of chlorite are found along biotite cleavage planes.

Kaolinite is present in most samples as pore-filling cement, ranging from traces to 9% in volume (average 2%). It commonly occurs as booklets, up to 20 µm thick, partially to completely filling the pore space. Kaolinite often formed adjacent to dissolved feldspars or enclosed within remnant clay coatings from partially dissolved feldspars (Fig. 19). In the Lewis 3 well, kaolinite completely replaced precursor grains. In volcanic rock fragments, feldspars partially altered to kaolinite while the rest of the grains remain unaltered. SEM-EDS analyses indicate that kaolinite contains a minor amount of Na and Sr, probably within undissolved remnants of detrital feldspars.

Carbonate

Carbonate cements occur in most of the samples, ranging from small traces to 57%. These include dolomite (Figs. 21, 23) and calcite (Figs. 24, 25), with calcite being the most abundant. Calcite occurs as poikilotopic cement filling the pore spaces and replacing quartz (Fig. 24), plagioclase (Fig. 24), K-feldspars, and volcanics. In early stages of calcite replacement, large portions of the grains remained unaltered and the minerals can be identified. In later stages of calcite replacement, the grains are completely replaced and cannot be identified. As a result, the porosity is reduced to 0 in several samples and the framework grains appeared to be floating.

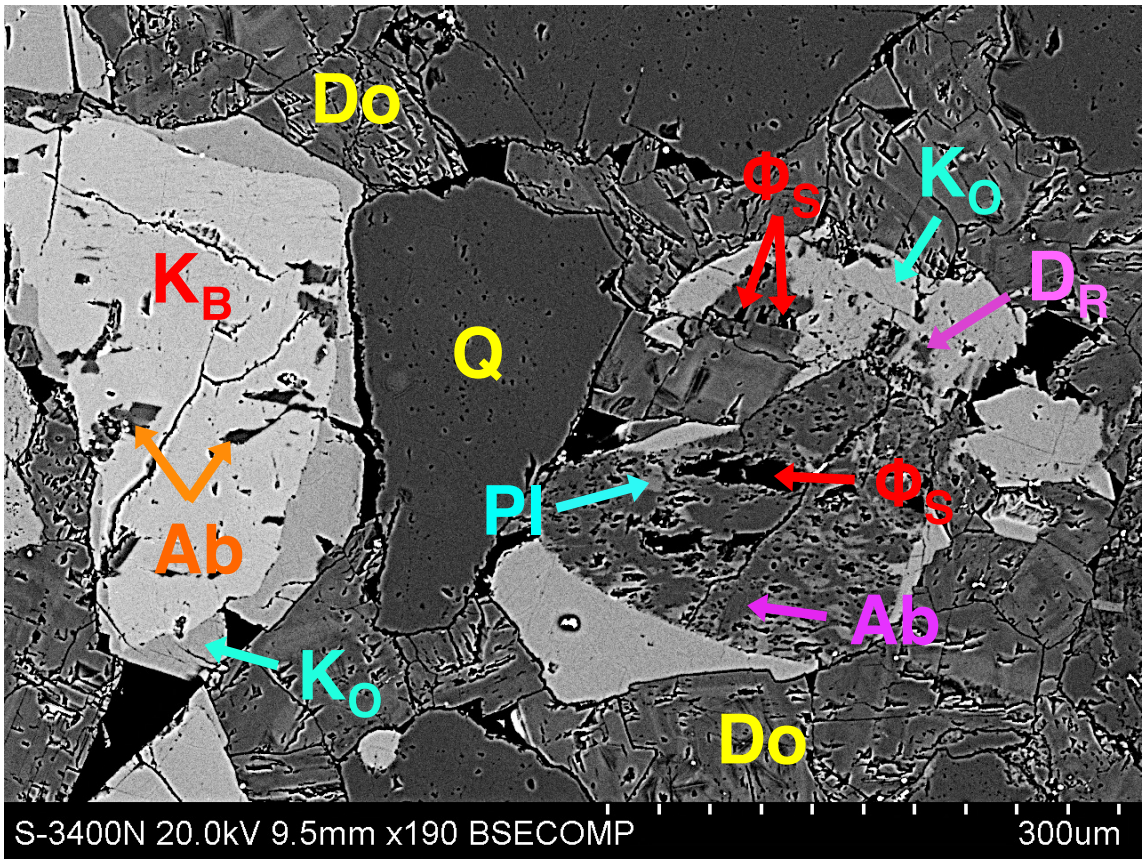


Fig. 23. SEM-BSE image of zoned dolomite (Do) cemented sandstone. Albitized (Ab) plagioclase (Pl) with remnants of original plagioclase and albitized Ba-rich K-feldspar (K_B) grains exhibit K-feldspar overgrowths (K_O), but quartz (Q) does not. Remnants of dolomite (D_R) within K-feldspar overgrowths (K_O) suggest that the overgrowths have replaced dolomite. Secondary porosity (Φ_S) within the plagioclase and dolomite indicate a later dissolution event that did not affect the authigenic K-feldspar. Also notice the cross-cutting relationship of K-feldspar overgrowth around euhedral dolomite, indicating K-feldspar formed after dolomite. Well: KCL 11-17, depth: 11,470 ft.

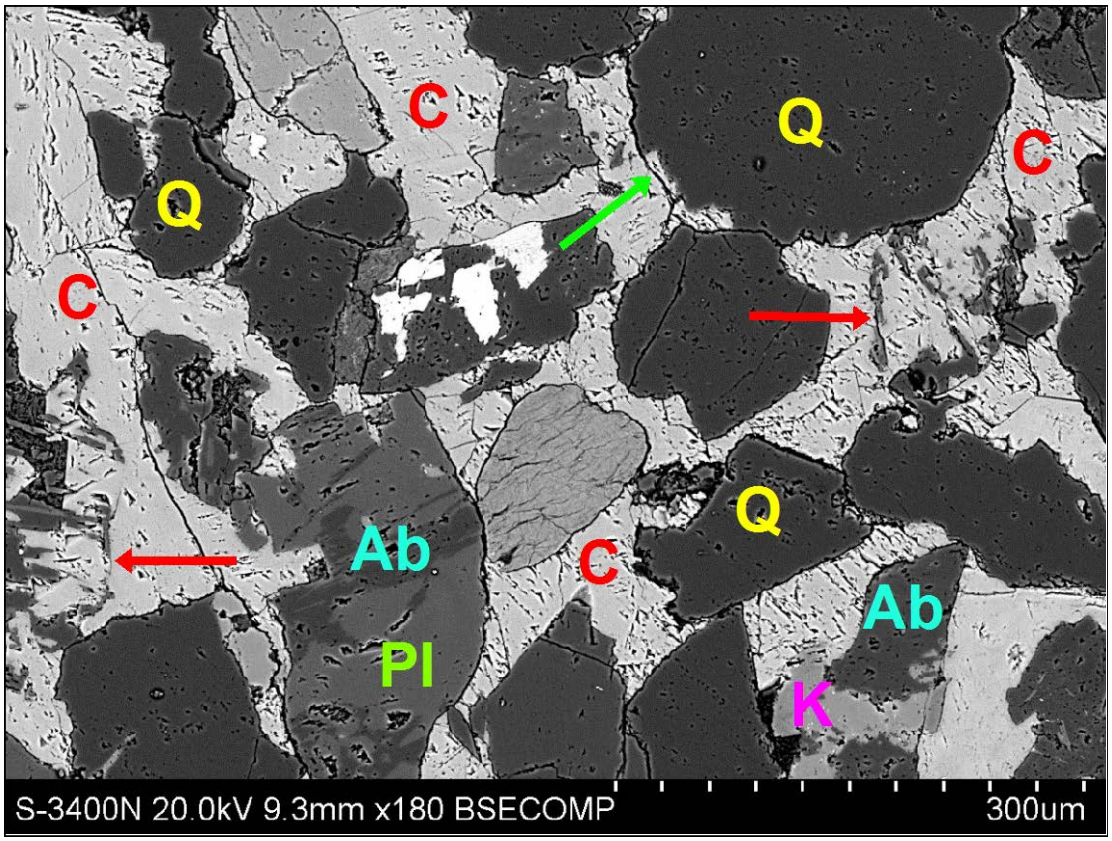


Fig. 24. SEM back-scattered electron (BSE) image of calcite (C), quartz (Q), and albitized (Ab) plagioclase (Pl) and K-feldspar (K). Calcite has replace quartz and plagioclase; the red and green arrows show the original plagioclase and quartz edges respectively. Well: ELR, depth: 13,464 ft.

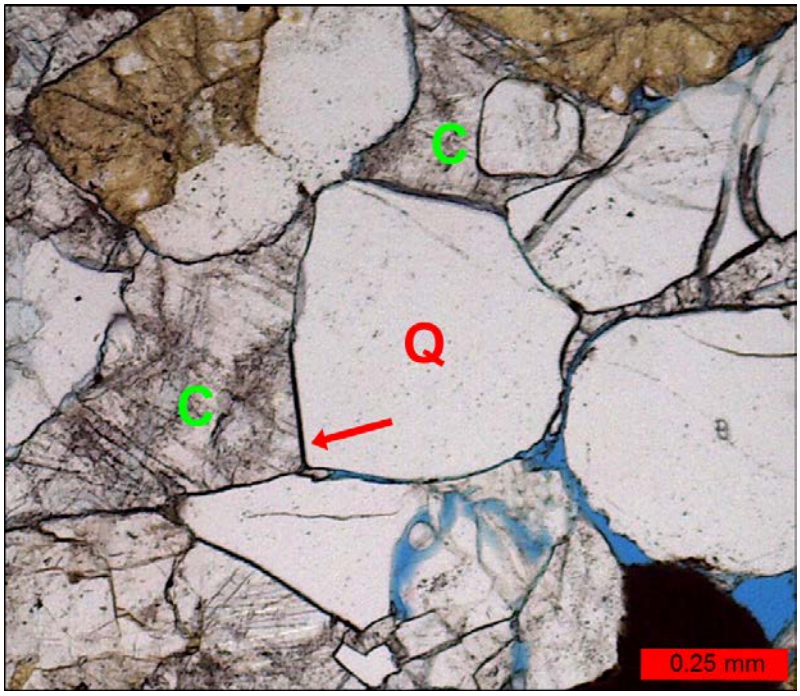


Fig. 25. Sharp contact between calcite (C) cement and quartz (Q) overgrowth (red arrow) suggests quartz overgrowth formed prior to calcite precipitation. Well: Campen 1, depth: 11,406 ft.

Albite

Authigenic albite replaced plagioclase (Figs. 6, 23, 24, 26) and K-feldspars (Figs. 8, 23). Albitization of detrital feldspars occurred along the fractures (Figs. 6, 8, 23, 24, 26) and/or original grain boundaries (Fig. 8). Some detrital feldspars in deeper samples (Fig. 8) are more albitized compared to detrital feldspars in shallower samples (Figs. 6, 23, 26). The average composition for albite in shallower samples is $Ab_{97.3}An_{2.2}Or_{0.5}$ and in deeper samples is $Ab_{98.5}An_{1.0}Or_{0.5}$. SEM-CL imaging revealed authigenic albite is non-luminescent (Figs. 6, 8) in these sandstones.

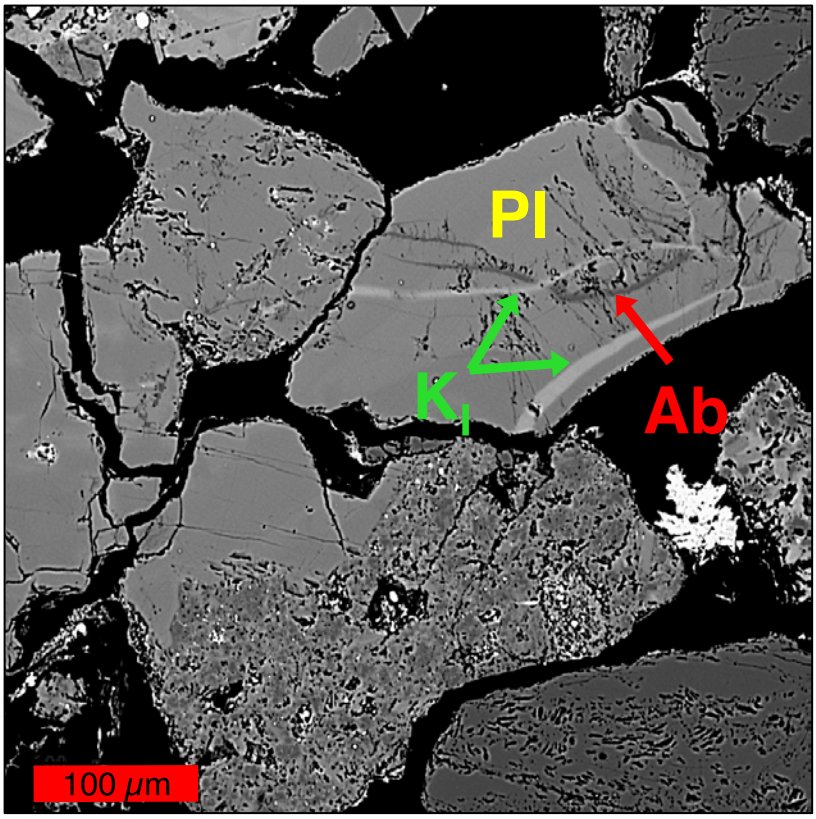


Fig. 26. SEM-BSE image of albitized (Ab) plagioclase (Pl) exhibiting K-feldspar infilled (K_I) fractures. The cross-cutting relationship between albite and K-feldspar infilled fractures indicates albitization occurred before authigenic K-feldspar. Well: KCL 11-17, depth: 11,324 ft.

K-feldspar

Authigenic K-feldspar occurred as overgrowths and within fractures in plagioclase (Figs. 6, 23, 26) and K-feldspar (Figs. 6, 22, 23). It is most abundant in shallower samples, especially in the KCL 11-17 well. The overgrowths usually exhibit an optical

discontinuity between the detrital grains, and they are non-luminescent (Fig. 6). In some cases K-feldspar overgrowths replaced dolomite cement (Fig. 23). Partial dissolution of the K-feldspar overgrowths occurred in deeper samples (Fig. 22). SEM-EDS analyses indicate the K-feldspar overgrowth is almost pure (Fig. 11) with average compositions of $Or_{98.9}Ab_{0.9}An_{0.2}$ in Vedder sandstones and $Or_{99.5}Ab_{0.4}An_{0.1}$ in Eocene sandstones.

Quartz

Authigenic quartz occurs as overgrowths (Figs. 7, 20, 25) and fills fractures (Figs. 7b, 15) within detrital quartz grains. Authigenic quartz is usually optically continuous with the detrital grains and often cannot be identified under the petrographic microscope. Some detrital quartz grains have clay coatings (Fig. 20), separating them from the overgrowths. In other cases, euhedral crystal faces (Figs. 7a, 25) indicate the presence of overgrowths. Fluid inclusion trains within detrital quartz grains suggest secondary-quartz-healed fractures (Fig. 20). Petrographic and SEM-BSE (Fig. 7a) images only show open fractures within detrital quartz grains, but SEM-CL images reveal non-luminescent secondary quartz that has healed fractures in detrital quartz grains (Fig. 7b). Continuing compaction resulted in subsequent formation of open fractures (Fig. 15).

Pseudomatrix

Pseudomatrix occurs scattered throughout the rock, ranging from 0 to 2% of the rock volume. It is most common in samples with small amounts of volcanic rock fragments. Pseudomatrix formed from squeezing of micas (Fig. 14) and rock fragments into the adjacent pore throats. Some partially dissolved feldspars formed pseudomatrix as well.

Rutile

Diagenetic rutile crystals occur in very small amounts within the Vedder sands. The crystals occur in association with pyrite crystals and clays. These subhedral to euhedral crystals are up to 20 µm long and 10 µm wide.

Barite

Barite cement was observed in very small amounts in three samples. It occurs as poikilotopic cement within the pore space and possibly replacing feldspars. The framework grains were tightly-packed before barite precipitation.

Anhydrite

Small amounts of anhydrite have been identified using SEM-EDS. It occurs as coatings on carbonate cements and between biotite cleavage planes. The actual amount of anhydrite is unknown as some probably dissolved during thin section manufacture.

Hydrocarbons

Although most hydrocarbons were removed during thin section manufacture, patches of hydrocarbons occur within pore spaces in most samples (Fig. 18). Volatile loss from these old cores most likely changed the nature of these hydrocarbons, so no attempt was made to further characterize them.

Porosity

Porosity within these sandstones varies from traces to 20% (Fig. 27, Table 1). While porosity fluctuates between samples collected from similar depth intervals, there is a general trend of porosity decreasing with depth. Intragranular porosity averages 0.5% and intergranular porosity averages 7% of the rock volume. Intragranular porosity is most likely of secondary origin while intergranular porosity can be of primary or secondary origin. Following the methodologies of Schmidt and McDonald (1979) and Shanmungam

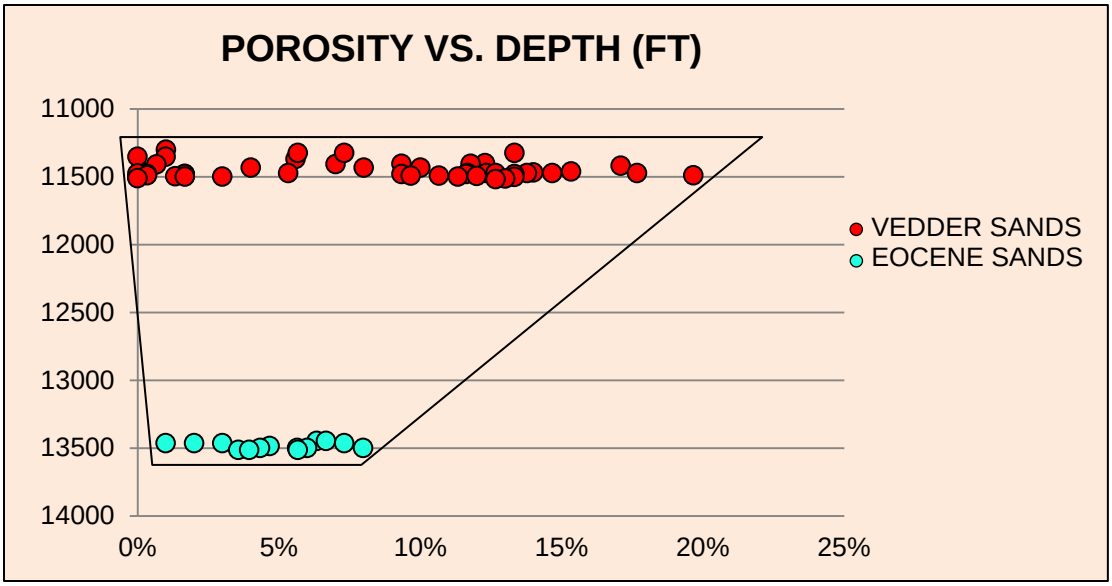


Fig. 27. Porosity decreases with increasing depth, N=63.

(1985), primary porosity in these rocks is estimated to range between 0 and 50% of the intergranular porosity. Porosity within graywackes is significantly less than within arenites due to the presence of matrix. Cementation by carbonates, as well as K-feldspar, and quartz, has significantly reduced porosity in some samples. The formation of pseudomatrix resulted in a minor porosity reduction.

Secondary porosity commonly resulted from dissolution of detrital feldspars (Figs. 15, 19), particularly plagioclase (Fig. 23). However, carbonate and K-feldspar cements, as well as detrital quartz, micas, and volcanics were also affected by dissolution. Figure 28 is a ternary diagram adjusted for grain dissolution (Harris, 1989) indicating shifts toward more quartz-rich compositions in the arenites but little change in the graywackes.

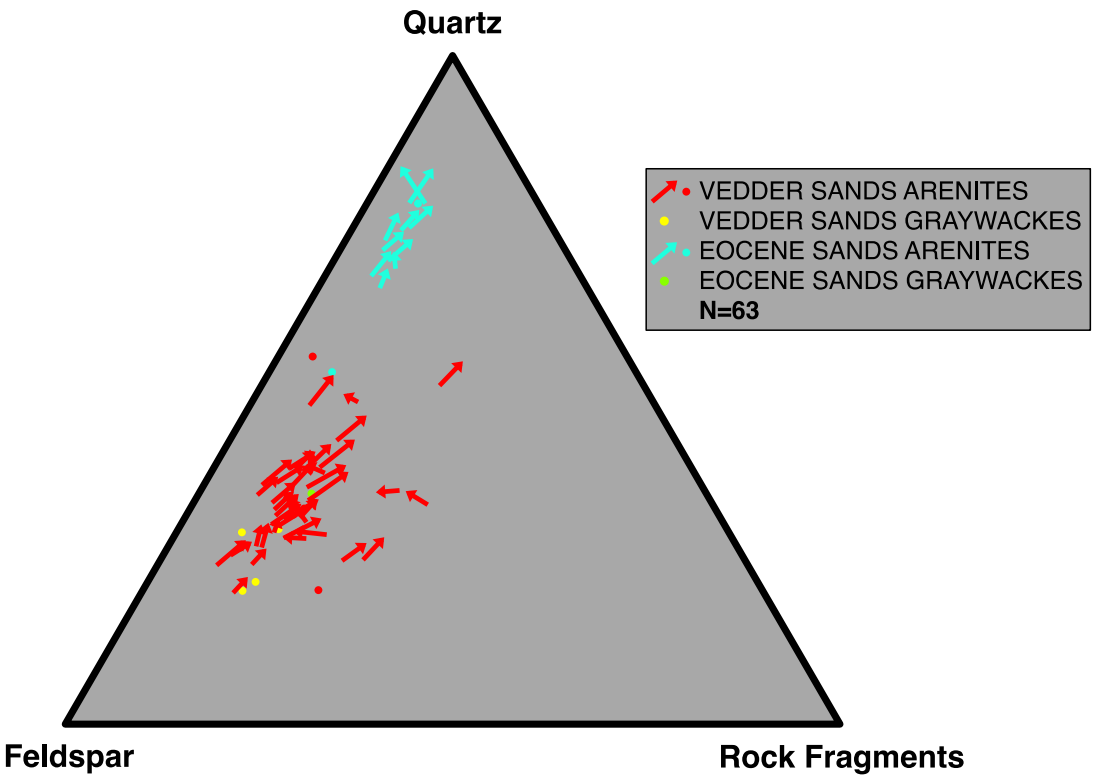


Fig. 28. QFRf ternary diagram for Vedder and Eocene sands. The compositions are adjusted for grain dissolution. The arrows point to the present composition, they originate from the reconstructed compositions (Harris 1989). This suggests that on-going dissolution results in more quartz-rich compositions. The Dots indicate no change in composition.

Mass Balance

The potential for mass transfer of aluminum into or out of the sands was investigated. The amounts of kaolinite cement present in the samples were compared to the amounts of kaolinite cement that would have been produced if all aluminum released during documented feldspar dissolution was incorporated into kaolinite. The percent imbalance of kaolinite suggests export or import of aluminum during diagenesis.

The amounts of kaolinite cement precipitated from dissolved plagioclase and K-feldspar assumes that there is 0% microporosity in the kaolinite. The microporosity of kaolinite in these sandstones was examined by using the SEM-BSE images from 650 to 1,300X magnifications. The results indicate kaolinite has an average of 40% microporosity. The amount of kaolinite cement, adjusted for 40% microporosity, that

could precipitate from one volume of dissolved plagioclase is 1.08 and one volume of dissolved K-feldspar is 0.76. The average volume of authigenic kaolinite is 0.92 of the volume of dissolved feldspars.

The percent imbalance of kaolinite is shown in Table 3. The results suggest aluminum export in 54% of the samples, aluminum import in 30%, and neither export or import of aluminum in 16%, at least on the scale of a thin section. These calculations are conservative in that completely dissolved (and thus unidentified) grains were not included, nor was any adjustment made for secondary porosity that may have been destroyed by subsequent compaction.

DISCUSSION

Various diagenetic processes have been identified in the Vedder and Eocene sands including compaction, deformation, dissolution, cementation, alteration, and recrystallization of minerals. These processes are controlled by the pore-water chemistry, depositional environment, temperature, and pressure (Hayes and Boles, 1992). The paragenetic sequence (Fig. 29) is established based on the textural relationships of the diagenetic minerals. These events started at the time of deposition and some continue to the present day.

The syndepositional formation of glauconite suggest these sandstones were deposited in submarine conditions between 328 to 984 ft (Jimenez-Millan et al., 1998), although Stonecipher (1999) concluded glauconite can be reworked and deposited in any depositional sequence. Glauconite grains can be altered from clays (Stonecipher, 1999), micas (Tapper and Fanning, 1968), fossil-rich sediments, and fecal pellets (Harder, 1980) in very early diagenesis. Glauconization of chert and feldspars ranging from partial to

complete suggests ongoing glauconization at deeper depths during early diagenesis.

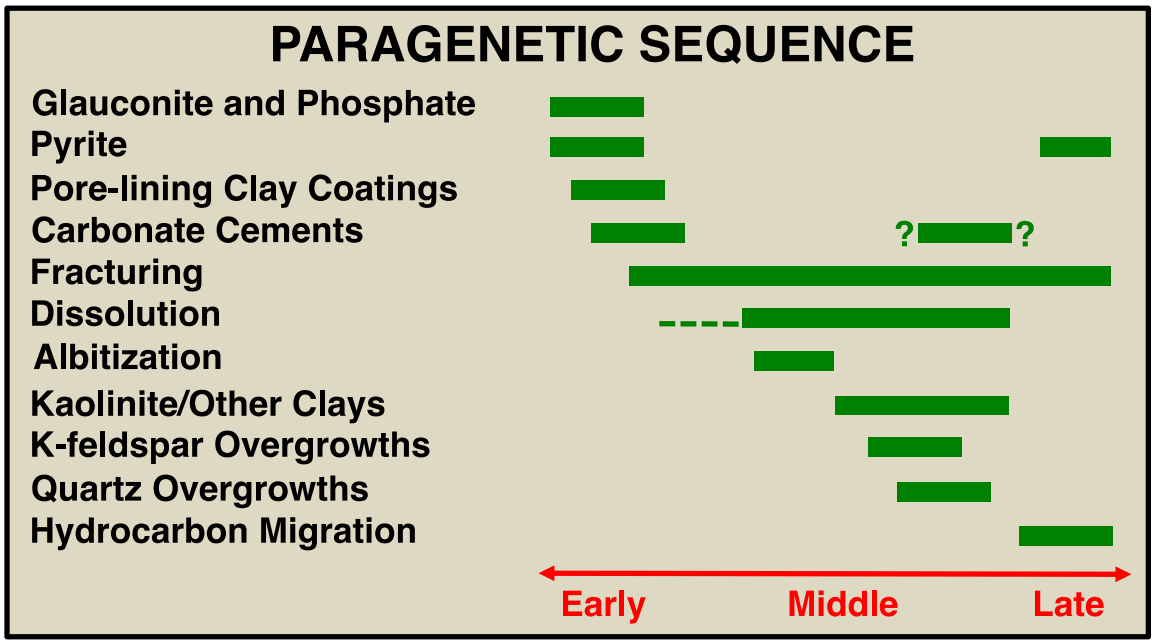


Fig. 29. Paragenetic sequence for the Vedder and Eocene sands.

Phosphate replaced quartz, feldspars, and glauconite (Fig. 17). The presence of phosphate nucleating on glauconite indicates phosphate formed after glauconite. Phosphate occurred in three zones (Fig. 17) suggests at least three episodes of phosphatization.

Some pyrite formed between cleavage planes and expanded the fabric of biotite. It also formed between feldspar and phosphate coatings. These suggest pyrite precipitation during early diagenesis.

Authigenic clays are present in almost all of the samples. They include chlorite, kaolinite (Fig. 19), and mixed-layer I/S (Fig. 22) and I/C. The precipitation of clays as pore-linings and pore-fillings reduced both the porosity and permeability. Authigenic clays were derived from many different sources and are discussed below.

Mixed-layer I/S and I/C often occur as coatings on detrital grains and cement crystals, and sometimes separate the detrital grains from overgrowths. This suggests that

the clay coatings formed during early diagenesis. I/S and I/C are more abundant in shallower samples than deeper samples. They may have formed from alteration of micas and volcanic grains. In deeper samples, these clays occur on the edges of partially dissolved quartz and feldspar (Fig. 22) grains, suggesting that the clays formed during later diagenesis.

Biotite has commonly been altered to chlorite and clay. Alteration typically occurred along the cleavage planes, which suggests the event occurred during late diagenesis after significant compaction.

Authigenic kaolinite occurs as booklets filling the pore space. It precipitated adjacent to partially and completely dissolved grains. In some instances kaolinite precipitated adjacent to remnants of feldspar within a remnant clay coating (Fig. 19) suggesting that Al^{3+} for kaolinite precipitation was derived from dissolved feldspar. Kaolinite cement formed after significant compaction and dissolution of the framework grains suggesting that it formed during late diagenesis.

Some calcite cement formed during early diagenesis. It precipitated into pore spaces and replaced framework grains. The framework grains sometimes can be identified by unreplaced remnants of the grains within the cement. In other instances, calcite cement filled the pore space and completely replaced the framework grains, and original pore spaces and framework grains can no longer be distinguished.

Dolomite crystals formed in pore spaces and between biotite cleavage planes. They are commonly finer than the framework grains. Some crystals exhibit clay coatings and are usually well formed (Fig. 21). This suggests that at least two episodes of dolomite precipitation have occurred. Dolomite also formed as poikilotopic cement that filled the

pore spaces and partially replaced quartz (Fig. 21), feldspars (Fig. 21), and calcite cement.

Compaction of the framework grains started after deposition. It rearranged the grains creating point and tangential contacts during early diagenesis. As compaction increased, long, concavo-convex, and sutured grain-to-grain contacts formed by pressure-induced dissolution. Micas (Fig. 14) and volcanic-rock fragments were often deformed thus creating pseudomatrix that filled the adjacent pore space. As a result, porosity and permeability were reduced.

The detrital grains within these sandstones contain an average of at least three contacts with adjacent grains (Table 2). Although these sandstones did not show a significant change in CI and TPI with depth, other sandstones in the western San Joaquin basin have shown an increase of CI and TPI with increasing depth (Taylor, 2007; Horton et al., 2009).

Compaction created fractures within individual grains and cement crystals. Fractures occurred in feldspars (Figs. 6, 8), micas, quartz (Figs. 7, 15), and dolomite-cement crystals (Fig. 16). This allowed the exchange of ions between the grains' interiors and pore fluids, resulting in formation of dolomite crystals between biotite cleavage planes as well as albitization (Figs. 6, 8, 23, 24, 26) and dissolution (Figs. 15, 19, 23) of feldspars. Other minerals that also underwent dissolution include micas, volcanics, quartz (Fig. 21), and carbonate cements (Fig. 23). Fracturing created various sizes of angular fragments. With increasing burial, those fragments rotated relative to each other changing the textures of the sandstones.

Albitization of detrital feldspars is common in these sandstones. The composition

of albite is almost pure (Fig. 11). Most of the feldspars in deeper samples (Fig. 8) are more albitized compared to feldspars in shallower samples (Figs. 6, 23, 26). Albitization replaced detrital plagioclase (Figs. 6, 23, 24, 26) and K-feldspar (Figs. 8, 23, 24), but not detrital albite (Fig. 8b). Albitization occurs in a wide (Gold, 1987; Boles and Ramseyer, 1988) or narrow (Boles, 1982; Morad et al., 1990) range of temperature in middle of diagenesis. Albitization may occur between 75°C (Morad et al., 1990) to 124°C, between 5,906 to 11,154 ft in depth at the Greeley oil field.

Authigenic quartz (Figs. 7, 15, 20, 25) and K-feldspar (Figs. 6, 22, 23, 26) are present in more than half of the samples. The absence of quartz and K-feldspar overgrowths in some calcite-cemented samples indicate calcite formed during early diagenesis before the quartz and K-feldspar overgrowths. In addition, the presence of euhedral quartz overgrowths in sharp contact with some calcite cement (Fig. 25) suggests authigenic quartz formed prior to late calcite precipitation during late diagenesis.

The cross-cutting relationship between the albite and K-feldspar-infilled fractures indicates that albitization occurred before precipitation of authigenic K-feldspar (Fig. 26). K-feldspar overgrowths replaced dolomite cement and penetrated into the albitized plagioclase grain (Fig. 23) indicating the overgrowth formed after precipitation of dolomite and dissolution of plagioclase.

Dissolution is most common in feldspars (Figs. 15, 19, 23). Preferential dissolution of feldspars shifted the composition of sands towards the quartz corner on the ternary diagrams as shown in Figures 10 and 28. Plagioclase (Fig. 9b) was affected by dissolution more than K-feldspar (Fig. 9c). Plagioclase in greywackes is more calcic than in the arenites, though the data are limited. Calcic-plagioclase was more susceptible to

dissolution as indicated by a shift towards more sodic compositions in deeper samples (Fig. 11) (Boles, 1984; Milliken et al., 1989). The significant loss of Ca-rich plagioclase between 11,300 ft and 13,512 ft suggests a pronounced period of dissolution at these depths.

The normal range of Sierran plagioclase is An_{15}-An_{50} (Boles and Ramseyer, 1988). Calcite-cemented Eocene (Famoso) sands at the nearby Wasco oil field contain plagioclase in the An_{30}-An_{50} range whereas uncemented sands do not (Horton et al., 2014). The loss of the most calcic-plagioclase (An_{30}-An_{50}) at Greeley was accompanied by decrease in the Sr contents of plagioclase (Fig. 12) suggesting Sr substitution for Ca (Schultz et al., 1989) in the plagioclase.

Hydrocarbon migration occurred during late diagenesis after significant dissolution of detrital and authigenic minerals. Continued hydrocarbon maturation within the reservoir resulted in formation of pyrite (Fig. 18) as Fe^{2+} in the pore waters reacted with sulfur liberated from the hydrocarbons.

Porosity was reduced in these sandstones by compaction, cementation (Figs. 6, 7, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26), precipitation of clays (Figs. 19, 20, 21, 22), and formation of pseudomatrix (Fig. 14); and it was increased by the dissolution of the framework grains (Figs. 15, 19, 21, 23) and cements (Fig. 23). As dissolution progressed, continued compaction further reduced primary porosity as well as secondary porosity, thus causing secondary intergranular porosity to resemble primary porosity (Schmidt and McDonald, 1979; Horton et al., 2009).

Mass balance calculations suggest, on the scale of a thin section, an overall export of aluminum (Table 3). These calculations do not take into account albitization of

plagioclase, dissolution of other alumino-silicates, secondary porosity for which the precursor mineral could not be determined, or any secondary porosity that may have been destroyed by continued compaction, all of which would have released additional aluminum into the pore fluids. Thus an overall export of aluminum from these sands is likely.

Laumontite cement has been widely documented in the San Joaquin basin (e.g. Bloch et al., 1993; Noh and Boles, 1993; Taylor, 2007) but no laumontite was observed during the present study. Laumontite can precipitate as result of dissolution or albitization of plagioclase (Boles and Coombs, 1977; Boles, 1982; Helmold and van de Kamp, 1984). Laumonite precipitation requires significant amounts of Si^{+4} and Na^{+} if albitization is involved (Helmold and van de Kamp, 1984). Dissolution of quartz provides some Si^{+4} ions and connate water could supply a small portion of Na^{+} ions (Boles and Coombs, 1977), but a large portion of Si^{+4} (Boles and Frank, 1979) ions and Na^{+} (Helmold and van de Kamp, 1984) ions may be derived from smectite converting to illite in the shale layers above and below these sandstones.

The formation of laumontite can occur at different temperatures and depths (McCulloh et al., 1979). The reported temperature of the Vedder sands at the Greeley field is 255ºF, but the temperature of the Eocene sands is unknown (California DOGGR, 1998). However, at the Wasco oil field, ~16 miles northwest of the Greeley field, the measured temperatures reported for the Standard Oil Mushrush 5 well (log on file with California DOGGR) were reported as 275ºF for the Vedder Formation and 293ºF for the Eocene sands. As the Eocene sands at Greeley are buried to approximately the same depth as the Vedder Formation at Wasco, an estimated temperature ~275ºF for the

Eocene sands at the Greeley field is reasonable. Laumontite cement is common in the Eocene sandstones and present in small amounts in the Vedder Sandstones at the Wasco oil field (R. Horton, personal communication), but it is absent at the Greeley field. Albitization (Figs. 6, 23, 24, 26) and dissolution (Fig. 23) of plagioclase is widespread in the Vedder and Eocene sands at the Greeley oil field, which could provide Ca^{+2} ions for laumontite precipitation. The lack of laumontite at the Greeley oil field suggests that the temperature of the Vedder sands at the Greeley field is too low for laumontite to form and the temperature of the Eocene sands is at the boundary in which laumontite could precipitate. It also suggests that these sands are currently at or very near their deepest burial depths.

This has significant implications for the structural history of this portion of the San Joaquin basin. The Greely oil field sits near the crest of the Bakersfield arch, and the Eocene sands occur at approximately 1,640 ft shallower depth than the Eocene sands at Wasco. If the Eocene sands at Greeley are currently at their maximum burial depth as indicated by the lack of laumontite, then the Bakersfield arch must have formed before deposition of the uppermost 1,640 ft of sediments in the overlying strata. At Wasco the top of the Pliocene Etchegoin Formation is approximately 4,347 ft thick with its top at a depth of approximately 4,396 ft (California DOGGR, 1998). At Greeley the Etchegoin Formation is only 3,904 ft thick with its top at a depth of 3,445 ft (California DOGGR, 1998). As the difference in elevation between the two oil fields is less than 66 ft, the differences in the burial depths and the thicknesses of what are generally interpreted as shallow marine sandstones (Scheirer and Magoon, 2007) are best explained by growth of

the Bakersfield arch during deposition of the Etchegoin Formation in Early to middle Pliocene time and continuing into the Late Pliocene or early Pleistocene.

SUMMARY

The Vedder and Eocene sands at the Greeley oil field are arkosic to subarkosic arenites and graywackes (Fig. 3). The sandstones contain abundant quartz, plagioclase and K-feldspars, and minor rock fragments. Common accessory minerals include biotite, muscovite, chlorite, epidote, glauconite, hornblende, titanite, pyrite, and zircon. The deeper Eocene samples are more quartz-rich than shallower Vedder (Oligocene) samples (Fig. 3) due to preferential dissolution of feldspars (Figs. 10, 28). Dissolution affected plagioclase (Fig. 9b) more than K-feldspar (Figs. 9c) and preferentially removed those with highest calcium contents (Fig. 11) in deeper samples, resulting in higher K-feldspar/plagioclase ratios and more Na-rich plagioclase.

Porosity within the Vedder sands ranges from 0 to 20% (Fig. 26); it is controlled by compaction, cementation (Figs. 6, 7, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26), and dissolution of framework grains (Figs. 15, 19, 21, 23) and cements (Fig. 23). Mechanical compaction is evidenced by long, concavo-convex and sutured grain-to-grain contacts, fractured and broken framework grains, fractures within cements (Fig. 16), and deformed labile grains. Compaction reduced primary porosity through readjustment of grains, fracturing and subsequent rotation of grain fragments, deformation of micas (Fig. 14) and labile grains, and precipitation of cements including quartz (Figs. 7, 15, 20, 25), K-feldspar (Figs. 6, 22, 23, 26), phosphate (Fig. 17), clays (Figs. 19, 20, 21, 22), calcite (Figs. 24, 25), dolomite (Figs. 21, 23), barite, anhydrite, and pyrite (Fig. 18). Other diagenetic processes included albitization of feldspars (Figs. 6, 8, 23, 24, 26),

glauconization of feldspars, quartz, and chert, alteration of biotite, phosphate replacing feldspars, glauconite (Fig. 17), and quartz, carbonate replacing framework silicates (Figs. 21, 24), and calcite replaced by dolomite. Dissolution of feldspars (Figs. 15, 19, 23), quartz (Fig. 21), volcanics, and micas created secondary porosity that may have significantly altered the QFRf (Fig. 28) and QFL ratios. Continued compaction further reduced porosity while continued dissolution of the framework grains maintained an open pore network thus facilitating the migration and accumulation of hydrocarbons.

ACKNOWLEDGEMENTS

This research is funded by: CSUB National Science Foundation Center for Research Excellence in Science and Technology (award #1137774), CSUB Weddle Scholarship, CSUB Graduate Student-Faculty Collaborative Initiative, CSUB Student Research Scholarship, Pacific Section – American Association of Petroleum Geologists, and San Joaquin Geological Society.

I wish to express my gratitude to the thesis committee, Dr. Robert Horton Jr., Dr. Dirk Baron, and Brian Taylor. Many thanks to Dr. Rober Horton Jr. for his guidance and support over the years.

Special thanks to Charles James and Eric Hierling at the California Well Sample Repository, Elizabeth Powers, Alyssa Kaess, and Stephanie Caffee.

Finally, I would like to thank my family and friends for their unconditional love and support throughout my graduate program.

REFERENCES

Bandy, O. L., and Arnal, R. E., 1969, Middle Tertiary basin development, San Joaquin Valley, California: Geological Society America Bulletin, v. 80, p. 783-820.

Bartow, J. A., 1991, The Cenozoic evolution of the San Joaquin Valley, California: U.S. Geological Survey Professional Paper 1501, 40 p.

Bartow, J. A., and McDougall, K., 1984, Tertiary stratigraphy of the southeastern San Joaquin Valley, California: U.S. Geol. Survey Bull. 1529-J, 41 p.

Bent, J. V., 1985, Petrographic reconnaissance of the upper Oligocene – middle Miocene sandstones of the San Joaquin basin, California (M.S. thesis): Stanford University, 144 p.

Bent, J. V., 1988, Paleotectonics and provenance of Tertiary sandstones of the San Joaquin Basin, California: in Graham, S.A., ed., Studies of the geology of the San Joaquin Basin: Pacific Section S.E.P.M., v. 60, p. 109-127.

Bloch, R. B., and Olson, H. C., 1990, Stratigraphy and structural history of the Lower and Middle Miocene Section, eastside San Joaquin Valley, *in* Kuespert, J. G., and Reid, S. A., eds., 1990, Structure, stratigraphy and hydrocarbon occurrences of the San Joaquin Basin, California, p. 287-291.

Bloch, S., Kelley, S. A., Corrigan, J. D, and Kelton, M. J., 1993, Predictable distribution pattern of laumontite in Paleogene sandstones of the Tejon Block, southern San Joaquin Basin (California)(abs.): AAPG and SEPM Annual Meeting Abstracts, v. 1993, p. 77.

Boles, J. R., 1982, Active albitization of Plagioclase, Gulf Coast Tertiary: American Journal of Science, v. 282, p. 165-180.

Boles, J.R., 1984, Secondary porosity reactions in the Stevens sandstone, San Joaquin Valley, California *in* McDonald, D.A. and Surdam, R.C., eds., Clastic Diagenesis: AAPG Memoir 37, p. 217-224.

Boles, J. R., and Coombs, D. S., 1977, Zeolite facies alteration of sandstones in the Southland Syncline, New Zealand: American Journal of Science, v. 277, p. 982-1012.

Boles, J. R., and Franks, S. G., 1979, Clay diagenesis in Wilcox sandstones of southwest Texas: implications of smectite diagenesis on sandstone cementation: Journal of Sedimentary Petrology, v. 49, p. 55-70.

Boles, J. R., and Ramseyer, L., 1988, Albitization of plagioclase and vitrinite reflectance as paleothermal indicators, San Joaquin basin *in* Graham, S.A., ed., Studies of the

Geology of the San Joaquin basin: Pacific Section SEPM, v. 60, p. 129-139.

California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (DOGGR), 1998, Oil and Gas Fields in California: Sacramento, CD-1, v. I, p. 192-193.

California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (DOGGR), 2014, Mushrush 5 well (UWI 02909487), http://owr.conservation.ca.gov/WellRecord/029/02909487/02909487 _1949-06-18_1Electric%20Log.pdf (accessed May 12, 2014).

Clarke, S. H., Jr., 1973, The Eocene Point of Rocks Sandstone: Provenance, mode of deposition and implications for the history of offset along the San Andreas fault in central California (Ph. D., Thesis): Berkley, California, University of California, 302 p.

Dickinson, W. R., 1970, Interpreting detrital modes of greywacke and arkose: Journal of Sedimentary Petrology, v. 40, p. 695-707.

Dott, R. H., Jr., 1964, Wacke, graywacke and matrix - what approach to immature sandstone classification?: Journal of Sedimentary Petrology, v. 34, p. 625-632.

Ehrenberg, S. N., 1990, Relationship between diagenesis and reservoir quality in sandstones of the Garn Formation, Haltenbanken, Mid-Norwegian continental shelf: AAPG Bulletin, v. 74, p. 1538-1558.

Galloway, W. E., 1979, Diagenetic control of reservoir quality in arc-derived sandstones: implications for petroleum exploration, *in* Scholle, P.A., and Schluger, P.R., eds., Aspects of Diagenesis: SEPM Spec. Pub. 26, p. 251-262.

Gautier, D. L., and Scheirer, A. H., 2007, Miocene total petroleum system – Lower Bakersfield Arch Assessment Unit of the San Joaquin Basin province: U.S. Geological Survey Professional Paper 1713, ch. 14, 17 p. [http://pubs.usgs.gov/pp/pp1713/14/pp1713_ch14.pdf].

Gold, P. B., 1987, Textures and geochemistry of authigenic albite from Miocene sandstones, Louisiana Gulf Coast: Journal of Sedimentary Petrology, v. 57, p. 353-362.

Grove, K., and Niemi, T. M., 2005, Late Quaternary deformation and slip rates in the northern San Andreas fault zone at Olema Valley, Marin County, California: Tectonophysics, v. 401, p. 231-250.

Harder, H., 1980, Syntheses of glauconite at surface temperatures: Clays and Clay Minerals, v. 28, no. 3, p. 217-222.

Harris, N. B., 1989, Diagenetic quartzarenite and destruction of secondary porosity: an example from the Middle Jurassic Brent sandstone of northwest Europe: Geology, v. 17, p. 361- 364.

Hayes, J. B., 1979, Sandstone diagenesis: the hole truth, *in* P.A. Scholle and P.R. Schluger, eds., Aspects of Diagenesis: SEPM Spec. Pub. 26, p. 127-139.

Hayes, M. J., and Boles, J. R., 1992, Volumetric relations between dissolved plagioclase and kaolinite in sandstones: implications for aluminum mass transfer in the San Joaquin basin, California *in* D.W. Houseknecht and E.D. Pittman, eds., Origin, diagenesis, and petrophysics of clay minerals in sandstones: SEPM Special Publication 47, p. 111-123.

Helmold, K. P. and van de Kamp, P. C., 1984, Diagenetic mineralogy and controls on albitization and laumontite formation in Paleogene arkoses, Santa Ynez Mountain, California *in* McDonald, D. A., and Surdam, R. C., eds, Clastic diagenesis: AAPG Memoir 37, p. 239-276.

Horton, Jr. R.A., McCullough, P.T., & Hanson, D.M., 2009, Grain dissolution, compaction, and development of secondary intergranular porosity, western San Joaquin Basin, California. *In* Knauer, L.C. & Britton, A. (eds) Contributions to the geology of the San Joaquin basin, California: Pacific Section AAPG, Special Publication, MP48, p. 141-165.

Horton, R. A., Jr., Olabisi, O. E., Kaess, A. B., Caffee, S. E., 2014, Diagenesis and porosity development of the Wasco oil field, California, USA: Geological Society (London) Conference: Reservoir Quality of Clastic and Carbonate Rocks: Analysis, Modelling and Prediction, London, U.K., p. 221-222.

Isaacson, K. A., and Blueford, J. R., 1984, Kreyenhagen Formation and related rocks – a history, *in* Blueford, J.R., ed., Kreyenhagen Formation and related rocks: Pacific Section SEPM, v. 37, p. 1-7.

Jimenez-Millan, J., Molina, J. M., Nieto, F., Nieto, L., and Ruiz-Ortiz, P. A., 1998, Glauconite and phosphate peloids in Mesozoic carbonate sediments (Eastern Subbetic Zone, Betic Cordilleras, SE Spain): Clay Minerals, v. 33, p. 547-559.

Lillis, P. G., and Magoon, L. B., 2007, Petroleum systems of the San Joaquin Basin Province, California-Geochemical Characteristics of Oil types, in Scheirer, A. H., ed., Petroleum Systems and Geologic Assessment of Oil and Gas in the San Joaquin Basin Province, California: U.S. Geological Survey Professional Paper 1713, ch. 9, 17 p. [pubs.usgs.gov/pp/pp1713/09/pp1713_ch09.pdf].

McCulloh, T. H., Cashman, S. M., and Stewart, R. J., 1979, Diagenetic baselines for interpretive reconstructions of maximum burial depths and paleotemperatures in clastic sedimentary rocks *in* Oltz, D. F., eds., A Symposium in Geochemistry:

Low Temperature Metamorphism of Kerogen and Clay Minerals: Soc. Econ. Paleont. Mineral, PSAAPG, p. 65-96.

Milliken, K. L., McBride, E. F., and Land, L. S., 1989, Numerical assessment of dissolution versus replacement in the subsurface destruction of detrital feldspars, Oligocene, south Texas: Journal of Sedimentary Petrology, v. 59, p. 740-757.

Morad, S., Bergan, M., Knarad, R., and Nystuen, J. P., 1990, Albitization of detrital plagioclase in Triassic reservoir sandstones from the Snorre Field, Norwegian North Sea: Journal of Sedimentary Petrology, v. 60, p. 411-425.

Niemi, T. M., and Hall, N. T., 1992, Late Holocene slip rate and recurrence of great earthquakes on the San Andreas fault in northern California: Geology, v. 20, p. 195-198.

Noh, J. H., and Boles, J. R., 1993, Origin of zeolite cements in the Miocene sandstones, North Tejon oil fields, California: Journal of Sedimentary Petrology, v. 63, p. 248-260.

Olson, H. C., Miller, G. E., and Bartow, J. A., 1986, Stratigraphy, paleoenvironment and depositional setting of Tertiary sediments, southeastern San Joaquin basin, 1986 Guidebook Pacific Section American Association of Petroleum Geologists meeting, Bakersfield, California, p.18-54.

Olson, H. C., 1988, Oligocene-middle Miocene depositional systems north of Bakersfield, California: Eastern basin equivalents of the Temblor Formation, *in* Graham, S. A., ed., 1988, Studies of the geology of the San Joaquin basin, Pacific Section, Society of Economic Paleontologists and Mineralogists, v. 60, p. 189-205.

Pettijohn, F. J., Potter, P. E., and Siever, R., 1987, Sand and Sandstone 2nd ed: New York, Springer-Verlag, 553 p.

Richardson, E. E., 1966, Structure contours on top of the Vedder sand, southeastern San Joaquin Valley, California: U.S. Geological Survey, Open-File Report, 15 p.

Scheirer, A. H., and Magoon, L. B., 2007, Neogene gas total petroleum system–Neogene nonassociated gas assessment unit of the San Joaquin basin province: U. S Geological Survey Professional Paper 1713, ch. 22, 14 p. [http://pubs.usgs.gov/pp/pp1713/14/pp1713_ch22.pdf].

Schmidt, V., and McDonald, D. A., 1979, Texture and recognition of secondary porosity in sandstones, *in* P.A. Scholle and P.R. Schluger, eds., Aspects of Diagenesis: SEPM Spec. Pub. 26, p. 209-225.

Schultz, J., Boles, J. R., and Tilton, G., 1989, Tracking calcium in the San Joaquin basin,

California: A strontium isotopic study of carbonate cements at North Coles Levee. Geochimica et Cosmochim. Acta, v. 53, p. 1991-1999.

Shanmugam, G., 1985, Significance of secondary porosity in interpreting sandstone composition: AAPG Bulletin, v. 69, p. 378-384.

Stonecipher, S. A., 1999, Genetic characteristics of glauconite and siderite: Implications for the origin of ambiguous isolated marine sand bodies, in Isolated shallow marine sand bodies: Sequence stratigraphic analysis and sedimentologic interpretation, SEPM Special Publication 64, 191-204.

Sullivan, J. C., and Weddle, J. R., 1960, Rio Bravo oil field, in Summary of operations, California oil fields: San Francisco, Calif., Annual Report of the State Oil and Gas Supervisor, v. 46, no. 1, p. 27-38.

Tapper, M., and Fanning, D. S., 1968, Glauconite pellets: similar x-ray patterns from individual pellets of lobate and vermiform morphology: Clays and Clay Minerals, v. 16, p. 275-283.

Taylor, B. L., 2007, Petrography and diagenesis of the Eocene Point of Rocks Sandstone, McKittrich oil field, Kern County, California (MS Thesis): Bakersfield, California, California State University, 273 p.

Wagoner, J., 2009, 3D Geologic Modeling of the Southern San Joaquin Basin for the Westcarb Kimberlina Demonstration Project – A status report. Lawrence Livermore National Laboratory, LLTNL-TR-410813, Livermore, CA.

Wilson, J. C., and McBride, E. F., 1988, Compaction and porosity evolution of Pliocene Sandstones, Ventura Basin, California: AAPG Bulletin, v. 72, p. 664-681.

APPENDIX I

Table 1. Petrographic data of the Vedder and Eocene sands.

Well	Depth (m)	Q	F	Rf	Li	AM	CC	MATRIX	CLC	OC	INTRA Φ	INTER Φ	OTHER
Campen 1	11370	30	23	9	2	0	30	2	0	0	0	6	0
	11400	37	29	10	5	0	10	0	1	0	0	12	0
	11406	35	38	10	3	1	9	0	1	0	0	7	0
KCL 11-17	11300	26	33	10	2	1	27	2	0	0	0	1	0
	11324	24	28	22	10	1	0	0	18	0	0	7	0
	11324	18	35	17	7	0	8	1	8	0	0	13	0
	11324	23	26	17	7	2	20	0	4	0	1	4	1
	11353	15	48	11	3	2	3	20	0	0	0	1	0
	11353	12	41	8	2	1	21	15	1	0	0	0	2
	11433	34	41	11	3	1	2	0	3	0	0	8	0
	11433	26	44	9	2	3	4	6	5	0	1	3	0
	11433	41	35	7	2	0	4	0	2	0	0	10	0
	11470	21	28	6	2	1	43	0	0	0	0	0	0
	11473	35	32	12	4	1	5	0	2	0	1	11	0
	11473	21	53	7	3	3	1	0	10	0	1	5	0
	11493	29	26	5	1	0	39	0	1	0	0	0	0
	11505	27	22	7	2	2	42	0	0	0	0	0	0
Lewis 3	11404	27	43	9	3	4	8	0	0	0	0	9	0
	11404	28	31	11	3	2	15	0	2	0	0	11	1
Lewis 4	11460	25	42	10	2	3	1	1	3	0	0	15	0
	11467	26	34	9	2	3	7	2	5	0	0	14	0
	11480	28	39	9	3	3	5	1	4	0	0	9	0
	11491	24	43	10	4	4	1	0	6	0	0	11	0
	11493	18	31	9	5	3	35	0	2	0	0	2	0
R.A. Moore 2	11408	13	10	1	0	2	57	0	0	16	0	1	0
	11418	22	42	12	5	2	3	0	2	0	7	10	0
R.A. Moore 3	11474	27	35	12	6	3	3	0	6	0	1	14	0
	11474	28	41	7	3	2	5	0	1	0	1	13	2
	11474	24	41	12	5	2	3	0	5	0	0	11	1
	11474	22	41	16	6	4	0	0	3	0	0	12	0
	11474	25	33	12	6	5	1	0	3	0	0	17	3
Scofield 1	11480	22	42	13	3	0	1	0	9	0	1	13	1
	11480	10	33	6	3	3	38	8	3	0	0	0	0
	11480	22	43	14	6	1	1	0	7	0	2	10	0
	11480	15	41	8	3	3	19	11	1	0	0	2	0
	11480	18	36	8	3	0	6	30	0	0	0	1	0
Vale 1	11475	15	34	5	1	7	0	28	9	0	0	0	2
	11489	15	38	6	1	6	18	15	1	0	0	0	0
	11490	27	34	7	1	2	4	3	3	0	0	20	0
	11492	23	42	12	6	1	12	0	1	0	0	10	0
	11493	19	35	9	6	3	19	0	2	0	1	11	0
	11497	17	35	9	3	4	20	4	9	0	0	1	0
	11499	24	35	7	1	3	9	0	9	0	0	11	2
	11501	11	33	13	1	2	2	0	0	36	0	2	0
	11511	16	38	7	4	1	7	0	0	28	2	1	0
	11513	17	45	6	6	2	7	0	9	0	0	13	0
	11517	22	37	10	1	2	15	4	9	0	0	0	0
	11499	24	44	11	0	1	1	0	4	0	0	13	0
	11499	26	43	6	2	2	3	0	7	0	0	13	1

Well	Depth (m)	Q	F	Rf	Li	AM	CC	MATRIX	CLC	OC	INTRA Φ	INTER Φ	OTHER
ELR	13446	70	14	6	1	1	1	0	2	0	1	6	0
	13447	56	20	6	1	2	1	0	8	0	3	3	0
	13464	17	25	7	0	22	0	24	5	0	0	1	0
	13464	73	13	5	0	0	2	0	0	0	0	7	0
	13464	39	30	6	2	5	0	0	18	0	1	1	0
	13464	66	21	5	1	2	0	0	2	0	1	2	0
	13484	71	15	5	0	1	0	0	4	0	1	4	0
	13499	61	19	6	1	1	1	0	6	0	0	6	0
	13499	63	16	5	1	1	10	0	0	0	0	4	0
	13499	68	15	7	2	1	1	0	1	0	0	8	0
	13499	65	20	4	1	3	0	0	2	0	1	5	0
	13512	61	25	7	2	1	0	0	2	0	0	3	0
	13512	66	19	4	1	2	0	0	4	0	0	4	0
	13512	61	22	5	1	0	0	0	4	0	0	5	1

Data are in percent.
Q = Quartz
F = Feldspar
Rf = Rock Fragments
Li = Lithics
AM = Accessory Minerals
CC = Carbonate Cemet
CLC = Clay Cement
OC = Other Cement
INTRA Φ = Intragranular Porosity
INTER Φ = Intergranular Porosity

APPENDIX II

Table 2. Contact index and tight-packing index of the Vedder and Eocene sands.

Well	Depth (m)	CI	TPI
Campen 1	11370	N/A	N/A
	11400	N/A	N/A
	11406	N/A	N/A
KCL 11-17	11300	N/A	N/A
	11324	N/A	N/A
	11324	N/A	N/A
	11324	N/A	N/A
	11353	N/A	N/A
	11353	N/A	N/A
	11433	5.8	4.5
	11433	N/A	N/A
	11433	N/A	N/A
	11470	N/A	N/A
	11473	N/A	N/A
	11473	6.1	4.7
	11493	N/A	N/A
	11505	N/A	N/A
Lewis 3	11404	N/A	N/A
	11404	N/A	N/A
Lewis 4	11460	N/A	N/A
	11467	N/A	N/A
	11480	2.9	2.3
	11491	5.7	5.1
	11493	N/A	N/A
R.A. Moore 2	11408	N/A	N/A
	11418	4.8	4.6
R.A. Moore 3	11474	5.9	5.3
	11474	N/A	N/A
	11474	5.8	4.4
	11474	5.6	4.8
	11474	6.1	6.0
Scofield 1	11480	N/A	N/A
	11480	5.9	5.4
	11480	5.7	5.2
	11480	N/A	N/A
	11480	N/A	N/A
Vale 1	11475	N/A	N/A
	11489	N/A	N/A
	11490	N/A	N/A
	11492	N/A	N/A
	11493	N/A	N/A
	11497	N/A	N/A
	11499	N/A	N/A
	11501	N/A	N/A
	11511	N/A	N/A
	11513	N/A	N/A
	11517	N/A	N/A
	11499	5.9	5.1
	11499	N/A	N/A

Well	Depth (m)	CI	TPI
ELR	13446	6.7	6.4
	13447	4.9	3.5
	13464	N/A	N/A
	13464	6.6	6.4
	13464	N/A	N/A
	13464	6.5	6.3
	13484	5.0	4.0
	13499	5.7	5.1
	13499	N/A	N/A
	13499	6.5	6.2
	13499	7.0	6.8
	13512	7.0	6.8
	13512	7.0	6.8
	13512	5.4	4.7

CI = Contact Index
TPI = Tight-Packing Index
NA = Not evaluated

APPENDIX III

Table 3. Mass balance data of the Vedder and Eocene sands.

Well	Depth (m)	K-feldspar	Plagioclase	Total Feldspar	*.92	Actual Kaolinite	% Imbalance	Export/Import
Campen 1	11370	1	3	4	3.7	0	-100%	Export
	11400	2	5	7	6.4	2	-69%	Export
	11406	7	5	12	11.0	1	-91%	Export
KCL 11-17	11300	1	1	2	1.8	1	-46%	Export
	11324	0	2	2	1.8	15	715%	Import
	11324	3	4	7	6.4	28	335%	Import
	11324	1	2	3	2.8	9	226%	Import
	11353	0	0	0	0.0	0	0%	Neutral
	11353	0	0	0	0.0	2	100%	Import
	11433	7	9	16	14.7	2	-86%	Export
	11433	1	5	6	5.5	8	45%	Import
	11433	7	7	14	12.9	3	-77%	Export
	11470	0	1	1	0.9	2	117%	Import
	11473	5	10	15	13.8	5	-64%	Export
	11473	4	7	11	10.1	7	-31%	Export
	11493	0	0	0	0.0	2	100%	Import
	11505	0	0	0	0.0	0	0%	Neutral
Lewis 3	11404	3	13	16	14.7	1	-93%	Export
	11404	6	14	20	18.4	5	-73%	Export
Lewis 4	11460	3	8	11	10.1	9	-11%	Export
	11467	0	2	2	1.8	15	715%	Import
	11480	5	2	7	6.4	16	148%	Import
	11491	5	14	19	17.5	14	-20%	Export
	11493	1	2	3	2.8	5	81%	Import
R.A. Moore 2	11408	0	0	0	0.0	0	0%	Neutral
	11418	5	16	21	19.3	6	-69%	Export
R.A. Moore 3	11474	5	17	22	20.2	10	-51%	Export
	11474	1	22	23	21.2	4	-81%	Export
	11474	4	19	23	21.2	9	-57%	Export
	11474	6	10	16	14.7	3	-80%	Export
	11474	2	29	31	28.5	8	-72%	Export
Scofield 1	11480	9	14	23	21.2	21	-1%	Export
	11480	1	0	1	0.9	0	-100%	Export
	11480	4	9	13	12.0	12	0%	Neutral
	11480	0	2	2	1.8	1	-46%	Export
	11480	0	0	0	0.0	0	0%	Neutral
Vale 1	11475	0	0	0	0.0	5	100%	Import
	11489	0	0	0	0.0	1	100%	Import
	11490	5	7	12	11.0	18	63%	Import
	11492	2	10	12	11.0	3	-73%	Export
	11493	2	7	9	8.3	7	-15%	Export
	11497	0	0	0	0.0	19	100%	Import
	11499	5	8	13	12.0	22	84%	Import
	11501	0	0	0	0.0	0	0%	Neutral
	11511	1	1	2	1.8	1	-46%	Export
	11513	10	12	22	20.2	19	-6%	Export
	11517	0	0	0	0.0	19	0%	Neutral
	11499	4	13	17	15.6	12	-23%	Export
	11499	1	7	8	7.4	13	77%	Neutral

Well	Depth (m)	K-feldspar	Plagioclase	Total Fedspar	*.92	Actual Kaolinite	% Imbalance	Export/Import
ELR	13446	3	8	11	10.1	0	-100%	Export
	13447	0	0	0	0.0	7	100%	Import
	13464	0	0	0	0.0	0	0%	Neutral
	13464	2	8	10	9.2	0	-100%	Export
	13464	0	0	0	0.0	0	0%	Neutral
	13464	2	1	3	2.8	0	-100%	Export
	13484	0	0	0	0.0	4	100%	Import
	13499	0	4	4	3.7	15	308%	Import
	13499	0	4	4	3.7	0	-100%	Export
	13499	0	7	7	6.4	0	-100%	Export
	13499	0	1	1	0.9	0	-100%	Export
	13512	0	2	2	1.8	0	-100%	Export
	13512	1	3	4	3.7	7	90%	Import
	13512	7	1	8	7.4	6	-18%	Export

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11517
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11517
SORTING: poorly sorted
SIZE: Fine sand

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS: 301
COMPACTION: tight - deformed labile + micas pt long - sutured contacts
ANGULARITY: subangular - rounded

COMMENTS

77
1. Quartz
Moncrystalline 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸
Polycrystalline |||
Microphanerite Granitic ||||
Volcanic Rock Fragment
Quartz Arenite
Other Sedimentary
Metaquartzite
Other Metamorphic
Chalcedony

44
2. K-Feldspar 41
Microcline 𝍸 𝍸 𝍸 𝍸 𝍸 ||
Orthoclase 𝍸 𝍸 ||||
Sanadine
Microphanerite Granitic = M ||| O
Volcanic Rock Fragment
Sedimentary
Metamorphic

102
3. Plagioclase
Microphanerite Granitic 𝍸
Volcanic Rock Fragment
Sedimentary
Metamorphic
𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||

3
4. Volcanics |||

8
5. Microphanerites
chert |||
metamorphic
Granitic - muscovite 𝍸

7
6. Accessory Minerals
Muscovite
Biotite ||
Glauconite

9
7. Carbonate Cement
Dolomite 𝍸 |||
Calcite |

8. Matrix / Pseudomatrix
Clay-Altered Grains

20
9. Clay Cement
Illite/Smectite 𝍸 ||
Kaolinite 𝍸 𝍸 |||

10. Intragranular Porosity
Quartz
K-Feldspar
Plagioclase
VRF Q
K
P
PRF Q
K
P

38
11. Intergranular Porosity 𝍸 𝍸 |
Fractures |
Fracture-induced dissolution
Oversize/elongate pores 𝍸 𝍸 𝍸 𝍸 𝍸
Grain-edge dissolution |
Other

2
12. Other
Sericite |
Myrmekite |

COMMEMTS

Myrmekite: plag + k-spar
- sericite: quartz + plag, chert
- Rutile needles in quartz
- carbonate cement replacing clays, quartz + feldspar.
- Some quartz grains are perfectly rounded.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K |	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q ||	vrfQ	prfQ
K	vrfK	prfK
P 𝍸 ||	vrfP	prfP

OTHER

1/20/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Cam-1 11370
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11370

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS: 310

SORTING: Mod - well sorted

SIZE: Med sand

COMPACTION: slightly compacted due to cement, abundant point contact.
ANGULARITY: Rounded

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic
   - chalcedony
2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic
3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic
4. Volcanics
5. Microphanerites
   - chert
   - metamorphic
   - Granitic - muscovite
6. Accessory Minerals
   - Muscovite
   - Hornblende
   - Biotite
   - Chlorite
7. Carbonate Cement
   - Calcite
   - Dolomite
8. Matrix / Pseudomatrix
   - Clay-Altered Grains
9. Clay Cement
10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase
    - VRF Q / K / P
    - PRF Q / K / P
11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other
12. Other
    - Myrmekite
    - Phosphate (shell or bone)
    - petroleum in intergranular

COMMEMTS

TS stained for K-spar + plag
K-spar contain blebs of quartz?
Poikilitic calcite cement replacing quartz, K-spar, plag, volcanics, cherts, common quartz overgrowth. Plag altering to chlorite. Kspar w/ myrmekitic texture are not replaced by albite. Albitization common in feldspar. sericitization of plag, clay

PARAGENESIS

- Grains deposited → dissolved → calcite formed in 2nd porosity
- or Grains deposited → $CaCO_3$ cement formed → dissolution → more $CaCO_3$ cement

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Cam-1 11400 T-1
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11400'
POINT COUNTS:

SORTING: Poorly to mod. sorted
COMPACTION: compacted; long grain contacts common

SIZE: Med sands
ANGULARITY: subangular - rounded

COMMENTS

1. Quartz (110)
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic (2)
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____
   - Chalcedony

2. K-Feldspar (33)
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite _____ M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase (52)
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - chert
   - metamorphic
   - Granitic - muscovite

6. Accessory Minerals (4)
   - Biotite
   - Muscovite
   - Hornblende
   - Sphene
   - Hornblende
   - zircon

7. Carbonate Cement (31)
   - calcite
   - Dolomite

8. Matrix / Pseudomatrix

Clay-Altered Grains

9. Clay Cement (3)
   - Kaolinite
   - Illite/smectite

10. Intragranular Porosity
    - Quartz — VRF Q, PRF Q
    - K-Feldspar — K, K
    - Plagioclase — P, P

11. Intergranular Porosity (37)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

12. Other (1)
    - Myrmekite
    - sericite
    - metamorphic chlorite exhibiting Berlin blue
    - phosphate (bone)

COMMEMTS

poikilitic calcite cement in pore space and replacing plag, quartz, k-spar, cherts, volcanics along fractures or etch. some plag. almost completely replaced by albite. quartz overgrowth. Quartz veins are common in volcanics. kaolinite books, some k-spar contain blebs of quartz.

PARAGENESIS

calcite cement (euhedral) → compaction → dissolution of other minerals → compaction → calcite fracture → more dissolution

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Cam-1 11406-2b
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11406

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

SIZE: Med. sand

COMPACTION: very tight: deformed labile + micas. sutured + long contacts common
ANGULARITY: Subangular - rounded

			COMMENTS
104	1. Quartz	Moncrystalline, Polycrystalline, Microphanerite Granitic, Volcanic Rock Fragment, Quartz Arenite, Other Sedimentary, Metaquartzite, Other Metamorphic	
49	2. K-Feldspar	Microcline, Orthoclase, Sanadine, Microphanerite (M, O), Volcanic Rock Fragment, Sedimentary, Metamorphic	
69	3. Plagioclase	Microphanerite Granitic, Volcanic Rock Fragment, Sedimentary, Metamorphic	
8	4. Volcanics		
16	5. Microphanerites	chert, metamorphic-chert, Granitic - Muscovite	
6	6. Accessory Minerals	Biotite, Musconite, Hornblende, sphene	
26	7. Carbonate Cement	Calcite, Dolomite	
1	8. Matrix / Pseudomatrix	Clay-Altered Grains	
2	9. Clay Cement	Illite/smectite, Kaolinite	
	10. Intragranular Porosity	Quartz, K-Feldspar, Plagioclase	VRF Q, K, P / PRF Q, K, P
21	11. Intergranular Porosity	Fractures, Fracture-induced dissolution, Oversize/elongate pores, Grain-edge dissolution	Other
	12. Other	Zoned ~~sanidine~~ plag, Hymenite, petro. in intragranular	-see sharpie mark; Sericite

COMMEMTS

-Zoned sanidine, rutile needles are common in quartz. Poikilitic calcite cement replacing plag, quartz, k-spar, + vol.
- Volcanic (plag) in quartz. Some plag are almost completely altered to albite
-Some k-spar contain blebs of quartz?

PARAGENESIS

- Calcite cement formed after deposition. Compaction cause calcite cement to fracture and more k-spar (feldspar) dissolved after. See pic

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

6/17/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13446 T3
FORMATION (AGE):
LOCATION: Greeley oil Field
DEPTH: 13,446

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod. sorted
SIZE: med - coarse sands

COMPACTION: very tight - little pt contact, abundant concavo-convex + long grained contacts
ANGULARITY: sub-round - round

			COMMENTS
1. Quartz	Moncrystalline	~~~~	
	Polycrystalline	|||	
	Microphanerite Granitic	||	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary _____		
	Metaquartzite		
	Other Metamorphic _____		
2. K-Feldspar	Microcline	~~~~	
	Orthoclase	~~~~	
	Sanadine		
	Microphanerite Granitic	M O |||	
	Volcanic Rock Fragment		
	Sedimentary _____		
	Metamorphic _____		
3. Plagioclase	Microphanerite Granitic	~~~~ |||	
	Volcanic Rock Fragment		
	Sedimentary _____		
	Metamorphic _____		
4. Volcanics	||||		
5. Microphanerites	chert	||	
	Granitic - Muscovite	||	
6. Accessory Minerals	Glauconite	|	Pyrite
	Sphene		Epidote
	Muscovite		Chlorite
	Zircon		
	Biotite	|	
7. Carbonate Cement	Calcite	|||	
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
9. Clay Cement	Illite/smectite	~~~~	
	Kaolinite		
10. Intragranular Porosity	Quartz	|	VRF Q / K / P; PRF Q / K / P
	K-Feldspar		
	Plagioclase	|	
11. Intergranular Porosity	Fractures	|	
	Fracture-induced dissolution		
	Oversize/elongate pores	~~~~	
	Grain-edge dissolution	| ~~~~	Other _____
12. Other	Phosphate coating		
	Pyrite cement		
	Myrmekite.		

4
3
0
5
2
17

COMMEMTS

- sericitation of F + Feldspar
- Q overgrowth - hard to see orig grain boundary.
- Illite/smectite coating on grains, formed in place
- Epidote replaced F, but not in diagenesis, but igneous
- F altering to clay (illite/smectite)
- metamorphic biotite - altering to chlorite?

Rutile needles in Q
- Inclusion trains in Q

PARAGENESIS

- calcite cementation along edge of grain.

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K |	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K |	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q ||	vrfQ |	prfQ
K |	vrfK	prfK
P ~~~~ |||	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13447-1
FORMATION (AGE):
LOCATION: Greeley oil Field
DEPTH: 13447'
SORTING: Moderately to poorly
SIZE: Med sand

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:
COMPACTION: very tight - deformed labile + mic long + sutured contacts.
ANGULARITY:

COMMENTS

174
59%
1. Quartz
Moncrystalline 卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌||| 卌卌卌||||
Polycrystalline 卌|
Microphanerite Granitic 卌|
Volcanic Rock Fragment
Quartz Arenite
Other Sedimentary
Metaquartzite
Other Metamorphic

35
11%
2. K-Feldspar
Microcline 卌卌卌卌||||
Orthoclase 卌|
Sanadine
Microphanerite Granitic ⟨ M|||| O|
Volcanic Rock Fragment
Sedimentary
Metamorphic

33
11%
3. Plagioclase
Microphanerite Granitic |||| 卌卌卌卌卌||||
Volcanic Rock Fragment
Sedimentary
Metamorphic

3
.01%
4. Volcanics |||

3
.01%
5. Microphanerites
Chert ||
Metamorphic
Microphanerite - muscovite |

6
.01%
6. Accessory Minerals
Biotite ||
Muscovite |
Epidote |
Glauconite |
Hornblende
Pyrite
sphene

2
.01%
7. Carbonate Cement
Calcite ||

8. Matrix / Pseudomatrix
Clay-Altered Grains

25
.08%
9. Clay Cement
Illite/Smectite 卌卌卌||||
Kaolinite 卌|

10
.03%
10. Intragranular Porosity |
Quartz |
K-Feldspar 卌||
Plagioclase |
VRF Q K P
PRF Q K P

10
.03%
11. Intergranular Porosity 卌|||
Fractures
Fracture-induced dissolution
Oversize/elongate pores
Grain-edge dissolution ||
Other

1
.00%
12. Other
pyrite cement |
petroleum in intragranular
Myrmekite

COMMEMTS

- stained for k-spar + plag
- phosphate (bone?)

Calcite cement replacing quartz overgrowth + plag. - Poikilitic calcite cement

Dissolution of k-spar + quartz.

Rutile needles + zircon inclusions in quartz

PARAGENESIS

Myrmekite in k-spar

- Some k-spar contain blebs of quartz

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q ||	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

6/23/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13464 T3
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field
ROCK NAME:
DEPTH: 13464
POINT COUNTS:

SORTING: poorly sorted
COMPACTION: very tight : grains are fractur

SIZE: fine sands - med
ANGULARITY: subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics

5. Microphanerites Chert

6. Accessory Minerals — 66
   - Biotite
   - Chlorite
   - Muscovite
   - Sphene
   - Pyrite
   - Epidote
   - Glauconite
   - Chlorite

7. Carbonate Cement — 1
   - Calcite

8. Matrix / Pseudomatrix — 73 - see back of page

Clay-Altered Grains

9. Clay Cement — 14
   - Illite Smectite

10. Intragranular Porosity — Ø
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q, K, P — PRF Q, K, P

11. Intergranular Porosity — 3
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other

12. Other — 0
    - Phosphate coating (?)
    - Pyrite cement
    - Petro in intra + intergranular

COMMEMTS

- sericite
- Glauconite replace F + Q + chert
- Glauconite often crushed by compaction
- Biotite altering to chlorite, Berlin blue
- Abundant heavy minerals
- Pyrite formed w/ glauconite
- Little or no Ø

PARAGENESIS

~~Glauconite replace F, chlorite replace glau~~ conite
- chlorite replace biotite
- Sericite replace F, glauconite replace sericite

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-113464 T4
PROJECT:
FORMATION (AGE):
LOCATION: Greeley oil field
ROCK NAME:
DEPTH: 13464
POINT COUNTS:

SORTING: Moderately sorted - well
COMPACTION: very tight: little pt contact, long + concave-convex contacts.
SIZE: med sands
ANGULARITY: subround

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite Granitic		
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite Granitic	M O	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite Granitic		
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	chert		
	granitic - muscovite		
6. Accessory Minerals	Epidote	Glauconite	
	Zircon	Muscovite	
	Pyrite		
	Sphene		
	Biotite		
7. Carbonate Cement	Calcite		
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
9. Clay Cement	Kaolinite		
	Muscovite-cement		
	Illite/smectite		
10. Intragranular Porosity	Quartz	VRF Q	PRF Q
	K-Feldspar	K	K
	Plagioclase	P	P
11. Intergranular Porosity	Fractures		
	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution	Other	
12. Other	Pyrite cement		
	Fossils		
	Petro in intragranular + intergran.	Phosphate	

1 5 0 1 0 22 0

COMMEMTS

Q overgrowth, F overgrowth, EXTENSIVE Q overgrowth, Myrmekite
Biotite alters to chlorite
F alters to clay.
Glauconite replacing F?
Laumontite cement?
Rutile needles in Q

PARAGENESIS

Abundant pressure induced dissolution, 10L some @ extreme concave-convex.

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
3 Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OTHER		

SANDSTONE PETROGRAPHY DATA

EXAMINED BY Horton

THIN SECTION: ELR-1 13464-5
FORMATION (AGE):
LOCATION: Greely O.I Field
DEPTH: 13464

PROJECT: Diemms

ROCK NAME:
POINT COUNTS:

SORTING: Poor-Moderate

COMPACTION: Very Tight - Deformed labiles, micas, long contacts, Grain interpenetration

SIZE: medium sand
Disrupted laminations of silt-clay

ANGULARITY: Subround-round

COMMENTS

1. Quartz 119	Moncrystalline 114 Polycrystalline 1111 Microphanerite Granite 1 Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____		
2. K-Feldspar 50	Microcline ~~HH~~ ~~HH~~ ~~HH~~ ~~HH~~ 1 Orthoclase ~~HH~~ ~~HH~~ ~~HH~~ 1 Sanadine Microphanerite Granitic M 111 / O Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	Much is perthitic, some contains blebs of Qtz ? Some is highly seriticized Some is Perthitic some microcline is unstained	
3. Plagioclase 46	Microphanerite Granitic 1111 Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	Much shows no stain (albite ?), Most is unstained Most has sericitic alteration some is water clear 42	
5 4. Volcanics		Many have largely dissolved and filled w/ petroleum	
4 5. Microphanerites	metamorphic Chert 111		
15 6. Accessory Minerals	Hornblende Glaucomite 11 Biotite ~~HH~~ ~~HH~~ Sphene Epidot	Opaque 12 Muscovite 1 Pyrite	
7. Carbonate Cement			
8. Matrix / Pseudomatrix		Highly Biref. Clays stained yellow (Illite ?) + fine micas with fine sand - coarse silt quartz, feldspars	
.....Clay-Altered Grains.....			
55 9. Clay Cement	Illite ?	Clay-silt laminations, stained yellow (K-rich), High birefrangent	
2 10. Intragranular Porosity	Quartz K-Feldspar Plagioclase 11 Volcanics	VRF Q K P	PRF Q K P
4 11. Intergranular Porosity	Fractures 11 Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution	Other _____	
12. Other	Petroleum mainly in intragranular pores		

COMMEMTS Stained for K-spar + Plag.
Plag staining is very faint
Most pore space is filled with oil, but some intragranular pores are open

Thin clay laminae
Late fractures in Quartz common (Not filled with petroleum)

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

6/15/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13464 -T6
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 13464'
SORTING: poorly sorted
SIZE: med-coarse grained

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:
COMPACTION: very tight, little point contact, abundant long + sutured.
ANGULARITY: subround

		COMMENTS
1. Quartz	Moncrystalline, Polycrystalline, Microphanerite Granitic, Volcanic Rock Fragment, Quartz Arenite, Other Sedimentary, Metaquartzite, Other Metamorphic	
2. K-Feldspar	Microcline, Orthoclase, Sanadine, Microphanerite Granitic (M, O), Volcanic Rock Fragment, Sedimentary, Metamorphic	
3. Plagioclase	Microphanerite Granitic, Volcanic Rock Fragment, Sedimentary, Metamorphic	
4. Volcanics		
5. Microphanerites	chert; granitic - muscovite	
6. Accessory Minerals	sphene, zircon, Biotite, Epidote, Muscovite; glauconite, Epidote, chlorite, pyrite	
7. Carbonate Cement	calcite	
8. Matrix / Pseudomatrix		
Clay-Altered Grains		
9. Clay Cement	Kaolinite, Illite/smectite	
10. Intragranular Porosity	Quartz, K-Feldspar, Plagioclase; VRF Q, K, P; PRF Q, K, P	
11. Intergranular Porosity	Fractures, Fracture-induced dissolution, Oversize/elongate pores, Grain-edge dissolution; Other	
12. Other	Phosphate coating, phosphate (bone), petro in intra + inter pores; pyrite cement.	

6
0
0
7
2
7

COMMEMTS

- Feldspar altering to sericite
- " have overgrowth of quartz
- Feldspar altering to clay (plag?)
- Glauconite replacing feldspar
- Bone replaced by quartz.
- yellow glauconite replacing F??? + phosphate?
- Chlorite exhibiting "Berlin" blue.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
2 Q	vrfQ	prfQ
3 K	vrfK	prfK
P	vrfP	prfP
OTHER		
_____		
_____		

thames

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13484-2
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 13484'
POINT COUNTS: 301

SORTING: Moderately sorted
COMPACTION: very tight - deformed labile + mica long, sutured, concavo-convex contacts.

SIZE: Med. sand
ANGULARITY: Rounded

COMMENTS

216
1. Quartz
Moncrystalline 𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸 𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸||||
Polycrystalline 𝍸|||
Microphanerite Granitic ||||
Volcanic Rock Fragment
Quartz Arenite
Other Sedimentary
Metaquartzite
Other Metamorphic

33
2. K-Feldspar
Microcline 𝍸𝍸𝍸𝍸|||
Orthoclase 𝍸||
Sanadine
Microphanerite Granitic < M || O |
Volcanic Rock Fragment
Sedimentary
Metamorphic

15
3. Plagioclase 𝍸𝍸||||
Microphanerite Granitic |
Volcanic Rock Fragment
Sedimentary
Metamorphic

1 4. Volcanics |

7
5. Microphanerites
Chert 𝍸|
Granitic- muscovite

3
6. Accessory Minerals
Epidote
Biotite
Muscovite
Hornblende
Pyrite ||
Sphene

1
7. Carbonate Cement
Calcite |

8. Matrix / Pseudomatrix
....Clay-Altered Grains.......

11
9. Clay Cement
Illite/smectite 𝍸||
Kaolinite ||||

3
10. Intragranular Porosity
Quartz
K-Feldspar |
Plagioclase ||
VRF Q
K
P
PRF Q
K
P

11
11. Intergranular Porosity 𝍸||||
Fractures
Fracture-induced dissolution
Oversize/elongate pores |
Grain-edge dissolution |
Other

1
12. Other
feldspar
pyrite cement
petroleum in intragranular porosity
Metamorphic chlorite - Berlin blue
Myrmekite |

COMMEMTS

Stained for K-spar + plag.

Illite/smectite/kaolinite cement in the pore space + b/w grains.

Poikilitic calcite cement and replacing other grains (Kspar + Q)

- Metamorphic chlorite w/ inclusions / TS defect + Berlin blue

PARAGENESIS

myrmekite.

Rutile needles + zircon inclusions in quartz

Myrmekite in K-spar + plag

- Some K-spar contain blebs of quartz?

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q |	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

Calcite cement ?

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13499-1
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 13499'
POINT COUNTS:
SORTING: Moderately-poorly
COMPACTION: very tight- deformed labile + mica long + sutured grain contacts
SIZE: Med. sand
ANGULARITY: subround - round

COMMENTS

192 1. Quartz
Moncrystalline 𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸𝍸 ||
Polycrystalline |||
Microphanerite Granitic 𝍸 |
Volcanic Rock Fragment |
Quartz Arenite
Other Sedimentary ________
Metaquartzite
Other Metamorphic ________

38 2. K-Feldspar
Microcline 𝍸𝍸𝍸𝍸𝍸||
Orthoclase 𝍸|||
Sanadine
Microphanerite ________ M || O
Volcanic Rock Fragment |
Sedimentary ________
Metamorphic ________

28 3. Plagioclase
Microphanerite Granitic |||| 𝍸𝍸𝍸𝍸|||
Volcanic Rock Fragment |
Sedimentary ________
Metamorphic ________

2 4. Volcanics ||

6 5. Microphanerites
metamorphic - |
chert |||
Granitic - muscovite ||

4 6. Accessory Minerals
Epidote
pyrite ||
Muscovite
glauconite
Hornblende
Biotite
Zircon
Siderite
Chlorite

2 7. Carbonate Cement
Calcite ||

8. Matrix / Pseudomatrix
.......Clay-Altered Grains.........

17 9. Clay Cement
Kaolinite 𝍸𝍸𝍸
Illite/smectite ||

10. Intragranular Porosity
Quartz
K-Feldspar
Plagioclase
VRF Q K P
PRF Q K P

17 11. Intergranular Porosity |||
Fractures
Fracture-induced dissolution
Oversize/elongate pores 𝍸𝍸||
Grain-edge dissolution ||
Other ________

1 12. Other
pyrite cement |
phosphate (bone)
Myrmekite (plag + k-spar)
petroleum in intergranular

COMMEMTS

stained for plag + k-feldspar
Myrmekite in plag grain
Rutile needles in quartz
Some k-spar contain blebs of quartz

PARAGENESIS

Clay cement formed on edge of grain and open pore system.
carbonate cement replacing other grains + formed in pore space.
igneous inclusions (plag + k-spar + rutile) in quartz

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q |	vrfQ	prfQ
K	vrfK	prfK
P |	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K ||	vrfK	prfK
P |	vrfP	prfP

OTHER

\-\-\-\-\-\-\-\-\-
\-\-\-\-\-\-\-\-\-

6/28/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-113499 T2
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 13,499'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: Moderately Sorted

SIZE: Med sands

COMPACTION: very tight - abundant long, concavo convex + sutured, little pt contact
ANGULARITY: subangular - rounded.

			COMMENTS
1. Quartz	Moncrystalline	~~~~	
	Polycrystalline	||	
	Microphanerite	Granitic ||	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline	~~~~	
	Orthoclase	~~~~	
	Sanadine		
	Microphanerite	Granitic ≤ M O	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic ~~~~	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics	|||		~~~~ ||||
5. Microphanerites	Chert	~~~~ |	
	Granitic - Muscovite	|	
6. Accessory Minerals	Pyrite	|	Muscovite
2	Glauconite		Zircon
	Biotite		Epidote
	Chlorite		
	Sphene		
7. Carbonate Cement	Calcite	~~~~ ~~~~ ~~~~ ~~~~ ||||	
29			
8. Matrix / Pseudomatrix			
0			
Clay-Altered Grains			
9. Clay Cement	Illite Smectite	|	
1	Kaolinite		
10. Intragranular Porosity	Quartz		VRF Q / K / P — PRF Q / K / P
0	K-Feldspar		
	Plagioclase		
11. Intergranular Porosity	Fractures		
13	Fracture-induced dissolution		
	Oversize/elongate pores	~~~~ ||||	
	Grain-edge dissolution		Other
12. Other	Phosphate (bone)		Pyrite cement |
1	Fossil - replaced by calcite		
	Petro in intragranular		

COMMEMTS

F altering to clay (illite/smectite)
Q overgrowth. F overgrowth.
calcite cement replacing fw grains
Biotite altering to chlorite.
Rutile needles in Q.
Myrmekite
Grains are more rounded than other TS

PARAGENESIS

calcite cement replacing fw grains
Pyrite often formed b/w biotite cleavage

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
2 Q||	vrfQ	prfQ
K	vrfK	prfK
4 P||||	vrfP	prfP

OTHER

6/28/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELF-1 13499-T3
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley
ROCK NAME:
DEPTH: 13499'
POINT COUNTS:

SORTING: Mod sorted.
COMPACTION: very tight

SIZE: Med Sands.
ANGULARITY: subangular to subround

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite	Granitic	M O
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	Chert		
	Granitic - Muscovite		
6. Accessory Minerals	Biotite		Pyrite
	Chlorite		Glauconite
2	Muscovite		Zircon
	Sphene		
	Epidote		
7. Carbonate Cement	Calcite		
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
3 9. Clay Cement	Illite/Smectite		
10. Intragranular Porosity	Quartz		VRF Q / K / P — PRF Q / K / P
1	K-Feldspar		
	Plagioclase		
11. Intergranular Porosity	Fractures		
23	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution		Other
12. Other	Pyrite cement		
	Petro in intragranular		

COMMEMTS

Biotite altering to chlorite
Myrmekite
Sericite (F)
F alters to sericite + clays
Q overgrowth.
Pyrite cement
-K-spar overgrowth
• Rutile needles in Q.

PARAGENESIS

Myrmekitic texture and partially altered to myrmekite from K-spar

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
5 Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

7/4/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13499-T4
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 13499

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: Mod. sorted

SIZE: med - coarse

COMPACTION: very tight - little pt contacts abundant concave convex + long contacts.
ANGULARITY: sub-angular to subrounded

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite	Granitic	M O
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	Chert		
6. Accessory Minerals	sphene		zircon
	Biotite		Glauconite
	Chlorite		Pyrite
	Epidote		
	Muscovite		
7. Carbonate Cement	Dolomite		
	Calcite		
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
9. Clay Cement	Illite / Smectite		
10. Intragranular Porosity	Quartz		VRF Q / K / P — PRF Q / K / P
	K-Feldspar		
	Plagioclase		
11. Intergranular Porosity	Fractures		
	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution		Other
12. Other	Pyrite cement		
	Petro in intragranular		

8
1
5
2
16

COMMEMTS
- Biotite altering to chlorite
- Sericite (F alters to sericite)
- Epidote replace F = VF (not diagenetic)
- Overgrowth: F + Q
- F alters zeolite
- Calcite replacing fw grains, but mainly filled open pore space.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-1 13512-1
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 13,512'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: well sorted

SIZE: med sands

COMPACTION: very tight: little pt contacts, abundant concavo-convex + long contacts!
ANGULARITY: subangular - subround

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite	Granitic	M O
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	Chert		
	Granitic-Muscovite		
6. Accessory Minerals	Muscovite		Pyrite
	Biotite		Glauconite
3	Epidote		
	Sphene		
	Zircon		
7. Carbonate Cement	Calcite		
1			
8. Matrix / Pseudomatrix			
0			
Clay-Altered Grains			
9. Clay Cement	Illite/Smectite		
5	Kaolinite		
10. Intragranular Porosity	Quartz		VRF Q / K / P
	K-Feldspar		PRF Q / K / P
	Plagioclase		
1			
11. Intergranular Porosity		Fractures	
10		Fracture-induced dissolution	
		Oversize/elongate pores	
		Grain-edge dissolution	Other
12. Other			
0			

COMMEMTS

K-spar overgrowth
-Myrmekite

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

P THIN SECTION: ELR-1 13512-T4
FORMATION (AGE):
LOCATION: Greeley oil Field
DEPTH: 13512

PROJECT:

ROCK NAME:
POINT COUNTS:

SORTING: Mod. sorted

COMPACTION: very tight

SIZE: Med sand

ANGULARITY: subround - round.

		COMMENTS
1. Quartz	Moncrystalline Polycrystalline Microphanerite Granitic Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____	
2. K-Feldspar	Microcline Orthoclase Sanadine Microphanerite Granite M O Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
3. Plagioclase	Microphanerite Granitic Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
4. Volcanics		
5. Microphanerites	Chert Granitic - Muscovite.	
5 6. Accessory Minerals	Zircon Sphene Biotite Muscovite Epidote	Glauconite Pyrite
0 7. Carbonate Cement	Calcite	
0 8. Matrix / Pseudomatrix	Clay-Altered Grains	
13 9. Clay Cement	Kaolinite Illite/smectite.	
1 10. Intragranular Porosity	Quartz K-Feldspar Plagioclase	VRF Q K P PRF Q K P
11 11. Intergranular Porosity	Fractures Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution	Other _____
0 12. Other		

COMMEMTS

Q overgrowth - abundant
F overgrowth
Rutile needle in Q
sericite
Myrmekite.

pt contacts are from overgrowth (Q).

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

PARAGENESIS

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: ELR-113512-5
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 13512'
POINT COUNTS:

SORTING: Moderately
COMPACTION: very tight-deformed labile + micas, long + sutured contacts
SIZE: Med sand
ANGULARITY: rounded

COMMENTS

186	1. Quartz	Moncrystalline, Polycrystalline, Microphanerite Granitic, Volcanic Rock Fragment, Quartz Arenite, Other Sedimentary, Metaquartzite, Other Metamorphic	
53	2. K-Feldspar	Microcline, Orthoclase, Sanadine, Microphanerite Granitic (M, O), Volcanic Rock Fragment, Sedimentary, Metamorphic	
20	3. Plagioclase	Microphanerite Granitic, Volcanic Rock Fragment, Sedimentary, Metamorphic	
2	4. Volcanics		
6	5. Microphanerites	Chert; Granitic - muscovite	
	6. Accessory Minerals	Muscovite, Glauconite, Hornblende, Epidote	Pyrite
	7. Carbonate Cement	Calcite	
1	8. Matrix / Pseudomatrix		
	Clay-Altered Grains		
12	9. Clay Cement	Illite/Smectite; Kaolinite	
1	10. Intragranular Porosity	Quartz, K-Feldspar, Plagioclase	VRF Q, K, P; PRF Q, K, P
16	11. Intergranular Porosity	Fractures; Fracture-induced dissolution; Oversize/elongate pores; Grain-edge dissolution	Other
4	12. Other	Petroleum in intergranular + intragranular; Myrmekite; Sericite	

COMMEMTS

- stained for plag + kspar
Myrmekite in plag grain
- Rutile needles in quartz grain.
- Quartz grains are more fractured than the TS above this depth.
- very little calcite cement observed

PARAGENESIS

- clay altering to sericite
- Fractured quartz / feldspar grains and dislocated grain fragments
- Some K-spar contain blebs of quartz?

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

5

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL11-17 11300.
FORMATION (AGE):
LOCATION: greeley oil Field
DEPTH: 11300

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

SIZE: med - coarse

COMPACTION: very tight, but grains replaced by calate.

ANGULARITY: subround - subangular

COMMENTS

1. Quartz
Moncrystalline 卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌
Polycrystalline ||
Microphanerite Granitic
Volcanic Rock Fragment
Quartz Arenite
Other Sedimentary
Metaquartzite
Other Metamorphic

2. K-Feldspar
Microcline 卌卌卌卌
Orthoclase 卌卌
Sanadine
Microphanerite Granitic M |||| O
Volcanic Rock Fragment
Sedimentary
Metamorphic

3. Plagioclase
Microphanerite Granitic 卌||||
Volcanic Rock Fragment
Sedimentary
Metamorphic
卌卌卌卌卌卌卌卌卌卌卌卌卌||||

4. Volcanics 卌||

5. Microphanerites Chert 卌||||

3 6. Accessory Minerals
Pyrite |
Glauconite
Biotite ||
Muscovite
Sphene

81 7. Carbonate Cement
Dolomite -1
calcite 卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌|

6 8. Matrix / 卌|
Pseudomatrix
Clay-Altered Grains

1 9. Clay Cement
Kaolinite |

0 10. Intragranular Porosity
Quartz
K-Feldspar
Plagioclase

VRF Q K P

PRF Q K P

3 11. Intergranular Porosity
Fractures
Fracture-induced dissolution
Oversize/elongate pores ||
Grain-edge dissolution |
Other

1 12. Other
phosphate |
petro in intergranular

COMMEMTS
- Bleached biotite
- Biotite altering to clay + chlorite.
- Myrmekite
- calcite replacing fw grains.
- F altering to clay

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q |	vrfQ	prfQ
K |	vrfK	prfK
P |	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11324 T1
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil Field
ROCK NAME:
DEPTH: 11324
POINT COUNTS:

SORTING: Fairly sorted
COMPACTION: very tight

SIZE: Med size
ANGULARITY: Angular - round.

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - chert
   - Granitic - Mus

6. Accessory Minerals
   - Biotite
   - Pyrite
   - sphene
   - Muscovite

4

7. Carbonate Cement
   - Dolomite

1

8. Matrix / Pseudomatrix
   - Clay-Altered Grains

9. Clay Cement
   - Kaolinite
   - Illite/smectite

15
38

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase

VRF	PRF
Q	Q
K	K
P	P

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

22

12. Other
    - Zeolites
    - petro in intergranular

COMMEMTS

- Sig [] of petro and volcanics.
- zoned plag
- Biotite alters to clay.
- pyrite in petro
- TPI high due to high [] of volcanic

PARAGENESIS

- Albite healed plag fractures
- Q overgrowth

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11324 - T3T4 PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field. ROCK NAME:
DEPTH: 11324 POINT COUNTS:

SORTING: Moderately sorted COMPACTION: tight ;

SIZE: Med sand ANGULARITY: subrounded - rounded

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite — M / O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics

5. Microphanerites
   - Chert
   - granitic - muscovite
   - shale
   - metamorphic chert

6. Accessory Minerals
   - zircon
   - biotite
   - muscovite

7. Carbonate Cement
   - Dolomite
   - Calcite

8. Matrix / Pseudomatrix
   - Clay-Altered Grains

9. Clay Cement
   - Kaolinite

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase
    - VRF Q / K / P
    - PRF Q / K / P

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other

12. Other
    - Phosphate - bone
    - Petroleum in intragranular
    - shell replaced by chert - enchiderm?

COMMEMTS

plag altered to zeolites + clay replaced plag
zoned plag
kaolinite books
rutile needles in quartz
abundant of dissolved feldspar
Plag overgrowth ? zone albite + healed fractures
• Myrmekite

PARAGENESIS

secondary ϕ often are created by unstable grains dissolution. Most unstable min are completely dissolved.

compaction → plag deformation + fracture → albite healed fractures + formed etch of grain

same w/ quartz

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11324 TS
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11324
POINT COUNTS:
SORTING: Poorly sorted
COMPACTION: Very tight
SIZE: Med sands
ANGULARITY: Angular - subround -

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - Mas

6. Accessory Minerals (6)
   - Biotite
   - Glauconite
   - Pyrite

7. Carbonate Cement (61)
   - Dolomite

8. Matrix / Pseudomatrix
   - Clay-Altered Grains

9. Clay Cement (13)
   - Kaolinite
   - Illite/smectite

10. Intragranular Porosity (4)

	VRF	PRF
Quartz	Q	Q
K-Feldspar	K	K
Plagioclase	P	P

11. Intergranular Porosity (13)
   - Fractures
   - Fracture-induced dissolution
   - Oversize/elongate pores
   - Grain-edge dissolution
   - Other _____

12. Other (4)
   - Phosphate

COMMEMTS
- stained TS.
- phosphate
- zeolite
- Biotite alters to clay.
- Q overgrowth

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

SEM

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KEL 11-17 11353 T1
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley
ROCK NAME:
DEPTH: 11353
POINT COUNTS:
SORTING: poorly sorted
COMPACTION: very tight
SIZE: fine - med
ANGULARITY: subangular - angular

COMMENTS

1. Quartz
   - Moncrystalline ||||
   - Polycrystalline
   - Microphanerite Granitic |||
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline ||||
   - Orthoclase ||||
   - Sanadine
   - Microphanerite Granitic M O ||||
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic ||||
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics ||||

5. Microphanerites Chert ||||

6. Accessory Minerals
   - Muscovite ||
   - Sphene
   - Biotite |||
   - Pyrite ||

7

7. Carbonate Cement
   - Dolomite ||||
   - Calcite ||

8

8. Matrix ||||
   Pseudomatrix

62

Clay-Altered Grains

9. Clay Cement

10. Intragranular Porosity
    - Quartz — VRF Q — PRF Q
    - K-Feldspar — K — K
    - Plagioclase | — P — P

1

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

2 ||

12. Other
    - Phosphate
    - Shell
    - Petro

COMMEMTS

- Biotite alters to clay + chlorite
- F alters to sericite.
- petro w/ pyrite blebs
- B

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SEM opaque cement

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KU 11-17 11353 TST6

PROJECT: Nguyen MS

FORMATION (AGE):

LOCATION: Greeley Oil Field

ROCK NAME:

DEPTH: 11353

POINT COUNTS:

SORTING: poorly sorted

COMPACTION: very tight

SIZE: Fine

ANGULARITY: Angular - Subangular

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - Mus

6. Accessory Minerals
   - Muscovite
   - Biotite
   - Sphene
   - Pyrite

3

7. Carbonate Cement
   - Dolomite

62

8. Matrix / Pseudomatrix

46

Clay-Altered Grains

9. Clay Cement
   - Kaolinite

2

10. Intragranular Porosity

	VRF	PRF
Quartz	Q	Q
K-Feldspar	K	K
Plagioclase	P	P

11. Intergranular Porosity
   - Fractures
   - Fracture-induced dissolution
   - Oversize/elongate pores
   - Grain-edge dissolution
   - Other _____

12. Other
   - Barite cement
   - white cement + opaque XP

6

COMMEMTS

- sig CJ of matrix
- some kind of cement ?
- zeolites

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____

_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11433 T1
PROJECT: Nguyen M.S
FORMATION (AGE):
LOCATION: Greeley oil Field
ROCK NAME:
DEPTH: 11433'
POINT COUNTS:
SORTING: Mod. sorted
COMPACTION: very tight.
SIZE: Med sands
ANGULARITY: subangular - subround.

		COMMENTS
1. Quartz	Moncrystalline Polycrystalline Microphanerite Granitic Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____	
2. K-Feldspar	Microcline Orthoclase Sanadine Microphanerite Granite M O Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
3. Plagioclase	Microphanerite Granitic Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
4. Volcanics		
5. Microphanerites	Chert Granitic-Mus	
6. Accessory Minerals	Muscovite Sphene Biotite Pyrite	
7. Carbonate Cement	Calcite Dolomite	
8. Matrix / Pseudomatrix		
Clay-Altered Grains		
9. Clay Cement	Kaolinite Illite/Smectite	
10. Intragranular Porosity	Quartz K-Feldspar Plagioclase	VRF Q K P PRF Q K P
11. Intergranular Porosity	Fractures Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution	Other _____
12. Other	Phosphate	

COMMEMTS

Biotite altering to clay
Myrmekite
, Q overgrowth
, F overgrowth (M/O/P)

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11433 T3
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11433'
POINT COUNTS:

SORTING: Poorly sorted
COMPACTION: very tight

SIZE: Med – crs. sand
ANGULARITY: Angular–subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic – M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites Chert, Granitic – Mus

6. Accessory Minerals (8)
   - Muscovite
   - Biotite
   - Pyrite
   - Sphene
   - Chlorite

7. Carbonate Cement (13)
   - Calcite
   - Dolomite

8. Matrix (17)
   - Pseudomatrix
   - Clay-Altered Grains

9. Clay Cement (15)
   - Kaolinite
   - Illite/Smectite

10. Intragranular Porosity (2)
    - Quartz — VRF Q, PRF Q
    - K-Feldspar — K, K
    - Plagioclase — P, P

11. Intergranular Porosity (10)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

12. Other phosphate coating

COMMENTS
F overgrowth + healed fractures.
Carbonate replacing fw grains.
Matrix
Biotite alters to clay, chlorite
Q overgrowth
B alters to chlorite.

PARAGENESIS
Myrmekite.

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: FCL 11-17 11433-5
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11433'
POINT COUNTS:

SORTING: Mod. sorted
COMPACTION: very tight

SIZE: Med sands
ANGULARITY: subangular - subround

		COMMENTS
1. Quartz	Moncrystalline Polycrystalline Microphanerite Granitic Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____	
2. K-Feldspar	Microcline Orthoclase Sanadine Microphanerite Granite Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	M O
3. Plagioclase	Microphanerite Granitic Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
4. Volcanics		
5. Microphanerites	Chert Granite - Plus.	
6. Accessory Minerals	Biotite Pyrite Muscovite Zircon	
7. Carbonate Cement	Dolomite Calcite	
8. Matrix / Pseudomatrix		
Clay-Altered Grains		
9. Clay Cement	Illite/Smectite Kaolinite	
10. Intragranular Porosity	Quartz K-Feldspar Plagioclase	VRF Q K P PRF Q K P
11. Intergranular Porosity	Fractures Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution	Other _____
12. Other	Bone-Phosphate	

COMMEMTS
- Myrmekite
- Q overgrowth.
- zeolites
- F overgrowth

PARAGENESIS
- calcite dolomite replacing fw grains
- Rutile needles in Q.

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11470.5
FORMATION (AGE): Vedder
LOCATION: Greeley oil field
DEPTH: 11470.5'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: moderately poor sorted bc of calcite cement
SIZE: med sand

COMPACTION: tight, mostly pt contact due to calcite cement.
ANGULARITY: subangular

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic 1
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic
   - Quartz in phosphate? 1
2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite M 01
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic
3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic
4. Volcanics
5. Microphanerites
   - metamorphic
   - chert
   - Granitic - muscovite 1
   - clay 1
6. Accessory Minerals
   - Biotite
   - Muscovite
   - Pyrite 1
   - Hornblende
   - 2
7. Carbonate Cement
   - calcite
   - dolomite
   - 30 < 11.8 / 12
8. Matrix / Pseudomatrix
   - Clay-Altered Grains 1
9. Clay Cement
   - Kaolinite 1
   - 2
10. Intragranular Porosity
    - Quartz — VRF Q, PRF Q
    - K-Feldspar — K, K
    - Plagioclase — P, P
11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores 1
    - Grain-edge dissolution
    - Other
    - 1
12. Other
    - Phosphate (bone?)
    - Petroleum in intragranular porosity

COMMEMTS

zoned plag
zeolite, altered from plag?
Myrmekite.
calcite replaces quartz, feldspar, chert, myrmekite, clays, biotite
some plag does not exhibit twinning, due to calcite cement?

PARAGENESIS

Feldspar overgrowth, then cement replaces overgrowth
Petro migration → pyrite
clay replaces feldspar → calcite replaces feldspar

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P 1	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: FCL 11-11473 T 3
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11473
POINT COUNTS:
SORTING: poorly sorted
COMPACTION: very tight
SIZE: Med sands
ANGULARITY: angular - subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - Plus 1

6. Accessory Minerals
   - Biotite
   - Pyrite
   - Muscovite
   - Sphene

2

7. Carbonate Cement
   - Dolomite
   - Calcite

+14

8. Matrix / Pseudomatrix

1

Clay-Altered Grains

9. Clay Cement
   - Kaolinite
   - Illite / smectite

7

10. Intragranular Porosity
    - Quartz — VRF Q / PRF Q
    - K-Feldspar — K / K
    - Plagioclase — P / P

3

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

34

12. Other
    - Sericite
    - Shell

COMMEMTS

Biotite alters to clay
• Myrmekite
• Q overgrowth.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KU 11-17 11473 T7
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11473
POINT COUNTS:
SORTING: Mod. sorted
COMPACTION: very tight
SIZE: Med sand
ANGULARITY: Angular - subrounded

COMMENTS

1. Quartz
- Moncrystalline
- Polycrystalline
- Microphanerite Granitic
- Volcanic Rock Fragment
- Quartz Arenite
- Other Sedimentary _____
- Metaquartzite
- Other Metamorphic _____

2. K-Feldspar
- Microcline
- Orthoclase
- Sanadine
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

3. Plagioclase
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

4. Volcanics

5. Microphanerites
- Chert
- Granitic-Mus
- Metamorphic chert

6. Accessory Minerals
- Biotite
- Muscovite
- Pyrite
- Sphene
- Zircon
- Glauconite
- Epidote

7. Carbonate Cement
- Dolomite
- Calcite

8. Matrix / Pseudomatrix

Clay-Altered Grains

9. Clay Cement
- Illite/Smectite
- Kaolinite

10. Intragranular Porosity
- Quartz
- K-Feldspar
- Plagioclase

VRF	PRF
Q	Q
K	K
P	P

11. Intergranular Porosity
- Fractures
- Fracture-induced dissolution
- Oversize/elongate pores
- Grain-edge dissolution
- Other _____

12. Other
- Phosphate (bone)

COMMENTS

Myrmekite
Biotite alters to Chlorite
F overgrowth

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11493 T1
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11493

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod

COMPACTION: very tight

SIZE: Med sands

ANGULARITY: subround, some subangular

		COMMENTS
1. Quartz	Moncrystalline Polycrystalline Microphanerite Granitic 1 Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____	
2. K-Feldspar	Microcline Orthoclase Sanadine Microphanerite Granite M O Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
3. Plagioclase	Microphanerite Granitic Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
4. Volcanics		
5. Microphanerites	Chert	
6. Accessory Minerals	Biotite Muscovite 1	
7. Carbonate Cement	Dolomite Calcite	
8. Matrix / Pseudomatrix	Clay-Altered Grains	
9. Clay Cement	Illite/smectite 1	
10. Intragranular Porosity	Quartz K-Feldspar Plagioclase	VRF Q K P PRF Q K P
11. Intergranular Porosity	Fractures Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution	Other _____
12. Other		

COMMEMTS

- Carbonate cement replacing fw grains. Did not see sphene/zircon.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: KCL 11-17 11505-1
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11505'

PROJECT:

ROCK NAME:
POINT COUNTS:

SORTING: Poorly sorted

COMPACTION: Not very tight, pt contact common.

SIZE: med sand

ANGULARITY: subangular - rounded

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - muscovite
   - Clay

6. Accessory Minerals
   - Biotite
   - Muscovite
   - Epidote
   - Pyrite
   - Zircon

7. Carbonate Cement
   - Calcite
   - Dolomite

8. Matrix / Pseudomatrix

Clay-Altered Grains

9. Clay Cement

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P — PRF Q / K / P

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution

    Other _____

12. Other
    - Phosphate (bone?)
    - Pyrite in petroleum?
    - Petroleum in intragranular

COMMEMTS

Myrmekite.
sericite of plag, zoned plag.
plag altered to zeolite?
calcite replaces: biotite, feldspar, quartz, epidote
sericitization of feldspar.
feldspar altering to clay
quartz overgrowth

PARAGENESIS

clay replaces biotite, calcite replaces clay. - mostly in this sample
calcite ppt in 2nd ϕ after grains have dissolved
silicates dissolved providing $Ca + CO_3$

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

Gad 606

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis 3 11404
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11404

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: moderately

SIZE: med

COMPACTION: very tight - concavevo + interpenetrating contacts

ANGULARITY: subrounded - rounded

COMMENTS

1. Quartz	Moncrystalline		
	Polycrystalline		
80	Microphanerite	Granitic	1
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
	Quartz cement		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite	Granitic	M O
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	Chert		Biotite (Bleached)
	metamorphic		
	Muscovite		
6. Accessory Minerals	Biotite		Epidote
	Muscovite		
13	Pyrite		
	Glauconite		
	Zircon Sphene		
7. Carbonate Cement	Dolomite		
24			
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
9. Clay Cement	Kaolinite	1	
10. Intragranular Porosity	Quartz		VRF Q / PRF Q
	K-Feldspar		K / K
	Plagioclase		P / P
11. Intergranular Porosity	Fractures		
28	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution	1	Other
12. Other	Phosphate		
	Petro in intragranular + inter		

COMMEMTS

- phosphate coating which contains fibrous min
- pyrite associated biotite
- phosphate replaced by silica?
- Myrmekite
- Altered biotite to clay
- quartz overgrowth

PARAGENESIS

Grains dep -> calcite thru out
Feldspar replaced by clay -> more compaction

- zeolite cement? or barite?

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
Biotite 1

Geol 606

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis 3 11404 T2
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11404

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

COMPACTION: very tight

SIZE: med

ANGULARITY: subrounded – rounded.

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite	Granitic M O	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	Chert		
	Muscovite		
6. Accessory Minerals	Glauconite		Hornblende
	Muscovite		
	Pyrite		
	Biotite		
	Zircon		
7. Carbonate Cement	Dolomite		
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
9. Clay Cement	Kaolinite	Kaolinite	special category of unknown
10. Intragranular Porosity	Quartz		VRF Q
	K-Feldspar		K
	Plagioclase		P
11. Intergranular Porosity	Fractures		
	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution		Other
12. Other	Phosphate (bone?)		
	Pyrite Cement		
	Petroleum	intergranular	

5 | 49 | 5 | 1 | 36 | 2

COMMEMTS

- sericite
- Biotite melted ??? metamorphic
- Dolomite replacing fw. grains.
- phosphate coating on grain.
- Large kaolinite books or zeolite cement.?
- myrmekite - zoned zircon

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis 4 11460
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11460

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: moderately sorted

SIZE: fine sand

COMPACTION: tight - pt contact common. deformed micas + labiles
ANGULARITY: Angular - subrounded

COMMENTS

85	1. Quartz	Moncrystalline ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| |||	
		Polycrystalline |	
		Microphanerite Granitic ||||| |||||	
		Volcanic Rock Fragment	
		Quartz Arenite	
		Other Sedimentary _____	
		Metaquartzite	
		Other Metamorphic _____	
		chalcedony |	
39	2. K-Feldspar	Microcline ||||| ||||| ||||| ||||| |||||	
		Orthoclase ||||| |||	
		Sanadine	
		Microphanerite Granitic M O |||||	
		Volcanic Rock Fragment	
		Sedimentary _____	
		Metamorphic _____	
98	3. Plagioclase	Microphanerite Granitic |||||	
		Volcanic Rock Fragment	
		Sedimentary _____	
		Metamorphic _____	
6	4. Volcanics	||||| |	
7	5. Microphanerites	Chert ||	
		Granitic - Muscovite |||||	
10	6. Accessory Minerals	Biotite ||||	Pyrite
		Muscovite |	
		Hornblende	
		Glauconite	
		Epidote	
2	7. Carbonate Cement	Calcite |	
		Dolomite |	
2	8. Matrix / Pseudomatrix		
	Clay-Altered Grains ||		
10	9. Clay Cement	Kaolinite ||||| ||	
		Illite/Smectite ||	
	10. Intragranular Porosity	Quartz	VRF Q / PRF Q
		K-Feldspar	K / K
		Plagioclase	P / P
46	11. Intergranular Porosity ||||| |||	Fractures ||
		Fracture-induced dissolution |
		Oversize/elongate pores ||||| ||||| ||||| ||||| ||||| ||||| ||||
		Grain-edge dissolution | Other _____
1	12. Other	Sericite
		Myrmekite |
		petroleum in intragranular

COMMEMTS

Dolomitization : clay
Sericite : plag, micro, quartz, chert
Kaolinite books
Sig [] of 2nd porosity observed, some of the grains are broken ↑, esp. plag. Not sig [] of carb. cement or petro.

PARAGENESIS

Albite replaced plag + K-spar along fracture + etch of grains.
- plag contain blebs of quartz?
some

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P |	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P |	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q |	vrfQ	prfQ
K |||	vrfK	prfK
P ||||| |	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis 4 11467.5
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11467.5'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: Moderately sorted

SIZE: Fine sand

COMPACTION: very tight - deformed labile + micas, long + sutured contacts common
ANGULARITY: subangular - rounded

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		Myrmekite
	Sanadine		
	Microphanerite	Granitic = M O	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	Plag myrmekite
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	Chert		
	Metamorphic		
	Granitic - muscovite		
6. Accessory Minerals	Biotite		chlorite
	Muscovite		sericite
10	Hornblende		
	Zircon		
7. Carbonate Cement	Calcite		
21	Dolomite		
8. Matrix / Pseudomatrix	Clay-Altered Grains		
9. Clay Cement	Illite / smectite		
21	Kaolinite		
10. Intragranular Porosity	Quartz		VRF Q / PRF Q
	K-Feldspar		K / K
	Plagioclase		P / P
11. Intergranular Porosity		Fractures	
		Fracture-induced dissolution	
41		Oversize/elongate pores	
		Grain-edge dissolution	Other
12. Other	Myrmekite		
	Fish scales		
	Petroleum in pore space + intragranular		

COMMEMTS

- Sericitization plag, k-spar, quartz
zoned calcite / dolomite cement are common
Plag + k-spar are almost completely altered to albite
Biotite altering to clay - purple muscovite observed
kaolinite books observed
carbonate cement replacing clays, + biotite

PARAGENESIS

Plag altering to clay kaolinite and overgrowth? see sharpie mark
k-spar contain blebs of quartz? (rounded)
- Metamorphic chlorite exhibiting Berlin blue
- Dissolution along etch of quartz grains are common
- Some

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis - 4 11480
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11480

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

COMPACTION: tight - pt contact common

SIZE: med sand

ANGULARITY: Angular - subrounded

			COMMENTS
1. Quartz	Moncrystalline		
	Polycrystalline		
	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
	Sanadine		
	Microphanerite	M O	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite	Granitic	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics			
5. Microphanerites	chert		
	Granitic - Muscovite		
	Metamorphic		
6. Accessory Minerals	Biotite		zircon
	Muscovite		sphene
	Glauconite		
	Hornblende		
7. Carbonate Cement	Dolomite		
	calcite		
8. Matrix / Pseudomatrix	Biotite altering to clay		
Clay-Altered Grains			
9. Clay Cement	Kaolinite		
	Illite/smectite		
10. Intragranular Porosity	Quartz		VRF Q / PRF Q
	K-Feldspar		K / K
	Plagioclase		P / P
11. Intergranular Porosity	Fractures		
	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution		Other
12. Other	Phosphate shell		
	Myrmekite		
	Petroleum in intergranular ϕ		

9
16
4
13
0
28
1

COMMEMTS

Volcanic → zeolites ? : altering volcanic glass
Sericitization : plag.
Quartz contain volcanic inclusions (plag)
Biotite altering to clay
Myrmekite
Quartz overgrowth (common)
Albite altering to clay

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis-4 11491
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11491

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod. sorted
SIZE: Med sand

COMPACTION: very tight.
ANGULARITY: Angular - subround.

COMMENTS

1. Quartz
- Moncrystalline
- Polycrystalline
- Microphanerite Granitic
- Volcanic Rock Fragment
- Quartz Arenite
- Other Sedimentary _____
- Metaquartzite
- Other Metamorphic _____

2. K-Feldspar
- Microcline
- Orthoclase
- Sanadine
- Microphanerite Granitic — M O
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

3. Plagioclase
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

4. Volcanics

5. Microphanerites Chert, Granitic - Muscovite

8

6. Accessory Minerals: Pyrite, Biotite, Sphene, Muscovite, Zircon; Glauconite

13

7. Carbonate Cement: Dolomite, Calcite

2

8. Matrix / Pseudomatrix
- Clay-Altered Grains

9. Clay Cement: Kaolinite, Illite/Smectite

18

10. Intragranular Porosity: Quartz, K-Feldspar, Plagioclase

	VRF	PRF
Q		
K		
P		

11. Intergranular Porosity

32

- Fractures
- Fracture-induced dissolution
- Oversize/elongate pores
- Grain-edge dissolution
- Other _____

12. Other: Fossils, Phosphate (bone), Retro in intragranular & coating

1

COMMEMTS

Zoned dolomite
Biotite altering to clay + chlorite
Dolomite nxt to biotite + pyrite b/w cleavage
- Sericite
- Myrmekite
- zeolite
- Forergrowth

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
4 Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
5 K	vrfK	prfK
14 P	vrfP	prfP

OTHER

_____
_____

7/21/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Lewis - 4 11493
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11493

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod sorted
SIZE: Med sand

COMPACTION: very tight
ANGULARITY: subangular - subrounded

		COMMENTS
1. Quartz	Moncrystalline Polycrystalline Microphanerite Granitic Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____	
2. K-Feldspar	Microcline Orthoclase Sanadine Microphanerite Granitic M O Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
3. Plagioclase	Microphanerite Granitic Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
4. Volcanics		
5. Microphanerites	Chert Granitic - Muscovite	
6. Accessory Minerals	Biotite Pyrite Glauconite Muscovite Sphene	
7. Carbonate Cement	Dolomite Calcite	
8. Matrix / Pseudomatrix		
Clay-Altered Grains		
9. Clay Cement	Kaolinite	
10. Intragranular Porosity	Quartz K-Feldspar Plagioclase	VRF Q K P PRF Q K P
11. Intergranular Porosity	Fractures Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution Other _____	
12. Other	phosphate coating petro	

10
105
0
5
0
5
0

COMMEMTS

Falters to zeolite -
carbonate replace FW grains
- Biotite alters to clay, pyrite wi biotite cleavage
- K-spar overgrowth
Dolomite replacing calcite.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Moore -2 11408-1
FORMATION (AGE): appeared as 11408-2 in Lefca
LOCATION:
DEPTH: 11408'

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted
SIZE: fine -med.

COMPACTION: floating due to sig. carbonate cement replacing fw grains
ANGULARITY: angular - subangular

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline ||
   - Orthoclase
   - Sanadine
   - Microphanerite — M / O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite Granitic |||
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics |

5. Microphanerites Chert

6. Accessory Minerals
   - Sphene
   - Pyrite |||
   - Glauconite ||
   - Biotite
   - Chlorite

5

172 7. Carbonate Cement
   - Calcite
   - Dolomite

8. Matrix / Pseudomatrix

Clay-Altered Grains

9. Clay Cement

10. Intragranular Porosity
   - Quartz — VRF Q / PRF Q
   - K-Feldspar — K / K
   - Plagioclase — P / P

11. Intergranular Porosity
   - Fractures
   - Fracture-induced dissolution
   - Oversize/elongate pores ||
   - Grain-edge dissolution
   - Other

2

49 12. Other
   - Phosphate
   - Pyrite cement
   - Petro in intra..t.nitu
   - Fossils (calcite tests) ||

COMMEMTS

-Fractured glauconite, dolomite replace glauconite along fracture and phosphate
-Abundant dolomite cement and phosphate nodules and coatings.
-zoned plag

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OTHER		

PARAGENESIS

Partially dissolved feldspar, plag, oil moved in, pyrite formed, phosphate coating, dolomite cement
- Glauconite -> fractured, coated phosphate -> phosphate replace glauconite -> dolomite replace glauconite

Geol 606

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Mor 2 11418-2
FORMATION (AGE):
LOCATION: Greeley oil Field
DEPTH: 11418'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: Moderately sorted

SIZE: Med sand

COMPACTION: Very tight - some pt contacts; sutured + concavo convex + long common

ANGULARITY: Angular to subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics

5. Microphanerites
   - chert
   - metamorphic chert
   - muscovite

6. Accessory Minerals
   - Biotite
   - Glauconite
   - Sphene
   - Pyrite
   - Muscovite
   - Zircon

6

7. Carbonate Cement
   - Dolomite

10

8. Matrix / Pseudomatrix

Clay-Altered Grains

9. Clay Cement
   - Kaolinite?
   - Illite / smectite

6

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P — PRF Q / K / P

22

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other

3

12. Other
    - Myrmekite
    - Phosphate? (bone)
    - Retro in intra

1

COMMEMTS

- Biotite altering to clay
- coating on Glauconite like 11408-1TS
- Stained for K-spar
- pure plag + quartz (myrmekite) or K-spar exhibiting myrmekitic texture
- sericitization of feldspar (saw 2
- Feldspar alters to zeolites

PARAGENESIS

Dolomite replacing framework grains

sig CJ of 2nd ϕ created by dissolution

- Feldspar (plag?) replaced by kaolinite?

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Mor 3 11474-2
FORMATION (AGE):
LOCATION: Greeley oil Field
DEPTH: 11474
SORTING: Poorly sorted
SIZE: Med sands

PROJECT:
ROCK NAME:
POINT COUNTS:
COMPACTION: Very tight, little pt. contact
ANGULARITY: angular to subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic M O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - Muscovite

6. Accessory Minerals
   - Sphene
   - Muscovite
   - Biotite
   - Pyrite
   - Glauconite

8

7. Carbonate Cement
   - Dolomite
   - Calcite

9

8. Matrix / Pseudomatrix
   - Clay-Altered Grains

9. Clay Cement
   - Kaolinite
   - Illite/smectite

18

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase

VRF Q K P — PRF Q K P

2

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other

42

12. Other
    - Zeolite cement??
    - Phosphate

1

COMMEMTS

- Biotite alters to clay
- F alters to zeolite, sericite
- F overgrowth
- phosphate coating on grains
- plag overgrowth - zoned - F fractures healed by overgrowth
- Hymenite.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

7/11/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Mor-3 11474B
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field
ROCK NAME:
DEPTH: 11,474'
POINT COUNTS:

SORTING: Mod. sorted
COMPACTION: very tight

SIZE: Med. Sand
ANGULARITY: subround /some angular

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - Muscovite

6. Accessory Minerals (6)
   - Muscovite
   - Biotite
   - Glauconite
   - Pyrite
   - Chlorite
   - Sphene
   - Glauconite
   - Zircon

7. Carbonate Cement (16)
   - Dolomite

8. Matrix / Pseudomatrix

Clay-Altered Grains

9. Clay Cement (4)
   - Kaolinite

10. Intragranular Porosity (3)
    - Quartz
    - K-Feldspar
    - Plagioclase
    - VRF Q / K / P
    - PRF Q / K / P

11. Intergranular Porosity (39)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other

12. Other (7)
    - Hematite coating
    - Phosphate (core)
    - petra in intragranular ϕ
    - Phosphate coating

COMMEMTS

Biotite altering to clay and chlorite
- sericite
- F alters to zeolite
Myrmekite
- F overgrowth.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Mor-3 11474-3a
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley
DEPTH: 11474
ROCK NAME:
POINT COUNTS:
SORTING: Mod sorted.
COMPACTION: very tight
SIZE: Med sand.
ANGULARITY: angular - subround

COMMENTS

1. Quartz
- Moncrystalline
- Polycrystalline
- Microphanerite Granitic
- Volcanic Rock Fragment
- Quartz Arenite
- Other Sedimentary
- Metaquartzite
- Other Metamorphic

2. K-Feldspar
- Microcline
- Orthoclase
- Sanadine
- Microphanerite Granitic M O
- Volcanic Rock Fragment
- Sedimentary
- Metamorphic

3. Plagioclase
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary
- Metamorphic

4. Volcanics

5. Microphanerites
- chert
- Granitic - Muscovite

6. Accessory Minerals
- Biotite
- Pyrite
- Sphene
- Muscovite

7

7. Carbonate Cement
- Dolomite
- Calcite

8

8. Matrix / Pseudomatrix
- Clay-Altered Grains

9. Clay Cement
- Kaolinite
- Illite/smectite

14

10. Intragranular Porosity
- Quartz
- K-Feldspar
- Plagioclase

VRF Q / K / P — PRF Q / K / P

1

11. Intergranular Porosity
- Fractures
- Fracture-induced dissolution
- Oversize/elongate pores
- Grain-edge dissolution
- Other

34

12. Other
- Phosphate (bone)
- sericite
- Phosphate coating like

3

COMMEMTS
- F alters to sericite + clay + zeolite.
- zeolite cement.
- Myrmekite.
- Myrmekitic texture
- Lots of zeolites
- Biotite alters to clay
- zoned dolomite.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SEM

8/19/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Mor - 3 11474-4
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field
ROCK NAME:
DEPTH: 11474
POINT COUNTS:
SORTING: Mod. sorted
COMPACTION: very tight.
SIZE: Med sands
ANGULARITY: Angular - round.

COMMENTS

1. Quartz	Moncrystalline	
	Polycrystalline	
	Microphanerite	Granitic II
	Volcanic Rock Fragment	
	Quartz Arenite	
	Other Sedimentary	
	Metaquartzite	
	Other Metamorphic	
2. K-Feldspar	Microcline	
	Orthoclase	
	Sanadine	
	Microphanerite	Granitic M O
	Volcanic Rock Fragment	
	Sedimentary	
	Metamorphic	
3. Plagioclase	Microphanerite	Granitic
	Volcanic Rock Fragment	
	Sedimentary	
	Metamorphic	
4. Volcanics		
5. Microphanerites	chert	
	Granitic - Muscovite	
6. Accessory Minerals	Pyrite	
	Biotite	
13	Muscovite	
	Epidote	
	Glauconite	
7. Carbonate Cement	Dolomite	
1		
8. Matrix / Pseudomatrix		
Clay-Altered Grains		
9. Clay Cement	Kaolinite	
10	Illite/smectite	
10. Intragranular Porosity	Quartz	VRF Q / PRF Q
	K-Feldspar	K / K
1	Plagioclase	P / P
11. Intergranular Porosity	Fractures	
	Fracture-induced dissolution	
37	Oversize/elongate pores	
	Grain-edge dissolution	Other
12. Other	Phosphate	
1	Zeolite cement ?	barite cement

COMMEMTS

- zeolite cement.
- Myrmekite.
- Myrmekite
- Biotite alters to clay
- echinoderm
- zeolite formed w/ Biotie clearage → see sharpe marlc

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

6/29/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: MOR-3 11474-75
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field.
DEPTH: 11474
ROCK NAME:
POINT COUNTS:

SORTING: Moderately sorted
COMPACTION: very tight

SIZE: Med
ANGULARITY: subangular - subround

COMMENTS

1. Quartz
- Moncrystalline
- Polycrystalline
- Microphanerite Granitic
- Volcanic Rock Fragment
- Quartz Arenite
- Other Sedimentary _____
- Metaquartzite
- Other Metamorphic _____

2. K-Feldspar
- Microcline
- Orthoclase
- Sanadine
- Microphanerite Granitic M O
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

3. Plagioclase
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

4. Volcanics

5. Microphanerites chert
granitic- muscovite

6. Accessory Minerals (15)
- Biotite
- chlorite
- Muscovite
- Glauconite
- Pyrite

7. Carbonate Cement (3)
- Calcite

8. Matrix / Pseudomatrix (0)

Clay-Altered Grains

9. Clay Cement (10)
- Kaolinite
- Illite/smectite

10. Intragranular Porosity (1)
- Quartz
- K-Feldspar
- Plagioclase

VRF Q
K
P

PRF Q
K
P

11. Intergranular Porosity (52)
- Fractures
- Fracture-induced dissolution
- Oversize/elongate pores
- Grain-edge dissolution

Other _____

12. Other (9)
- Phosphate (bone)
- Fossils
- Petro in intragranular

Pyrite cement 1
Barite ~~zeolite~~
phosphate coating

COMMEMTS
- Biotite altering to clay, chlorite, sericite
- F alters to zeolites. Zeolite cements.
- Myrmekite
- Abundant secondary ϕ caused by dissolution
- Zoned plag.
- Hematite coating on grain
- F overgrowth + Q overgrowth

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

8 Q	vrfQ		prfQ
3/< K	vrfK		prfK
P	vrfP	2	prfP

OTHER

_____
_____

#59

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: SCh-1 11480
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11480

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod sorted
SIZE: Med sands

COMPACTION: very tight : little pt contact
ANGULARITY: angular – subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic – M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites chert

6. Accessory Minerals (Ø)
   - Biotite
   - Muscovite
   - sphene
   - Glauconite.

7. Carbonate Cement (2)
   - Dolomite

8. Matrix / Pseudomatrix (Ø)
   - Clay-Altered Grains

9. Clay Cement (26)
   - Kaolinite
   - Illite/smectite

10. Intragranular Porosity (2)
    - Quartz
    - K-Feldspar
    - Plagioclase

VRF	PRF
Q	Q
K	K
P	P

11. Intergranular Porosity (38)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

12. Other (2)
    - phosphate (bone?)
    - shell echinoderm?

COMMEMTS

- F alters to zeolites, sericite.
- Myrmekite
- K-spar overgrowth - zoned
- stained for K-spar
- Q overgrowth
- pt contact mainly from overgrowth

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Sch-1 11480 #58
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11480

PROJECT: Nguyen M.S.
ROCK NAME:
POINT COUNTS:

SORTING: Poorly sorted
SIZE: fine sands.

COMPACTION: very tight
ANGULARITY: angular to subround

			COMMENTS
30	1. Quartz	Moncrystalline Polycrystalline Microphanerite Granitic Volcanic Rock Fragment Quartz Arenite Other Sedimentary _____ Metaquartzite Other Metamorphic _____	
	2. K-Feldspar	Microcline Orthoclase Sanadine Microphanerite Granitic M O Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
	3. Plagioclase	Microphanerite Granitic Volcanic Rock Fragment Sedimentary _____ Metamorphic _____	
	4. Volcanics		
	5. Microphanerites	chert	
8	6. Accessory Minerals	Muscovite Biotite Pyrite Glauconite	
113	7. Carbonate Cement	Dolomite Calcite	
23	8. ~~Matrix~~ Pseudomatrix		
		Clay-Altered Grains	
8	9. Clay Cement	Illite/smectite Kaolinite	
0	10. Intragranular Porosity	Quartz K-Feldspar Plagioclase	VRF Q K P PRF Q K P
1	11. Intergranular Porosity	Fractures Fracture-induced dissolution Oversize/elongate pores Grain-edge dissolution	Other _____
	12. Other	Shell	

COMMEMTS
- staind for K-spar
Dolomite replacing fw grains (dolomite appear zoned)
- Myrmekite.
- Biotite alters to clay.

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OTHER		
_____		
_____		

PARAGENESIS

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Scho-1 11480 T4
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley Oil Field
ROCK NAME:
DEPTH: 11480
POINT COUNTS:

SORTING: Mod Sorted
COMPACTION: very tight

SIZE: Med - fine
ANGULARITY: subangular - round

COMMENTS

1. Quartz
- Moncrystalline
- Polycrystalline
- Microphanerite Granitic
- Volcanic Rock Fragment
- Quartz Arenite
- Other Sedimentary _____
- Metaquartzite
- Other Metamorphic _____

2. K-Feldspar
- Microcline
- Orthoclase
- Sanadine
- Microphanerite Granitic — M O
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

3. Plagioclase
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary _____
- Metamorphic _____

4. Volcanics

5. Microphanerites Chert

6. Accessory Minerals (4)
- Pyrite
- Biotite
- Muscovite
- sphene
- zircon

7. Carbonate Cement (2)
- Dolomite

8. Matrix / Pseudomatrix (1)

Clay-Altered Grains

9. Clay Cement (22)
- Illite/smectite
- Kaolinite

10. Intragranular Porosity (5)
- Quartz — VRF Q, PRF Q
- K-Feldspar — VRF K, PRF K
- Plagioclase — VRF P, PRF P

11. Intergranular Porosity (30)
- Fractures
- Fracture-induced dissolution
- Oversize/elongate pores
- Grain-edge dissolution
- Other _____

12. Other (1)
- phosphate
- abundant petro

COMMEMTS

Abundant petroleum
F overgrowth.
zeolites
F alters to sericite, clay

PARAGENESIS

F dissolved & overgrowth remained.
Q overgrowth?

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OTHER	volcanic	

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: SCU-1 11480 T6
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11480

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

SIZE: fine sands

COMPACTION: very tight : pt contacts abundant
ANGULARITY: Angular - subround.

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

4. Volcanics

5. Microphanerites Chert
   Granitic-Muscovite

6. Accessory Minerals
   - Biotite
   - Pirite
   - Muscovite
   - Zircon
   - Glauconite
   - Sphene

B

7. Carbonate Cement
   - Dolomite
   - Calcite

58

8. Matrix
   Pseudomatrix
   Clay-Altered Grains

34

9. Clay Cement
   - Kaolinite
   - Illite/smectite

3

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P
    PRF Q / K / P

0

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution

    Other

5

12. Other
    - Shells (echinoderm)
    - Retro blebs

0

COMMEMTS

- Biotite altering to clay + chlorite
- Matrix may contain illite/smectite & kaolinite.
- Myrmekite
- Fovergrowth

PARAGENESIS

- Dolomite replacing calcite

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

5 THIN SECTION: Sch - 11480-7

PROJECT: Nguyen MS

FORMATION (AGE):

LOCATION: Greeley

ROCK NAME:

DEPTH: 11480

POINT COUNTS:

SORTING: well sorted

COMPACTION: very tight

SIZE: Fine

ANGULARITY: Angular - subround

COMMENTS

1. Quartz	Moncrystalline	
	Polycrystalline	
	Microphanerite	Granitic 1
	Volcanic Rock Fragment	
	Quartz Arenite	
	Other Sedimentary _____	
	Metaquartzite	
	Other Metamorphic _____	
2. K-Feldspar	Microcline	
	Orthoclase	
	Sanadine	
	Microphanerite	Granitic M O
	Volcanic Rock Fragment	
	Sedimentary _____	
	Metamorphic _____	
3. Plagioclase	Microphanerite	Granitic
	Volcanic Rock Fragment	
	Sedimentary _____	
	Metamorphic _____	
4. Volcanics		
5. Microphanerites	Chert	
6. Accessory Minerals	Sphene	
	biotite	
	Muscovite	
	zircon	
7. Carbonate Cement	Dolomite	
	Calcite	
8. Matrix / Pseudomatrix		
Clay-Altered Grains	1	
9. Clay Cement		
10. Intragranular Porosity	Quartz	VRF Q / PRF Q
	K-Feldspar	K / K
	Plagioclase 1	P / P
11. Intergranular Porosity	Fractures 1	
	Fracture-induced dissolution	
	Oversize/elongate pores 1	
	Grain-edge dissolution	Other _____
12. Other	Phosphate	
	Shell 1	

18

90

1

1

4 fractures along lamination

1

COMMEMTS

laminated

Matrix - contains clays + some petro

F overgrowth

- Biotite alters to clay

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____

_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11475
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11475'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

COMPACTION: very tight. little pt contai

SIZE: very fine sand

ANGULARITY: subangular - subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites Chert
   granitic - muscovite

6. Accessory Minerals
   - Muscovite
   - Pyrite
   - Glauconite
   - Biotite
   - Sphene

22

7. Carbonate Cement
   - Calcite

0

8. Matrix / Pseudomatrix

85

Clay-Altered Grains

9. Clay Cement
   - Illite/smectite

26

10. Intragranular Porosity
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P — PRF Q / K / P

0

11. Intergranular Porosity
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution

    Other _____

0

12. Other
    - Phosphate (bone)
    - Petro in intergranular

5

COMMEMTS
- Abundant matrix : clay + organic
- Biotite altering to chlorite
- stained for K-spar

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

7/10/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11489
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11489

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

SIZE: fine to med sand

COMPACTION: very tight : abundant long contacts
ANGULARITY: angular - subrounded

COMMENTS

1. Quartz
- Moncrystalline
- Polycrystalline
- Microphanerite Granitic
- Volcanic Rock Fragment
- Quartz Arenite
- Other Sedimentary
- Metaquartzite
- Other Metamorphic

2. K-Feldspar
- Microcline
- Orthoclase
- Sanadine
- Microphanerite Granitic — M O
- Volcanic Rock Fragment
- Sedimentary
- Metamorphic

3. Plagioclase
- Microphanerite Granitic
- Volcanic Rock Fragment
- Sedimentary
- Metamorphic

4. Volcanics

5. Microphanerites
- chert
- granitic - muscovite

6. Accessory Minerals (18)
- Pyrite
- Glauconite
- Sphene
- Biotite
- Chlorite
- Muscovite

7. Carbonate Cement (55)
- Dolomite
- Calcite

8. Matrix (45)
- Pseudomatrix
- Clay-Altered Grains

9. Clay Cement (4)
- Illite/smectite

10. Intragranular Porosity (0)
- Quartz
- K-Feldspar
- Plagioclase

VRF Q / K / P — PRF Q / K / P

11. Intergranular Porosity (1)
- Fractures
- Fracture-induced dissolution
- Oversize/elongate pores
- Grain-edge dissolution

Other

12. Other (1)
- fossil
- phosphate coating
- petroleum coated mica and in intragranular

COMMEMTS
- stained for K-spar
- sericite
- Metamorphic biotite
- Little ϕ
- K-spar exhibiting myimetitic texture
- Abundant matrix
  - Matrix contains clay
  - " " organics

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

PARAGENESIS

- Biotite altering to clay and chlorite, chlorite exhibiting blue in color

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen
THIN SECTION: Vale-1 11490
FORMATION (AGE):
LOCATION: Greeley
DEPTH: 11490'
PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted
SIZE: Fine sands
COMPACTION: slightly compacted
ANGULARITY: subangular

COMMENTS

1. Quartz
Moncrystalline 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 ||||
Polycrystalline |
Microphanerite Granitic ||
Volcanic Rock Fragment
Quartz Arenite
Other Sedimentary
Metaquartzite
Other Metamorphic

2. K-Feldspar
Microcline 卌 卌 ||
Orthoclase 卌 卌 卌 卌 卌 卌 ||||
Sanadine
Microphanerite Granitic — M || O ||
Volcanic Rock Fragment |
Sedimentary
Metamorphic

3. Plagioclase
Microphanerite Granitic 卌 卌
Volcanic Rock Fragment
Sedimentary
Metamorphic
卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 |||

4. Volcanics |||

5. Microphanerites Chert ||
Granitic-Muscovite ||||

6. Accessory Minerals
Glauconite
Biotite |
sphene
Muscovite |
Hornblende
Zircon
Epidote

6

7. Carbonate Cement
Dolomite 卌 卌 ||
Calcite

12

8. Matrix / Pseudomatrix

0

Clay-Altered Grains 卌 |||

9. Clay Cement
kaolinite 卌 卌
illite/smectite

18

10. Intragranular Porosity
Quartz
K-Feldspar
Plagioclase
VRF Q
K
P
PRF Q
K
P

0

11. Intergranular Porosity 卌 卌 卌 |||
Fractures ||
Fracture-induced dissolution |
Oversize/elongate pores 卌 卌 卌 卌 卌 卌 卌 |
Grain-edge dissolution ||
Other

59

12. Other
Myrmekite
Sericite
Petro in intra- + intergranular
Ankerite in biotite? see Sharpe mark.

COMMEMTS

- Sericitization: plag, K-spar
- K-spar exhibiting myrmekitic texture? + plag
- Biotite altering to clays & leached
- Some grains are completely altered to sericite
- Metamorphic grains w/ carbonate veins + quartz veins.
- zoned plag is common

PARAGENESIS

- volcanics - zeolite - fibrous + clay coated?
- Calcite replaced by dolomite
- Albite replaced plag, some plag grains are almost completely replaced by albite

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P |	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q |	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

4

Q |||	vrfQ	prfQ
K 卌	vrfK	prfK
P 卌 ||	vrfP	prfP

12

OTHER

6/12/13

SANDSTONE PETROGRAPHY DATA

THIN SECTION: Vale-1 11492 T3C
FORMATION (AGE):
LOCATION: Greeley oil Field
DEPTH: 11492

EXAMINED BY: Nguyen
PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod. sorted

SIZE: Med Sands

COMPACTION: very tight: little pt contacts concavo-convex + long contacts common
ANGULARITY: Subangular - subround.

COMMENTS

1. Quartz
   - Moncrystalline 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||
   - Polycrystalline ||
   - Microphanerite Granitic |
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary
   - Metaquartzite
   - Other Metamorphic

2. K-Feldspar
   - Microcline 𝍸 𝍸 𝍸 𝍸 ||||
   - Orthoclase 𝍸 𝍸 |||
   - ~~Sanadine~~
   - Microphanerite Granite M || O
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

3. Plagioclase
   - Microphanerite Granitic 𝍸 |
   - Volcanic Rock Fragment
   - Sedimentary
   - Metamorphic

𝍸 |||

4. Volcanics 𝍸 𝍸 𝍸 |||| \

5. Microphanerites
   - Chert 𝍸 |||
   - Granitic - Muscovite |

6. Accessory Minerals — 2
   - Pyrite |
   - Muscovite
   - Biotite
   - Zircon

7. Carbonate Cement — 35
   - Dolomite 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸
   - Calcite

8. Matrix / Pseudomatrix — 0

Clay-Altered Grains

9. Clay Cement — 3
   - Illite/smectite
   - Clay (kao) |||

10. Intragranular Porosity — 0
   - Quartz
   - K-Feldspar
   - Plagioclase

VRF Q
K
P

PRF Q
K
P

11. Intergranular Porosity — 29
   - Fractures
   - Fracture-induced dissolution
   - Oversize/elongate pores 𝍸 𝍸 𝍸 𝍸 𝍸 ||
   - Grain-edge dissolution |||

Other

12. Other — 0

COMMEMTS

Biotite altering to clay
F altering to clay/zeolites
F overgrowth
Myrmekite
Dolomite replacing few grains

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q ||	vrfQ	prfQ
K	vrfK	prfK
P |	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q 𝍸 ||	vrfQ	prfQ
K ||	vrfK	prfK
P 𝍸 ||||	vrfP	prfP

OTHER

vol rf ||

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11493
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11493

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Mod sorted

SIZE: med sand

COMPACTION: very tight: abundant concavo-convex & long contacts, little pt. contacts.
ANGULARITY: angular - subangular

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites
   - Chert
   - Granitic - Muscovite

6. Accessory Minerals (9)
   - Pyrite
   - Biotite
   - Muscovite
   - Sphene
   - Zircon

7. Carbonate Cement (58)
   - Dolomite
   - Calcite

8. Matrix / Pseudomatrix (0)

Clay-Altered Grains

9. Clay Cement (7)
   - Kaolinite

10. Intragranular Porosity (4)
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P — PRF Q / K / P

11. Intergranular Porosity (32)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

12. Other (0)

COMMEMTS

Biotite alters to clay
F alters to zeolites
Q overgrowth
sericite.

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11497
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11497
SORTING: poorly sorted
SIZE: Med sand

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:
COMPACTION: very tight, little pt contacts
ANGULARITY: subround - subangular

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic 1
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granite M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites Chert
   Granitic - Muscovite 1

6. Accessory Minerals (11)
   - Sphene
   - Zircon
   - Pyrite
   - Biotite
   - Muscovite
   - Glauconite

7. Carbonate Cement (60)
   - Dolomite

8. Matrix / Pseudomatrix (12)

Clay-Altered Grains

9. Clay Cement (28)
   - Illite / Smectite
   - Kaolinite

10. Intragranular Porosity (0)
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q K P — PRF Q K P

11. Intergranular Porosity (4)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution

    Other _____

12. Other (1)
    - Phosphate coating 1
    - Petro in Intra

COMMEMTS

Some matrix
FW grains replaced by dolomite
pyrite cement
Muscovite - green
Biotite altering to clay
zeolites from F alteration
· zoned zircon

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen
THIN SECTION: Vale-1 11499 #31
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field
DEPTH: 11499'
ROCK NAME:
POINT COUNTS:
SORTING: Poorly sorted
COMPACTION: mod. compacted. deformed micas, point contacts, little sutured/long contacts
SIZE: Fine sand
ANGULARITY: Angular - subangular

COMMENTS

81 1. Quartz
Moncrystalline 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 |||
Polycrystalline 𝍸
Microphanerite Granitic 𝍸 |||
Volcanic Rock Fragment
Quartz Arenite
Other Sedimentary
Metaquartzite
Other Metamorphic
chalcedony

38 2. K-Feldspar
Microcline 𝍸 𝍸 𝍸 𝍸
Orthoclase 𝍸 𝍸 𝍸
Sanadine
Microphanerite — M || O |
Volcanic Rock Fragment
Sedimentary
Metamorphic

16 3. Plagioclase
Microphanerite Granitic 𝍸 |
Volcanic Rock Fragment
Sedimentary
Metamorphic

𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸

2 4. Volcanics ||

5 5. Microphanerites
Chert |
Granitic - Muscovite ||||

9 6. Accessory Minerals
Biotite ||||
Muscovite
Glauconite |
Sphene
Pyrite
Epidote

27 7. Carbonate Cement
Dolomite 𝍸 𝍸 𝍸 𝍸
calcite 𝍸 ||

1 8. Matrix / Pseudomatrix |

Clay-Altered Grains

26 9. Clay Cement
Illite/smectite ||||
Kaolinite 𝍸 𝍸 𝍸 𝍸 ||

10. Intragranular Porosity
Quartz
K-Feldspar
Plagioclase
VRF Q
K
P
PRF Q
K
P

34 11. Intergranular Porosity 𝍸 𝍸 𝍸 ||
Fractures
Fracture-induced dissolution
Oversize/elongate pores 𝍸 𝍸 ||
Grain-edge dissolution 𝍸
Other

5 12. Other
Sericite
Myrmekite
petro in intragranular + intergranular
~~Barite~~
Laumontite cement |
incomplete clay alter to $CaCO_3$ ||||

COMMEMTS

ritization: chert, plag, + quartz, k-spar, clay
plag is the most deformed min. Dolo/calcite cement is quite abundant, some dolomite crystals are euhedral, others are poikilitic. Grains are slightly compacted, mostly pt contact, little long grain + sutured contacts.

SECONDARY INTERGRANULAR POROSITY
FRACTURE-INDUCED DISSOLUTION
Q vrfQ prfQ
K vrfK prfK
P vrfP prfP
GRAIN-EDGE DISSOLUTION
Q | vrfQ prfQ
K ||| vrfK prfK
P | vrfP prfP
OVERSIZE/ELONGATE PORES
Q ||| vrfQ prfQ
K || vrfK prfK
P 𝍸 || vrfP prfP
OTHER

PARAGENESIS

Biotite being replaced by clay minerals
Carbonate cement replacing quartz, feldspar, clays, and micas
Abundant dissolution of grains - k-spar
clay coating prior to Feldspar dissolution. Hydrocarbon replaing carbonate cement

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale 11499T1
FORMATION (AGE):
LOCATION: Greeley
DEPTH: 11,499'

PROJECT: Nguyen MS

ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

COMPACTION: packed, not alot of sutured and concave convex

SIZE: fine - med sand

ANGULARITY: angular - subround

COMMENTS

1. Quartz (33, 5)
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar (38, 6)
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase (24, 62)
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics (Ø)

5. Microphanerites (5)
   - Chert
   - Microphanerite - Mus

6. Accessory Minerals (7)
   - Muscovite
   - Biotite
   - Glauconite
   - Pyrite

7. Carbonate Cement (6)
   - Dolomite
   - Calcite

8. Matrix (78) / Pseudomatrix

Clay-Altered Grains (+31) (109)

9. Clay Cement

10. Intragranular Porosity

	VRF	PRF
Quartz	Q	Q
K-Feldspar	K	K
Plagioclase	P	P

11. Intergranular Porosity (fractures lam) (5)
   - Fractures
   - Fracture-induced dissolution
   - Oversize/elongate pores
   - Grain-edge dissolution
   - Other _____

12. Other (1)
   - phosphate
   - petro
   - shell phosphate

COMMEMTS

stained TS for K-spar.
Matrix w/ fractures. Less matrix appeared along fracture
phosphate coating
Dolomite cement.
phosphate replacing q, F, chert, volcanics
Sig % of matrix

PARAGENESIS

carbonate cement replacing flw grains
Pyrite in petro

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11499
FORMATION (AGE):
LOCATION: Greeley
DEPTH: 11499

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: poorly sorted

COMPACTION: very tight, concavo convex + sutured

SIZE: sm - med sand

ANGULARITY: Angular - subangular

COMMENTS

1. Quartz	Moncrystalline		
49	Polycrystalline		
	Microphanerite Granitic		
2	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
2. K-Feldspar	Microcline		
	Orthoclase		
31	Sanadine		
4	Microphanerite Granitic	M / O	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase 7	Microphanerite Granitic		
	Volcanic Rock Fragment 1		
	Sedimentary		
82	Metamorphic		
6 4. Volcanics			
5. Microphanerites	Chert		
3			
6. Accessory Minerals	Muscovite	sphene	
	Biotite		
4	Pyrite		
	Zircon		
	Glauconite		
7. Carbonate Cement	Calcite		
20	Dolomite		
8. Matrix / Pseudomatrix			
Clay-Altered Grains			
1 9. Clay Cement	Kaolinite 1		
10. Intragranular Porosity	Quartz	VRF Q	PRF Q
	K-Feldspar	K	K
7	Plagioclase	P	P
11. Intergranular Porosity	Fractures		
	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution	Other	
83 12. Other	Phosphate		
	Petro		

COMMEMTS
TS stained for K-spar
pyrite w/i petro
Sig[?] of phosphate cement

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K 1	vrfK	prfK
P 1	vrfP	prfP

OTHER

SANDSTONE PETROGRAPHY DATA

THIN SECTION: Vale-1 11501 | EXAMINED BY: Nguyen
FORMATION (AGE): | PROJECT: Nguyen US
LOCATION: Greeley oil field | ROCK NAME:
DEPTH: 11501' | POINT COUNTS:

SORTING: Mod-poorly sorted | COMPACTION: Slightly compacted-deformed labile+micas, mostly pt contacts
SIZE: Fine Sand | ANGULARITY: angular-subround

			COMMENTS
1. Quartz	Moncrystalline	54	
	Polycrystalline		
	Microphanerite Granitic		
	Volcanic Rock Fragment		
	Quartz Arenite		
	Other Sedimentary		
	Metaquartzite		
	Other Metamorphic		
	chalcedony		
2. K-Feldspar	Microcline	29	
	Orthoclase		
	Sanadine		
	Microphanerite M O		
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
3. Plagioclase	Microphanerite Granitic	116	
	Volcanic Rock Fragment		
	Sedimentary		
	Metamorphic		
4. Volcanics		4	
5. Microphanerites	Chert	5	
	Granitic-musconte		
6. Accessory Minerals	Biotite	7	
	Sphene		
	Musconte		
	Glauconite		
7. Carbonate Cement	Dolomite	21	
	calcite		
8. Matrix / Pseudomatrix		0	
Clay-Altered Grains			
9. Clay Cement	Illite/Smectite	27	
	Kaolinite		
10. Intragranular Porosity	Quartz	0	VRF Q / PRF Q
	K-Feldspar		K / K
	Plagioclase		P / P
11. Intergranular Porosity	Fractures	40	
	Fracture-induced dissolution		
	Oversize/elongate pores		
	Grain-edge dissolution		Other
12. Other	zeolite, ~~Laumontite~~ cement		
	Sericite		
	Myrmekite		

zoned sanidine
Petroleum in intragranular + intergranular

COMMEMTS

Sericitization: plag + K-spar
Carbonate cement: plag, K-spar, quartz, clay. They formed in pore space, along fractures, + grain etch
- Rutile needle in quartz, QKP exhibit grain edge dissolution.
- Biotite altered to clay, then clay being altered to dolomite
- Plag altering to clay

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
GRAIN-EDGE DISSOLUTION		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP
OVERSIZE/ELONGATE PORES		
Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER
_____
_____

7/20/13

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11511 - 14c
PROJECT: Nguyen MS
FORMATION (AGE):
LOCATION: Greeley oil field
ROCK NAME:
DEPTH: 11,511'
POINT COUNTS:
SORTING: poorly sorted
COMPACTION: very tight, little pt contac
SIZE: med sand
ANGULARITY: angular - subround

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic — M / O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites Chert
   Granitic - Muscovite

6. Accessory Minerals (7)
   - Pyrite
   - Biotite
   - Muscovite
   - Glauconite
   - Sphene

7. Carbonate Cement (46)
   - Dolomite
   - Calcite

8. Matrix / Pseudomatrix (12)

Clay-Altered Grains

9. Clay Cement (26)
   - Illite/smectite
   - Kaolinite

10. Intragranular Porosity (0)
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P — PRF Q / K / P

11. Intergranular Porosity (0)
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution

    Other _____

12. Other (1)
    - Shell / phosphate
    - petro
    - phosphate coating

COMMEMTS

Matrix (little.)
sericite + zeolite as a product of F alteration
Biotite altering to clay.
zoned dolomite
O + F overgrowth

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OTHER

_____
_____

SANDSTONE PETROGRAPHY DATA

EXAMINED BY: Nguyen

THIN SECTION: Vale-1 11513a
FORMATION (AGE):
LOCATION: Greeley Oil Field
DEPTH: 11513'

PROJECT: Nguyen MS
ROCK NAME:
POINT COUNTS:

SORTING: Poorly sorted
SIZE: Med - fine sand

COMPACTION: tight: some pt contact
ANGULARITY: Angular - subrounded

COMMENTS

1. Quartz
   - Moncrystalline
   - Polycrystalline
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Quartz Arenite
   - Other Sedimentary _____
   - Metaquartzite
   - Other Metamorphic _____

2. K-Feldspar
   - Microcline
   - Orthoclase
   - Sanadine
   - Microphanerite Granitic M O
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

3. Plagioclase
   - Microphanerite Granitic
   - Volcanic Rock Fragment
   - Sedimentary _____
   - Metamorphic _____

4. Volcanics

5. Microphanerites Chert, Granitic - Muscovite

6. Accessory Minerals — 4
   - Muscovite
   - Biotite
   - Pyrite
   - Glauconite

7. Carbonate Cement — 4
   - Dolomite
   - Calcite

8. Matrix / Pseudomatrix
   - Clay-Altered Grains

9. Clay Cement — 13
   - Kaolinite
   - Illite/Smectite

10. Intragranular Porosity — 0
    - Quartz
    - K-Feldspar
    - Plagioclase

    VRF Q / K / P — PRF Q / K / P

11. Intergranular Porosity — 39
    - Fractures
    - Fracture-induced dissolution
    - Oversize/elongate pores
    - Grain-edge dissolution
    - Other _____

12. Other — 1
    - Phosphate (bone, coating)

COMMEMTS
- Sig. CJ of F dissolution
- Minor carbonate cement
- Myrmekite
- F alters to sericite + zeolite
- Dolomite w/ mica cleavage + Pyrite

PARAGENESIS

SECONDARY INTERGRANULAR POROSITY

FRACTURE-INDUCED DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

GRAIN-EDGE DISSOLUTION

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

OVERSIZE/ELONGATE PORES

Q	vrfQ	prfQ
K	vrfK	prfK
P	vrfP	prfP

Q 4
F 17

OTHER
_____
_____