CHAPTER 4

LITHOLOGIC DESCRIPTION

The descriptions of lithology were compiled based on petrography and scanning electron microscope (SEM) with energy dispersive spectroscopy (EDS). The petrographic study includes the relationship between depositional and diagenetic characteristics, and the physical and chemical properties such as grain size, mineralogy, textures, type of cement and nature of matrix, porosity. SEM analysis was applied for better understanding on the clay distribution related with pore structures.

Available core chips were extracted from conventional core samples of well B. The Table 4.1 lists the examined core samples with their depth and representative reservoir horizons.

Table 4.1 The core samples with their collected depth and reservoir portion.

Sample No.	Recoverable depth (mMD)	Reservoir position
Well-B-01	1152.32	KR2-6
Well-B-02	1156.40	KR2-7
Well-B-03	1159.71	KR2-7
Well-B-04	1161.41	KR2-7
Well-B-05	1182.72	KR2-8A
Well-B-06	1186.22	KR2-8A
Well-B-07	1192.50	KR2-8A
Well-B-08	1194.51	KR2-8A
Well-B-09	1197.84	KR2-8A
Well-B-10	1199.06	KR2-8A

Figure 4.1, the classification of sandstone by after Dott (1964), as modified by Potter, Pettijohn and Siever (1972) is referred to identify the samples under petrographic study.

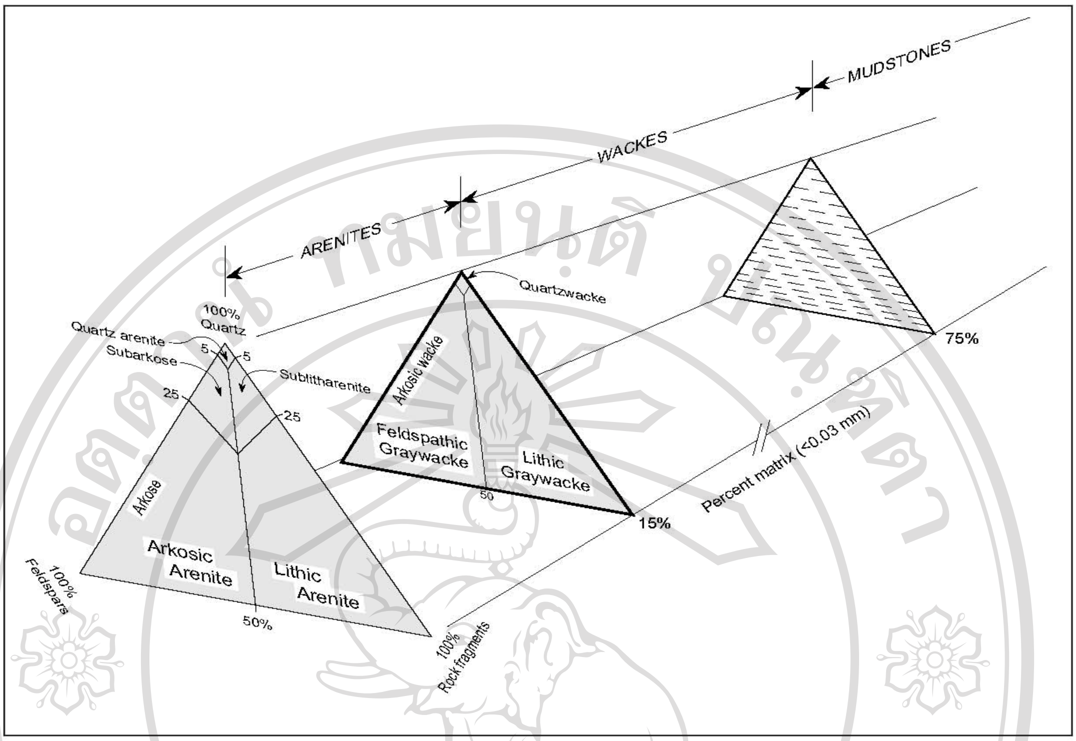


Figure 4.1 Classification of sandstones (after Dott, 1964, as modified by Potter, Pettijohn and Siever, 1972).

According to the examining and distinguishing of the samples under microscope and on photography of SEM, the samples were classified as major Lithic Arenite and minor amount of Lithic Graywacke.

Very fine to very coarse grain sand-sized dominated quartz with rock fragments (granule to pebbles sizes with predominantly dolomitic limestone, schist and lithic pebbles) are surrounded by matrix. Feldspars were observed rarely. Most of quartz grains were very angular to subrounded while rock fragments show subrounded to well rounded in shapes. Very poor sorting to poor sorting grains were cemented by calcite. Point contact, interlocking, overgrowth and floating nature of grains were observed in samples. Low to moderate maturity of texture and mineralogy was estimated. Kaolinite clays were mainly detected as vermicular and scattering around grains and pores. The clays lined and filled in intergranular pores and occluded the network of porosity. Minimum 5% of to maximum 12% of porosity was estimated based on texture, matrix and evidence of hydrocarbon replacements. Detail studies of samples were described as follows.

4.1 Petrographic analysis based on thin sections

4.1.1 Petrographic description of sample no. Well-B-01

The sample consists of 36% of quartz and 60% of lithic fragments without feldspar. 4% of the mica (probable muscovite) scatters in matrix. 6% of calcite cement and 25% of the matrix were estimated. Quartz grains are very fine to coarse sand-sized. The grains are angular to subangular in shapes and poorly sorted with very low to moderate sphericity. Dolomitic limestone rock fragments are coarse and subrounded in shapes. Small grain sand-sized quartzes, mud clasts and mica flakes are scattered in matrix. Based on the composition, the sample is very fine to coarse grained sand-sized Lithic Graywacke (Dott, 1964). Intergranular pores are filled with clay and 5% to 10% of porosity was estimated. Replacement of hydrocarbon was observed in this sample (Figure 4.1.1, A, B).

4.1.2 Petrographic description of sample no. Well-B-02

The sample is composed of 35% of quartz, 63% of rock fragments (dolomitic limestone and schist) and 2% of mica. 10% of matrix and 8% of calcite cement were determined. Quartz grains are very fine to coarse sand-sized, angular to subrounded with low sphericity and poor to moderate sorting. Schist fragments are elongated and bended, and dolomitic limestone grains are subrounded. Rock fragments and some quartz grains have interlocking contacts. Most grains float in matrix. According to the compositions, the sample was classified as Lithic Arenite (Dott, 1964). Minimum of 8% to maximum of 10% porosity are estimated for this sample. Hydrocarbons replaced intergranular pores and stained the matrix (Figure 4.1.2, A, B).

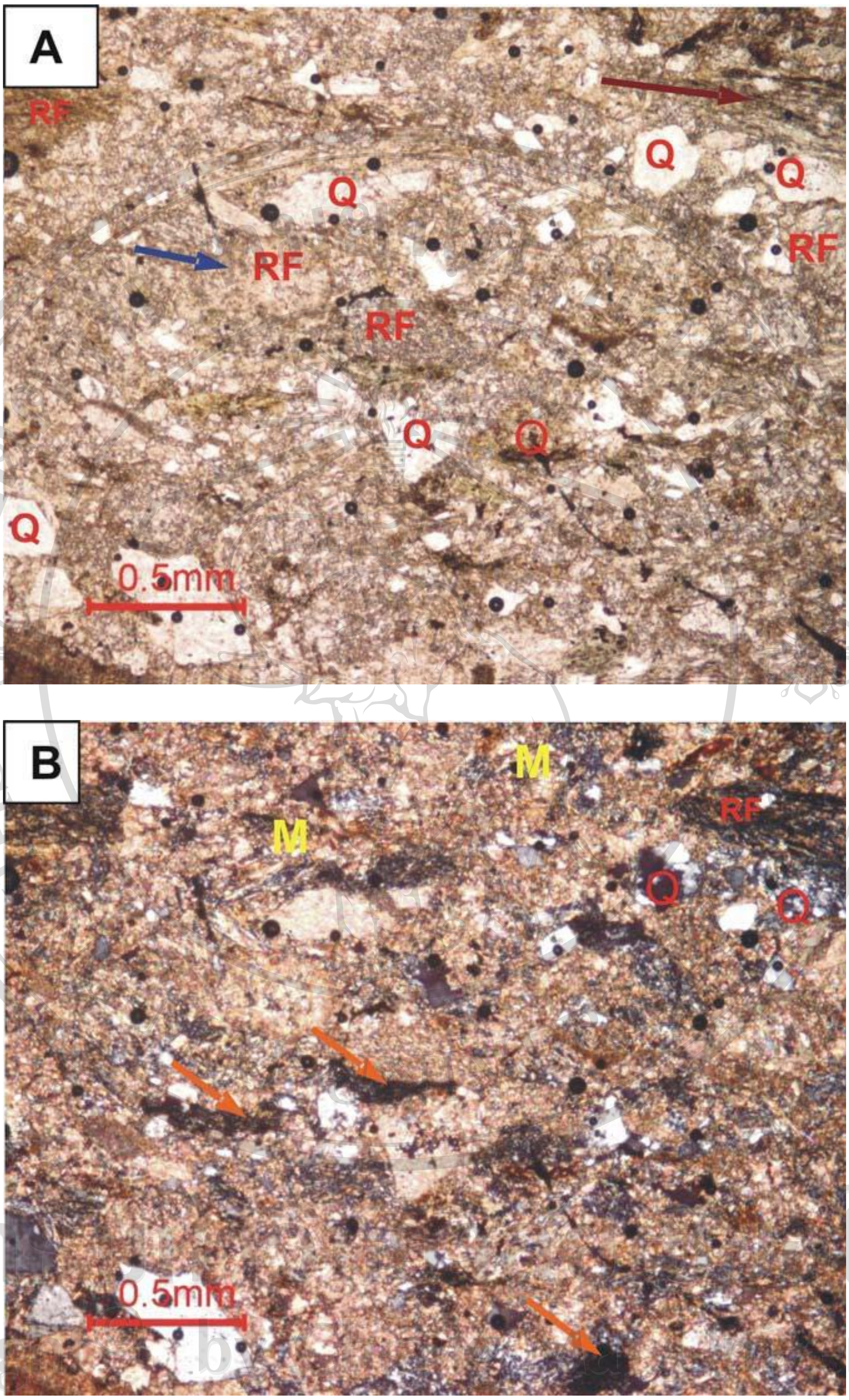


Figure 4.1.1 Thin section Well-B-01, photomicrograph of plane polarized light (A) and cross polarized light (B). Very fine to coarse grain sand-sized quartz (Q) and rock fragments (RF) are found in matrix. Fine clasts and quartz grains are dimly alternated in Figure A. Red arrows indicate the schist fragments. Replacement of hydrocarbon (brown arrow) and secondary growth by calcite (blue arrow) are observed. Mica filled pores are encountered and 10% of porosity was estimated.

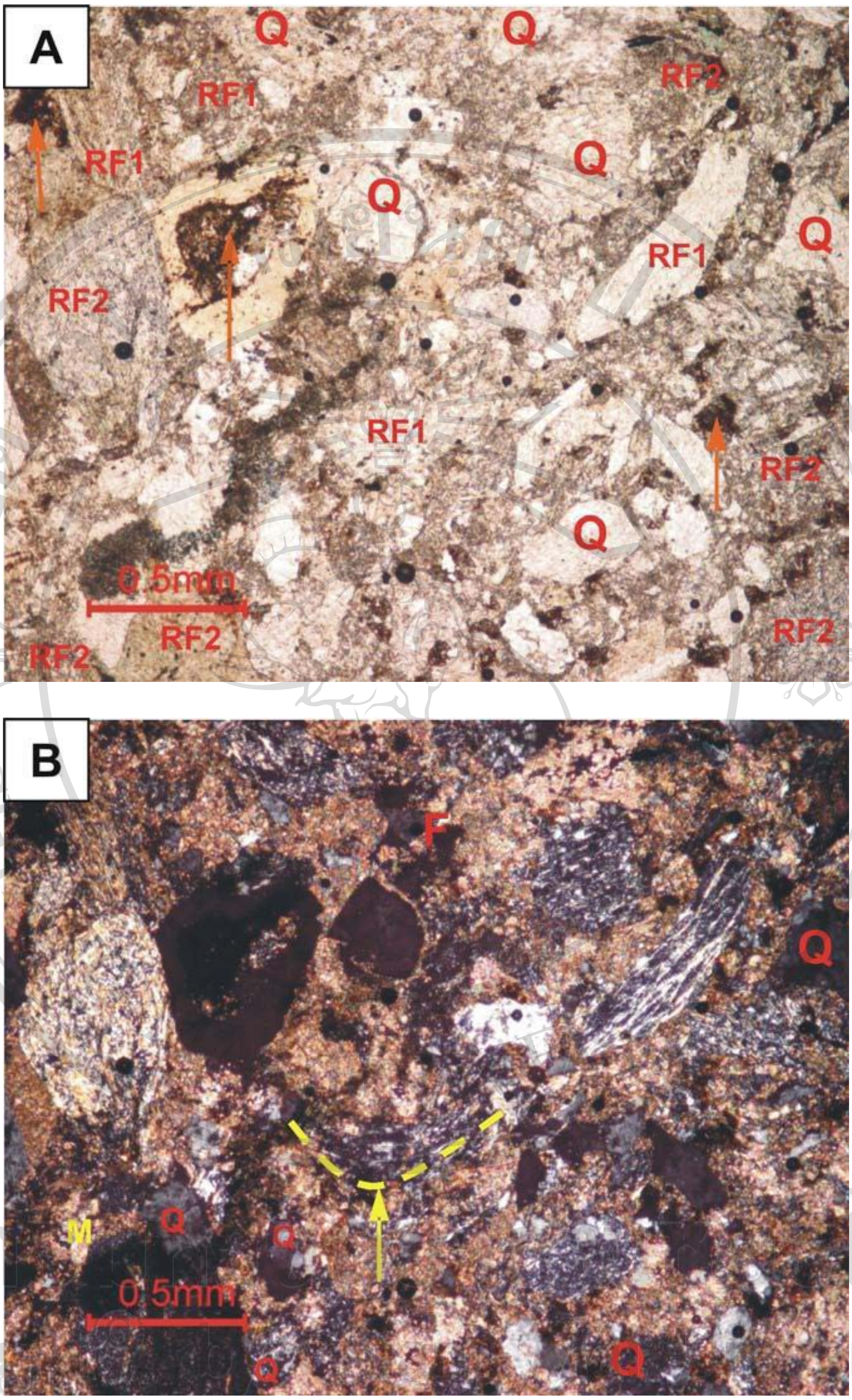


Figure 4.1.2 Thin section Well-B-02, photomicrograph of plane polarized light (A) and cross polarized light (B). Quartz (Q) and rock fragments (RF1=schist and RF2=dolomitic limestone) mostly float in matrix. Brown arrow indicates hydrocarbon straining and yellow arrow with dotted line marks bended schist. Maximum 10% of intergranular porosity was encountered in this view.

4.1.3 Petrographic description of sample no. Well-B-03

The sample is comprised 85% of quartz and 15% of rock fragments (dolomitic limestone). 30% of matrix supported to the grains and 5% of calcite cement was estimated. Grains are fine to coarse sand-sized, angular to subrounded with low sphericity and poor sorting in matrix. Point-contact grains are observed. Dolomitic fragments are fine to coarse sand-sized and subrounded in shapes. Traces of oriented grain are visible under cross polarized light and low to moderate compaction was estimated. Based on the composition, the sample was classified as Lithic Graywacke (Dott, 1964). 8% of porosity was estimated. Dusty color quartz shows trace of inclusion. Hydrocarbon replaced in matrix and clearly identified under plane polarized light (Figure 4.1.3, A, B).

4.1.4 Petrographic description of sample no. Well-B-04

The sample is mainly composed of 40% of quartz grains and 58% of rock fragments (dolomitic limestone and schist). 2% of mica was studied in this sample. 14% of matrix and 8% of calcite cement were approximately observed. The grains are medium to very coarse sand-sized and angular to subrounded. Rock fragments were subrounded to well rounded with moderate sphericity. Dolomitic limestone and schist fragments have interlocking contacts and float in matrix. Grains are poorly cemented and poor to very poorly sorted in matrix. Based on the composition, the sample is classified as Lithic Arenite (Dott, 1964). Not more than 10% of porosity was estimated in this sample. Quartz grains were fractured and that was supposed as moderate compaction with chemical solutions was effective on grains (Figure 4.1.4, A, B).

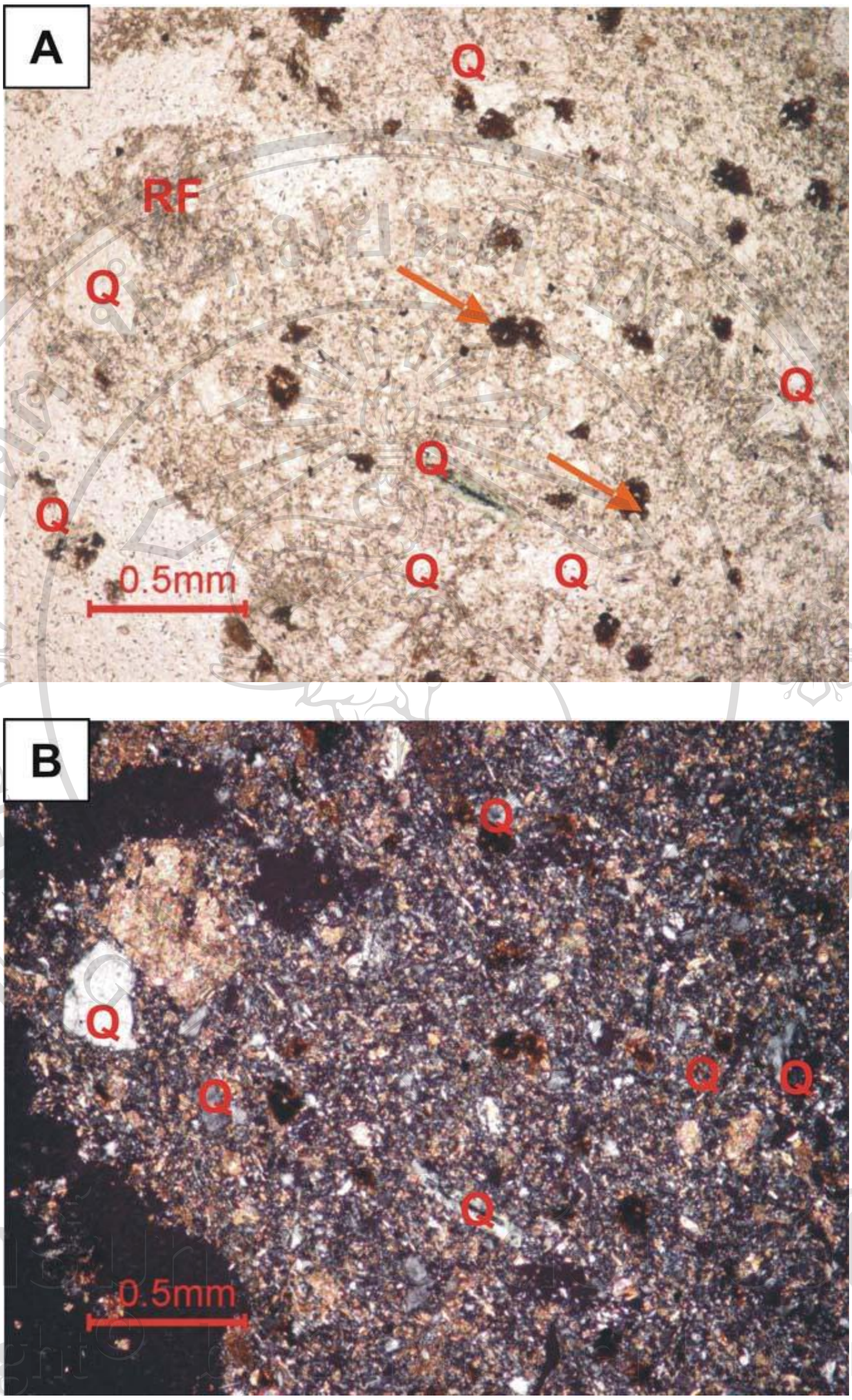


Figure 4.1.3 Thin section Well-B-03, photomicrograph of plane polarized light (A) and cross polarized light (B). Fine-to coarse-grained sand-sized quartzes are abundant in matrix. Dolomitic limestone fragments (RF) show mottled color under cross polarized light. Hydrocarbon replacement in pores was indicated with brown arrows. Weakly oriented fragments were observed in Figure B.

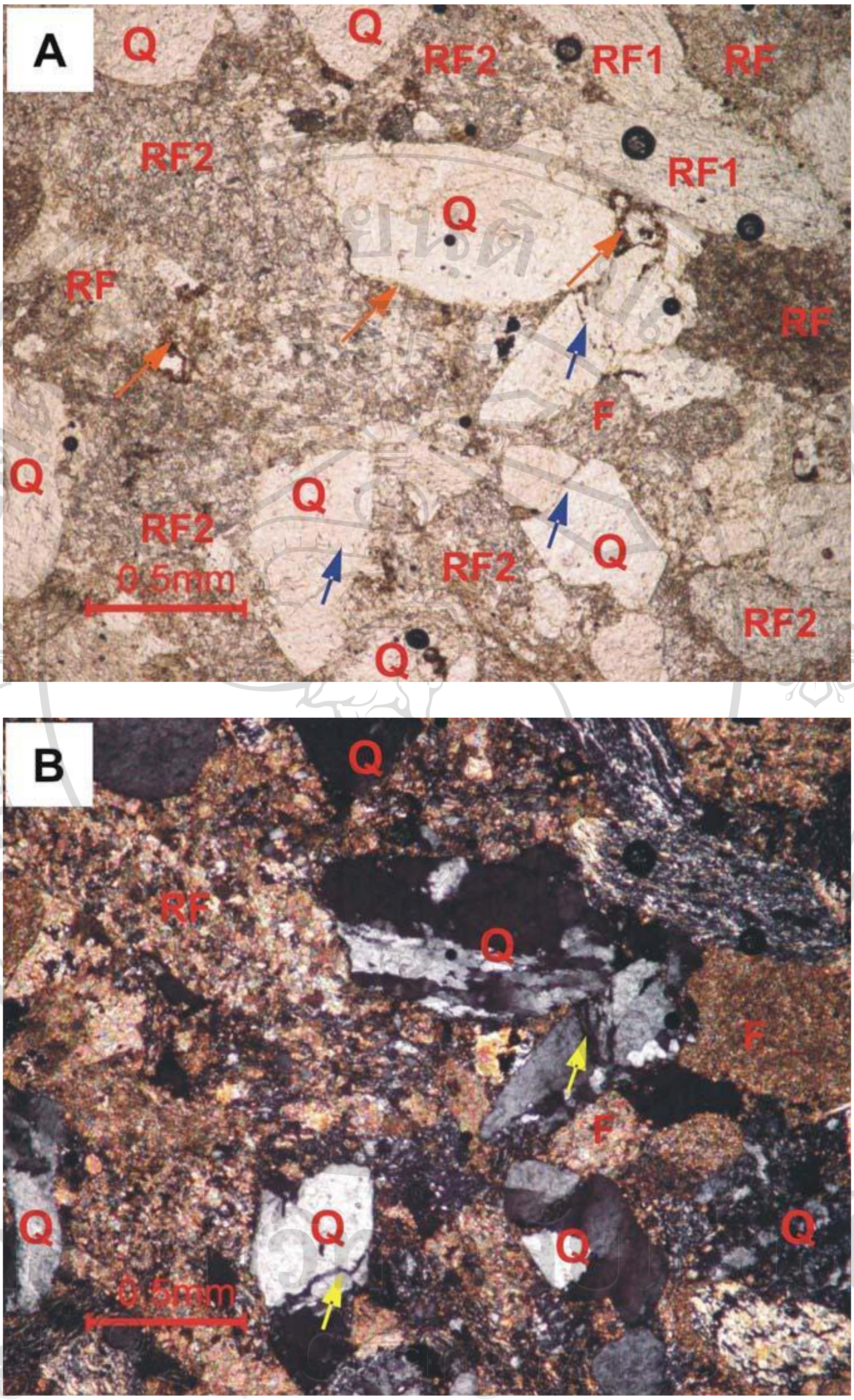


Figure 4.1.4 Thin section Well-B-04, photomicrograph of plane polarized light (A) and cross polarized light (B). This sample is partially grain supported. Quartz grains (Q) and rock fragments (RF=lithic fragment, RF1=schist, RF2=dolomitic limestone) have interlocking contacts. Brown arrows indicate the trace of hydrocarbon in intergranular pores. Blue and yellow arrows indicate micro-fracture in quartz grains.

4.1.5 Petrographic description of sample no. Well-B-05

32% of quartz and 68% of rock fragments were mainly composed. 12% of matrix and 8% of calcite cement were estimated. Quartz grains are medium to course sand-sized, very angular to subangular, poorly sorted, and grain supported. Rock fragments are elongated and very coarse grained sand-sized. Dolomitic limestone, schist fragments and polycrystalline quartz grains are packed together. Sub-parallel orientation of quartz and rock fragments, and fracture in quartz grain suggest low to moderate compaction. Based on the composition, the sample was classified as Lithic Arenite (Dott, 1964). Around 8% of porosity was determined (Figure 4.1.5, A and B).

4.1.6 Petrographic description of sample no. Well-B-06

The sample was composed of 47% of quartz and 51% of limestone rock fragments with minor amount of mica (2%). 5% of shell fragments were recorded in this sample. The calcite cement is almost 7% and 11% of matrix was estimated. Quartz grains are fine to very coarse sand-sized, angular to subrounded and elongated in shape with very low sphericity. Limestone fragments are subrounded to rounded. Poorly sorted grains are observed with irregular contacts between quartz and limestone fragments. Based on composition, the sample was classified as Lithic Arenite (Dott, 1964). 7% porosity was estimated. Minor amount of hydrocarbon replacement in pores was observed (Figure 4.1.6, A and B).

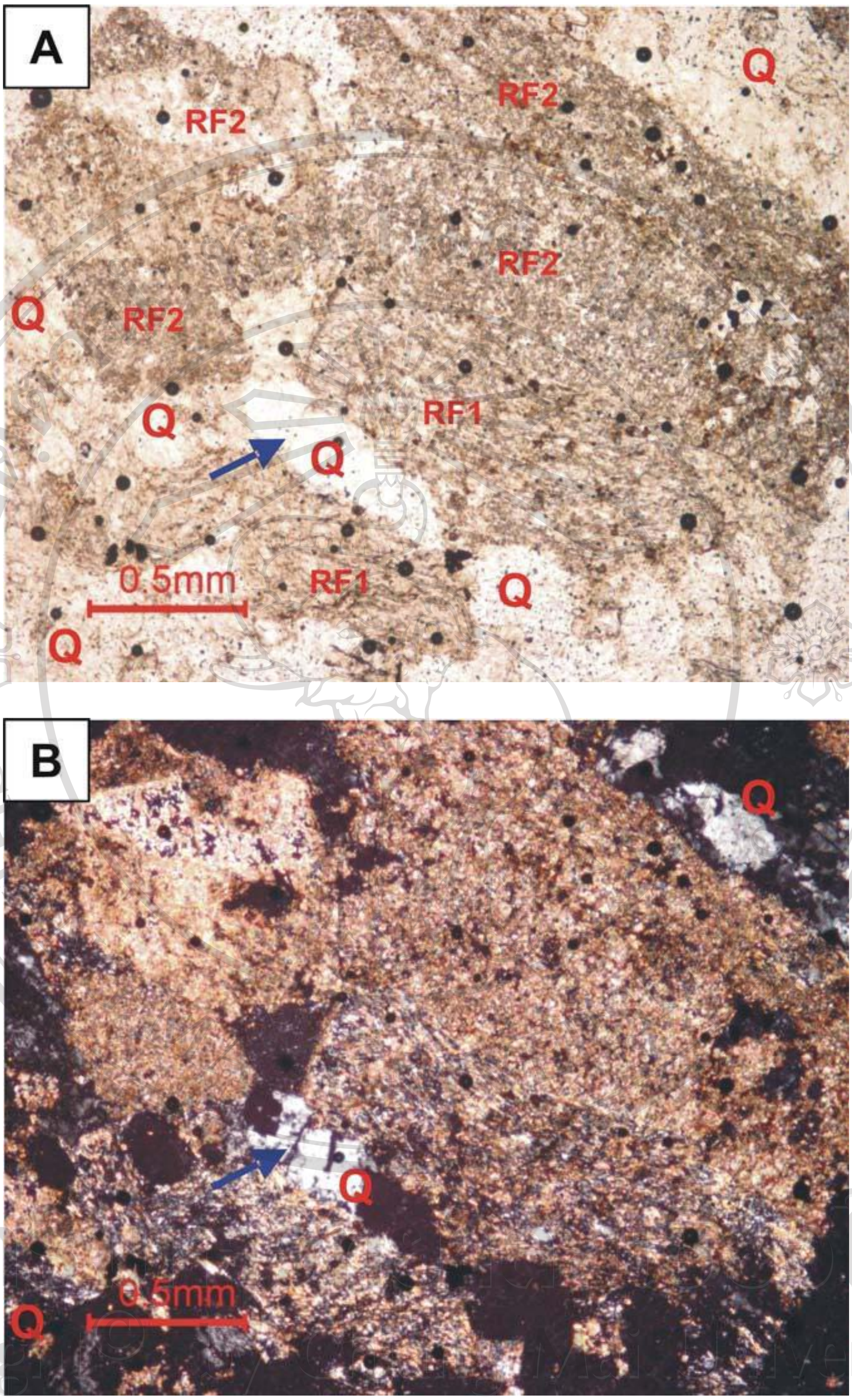


Figure 4.1.5 Thin section Well-B-05, photomicrograph of plane polarized light (A) and cross polarized light (B). Quartz (Q) and rock fragments (RF1=schist and RF2=dolomitic limestone) are partially supported by matrix. The fractures in quartz (blue yellows) was clearly observed.

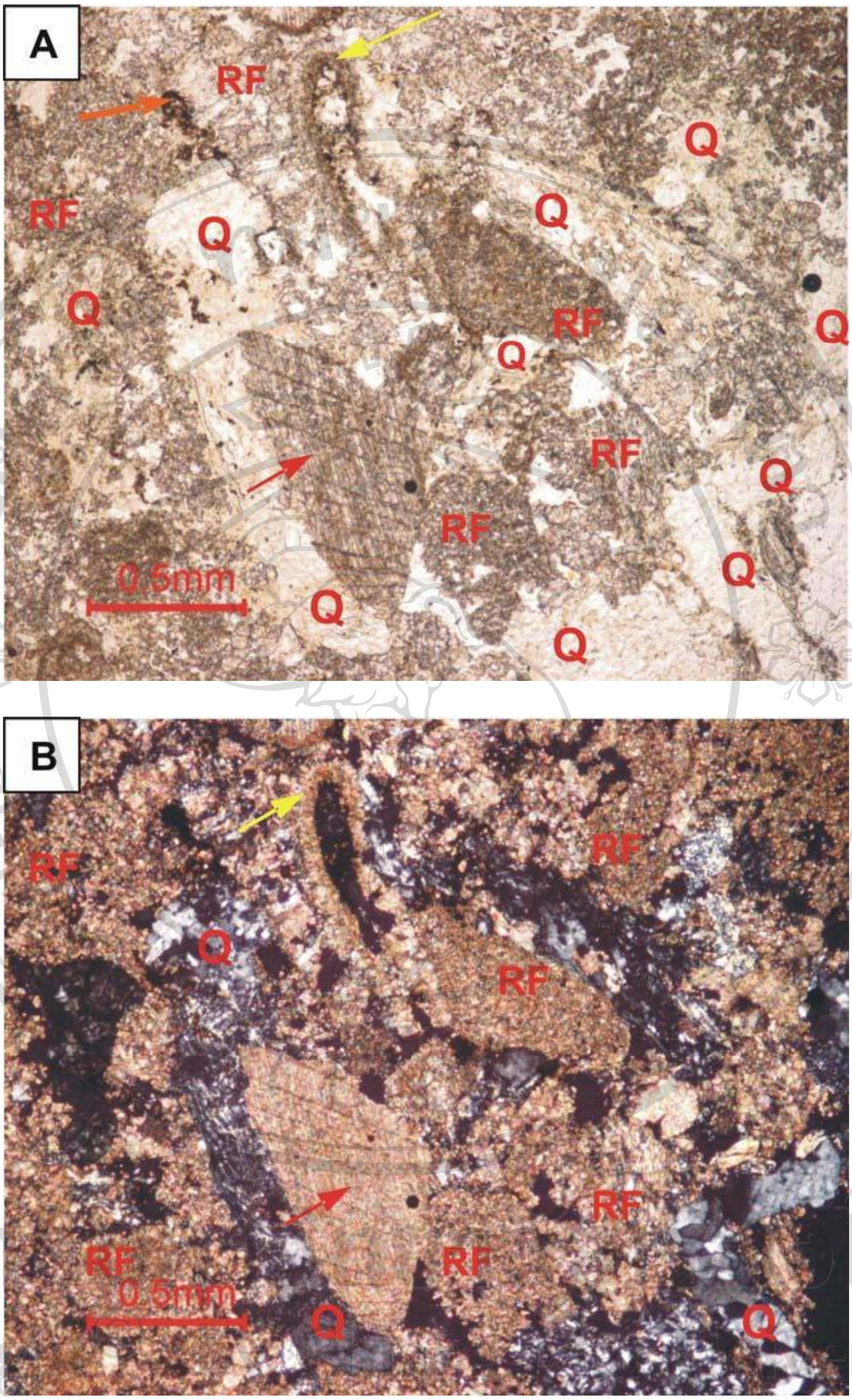


Figure 4.1.6 Thin section Well-B-06, photomicrograph of plane polarized light (A) and cross polarized light (B). The figures show irregular contacts between polycrystalline quartz grains (Q) and limestone fragments (RF). Yellow arrows indicate calcite growth on lithic fragments. Red arrows indicate calcite coated shell fragment. The hydrocarbon replaced in intergranular pores (brown arrow).

4.1.7 Petrographic description of sample no. Well-B-07

The sample was composed of 35% of quartz, 25% of feldspar and 40% of rock fragments. It has 15% of matrix and 10% of calcite cement. Minor amount of mica flakes scatter in matrix. Quartz grains are fine to very coarse sand-sized and poorly sorted with point contacts. They are angular to well rounded with moderate sphericity. Rock fragments are well rounded and elongated with growth character on their edges by calcite. The grains are partly matrix supported. Elongated fragments were reoriented and moderate compaction was presumed. Based on composition, Lithic Arenite is an appropriate name of this sample (Dott, 1964). Minimum of 7% to maximum of 10% porosity are encountered. Hydrocarbons stains in intergranular pores were clearly observed under plane polarized light (Figure 4.1.7, A and B).

4.1.8 Petrographic description of sample no. Well-B-08

27% of quartz, 27 % of feldspar and 42% of rock fragments were mainly composed in this sample. Minor amount of mica (3%) and less than 1% of heavy mineral (pyrite) were observed. 15% of calcite cement and 7% of matrix were estimated. Quartz grains are medium to very coarse sand-sized, poor to very poorly sorted, angular to subrounded in shape with low sphericity. Pebbles were subrounded and elongate. The grains have irregular contacts. Feldspars (F) show crystal form with fractures and trace of inclusion. Rock fragments are schist (RFs) and dolomitic limestone (RF) with irregular forms. Based on composition, the sample was classified as Lithic Arenite (Dott, 1964). Maximum 8% of porosity was estimated (Figure 4.1.8, A and B).

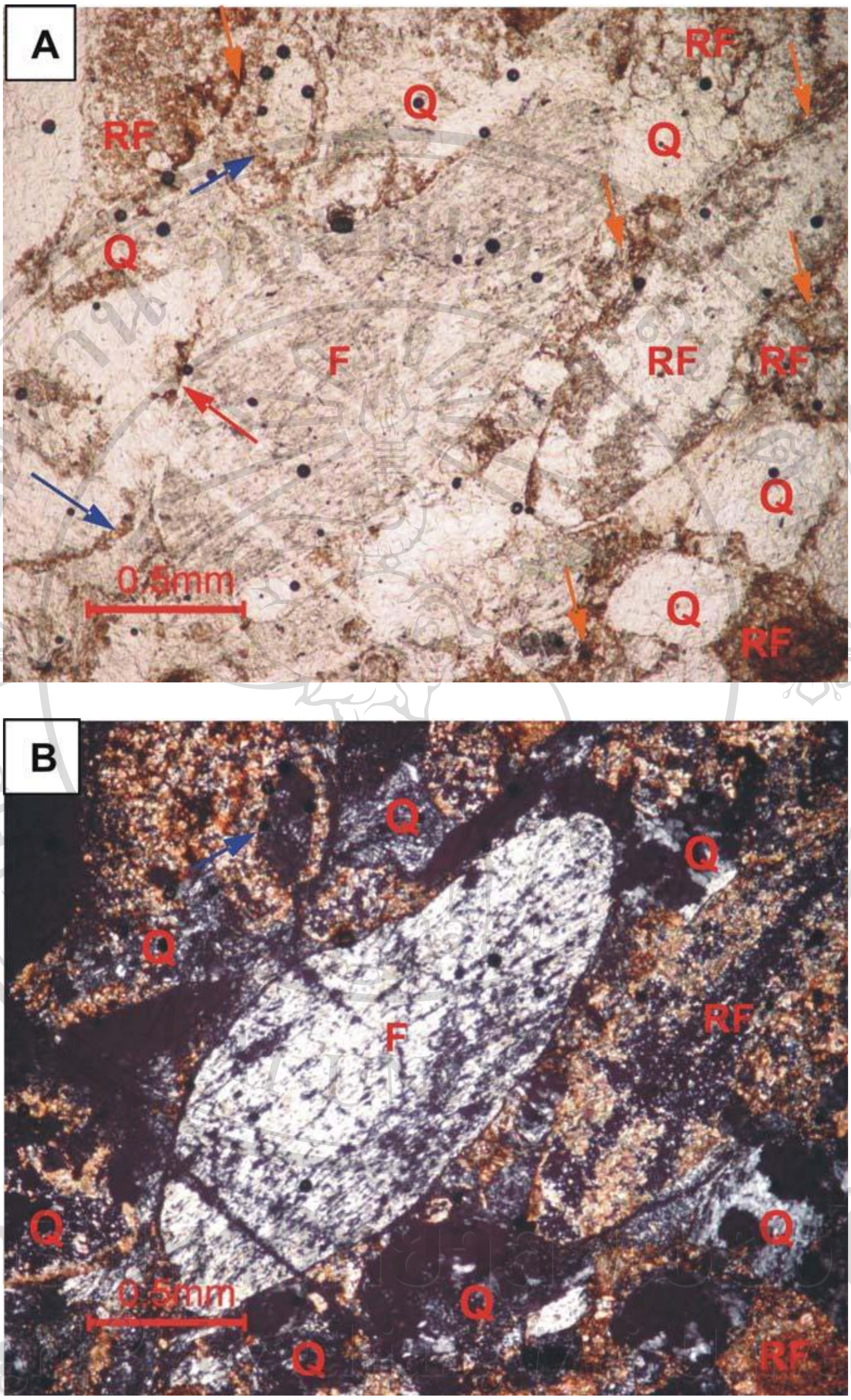


Figure 4.1.7 Thin section Well-B-07, photomicrograph of plane polarized light (A) and cross polarized light (B). Subrounded dolomitic limestone rock fragments (RF), feldspar (F), and quartz (Q) have point contacts. Blue arrows indicate calcite growth. The replacement of hydrocarbons was indicated by brown arrows. Red arrow indicates to the growth outline of feldspar under plane polarized light (Figure A).

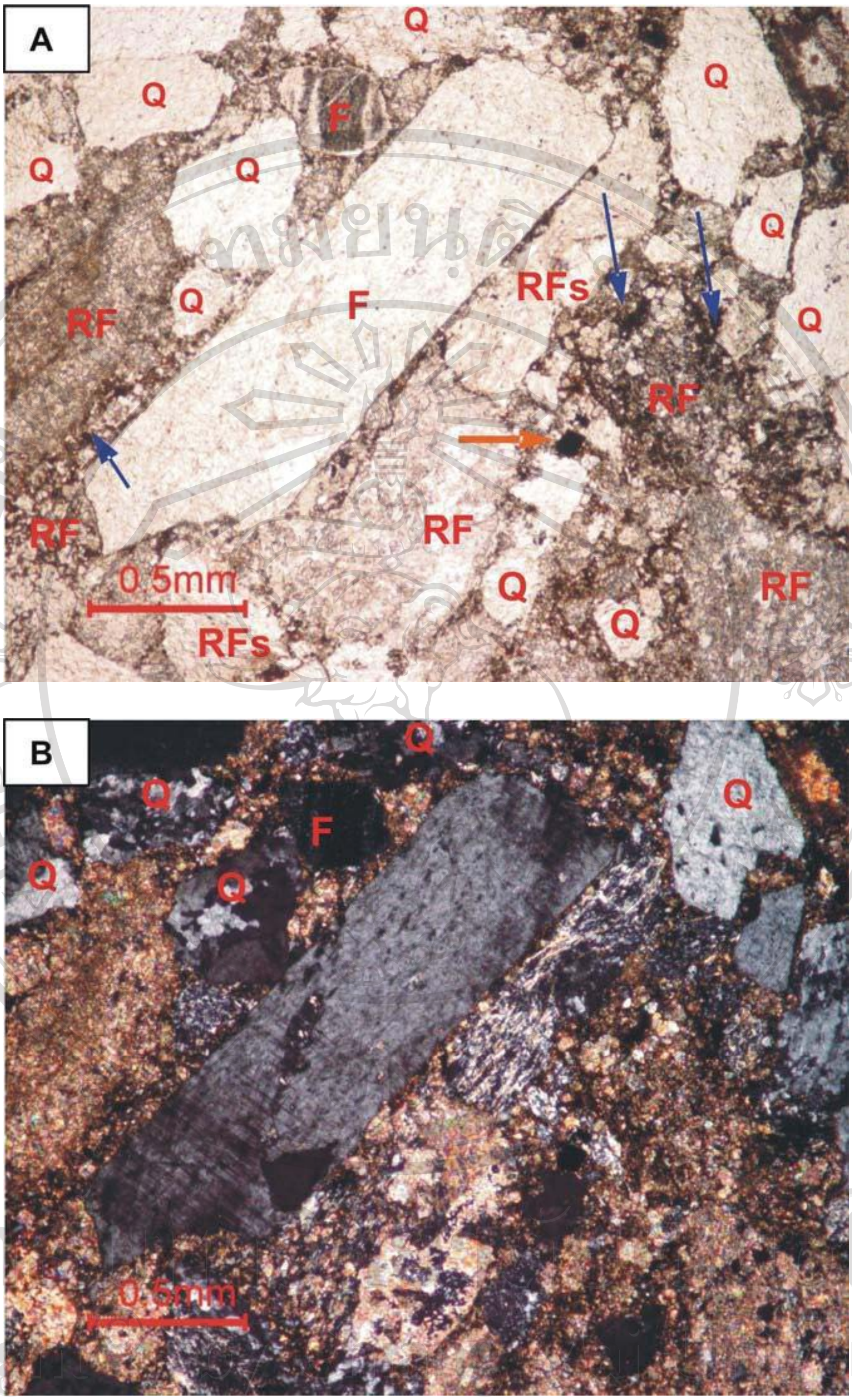


Figure 4.1.8 Thin section Well-B-08, photomicrograph of plane polarized light (A) and cross polarized light (B). Feldspar (F) and pyrite (brown arrow) were rarely recorded in this sample. Quartz (Q), schist (RFs) and dolomitic limestone (RF) fragments were observed as grain supported texture. Clay and fine-grained clasts filled between lithic fragments. Fractures were identified in feldspars with trace of inclusion. Blue arrows indicate the replacements of hydrocarbon in intergranular pores. 8% of porosity was estimated in this view.

4.1.9 Petrographic description of sample no. Well-B-09

50% of quartz, 7% of feldspar and 40% of limestone fragments are mainly composed in this sample. A grain of pyrite was observed. 2% of fragments coated with fine-grain calcite and microscopic multi-interlayer were observed as fossil fragments. 9% of calcite cement and 5% of matrix were estimated. Quartz grains are very fine to very coarse sand-sized, very poor to poorly sorted, and angular to subangular with very low sphericity. Quartz, feldspar and limestone fragments were identified as having a grain-supported texture with irregular contacts. Based on composition, the sample was classified as Lithic Arenite (Dott, 1964). 8% of porosity was estimated. Fractures with trace of inclusion appear in feldspars. Secondary growth rim by calcite developed in chert. Replacement of hydrocarbon in pores was identified. (Figure 4.1.9, A, B).

4.1.10 Petrographic description of sample no. Well-B-10

The sample was composed of 53% of quartz, 46% of rock fragments and very little amount of heavy mineral (pyrite). 9% of calcite cement and 5% of matrix were approximated. Quartz grains are fine to very coarse sand-sized, angular to subrounded and poorly sorted. Dolomitic limestone fragments were subrounded to elongated. Pyrite crystal was observed as opaque sub-hedral form. Based on composition, the sample was classified as Lithic Arenite (Dott, 1964). Replacements of hydrocarbon in intergranular pores are present. 12% of porosity was estimated (Figure 4.1.10, A and B).

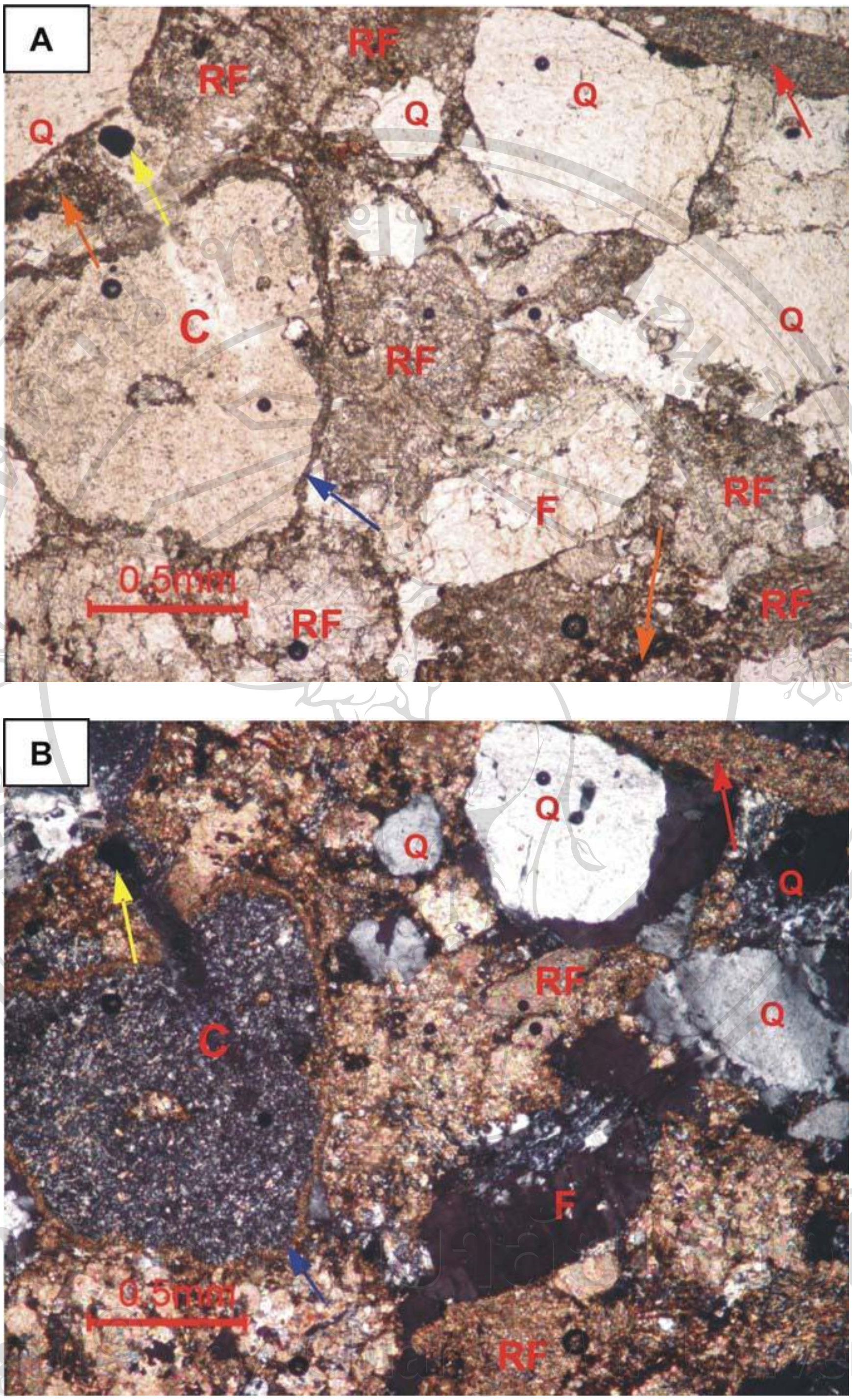
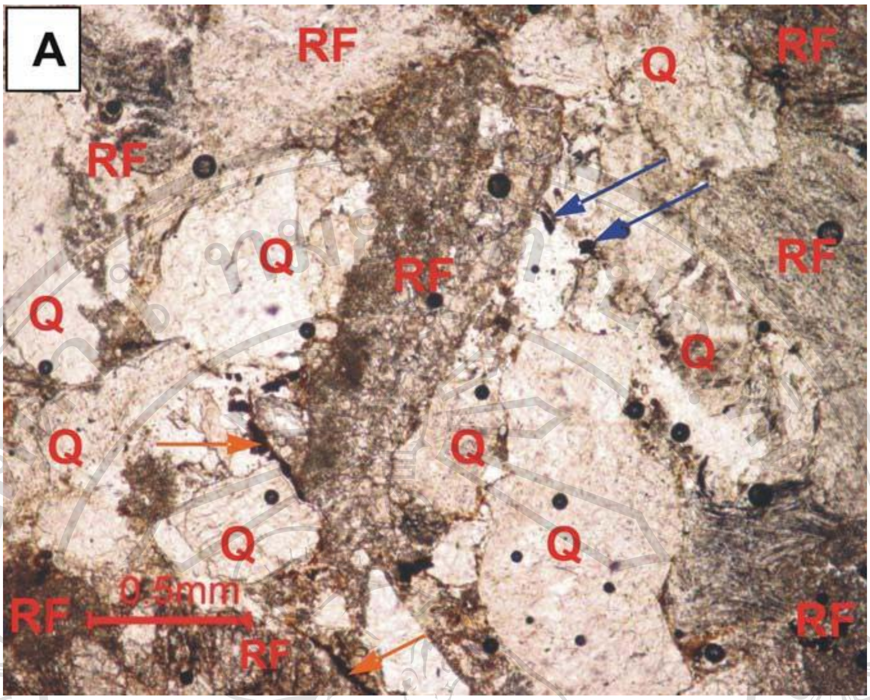


Figure 4.1.9 Thin section Well-B-09, photomicrograph of plane polarized light (A) and cross polarized light (B). Coarse-to very coarse-grained quartz (Q), chert (C), dolomitic limestone (RF) fragments and feldspar (F) have irregular contacts with matrix. Secondary overgrowth of calcite on edges of chert (blue color arrows) and hydrocarbons replacement in intergranular pores (brown arrows) were well identified in this view. Red arrows indicate calcite growths layers on fossil fragment. Yellow arrows point to pyrite crystal.



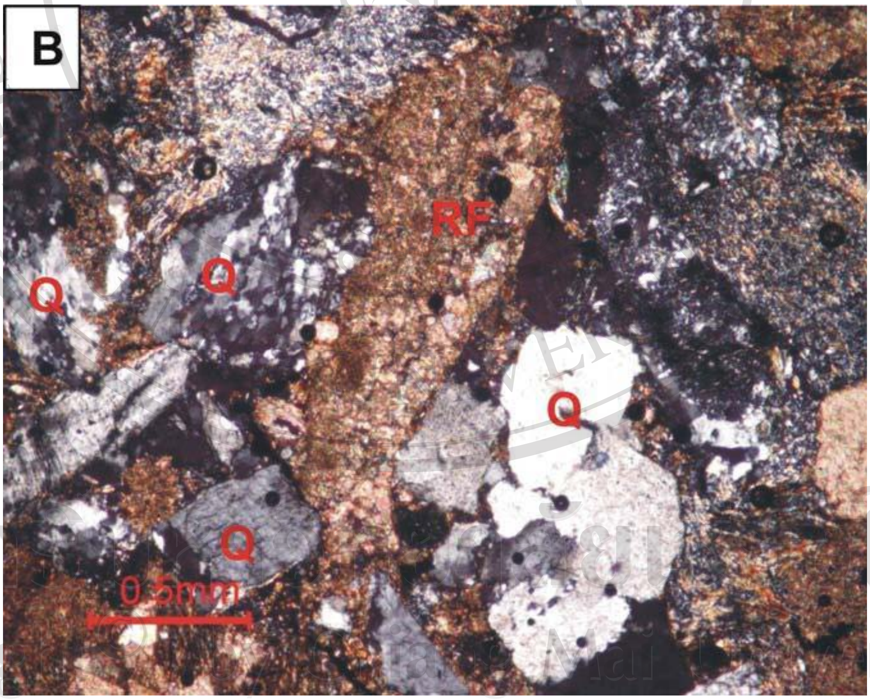


Figure 4.1.10 Thin section Well-B-10, photomicrograph of plane polarized light (A) and cross polarized light (B). Overgrowth of polycrystalline quartz (Q) and dolomitic limestone fragments (RF) are formed as a grain-supported texture. Pyrite crystals were observed as opaque sub-hedral forms (blue arrows). Brown arrows indicate to the replacements of hydrocarbon.

4.2 Analysis of core samples under Scanning Electron Microscopy (SEM)

4.2.1 SEM description of sample no. Well-B-01

The sample is the very fine- to coarse-grained Lithic Graywacke in which much of the intergranular pore network has been plugged by randomly oriented platelets of kaolinite. A cluster of loosely quartz grains also plug intergranular pore. Partly vermicular kaolinites surround the pores. The plates have a width of 4 micrometers and a length of 8 micrometers (Figure 4.2.1 A, B).

4.2.2 SEM description of sample no. Well-B-02

The sample is very fine- to coarse-grained Lithic Arenite. The surfaces of quartz grains are coated with very thin clays. The clay flakes are mostly oriented sub-parallel to the grain surface and some are at high angle to the grains. Kaolinite displays characteristic booklet crystal morphology that is a result of precipitation as cement. They float and occlude the pore channels (Figure 4.2.2 A, B).

4.2.3 SEM description of sample no. Well-B-03

The sample is fine- to coarse-grained Lithic Graywacke with intergranular pores plugged by random platelets of kaolinites. The grain surfaces were enveloped by random clay booklets (Figure 4.2.3A). Kaolinites reduced the pore throats and formed sub-parallel to pore walls (Figure 4.2.3 A, B).

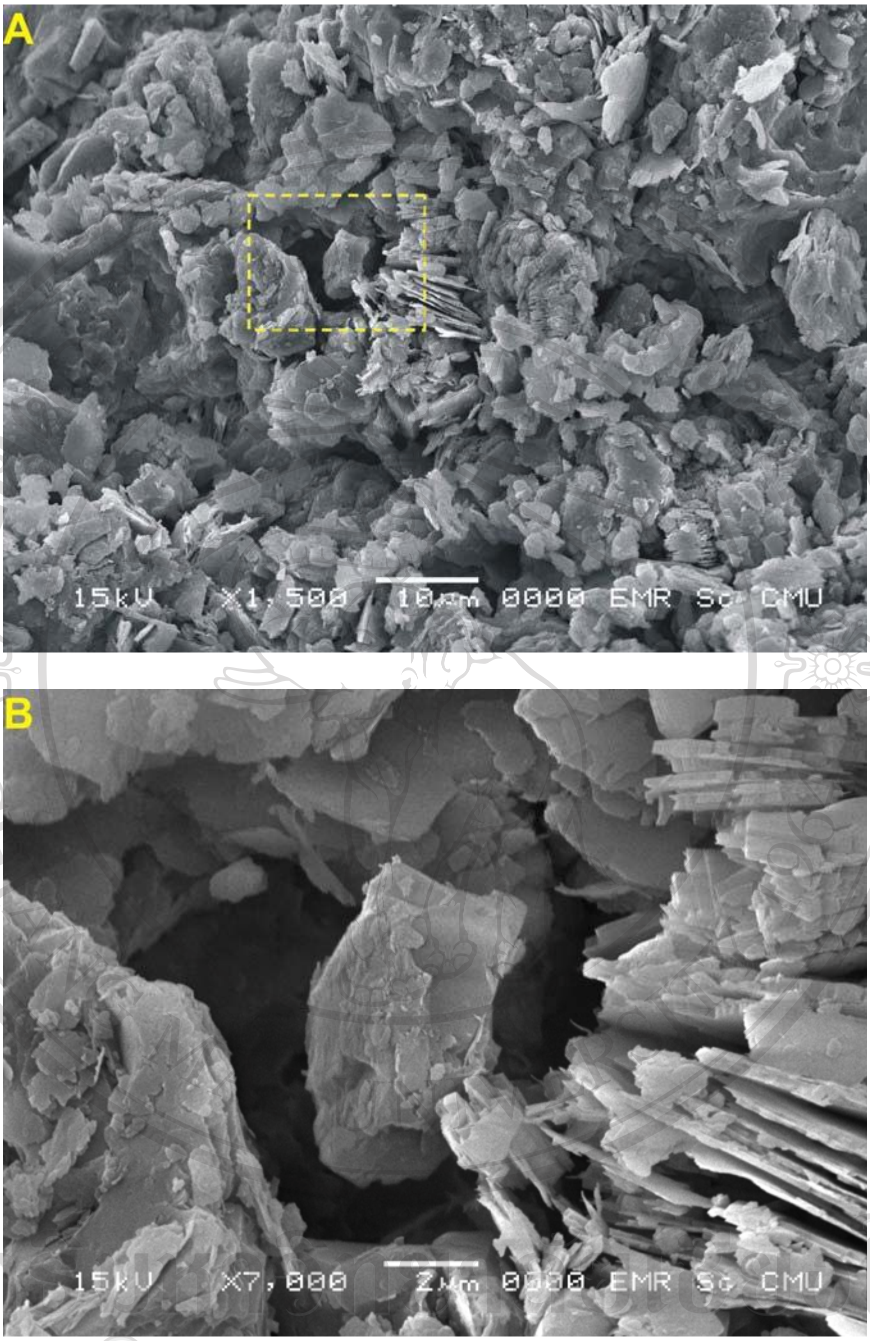


Figure 4.2.1 Scanning electron micrograph of sample Well-B-01. The random oriented kaolinite platelets are overgrowth on crystal grains (Figure A). Figure B shows an enlargement of Figure A and a cluster of loose quartz grain plugs the center of an intergranular pore. Vermicular kaolinites are loose and arranged around the pore.

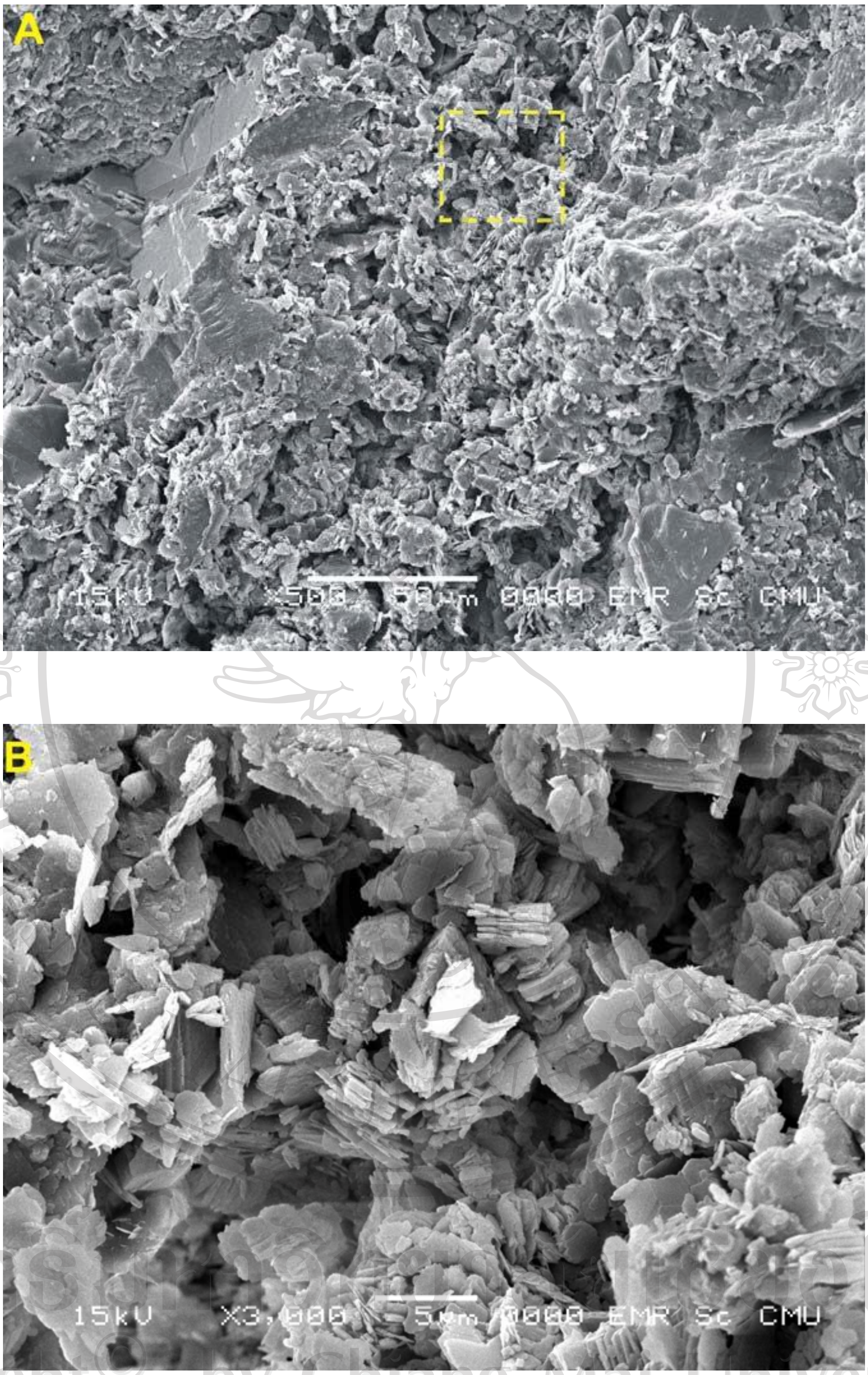


Figure 4.2.2 Scanning electron micrograph of sample Well-B-02. The random oriented kaolinite platelets are scattered on crystal grains (Figure A). Smooth edges of crystals are presumed a result of chemical dissolution. Figure B is an enlargement of Figure A and it shows a semi-vermicular and scattered kaolinite books plugging the intergranular pores. The clay plates are loosely packed and porosity was reduced by micro clay plates filling.

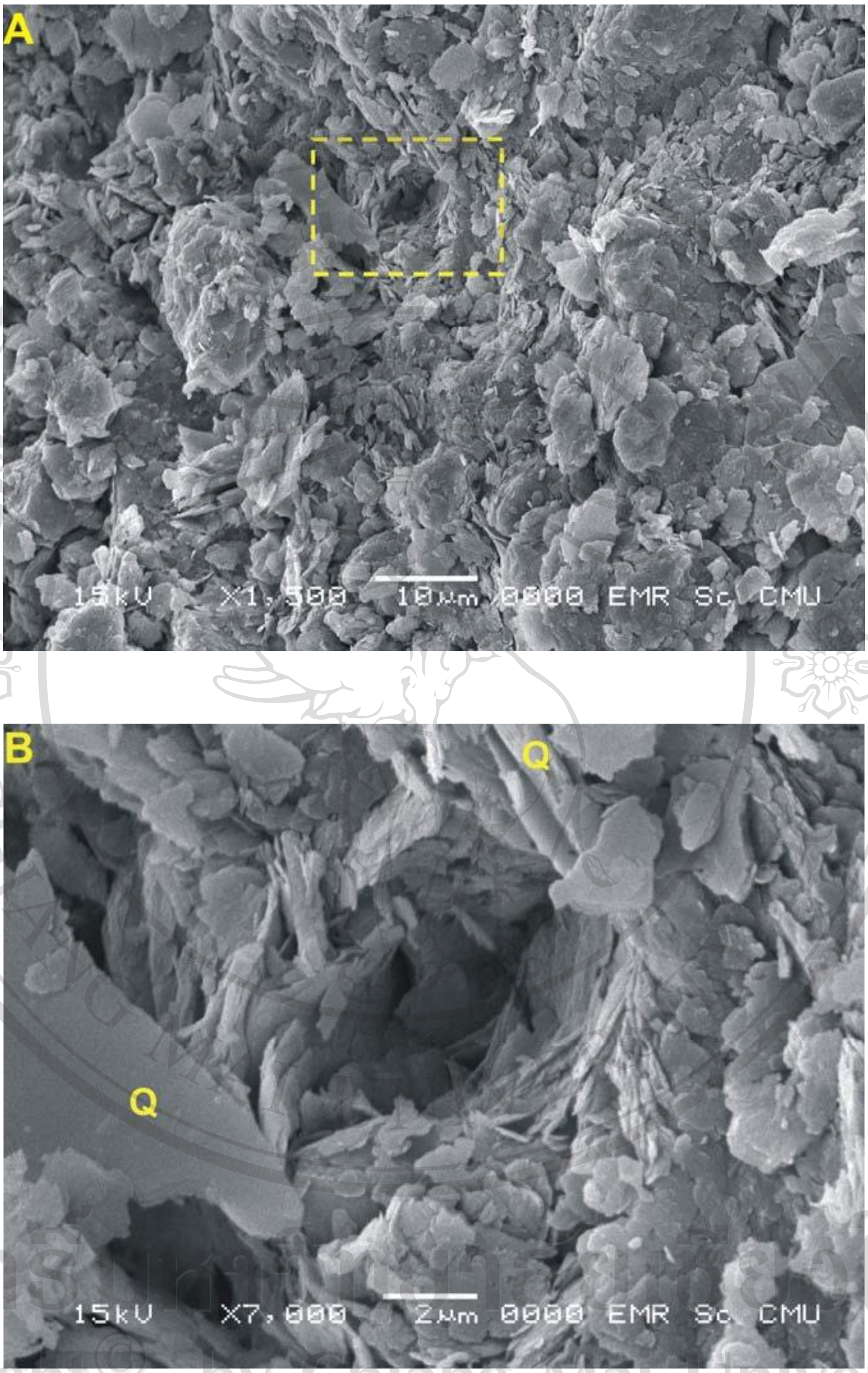


Figure 4.2.3 Scanning electron micrograph of sample Well-B-03. In the low magnification view (x1500), the grains are covered by randomly orientated clay booklets (Figure A). Figure B is the high magnification (x7000) of the yellow rectangular in the Figure A. It shows that the clay booklets are sub-parallel to pore walls and partially occlude to pores throat. Quartz grains (Q) show sheet-like forms and EDS analysis confirmed its chemical composition.

4.2.4 SEM description of sample no. Well-B-04

The sample is medium- to very coarse-grained Lithic Arenite. Clays are found as typical flaky and filamentous crystals covering grains. Most crystals are lined with the growth of clay platelets filling the pores. Sharp edges of calcite crystals suggest little or no dissolution (Figure 4.2.4 A, B).

4.2.5 SEM description of sample no. Well-B-05

The sample is medium- to coarse-grained Lithic Arenite. The dispersed pores are plugged by tight and tiny kaolinite books about 10 micrometer in size. The extensive intergranular porosities were filled by loose clay pellets (Figure 4.2.5 A, B).

4.2.6 SEM description of sample no. Well-B-06

The sample is fine- to very coarse-grained Lithic Arenite. The Figure A shows calcite crystals with distribution of clay books. Most of pores were plugged or covered by random clay platelets and very fine-grained calcite. Smooth pore walls were observed under high magnification. The feature suggests that the intergranular pores formed between ductile grains and plastic deformation affected the grains (Figure 4.17 A, B).

4.2.7 SEM description of sample no. Well-B-07

The sample is fine- to very coarse-grained Lithic Arenite. Ductile clays cover fragments and crystals (Figure 4.2.7A). The surfaces of grains were also coated by tiny calcite grains (Figure 4.2.7B). Quartz overgrowth was observed. Poorly sorted quartz grains float in matrix (Figure 4.2.7 A, B).

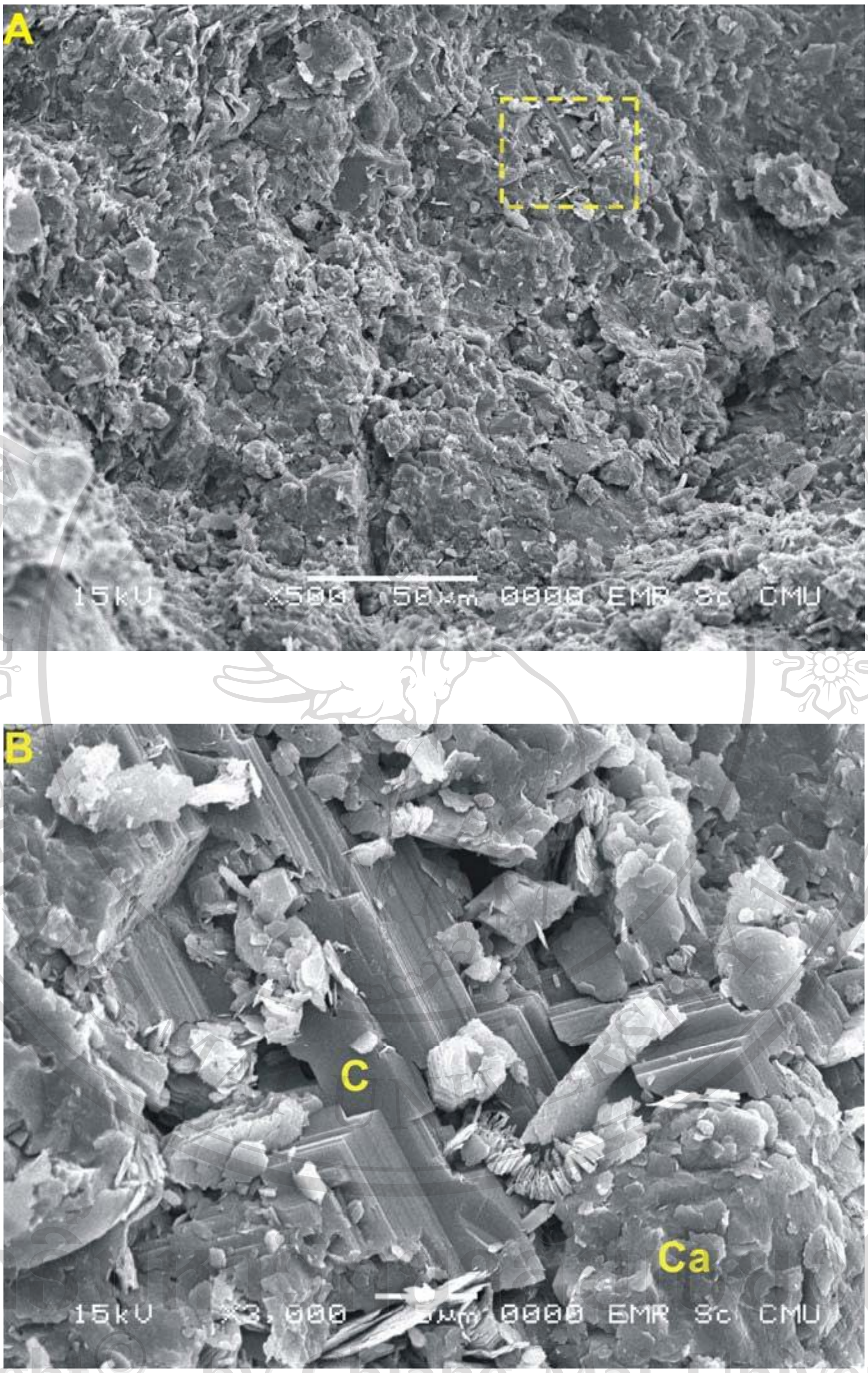


Figure 4.2.4 Scanning electron micrograph of sample Well-B-04. Figure A shows the morphological feature of crystals covered by clay. Figure B displays an enlargement of the yellow rectangle in Figure A. It shows quartz grains and calcite crystals (C) with randomly oriented vermicular clay booklets. Amorphous carbonate grains (Ca) were confirmed with its chemical composition by EDS analysis.

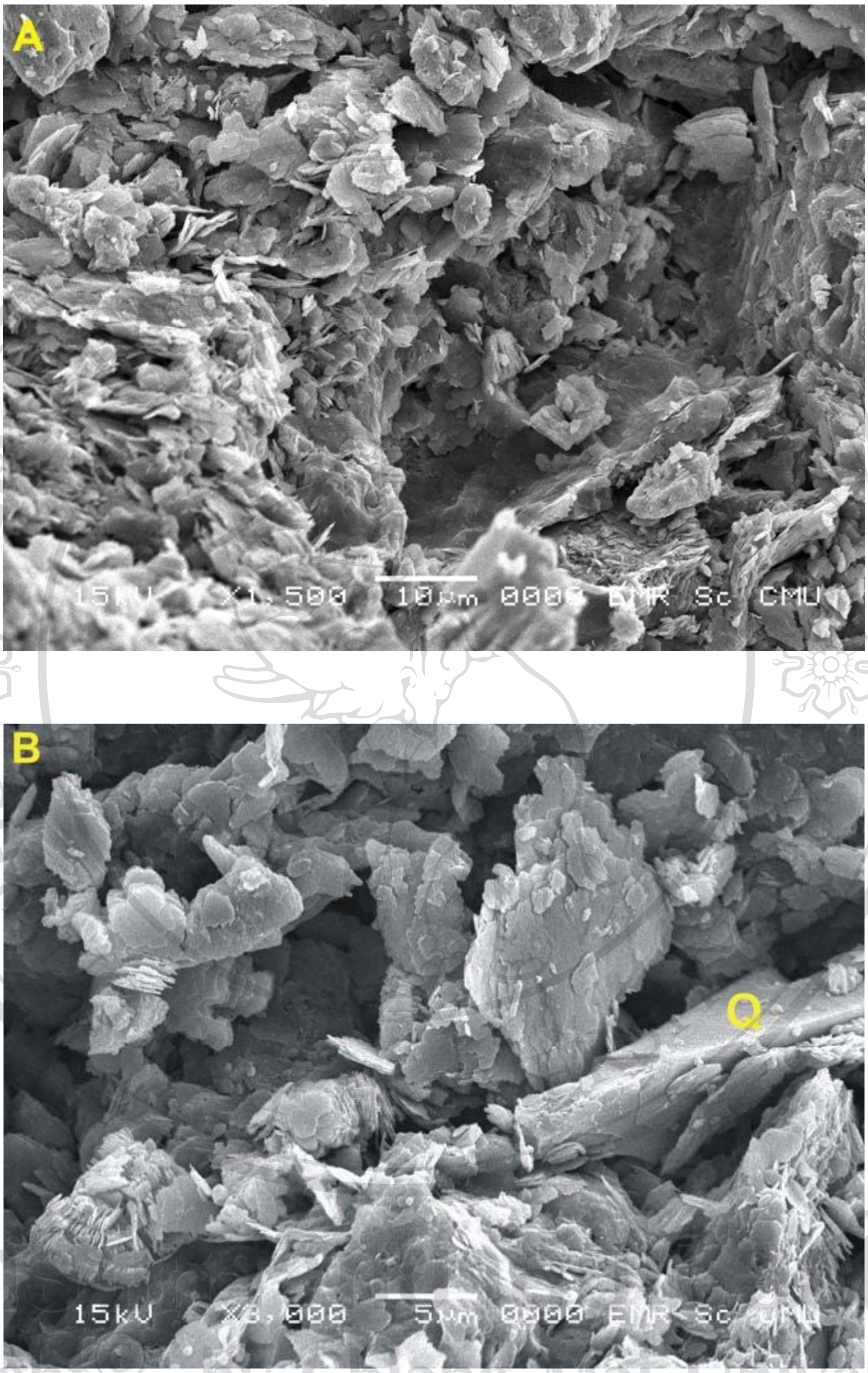


Figure 4.2.5 Scanning electron micrograph of sample Well-B-05. The Figure A illustrates the random orientation of tight and loose clay books in pores. Micro-pores are well observed and sub-hedral quartz (Q) was partially coated by calcite (Figure B).

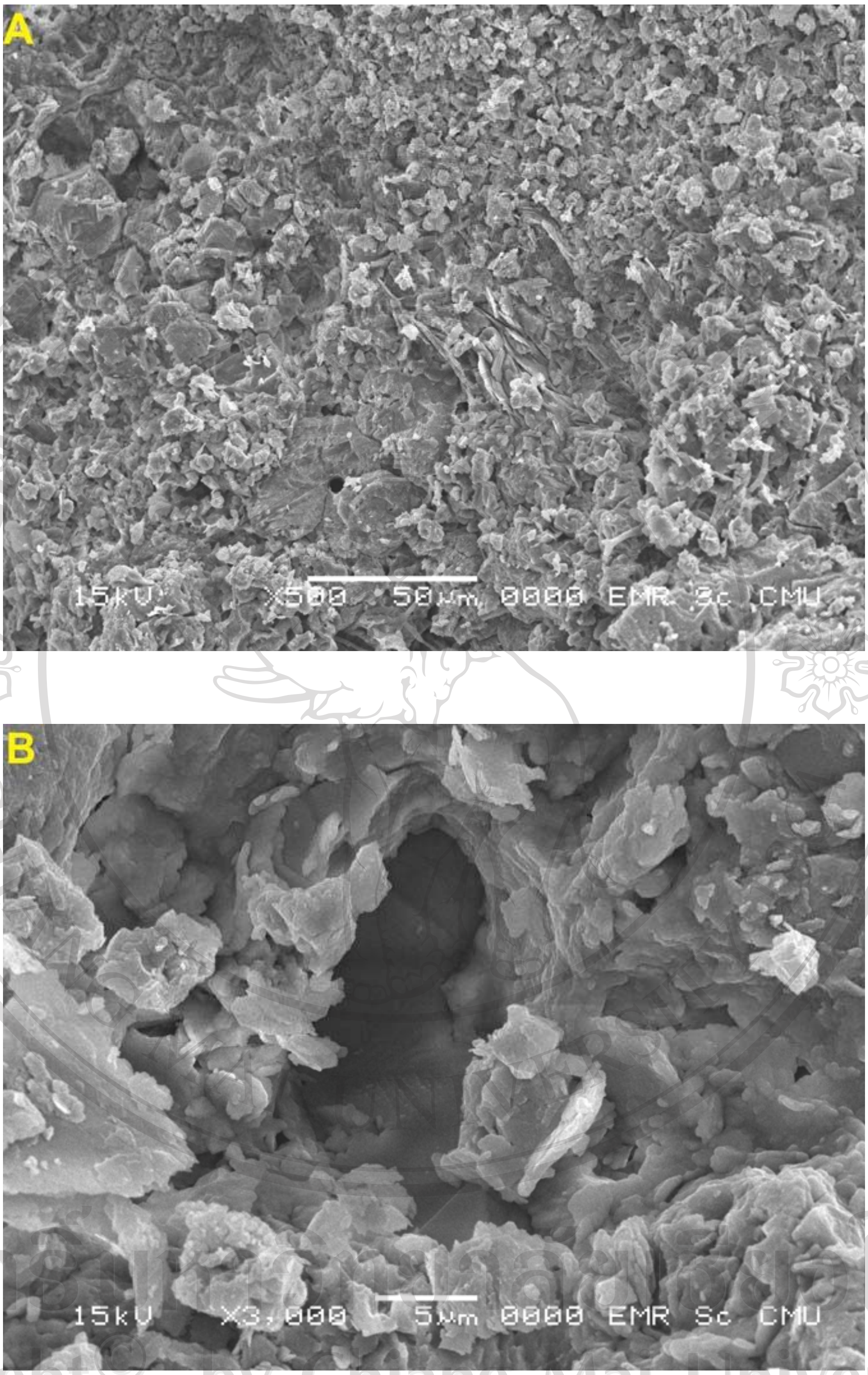


Figure 4.2.6 Scanning electron micrograph of sample Well-B-06. Figure A shows the crystal forms of calcite and distribution of clay books. Most of pores were plugged and covered by randomly oriented clay flakes and very fine calcite grains (Figure A). Figure B shows the pore networks with clay books around pore walls. A certain degree of dissolution is evident.

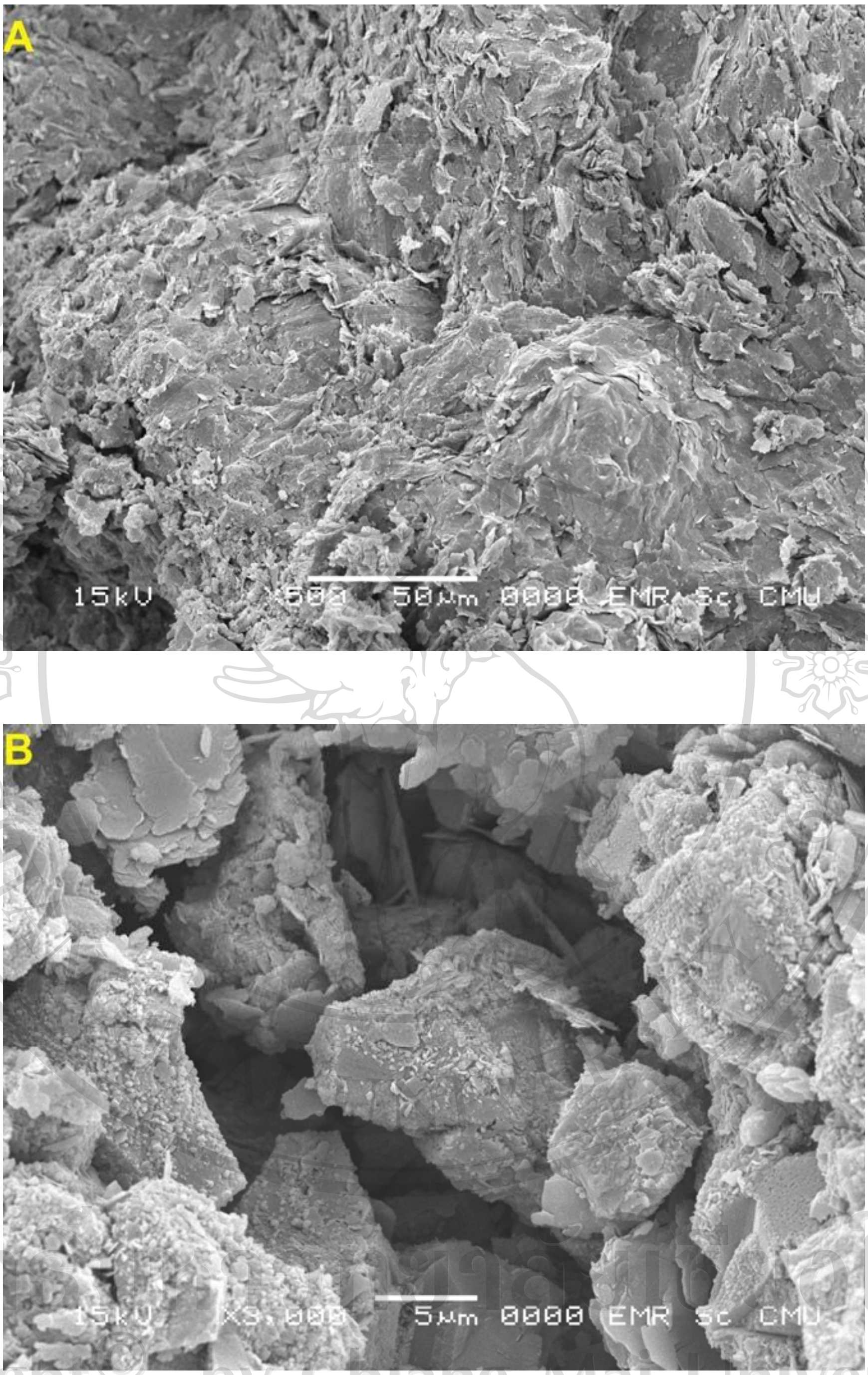


Figure 4.2.7 Scanning electron micrograph of sample Well-B-07. Figure A shows the morphological features of grains and ductile clay coating. Most surfaces of the grains (possibly quartz) are coated by microscopic calcite (Figure B).

4.2.8 SEM description of sample no. Well-B-08

The sample is medium- to very coarse-grained Lithic Arenite. Kaolinite was assumed a result of either direct replacement of unstable grains or filling of intergranular pores. Small euhedral crystal of authigenic calcite was observed in the matrix and small clay plates were identified in Figure 4.2.8B (Figure 4.2.8 A, B).

4.2.9 SEM description of sample no. Well-B-09

The sample is fine- to very coarse-grained Lithic Arenite. Figure 4.2.9A shows the surface characters of sample. Calcite overgrowth was observed together with micro pores between crystals. Booklets of kaolinite, small hexagonal quartz and calcite grains are present in Figure 4.2.9B (Figure 4.2.9 A, B).

4.2.10 SEM description of sample no. Well-B-10

The sample is fine- to very coarse-grained Lithic Arenite. Quartz and calcite grains with sugary texture are observed in Figure 4.2.10A. Euhedral quartz (Q) with thick clay booklets and overgrowth of calcite (C) are clearly present in Figure 4.2.10B (Figure 4.2.10 A, B).

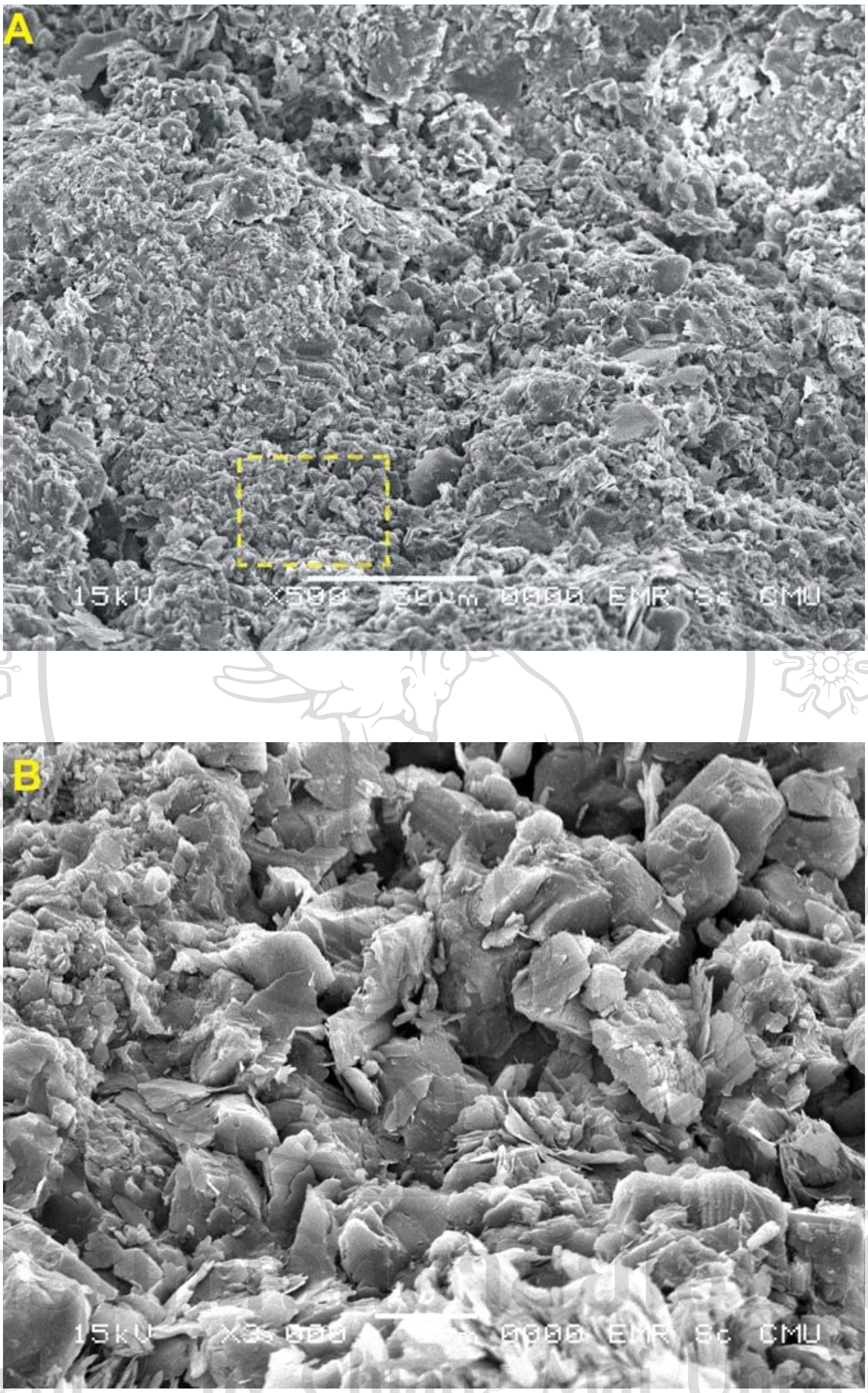


Figure 4.2.8 Scanning electron micrograph of sample Well-B-08. Figure A shows the surface features under low magnification (x500). Small euhedral crystals of authigenic calcite and small clay plates envelop in intergranular pores are identified in Figure B.

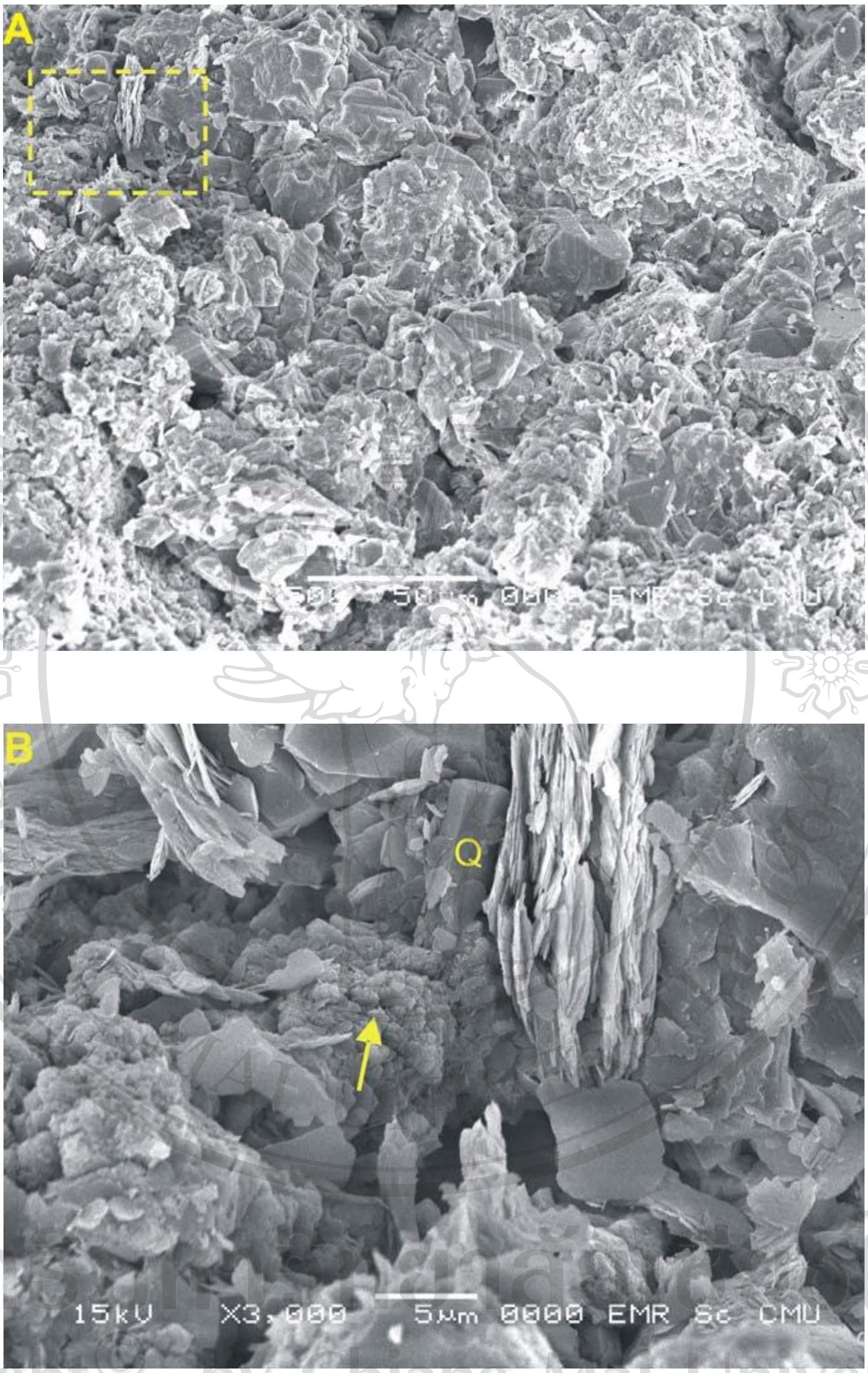


Figure 4.2.9 Scanning electron micrograph of sample Well-B-09. The calcite overgrowths with micro pores between crystals are present (Figure A). Kaolinite plates, small hexagonal quartz (Q) and calcite grains are observed in Figure B. The quartz is coated by very fine-grained calcite and the chemical composition of which was confirmed by EDS analysis. Yellow arrow indicates ferric carbonate.

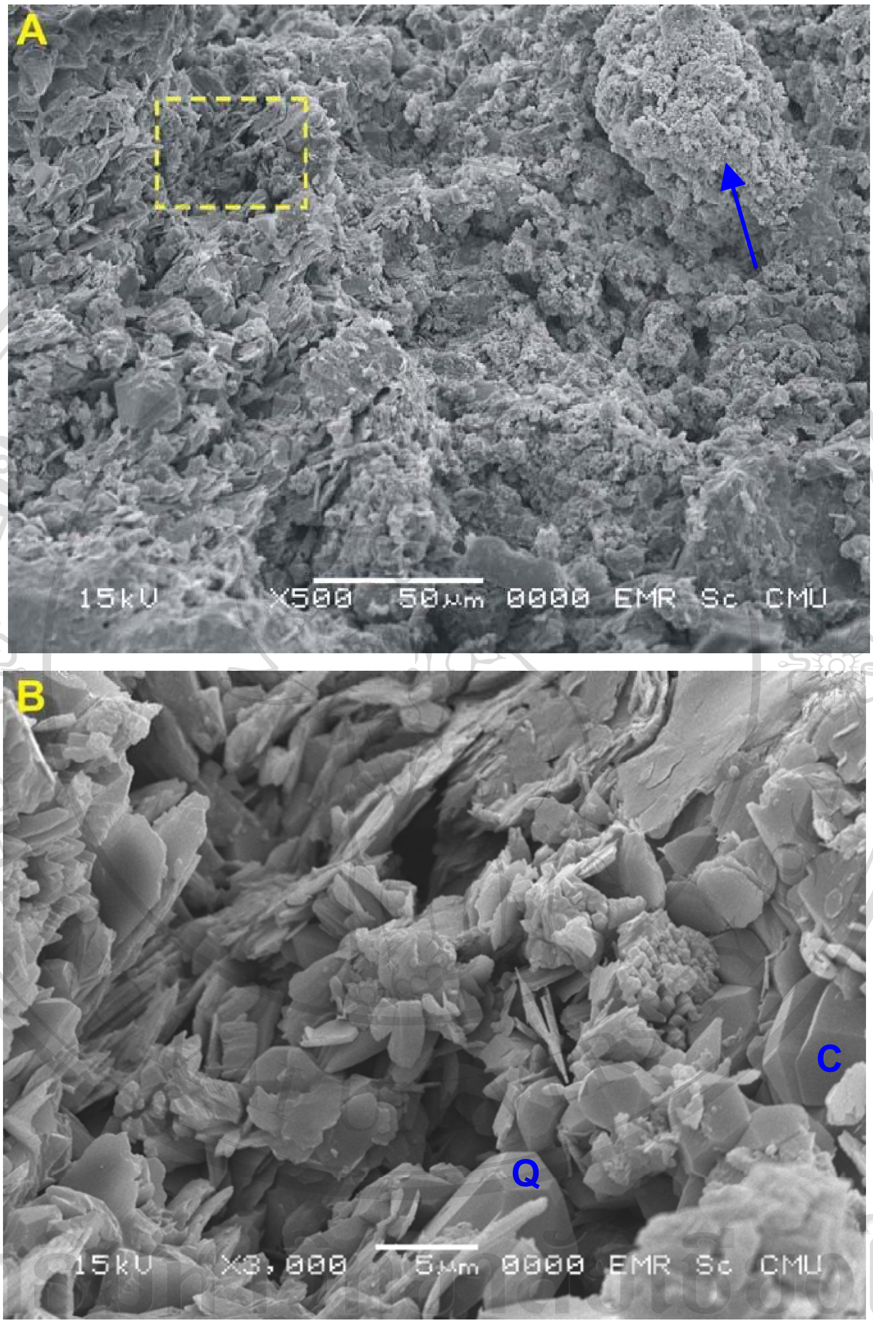


Figure 4.2.10 Scanning electron micrograph of sample Well-B-10. Calcite coated crystals (possibly quartz) were detected in Figure A (blue arrow). Quartz develops in the left portion of Figure A. Clay booklets with euhedral quartz (Q) and overgrowth of calcite (C) are clearly observed in Figure B.

Energy Dispersive Spectroscopy (EDS) of SEM analyses for the samples are attached in appendix-A.