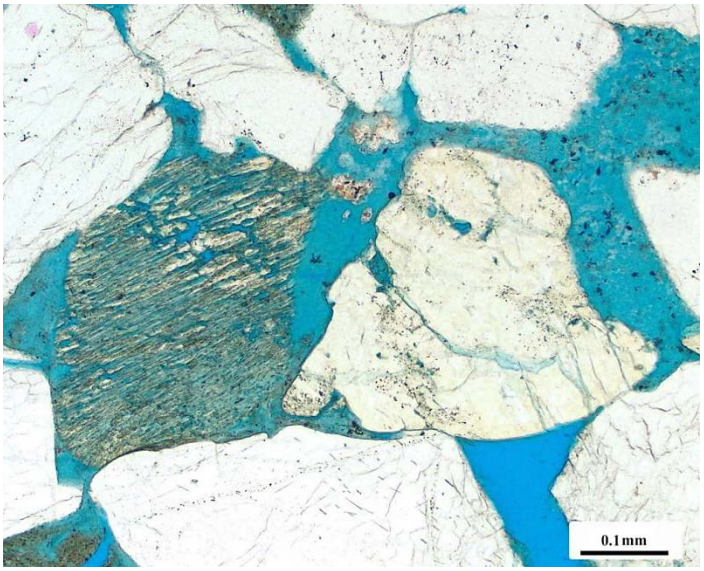
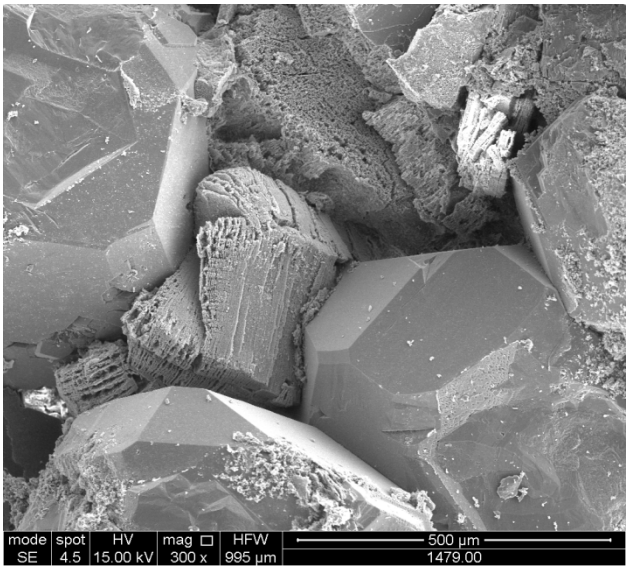
PETROLEUM SERVICES

Petrologic Analysis of Conventional Core Samples

Australia Department of Mines and Petroleum
GSWA Harvey 2, Harvey 3, and Harvey 4 Wells
Perth Basin, Australia





Houston ATC Job File No.: 150878G

December 2015

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December 15, 2015

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RE: Petrologic Analysis of GSWA Harvey 2, Harvey 3, and Harvey 4 Wells

This report presents the results of X-ray diffraction analysis (XRD), standard thin section petrography, and scanning electron microscopy (SEM) of thirty-four core samples from the **GSWA Harvey 2, Harvey 3, and Harvey 4 Wells, Perth Basin, Australia.** Table 1 lists the analytical program, previously-reported measured porosity, permeability, and grain density, as well as the lithology of each sample. The formation names for each sample are client-provided and are preliminary at this writing. Table 2 lists the XRD results. Figure 1 shows the Bulk Mineralogy XRD results in bar chart form. Figure 2 shows the relative clay mineralogy of each sample. Plates 1-34 document the petrographic observations and include the thin section and SEM micrograph descriptions. The purpose of this study is to determine the mineralogy, fabric and texture, mineral relations, presence of authigenic minerals, and to document the pore types. An overall project goal is to characterize the samples for suitability as a carbon capture and storage facility. These petrographic results will supplement an earlier stratigraphic study of reservoir and caprock seals in the GSWA Harvey 1 well (Olierook, 2014).

Harvey 2 Well

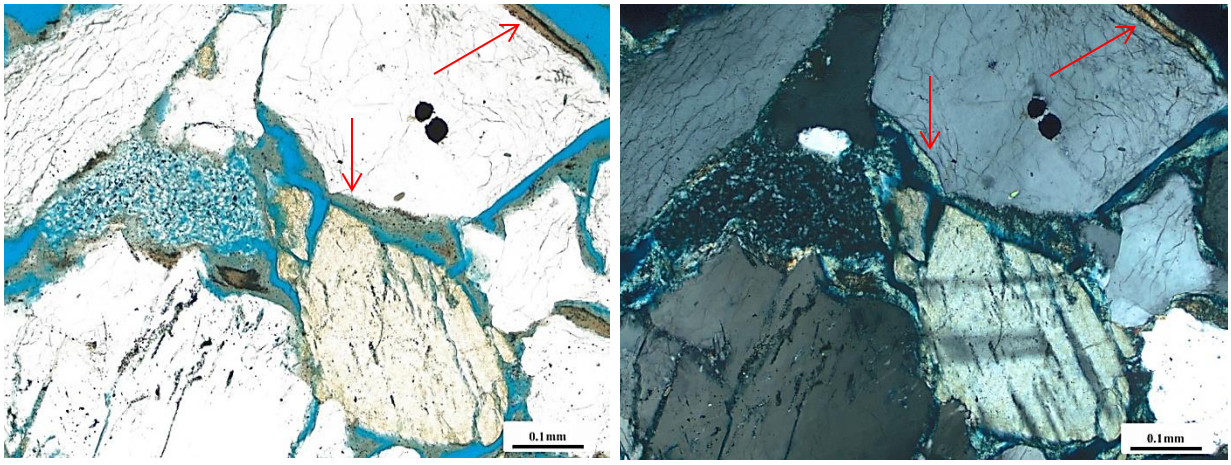
Two sandy claystone samples from the Yalgorup Member were analyzed from this well. The samples are both composed predominantly of smectite-rich mixed-layer illite/smectite and kaolin. In this study, “kaolin” is used to include intermixed kaolinite and dickite. Dickite has a distinguishably higher degree of crystallinity than kaolinite in XRD patterns from this data set. The moderate amounts of illite & mica and chlorite occur as detrital material. The abundant clay matrix is variably stained with goethite (Plate 2A). Areas of illite/smectite exhibit well-aligned clay platelets suggesting possible infiltrated clay structures (Plate 2B). The quartz and feldspar identified in XRD occur as scattered silt to lower very fine sand-size grains. Interparticle micropores are inferred to exist in the clay matrix. No macropores are visible in thin section.

Harvey 3 Well

Twenty-six of the samples in this study are from the Harvey 3 well (Table 1). Seventeen Harvey 3 well samples are sandstones and nine are claystones or mudstones. The two Eneabba shale samples are distinguished by their hematite or goethite with chaotic to brecciated fabric (Plate 3A) and possible clay-filled vertisol structures (Plate 4A). Both samples are composed predominantly of smectite-rich mixed-layer illite/smectite and common kaolin, based on XRD results. Minor amounts of grain-replacing kaolin is associated with minor intercrystal micropores (Plate 3D). Interparticle micropores occur between matrix clay platelets (Plate 4D).

The Yalgorup Member includes sandstone, argillaceous sandstone, kaolin-rich sandstone, calcite-cemented sandstone and sandy claystone. Most of the sandstones are coarse-grained, with several medium-grained sandstones. Framework grain composition of the sandstones varies only slightly with varying amounts of quartz, feldspars, and plutonic lithic grains. Sorting ranges from poor (Plate 5A) to moderately well (Plate 6A). Most of the samples exhibit massive fabric, with mostly long grain contacts, indicating moderate compaction. Samples with slightly greater and less compaction are noted. Faint lamination that is defined by the presence of aligned biotite and altered biotite is observed in several samples (Plate 6A). The argillaceous sandstone from 1079.85 meters exhibits a distinctive brecciated fabric with a possible cross-cutting microfault zone (Plate 9A).

Distinctive mechanically infiltrated clay fabrics are observed in two samples from the Yalgorup Member. The plane-light and crossed nicols photos below show illite/smectite grain-coating clay. The well-aligned aligned clay platelets termed cutans (arrows) forms in the meniscal water at grain surfaces. The sandstones with cutans rarely contain significant kaolinite.



The sandstone with the most kaolin is from 863.00 meters. Two forms of kaolin can be observed in most of the sandstones in this study: *grain-size* grain-replacing kaolin (after biotite) and *finely crystalline* kaolinite that is highly microporous and which fills pores and replaces grains (Plate 6B). Many of the replaced biotite flakes show heavy kaolinite/dickite replacement (Plate 10B).

Arcuate vermicular stacks of finely crystalline kaolinite are visible in both thin section (Plate 10B) and SEM (Plate 19D).

One sandstone is cemented with calcite (1258.05 meters). Framework grain composition is comparable to adjacent sandstones. The intergranular areas of this sandstone are occupied almost entirely by calcite (Plate 12A). Macropores observed in thin section include minor intragranular dissolution pores (Plates 12B and 12D). Intercrystal micropores associated with kaolinite-replaced grains are also observed.

Other authigenic minerals include quartz overgrowths (Plate 7D) and K-feldspar overgrowths (Plate 6D). The overgrowths are best observed in SEM images.

Measured porosity for Yalgorup Member sandstones ranges from 5.8% to 29.7%. The lowest measured porosity corresponds to the calcite-cemented sandstone, and the argillaceous sandstone is the second lowest. The highest porosity corresponds to the sample that also has the highest measured permeability (760.15 meters). This poorly sorted coarse-grained sandstone exhibits well-connected intergranular pores, intragranular dissolution pores, highly microporous authigenic kaolinite cement, and no calcite cement or clay matrix (including cutans).

The six claystone samples in the Yalgorup Member in the Harvey 3 well exhibit a variety of clay compositions. Total clay content in the claystone ranges from 59.5% to 73.3% (Table 2). Chlorite content is noticeable higher in the sample from 965.64 meters and the sample is green-colored in hand sample and thin section (Plate 8A). The percent smectite in the mixed-layer illite/smectite ranges from a low of 25-35% to a high of 60-70% (Table 2). Goethite occurs in the kaolinitic claystone sample from 1416.65 meters and appears to stain possible root traces and intraclasts. Mottled fabrics (Plate 15A), geopetal fabrics (Plate 8A), clotted illitic fabrics (Plate 13B), and possible rooted structures suggest that the claystones and mudstones underwent weathering and soil development.

Wonnerup Member samples include eight mostly massive, coarse-grained sandstones. Framework grains include abundant quartz that is mostly monocrystalline. Lesser polycrystalline quartz is observed as the largest grains. Moderate to common K-feldspar occurs as single grains and within plutonic lithic fragments. Plagioclase is noticeably low, based on both XRD results and thin sections. Oversized (Plate 27A) and grain-sized patches of kaolinite suggest extensive grain replacement. The rare plagioclase grains observed in thin section exhibit intragranular pores (Plate 25A). Medium and coarse grains of biotite and muscovite (Plate 25A) can occur adjacent to heavily altered micas that are being replaced by intermixed kaolinite and dickite (Plate 25B and Plate 24D). The replacement by kaolinite/dickite renders the biotite flakes more microporous (Plate 24B). Accessory garnet is noted in many of the sandstones (Plate 27B). Detrital clay matrix, including cutans, is notably absent from these sandstones.

Authigenic minerals in the Wonnerup sandstones include grain-size biotite-replacing kaolin (Plate 24D) and finely crystalline kaolinite that is highly microporous and which fills pores and replaces grains (Plate 23D). Curving vermicular stacks of finely crystalline kaolinite are visible

in thin section (Plate 27B) and SEM (Plate 28D). Quartz overgrowths (Plates 21B and 26C) are an important binding cement in these sandstones.

Pore types observed include abundant intergranular pores (Plate 22A), intragranular pores in heavily leached K-feldspar grains (Plate 21D), intragranular fractures, also typically found in K-feldspar grains (Plate 22A) and intercrystal micropores associated with authigenic finely crystalline kaolinite (Plate 23D). Exfoliation of biotite and kaolinite/dickite replacement also creates intraparticle micropores (Plate 25D). Measured porosity of Wonnerup Member sandstones ranges from a low of 17.9% to a high of 23.2%. Permeability ranges from 18.2 to 3700 md.

Harvey 4 Well

The six Harvey 4 samples are from the Eneabba shale (one sandstone and three claystones) and Yalgorup Members (two sandstones). The shallower sandstone is lower fine-grained and moderately well sorted, but exhibits a more disrupted and fragmented fabric, suggesting coring-induced damage. Cutans are observed but are typically broken (Plate 29B) or spalled off. Kaolinite in the sample appears to be grain-replacing.

Three sandy claystones make up the remaining Eneabba shale samples. Clay content ranges from 49.6% to 73.9% with smectite-rich mixed-layer illite/smectite predominant. Two of the samples exhibit poorly sorted grains that range up to very coarse sand size. Circular to oval illitic clay structures (Plate 31B) in the claystones suggest rooted zones within a soil profile. Trace to minor amounts of hematite stain intraclasts or the matrix in the samples. No macropores are visible in thin section. Interparticle micropores are inferred to exist in the clay matrix.

The Yalgorup sandstones are similar in texture and framework composition but exhibit distinctly different clay composition and pore types. The sample from 1326.25 meters is characterized by thick, well-formed mechanically infiltrated clay cutans and minor intergranular pores. Smectite-rich mixed-layer illite/smectite is the most abundant clay type in the cutans. In contrast, the sandstone from 1793.00 meters contains more kaolin clay and moderate amounts of intergranular pores. The abundant intergranular kaolin clay is highly microporous (Plate 34B). The minor amount of mixed-layer illite/smectite is low in smectite. The high permeability in the sample from 1793.00 meters may reflect the abundance of microporous intergranular kaolin.

Comparison with the Harvey 1 Well reservoir and caprocks

In their 2014 study of the Harvey 1 well, Olierook and others determined that highly porous and permeable sandstones of the Wonnerup Member may be suitable reservoirs for CO_2 sequestration. Minerals thought to react with CO_2 and brine, such as plagioclase and pyroxene occur in trace amounts or were not observed. K-feldspar content ranges from 6.9% to 13.5% and illite and mica content ranges from 0.7% to 2.8%, based on XRD results. Much of the biotite that occurs as sand-size detrital flakes is already heavily altered to kaolin (Plate 24B and 24D).

They also noted that the more lithologically heterogeneous Yalgorup Member could act as caprock and seal to the underlying Wonnerup reservoir. The results from the Harvey 3 well in this study further document the highly variable total clay content and clay species (Figure 2) in the Yalgorup Member claystones. The smectite content in the Yalgorup Member samples shows variation between samples (Table 2). Chlorite is common in one Yalgorup claystone sample (Plate 8A). These petrographic results should aid in the refinement of the stratigraphic framework of the target reservoir and caprock for the carbon sequestration study.

Thank you for the opportunity to work on these samples. Please contact me at mary.nelis@corelab.com if you have questions about this report.

Sincerely,



Mary Nelis
Senior Geologist
Core Laboratories Houston ATC

RESOURCES

Folk, R. L., 1980, Petrology of sedimentary rocks: Hemphill Publishing Co., Austin, Texas, 184 p.

Olierook, H.K.H., et al., (2014), Facies-based rock properties characterization for CO2 sequestration: GSWA Harvey 1 well, Western Australia. Marine and Petroleum Geology, v. 50, pp. 83-102.

Wilson, M.D., and Pittman, E.D., 1977, Authigenic clays in sandstones. Recognition and influence on reservoir properties and paleoenvironmental analysis: JSP, v. 47, p. 3-31.

Sordon, J., 1980, Precise identification of illite/smectite interstratifications by X-Ray powder diffraction: Clays and Clay Minerals, v.28, p. 401-411.

Sordon, J., 1984, X-Ray powder diffraction identification of illitic materials: Clays and Clay Minerals, v. 32, p. 337-349.

ANALYTICAL PROCEDURES

Thin Sections

Thin sections were prepared by first impregnating the samples with blue-dyed epoxy to augment cohesion and to prevent loss of material during grinding. Each thinly sliced sample was mounted on a frosted glass slide and then cut and ground in oil to a thickness of 30 microns. Dual carbonate stain was applied to differentiate between carbonate minerals. K-feldspar stain was applied to distinguish K-feldspar from plagioclase. The thin sections were analyzed using standard petrographic techniques in plane-polarized and cross-polarized light. The images in this report have been calibrated for on-screen viewing.

Scanning Electron Microscopy (SEM)

For the SEM/EDS Study, the samples were broken to form fresh surfaces. Each sample was then mounted on an aluminum stub and coated with a thin film of Iridium (Ir) using a Leica EM ACE600 coating unit. The SEM micrographs are secondary electron images taken with a digital imaging system attached to a FEI Quanta FEG250 Scanning Electron Microscope operating at 15kV. Qualitative elemental data of selected phases observed during the SEM study were obtained through the use of an interfaced Thermo Fisher Noran System 7 energy dispersive spectroscopy (elemental X-ray) unit equipped with a Si (Li) detector. Recognition of any authigenic clays was based on the criteria proposed by Wilson and Pittman (1977).

X-ray Diffraction (XRD)

Sample Preparation

Samples submitted for whole-rock and clay-fraction XRD mineral analyses are first cleaned of obvious drilling contaminants and then disaggregated in a mortar and pestle. Approximately five grams of each sample are transferred to isopropyl alcohol and pulverized using a McCrone micronizing mill. The resultant powders are dried, disaggregated, and packed into aluminum sample holders to produce random whole-rock mounts. A separate split of each sample is dispersed in a dilute sodium phosphate solution using a sonic probe. The suspensions are then centrifugally size-fractionated to isolate clay-size (<4 micron ESD) materials for a separate clay-fraction mount. The suspensions are then vacuum-deposited on silver membrane filters to produce oriented clay mineral aggregates. Membrane mounts are attached to stainless steel slugs and exposed to ethylene glycol vapor for a minimum of 24 hours.

Analytical Procedures

XRD analyses of the samples are performed utilizing a Scintag or Philips automated powder diffractometer equipped with a copper source (40kV, 40mA) and a solid state or scintillation detector. The whole rock samples are analyzed over an angular range of 2-60 degrees 2-theta at a scan rate of one degree/minute. The glycol-solvated clay-fraction mounts are analyzed over an angular range of 2-50 degrees 2-theta at a rate of 1.5 degrees/minute. Semi-quantitative determinations of whole-rock and phyllosilicate mineral amounts are done utilizing integrated peak areas (derived from peak-decomposition / profile-fitting methods) and empirical

reference intensity ratio (RIR) factors determined specifically for the diffractometer used in data collection. The total clay mineral (including mica) abundance of each sample is determined from the whole-rock XRD patterns using combined {00l} and {hkl} clay mineral reflections and suitable empirical RIR factors. XRD patterns from glycol-solvated clay-fraction samples are analyzed using techniques similar to those described above. Determinations of mixed-layer clay ordering and expandability are done by comparing experimental diffraction data from the glycol-solvated clay mineral aggregates with simulated one dimensional diffraction profiles generated using the program NEWMOD written by R.C. Reynolds.

TABLE 1

Australia Department of Mines and Petroleum, Harvey 2,3, & 4 Wells

ANALYTICAL PROGRAM AND SAMPLE SUMMARY

Sample ID	Well	Formation*	Depth (m):	Thin Section Plate #	SEM	XRD	Porosity (%)	Permeability (md)	Grain Density (g/cc)	Lithology:
PSH 8	Harvey-2	Yalgorup Mbr.	**511.04**	**1**	**X**	**X**	na	na	na	**sandy claystone**
PSH 11	Harvey-2	Yalgorup Mbr.	**790.68**	**2**	**X**	**X**	na	na	na	**sandy claystone**
PSH 7	Harvey-3	Eneabba shale	**725.44**	**3**	**X**	**X**	na	na	na	**sandy hematitic mudstone**
PSH 9	Harvey-3	Eneabba shale	**740.70**	**4**	**X**	**X**	na	na	na	**sandy claystone**
142	Harvey-3	Yalgorup Mbr.	**760.15**	**5**	**X**	**X**	29.7	4420.0	2.64	**sandstone**
147	Harvey-3	Yalgorup Mbr.	**863.00**	**6**	**X**	**X**	23.4	18.9	2.64	**kaolin-rich sandstone**
152	Harvey-3	Yalgorup Mbr.	**919.00**	**7**	**X**	**X**	28.3	6610.0	2.63	**sandstone**
PSH 11	Harvey-3	Yalgorup Mbr.	**965.64**	**8**	**X**	**X**	na	na	na	**slightly sandy claystone**
163	Harvey-3	Yalgorup Mbr.	**1079.85**	**9**	**X**	**X**	9.6	2.2	2.66	**argillaceous sandstone**
168	Harvey-3	Yalgorup Mbr.	**1179.70**	**10**	**X**	**X**	27.5	928.0	2.65	**kaolin-rich sandstone**
PSH 15	Harvey-3	Yalgorup Mbr.	**1226.38**	**11**	**X**	**X**	na	na	na	**sandy claystone**
175	Harvey-3	Yalgorup Mbr.	**1258.05**	**12**	**X**	**X**	5.8	0.0	2.65	**calcite-cemented sandstone**
PSH 18	Harvey-3	Yalgorup Mbr.	**1291.61**	**13**	**X**	**X**	na	na	na	**sandy claystone**
183	Harvey-3	Yalgorup Mbr.	**1335.50**	**14**	**X**	**X**	20.2	36.4	2.62	**sandstone**
PSH 24	Harvey-3	Yalgorup Mbr.	**1353.81**	**15**	**X**	**X**	na	na	na	**sandy claystone**
187	Harvey-3	Yalgorup Mbr.	**1394.30**	**16**	**X**	**X**	18.1	17.8	2.63	**sandstone**
186	Harvey-3	Yalgorup Mbr.	**1395.70**	**17**	**X**	**X**	20.5	333.0	2.64	**sandstone**
PSH 28	Harvey-3	Yalgorup Mbr.	**1406.33**	**18**	**X**	**X**	na	na	na	**sandy claystone**
4	Harvey-3	Yalgorup Mbr.	**1414.00**	**19**	**X**	**X**	21.4	21.2	2.64	**sandstone**
PSH 30	Harvey-3	Yalgorup Mbr.	**1416.65**	**20**	**X**	**X**	na	na	na	**slightly silty claystone**
11	Harvey-3	Wonnerup Mbr.	**1420.00**	**21**	**X**	**X**	23.2	35.1	2.64	**sandstone**
35	Harvey-3	Wonnerup Mbr.	**1444.00**	**22**	**X**	**X**	18.0	582.0	2.63	**sandstone**
53	Harvey-3	Wonnerup Mbr.	**1462.00**	**23**	**X**	**X**	19.8	1030.0	2.63	**sandstone**
70	Harvey-3	Wonnerup Mbr.	**1479.00**	**24**	**X**	**X**	18.5	309.0	2.64	**sandstone**
91	Harvey-3	Wonnerup Mbr.	**1500.00**	**25**	**X**	**X**	20.3	18.2	2.65	**sandstone**
110	Harvey-3	Wonnerup Mbr.	**1519.00**	**26**	**X**	**X**	17.9	2070.0	2.63	**sandstone**
135	Harvey-3	Wonnerup Mbr.	**1544.00**	**27**	**X**	**X**	18.4	633.0	2.64	**sandstone**
140	Harvey-3	Wonnerup Mbr.	**1549.00**	**28**	**X**	**X**	18.5	3700.0	2.68	**sandstone**
PSH 1	Harvey-4	Eneabba shale	**893.04**	**29**	**X**	**X**	na	na	na	**sandstone**
PSH 5	Harvey-4	Eneabba shale	**899.12**	**30**	**X**	**X**	na	na	na	**slightly sandy claystone**
PSH 7	Harvey-4	Eneabba shale	**902.78**	**31**	**X**	**X**	na	na	na	**sandy claystone**
PSH 10	Harvey-4	Eneabba shale	**906.33**	**32**	**X**	**X**	na	na	na	**sandy claystone**
1A	Harvey-4	Yalgorup Mbr.	**1326.25**	**33**	**X**	**X**	20.0	371.0	2.63	**sandstone**
4	Harvey-4	Yalgorup Mbr.	**1793.00**	**34**	**X**	**X**	21.1	2230.0	2.64	**sandstone**

**The GSWA is currently reviewing the stratigraphy of the southern Perth Basin, including the usage of units originally defined in the northern Perth Basin. The formation names and tops quoted in the DMP's Harvey studies are therefore preliminary and may be subject to change following this review.*

Australia Department of Mines and Petroleum
Harvey 2, Harvey 3, and Harvey 4 Wells
Perth Basin, Australia

Table 2

File: 150878

Mineralogy Determined by X-ray Diffraction

Sample ID	Depth (m):	Whole Rock Mineralogy (Weight %)								Clay Mineralogy (Weight %)				
		Quartz	K-Feldspar	Plagioclase	Calcite	Hematite	Goethite	Pyrite	Total Clay	Illite / Smectite	Illite & Mica	Kaolin*	Chlorite	% Smectite in I/S
PSH 8	511.04	15.3	4.8	7.0	0.0	0.0	3.1	0.6	69.3	37.5	4.0	21.6	6.2	20-30%
PSH 11	790.68	25.4	6.7	1.8	0.0	0.0	6.1	0.5	59.4	27.3	6.4	20.3	5.4	40-50%
PSH 7	725.44	41.8	13.4	1.0	0.0	1.2	0.0	0.6	42.1	24.0	4.5	11.4	2.2	20-30%
PSH 9	740.70	30.0	7.7	1.0	0.0	0.6	2.2	0.4	57.9	33.6	6.4	14.8	3.1	40-50%
142	760.15	75.8	10.8	0.6	0.0	0.0	0.0	0.0	12.7	0.0	1.0	10.2	1.5	20-30%
147	863.00	44.8	12.6	0.8	0.0	0.0	0.0	0.0	41.6	5.8	3.8	29.5	2.5	40-50%
152	919.00	73.0	15.1	0.6	0.0	0.0	0.0	0.0	11.3	1.4	1.3	7.6	1.0	20-30%
PSH 11	965.64	29.4	5.2	0.5	0.0	0.0	0.0	1.7	63.2	17.8	7.7	16.5	21.2	40-50%
163	1,079.85	46.1	10.6	9.0	0.0	0.5	0.0	0.4	33.4	29.3	2.4	1.2	0.5	20-30%
168	1,179.70	77.2	3.8	0.4	0.0	0.0	0.0	0.3	18.3	0.0	1.0	15.4	1.9	40-50%
PSH 15	1,226.38	30.0	8.5	5.2	0.0	1.2	0.0	0.5	54.6	37.0	10.2	5.3	2.1	20-30%
175	1,258.05	40.5	16.4	9.8	24.4	0.0	0.0	0.0	8.8	5.2	2.0	1.2	0.4	40-50%
PSH 18	1,291.61	18.1	5.6	9.7	0.0	2.6	0.0	0.0	64.0	39.0	7.8	14.5	2.7	20-30%
183	1,335.50	43.7	22.6	13.5	1.8	0.0	0.0	0.0	18.4	15.0	2.0	1.1	0.3	40-50%
PSH 24	1,353.81	18.1	8.5	11.4	0.0	0.7	1.8	0.0	59.5	39.7	7.7	9.4	2.7	20-30%
187	1,394.30	69.3	19.1	0.6	0.0	0.0	0.0	0.0	10.9	4.3	1.3	4.7	0.6	40-50%
186	1,395.70	67.9	18.2	0.8	0.0	0.0	0.0	0.0	13.1	7.4	2.1	2.9	0.7	20-30%
PSH 28	1,406.33	22.7	9.8	1.1	0.0	0.0	6.3	0.0	60.2	18.3	6.4	31.2	4.3	40-50%
4	1,414.00	66.9	14.8	0.6	0.0	0.0	0.0	0.0	17.6	2.3	1.6	12.7	1.0	20-30%
PSH 30	1,416.65	13.8	2.6	0.6	0.0	0.0	9.6	0.0	73.3	12.9	5.1	49.4	5.9	40-50%
11	1,420.00	55.4	6.0	0.3	0.0	0.0	0.0	0.0	38.4	2.7	2.8	28.1	4.8	20-30%
35	1,444.00	71.1	13.5	0.4	0.0	0.0	0.0	0.0	14.9	1.5	1.7	10.7	1.0	40-50%
53	1,462.00	75.7	13.0	0.5	0.0	0.0	0.0	0.3	10.4	1.9	1.2	6.2	1.1	20-30%
70	1,479.00	73.5	8.3	0.2	0.0	0.0	0.0	0.0	18.0	1.7	1.6	12.8	1.9	40-50%
91	1,500.00	63.5	9.1	0.6	0.0	0.0	0.0	0.0	26.9	2.1	2.2	17.2	5.4	20-30%
110	1,519.00	85.9	7.1	0.2	0.0	0.0	0.0	0.0	6.8	1.6	0.8	3.8	0.6	40-50%
135	1,544.00	79.8	13.3	0.5	0.0	0.0	0.0	0.0	6.4	1.0	0.7	3.7	1.0	20-30%
140	1,549.00	85.8	7.1	0.4	0.0	0.0	0.0	0.0	6.7	2.2	1.0	3.0	0.5	40-50%
PSH 1	893.04	60.8	14.2	3.5	0.0	0.0	0.0	0.0	21.5	7.9	1.7	10.6	1.3	20-30%
PSH 5	899.12	20.9	3.0	1.2	0.0	0.9	0.0	0.0	73.9	57.4	3.1	10.1	3.3	40-50%
PSH 7	902.78	43.1	3.9	1.9	0.0	1.5	0.0	0.0	49.6	39.2	4.0	4.2	2.2	20-30%
PSH 10	906.33	31.4	2.4	1.3	0.0	0.4	0.0	0.0	64.5	50.9	3.1	8.0	2.5	40-50%
1A	1,326.25	44.3	25.7	13.8	0.0	0.0	0.0	0.0	16.2	12.8	2.4	0.7	0.3	20-30%
4	1,793.00	70.7	11.8	0.4	0.0	0.0	0.0	0.0	17.1	1.9	1.4	12.5	1.3	40-50%

*Kaolin includes kaolinite and dickite

Figure 1
Harvey 2, Harvey 3, Harvey 4 Wells, Perth Basin, Australia

Whole Rock Mineralogy Determined by X-ray Diffraction

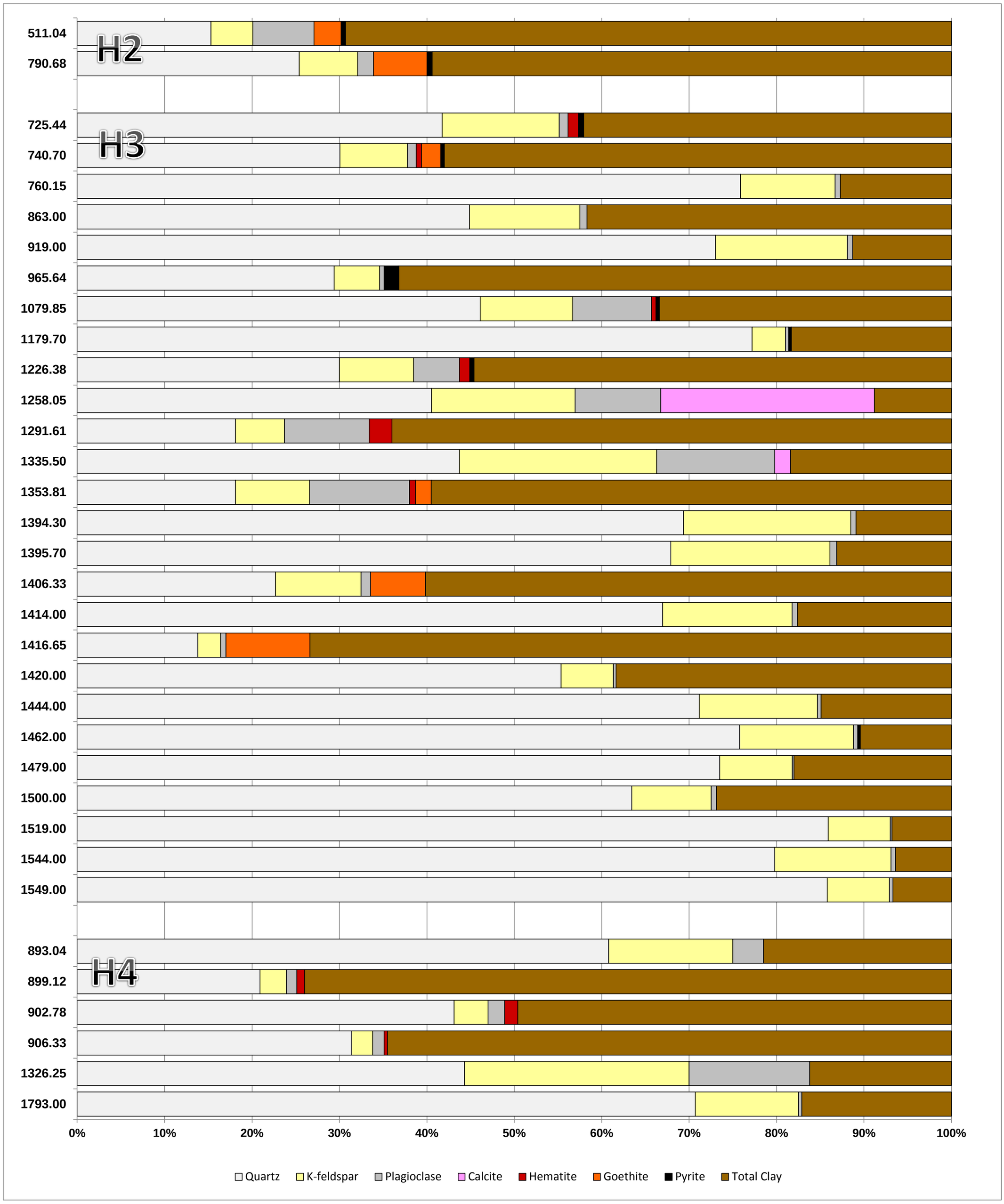


Figure 2
Harvey 2, Harvey 3, Harvey 4 Wells, Perth Basin, Australia
Relative Clay Mineralogy Determined by X-ray Diffraction

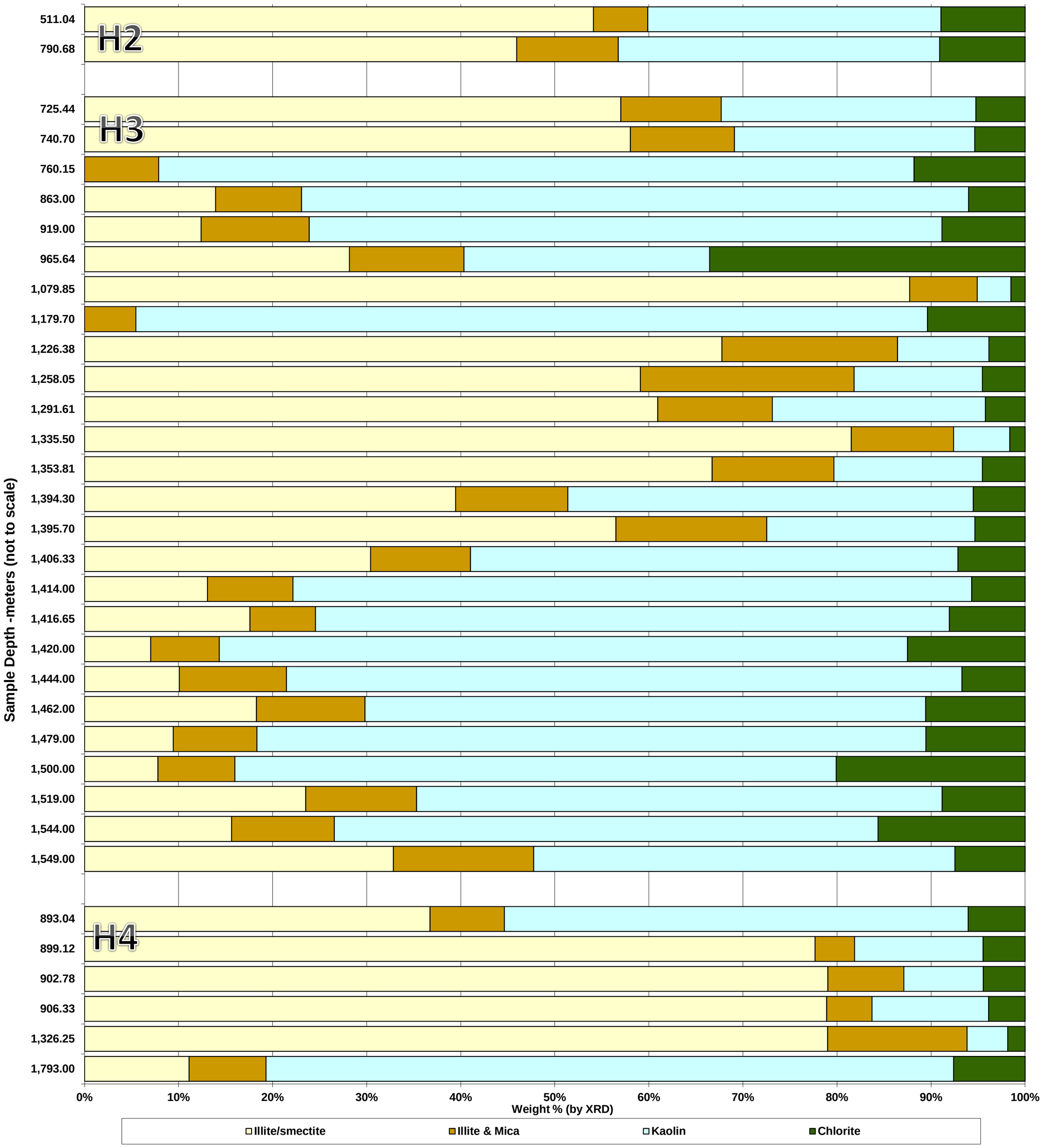
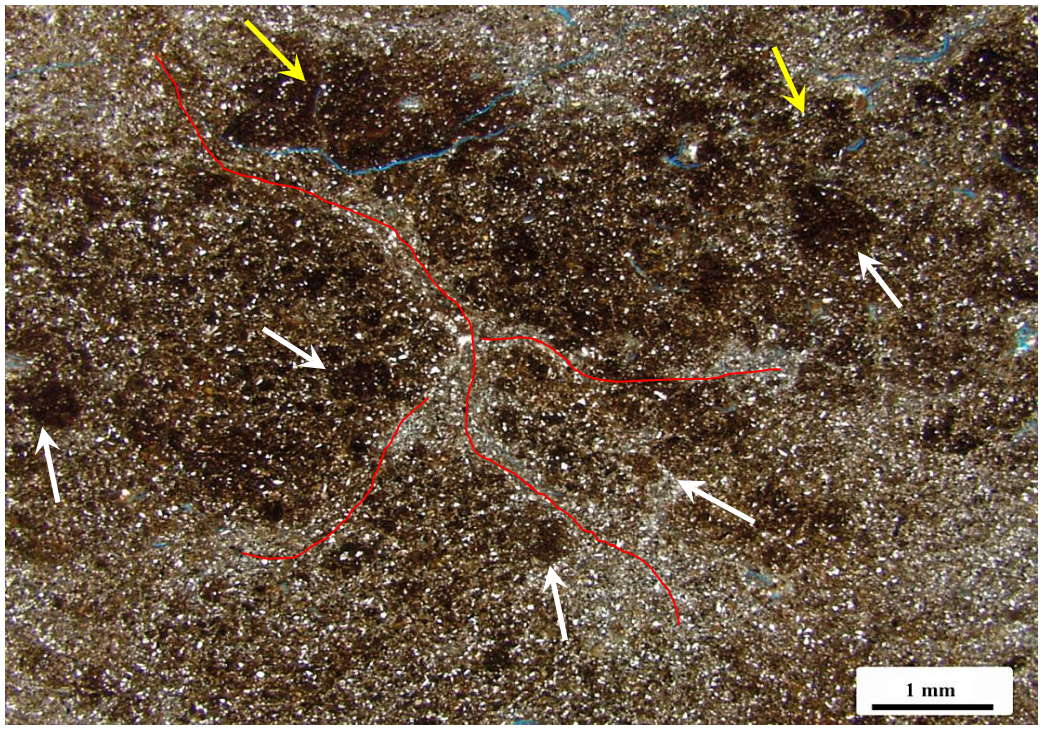


PLATE 1

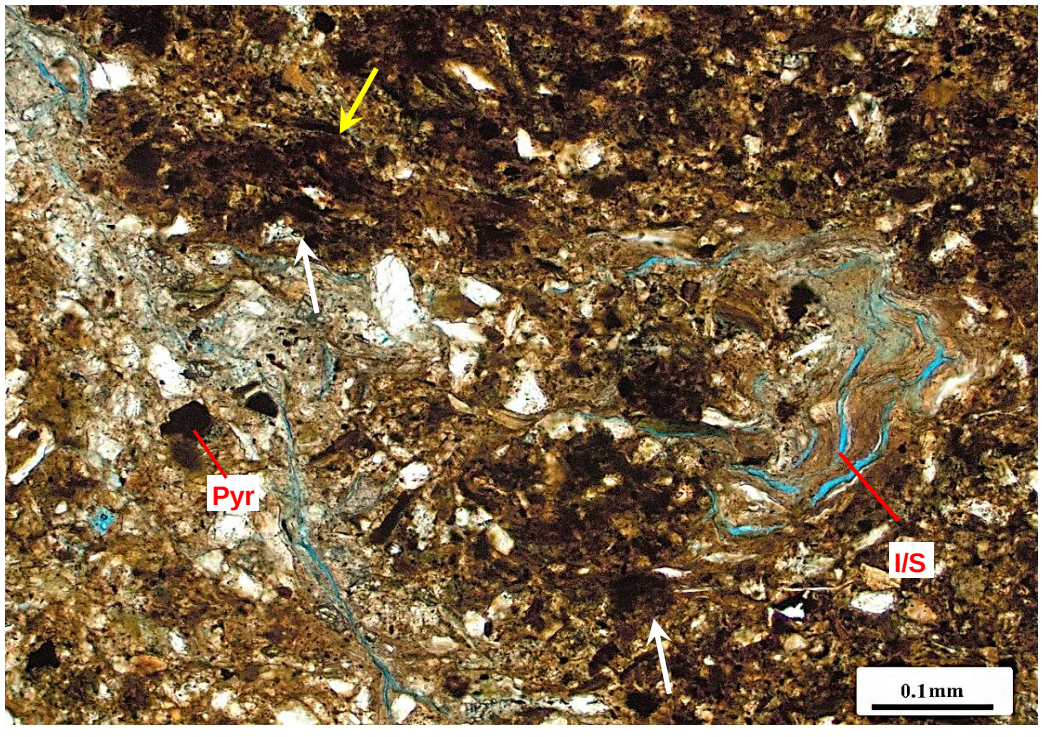
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-2
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 511.04
Sample ID: PSH 8

A



B



**The GSWA is currently reviewing the stratigraphy of the southern Perth Basin, including the usage of units originally defined in the northern Perth Basin. Formation names and tops quoted in the DMP's Harvey studies are therefore preliminary and may be subject to change following this review.*

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

Sample Description

Lithology: sandy claystone

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.073 (L. very fine sand)
Grn.Sorting: moderately well

Structures:
massive to mottled; clots and anastomosing to branching patches of illitic clay

Framework Grains:
common quartz; moderate plagioclase; minor K-feldspar and plutonic lithic fragments, argillaceous intraclasts (hematite-stained)

Accessory Grains:
common mica; minor plant fragments, heavy mineral grains; trace chlorite

Matrix:
abundant clay matrix

Cements:
pervasive hematite stain of matrix clay

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	15.3	Goethite	3.1
K-Feldspar	4.8	Hematite	0.0
Plagioclase	7.0	Pyrite	0.6
Calcite	0.0	Total Clay	69.3

Clay Abundance (Weight %)

Illite / Smectite	37.5	Kaolin*	21.6
Illite & Mica	4.0	Chlorite	6.2

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a silty to sandy claystone with evenly dispersed grains (white flecks). Several areas of the thin section show hematite-stained clay-rich intraclasts or clots (white arrows). Detrital muscovite and biotite flakes are present. The red lines trace a non-hematitic structure interpreted to reflect rooting Authigenic pyrite occurs as distinct framboids (Pyr). The yellow arrows indicate patches with the greatest hematite staining. Photo B features an illite/smectite (I/S) structure that consists of well aligned pure clay platelets (no detrital silt). The structure may represent infiltrated clay. The epoxy-filled fractures (blue) are a consequence of the smectite-rich clay.

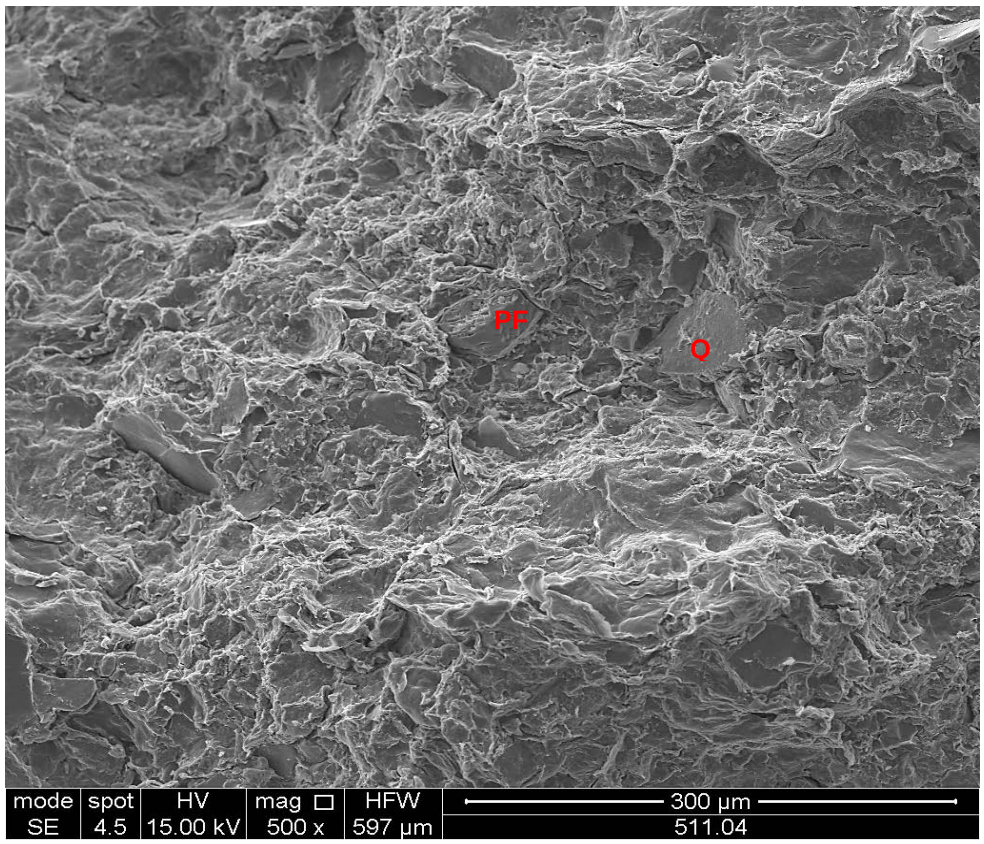
PLATE 1 (cont'd)

Scanning Electron Microscopy

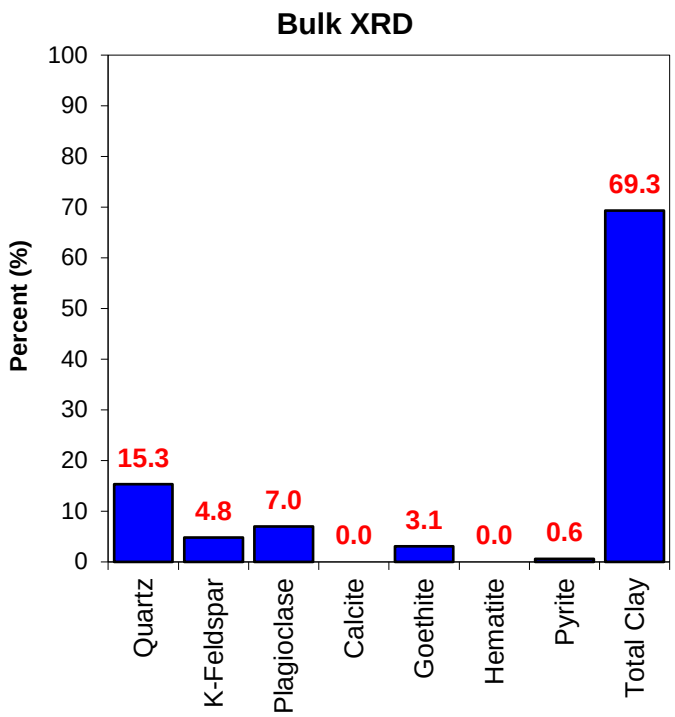
Company: Australia Department of Mines and Petroleum
Well: Harvey-2
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 511.04
Sample ID: PSH 8

Lithology: sandy claystone

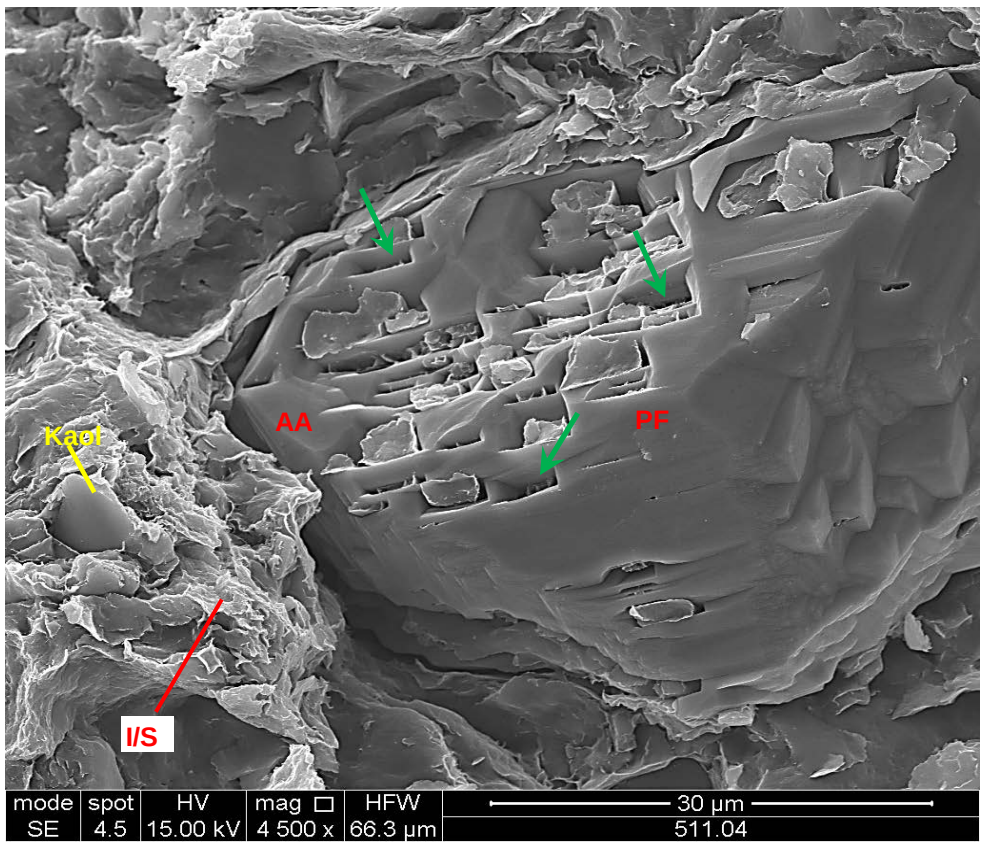
C

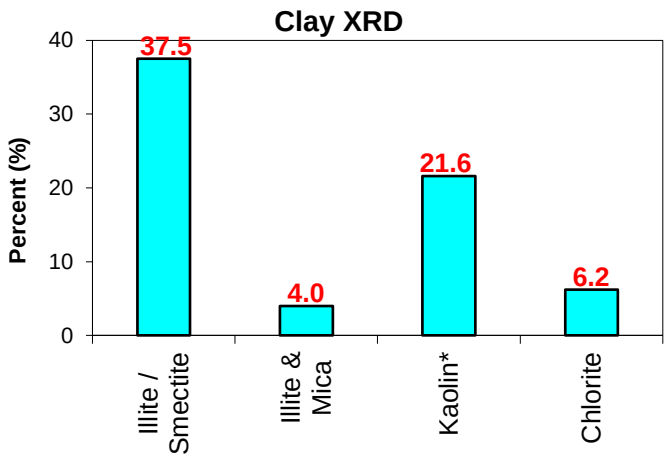


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses of this sample show scattered grains that include quartz (Q) and plagioclase (PF) in the abundant clay matrix. Mixed-layer illite/smectite is the most abundant clay type (I/S) although kaolinite (Kaol) is also identified using EDS analysis. The clay matrix shows minor interparticle micropores. The plagioclase grain featured in Image D exhibits euhedral overgrowths (AA) and probable dissolution pits (arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

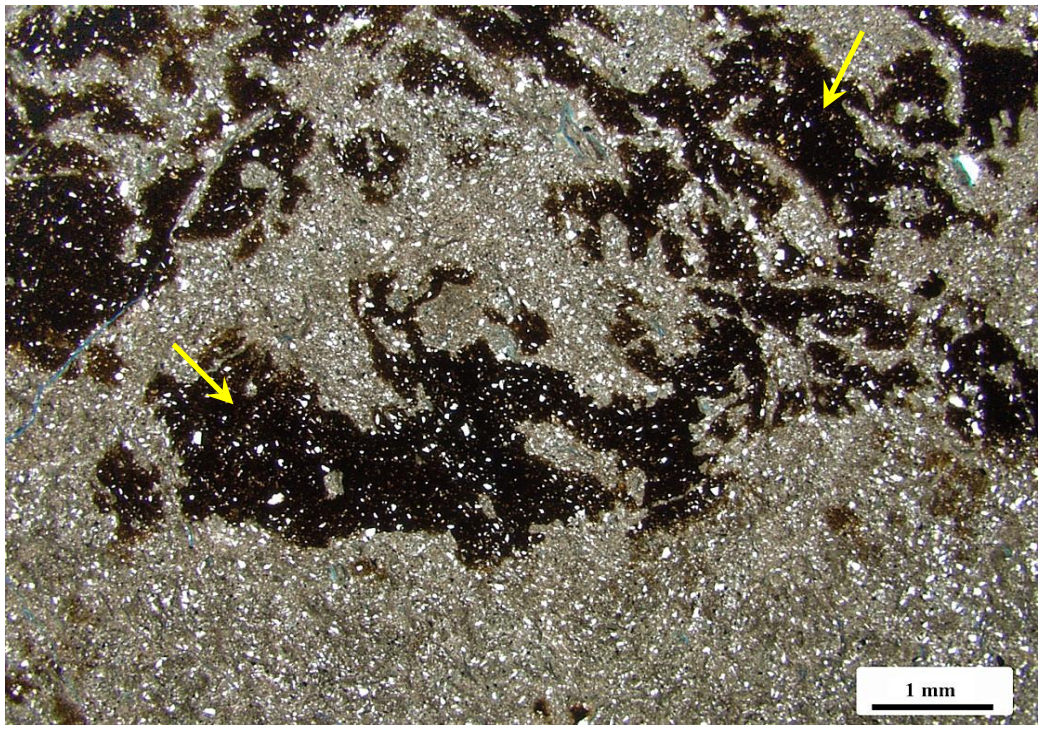
**Core analysis data taken at na psi*

PLATE 2

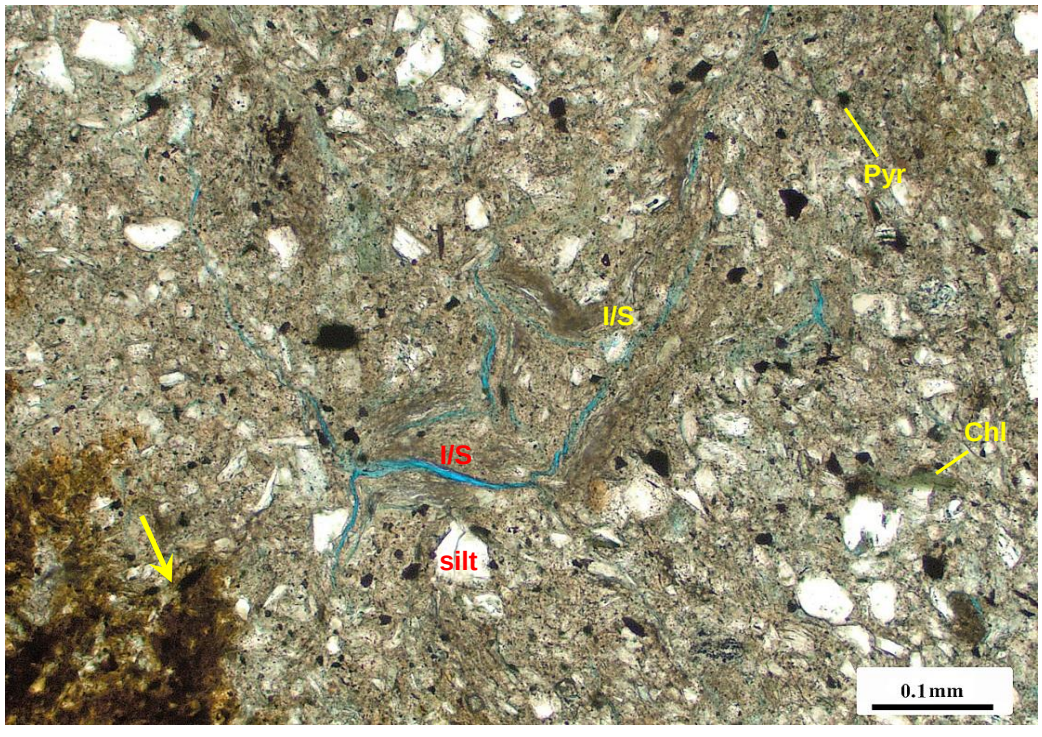
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-2
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 790.68
Sample ID: PSH 11

A



B



Sample Description

Lithology: sandy claystone

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.079 (L. very fine sand)
Grn.Sorting: moderate

Structures:
mottled with clots of illitic clay; hematitic infiltration sediment with clasts of host mudrock

Framework Grains:
abundant quartz; minor K-feldspar and plutonic lithic fragments; minor altered biotite

Accessory Grains:
common mica; minor plant fragments; trace chlorite

Matrix:
abundant clay matrix

Cements:
minor pyrite associated with plant fragments; patchy hematite stain of some matrix

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	25.4	Goethite	6.1
K-Feldspar	6.7	Hematite	0.0
Plagioclase	1.8	Pyrite	0.5
Calcite	0.0	Total Clay	59.4

Clay Abundance (Weight %)

Illite / Smectite	27.3	Kaolin*	20.3
Illite & Mica	6.4	Chlorite	5.4

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a sandy claystone with evenly dispersed silt to lower very fine sand grains (white flecks). Matrix clay platelets exhibit a mottled fabric. Areas of the thin section show mottled hematite-staining (yellow arrows). Minor detrital chlorite (Chl), muscovite, and biotite flakes are present. Authigenic pyrite occurs as dispersed framboids (Pyr). Photo B features an illite/smectite (I/S) structure that consists of well-aligned pure clay platelets (no detrital silt). The structure may represent infiltrated clay or a root zone. The epoxy-filled fractures (blue) are a consequence of the smectite-rich clay.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

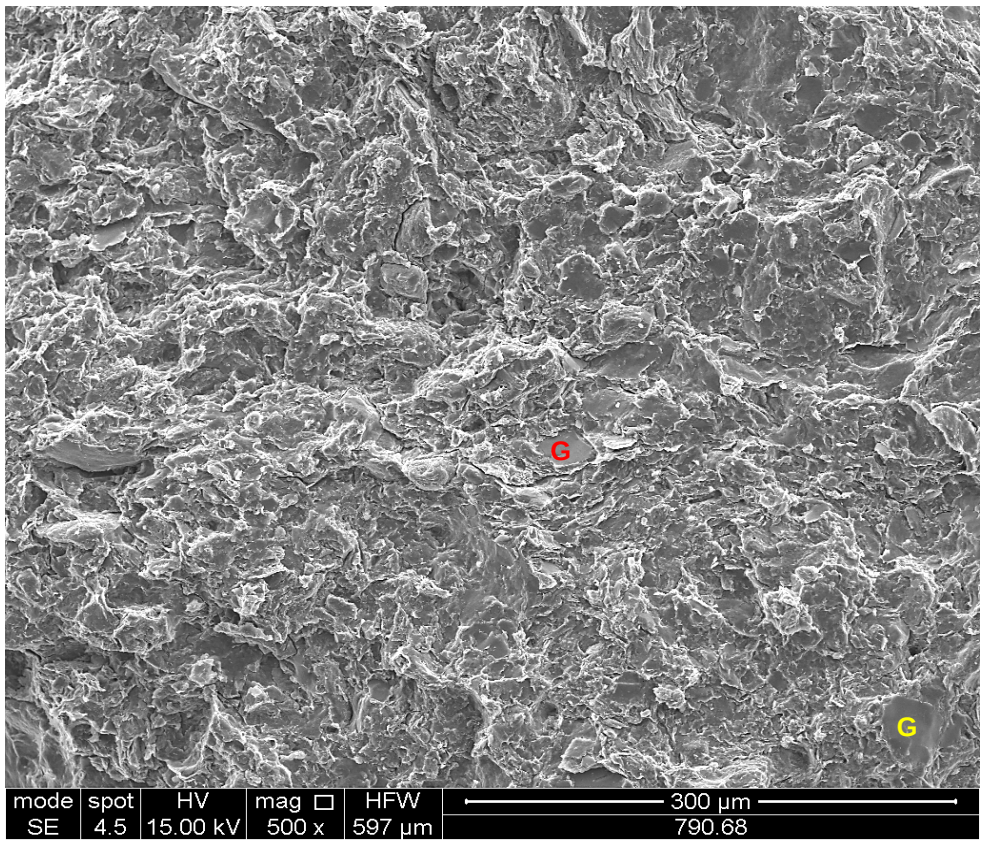
PLATE 2 (cont'd)

Scanning Electron Microscopy

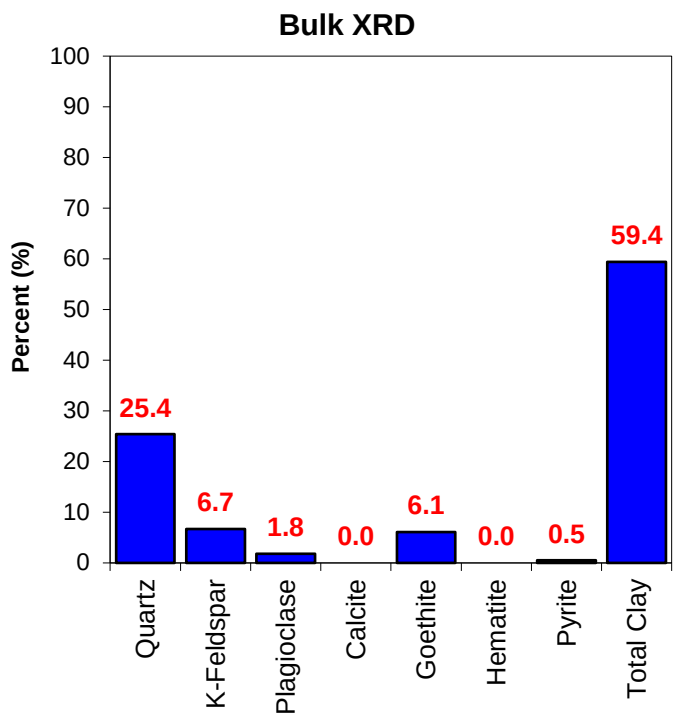
Company: Australia Department of Mines and Petroleum
Well: Harvey-2
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 790.68
Sample ID: PSH 11

Lithology: sandy claystone

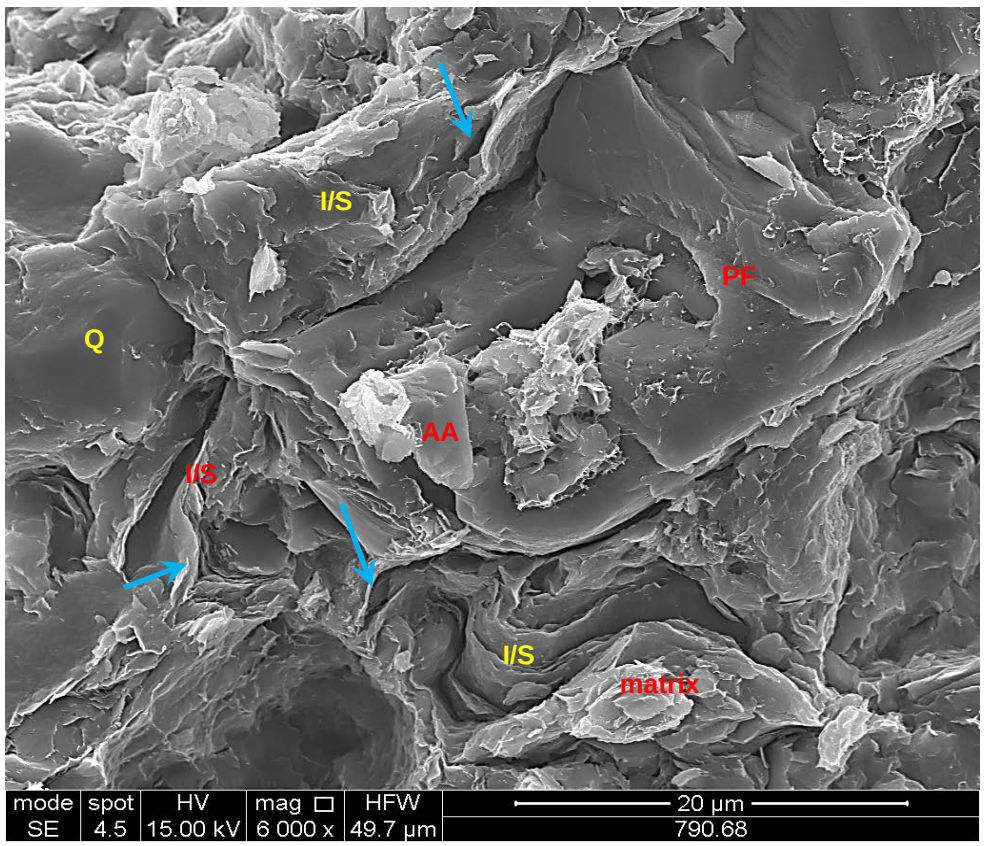
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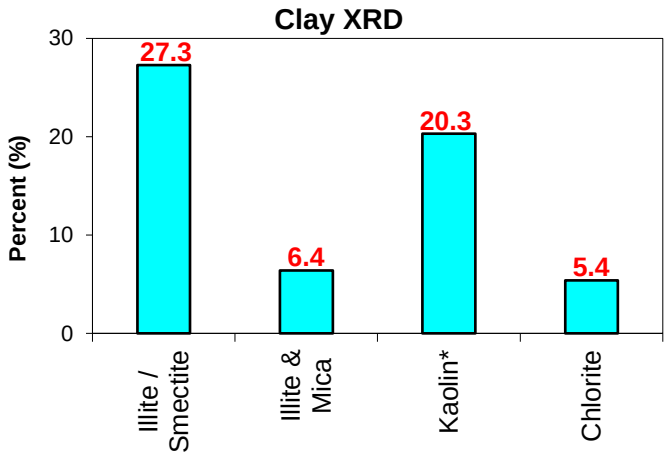


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows grains including quartz (Q) and plagioclase (PF) in the abundant clay matrix. XRD analysis indicates that mixed-layer illite/smectite (I/S) is the most abundant matrix clay type. Interparticle micropores are associated with the clay matrix (blue arrows). A possible authigenic albite (AA) overgrowth is noted on the plagioclase grain.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

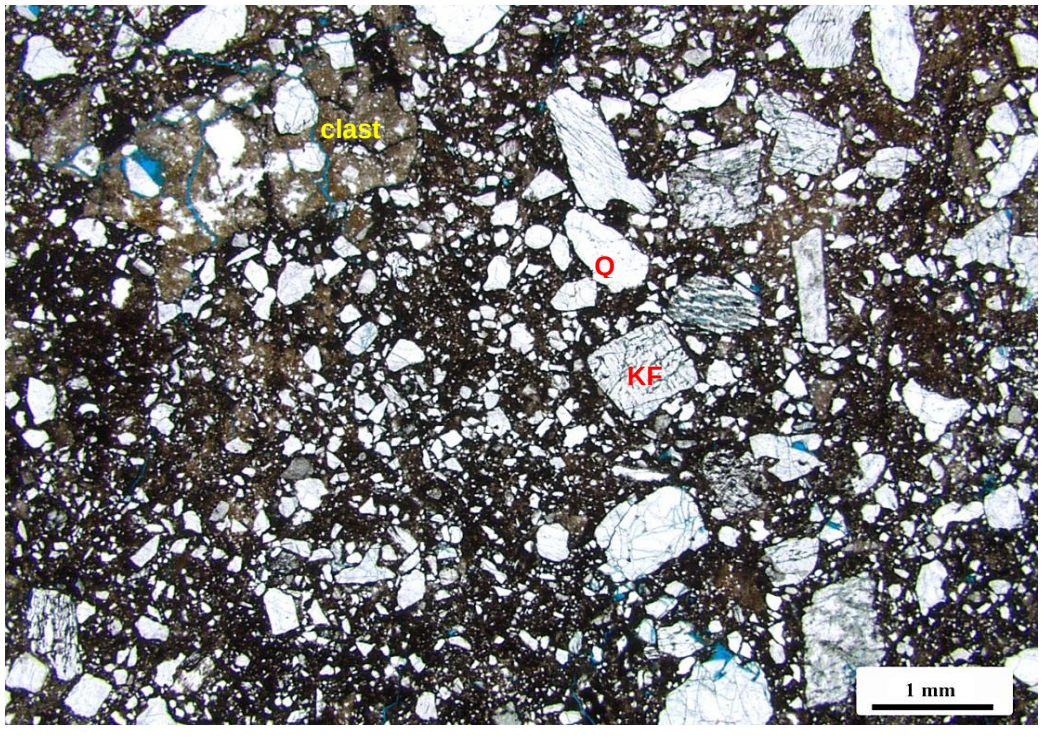
**Core analysis data taken at na psi*

PLATE 3

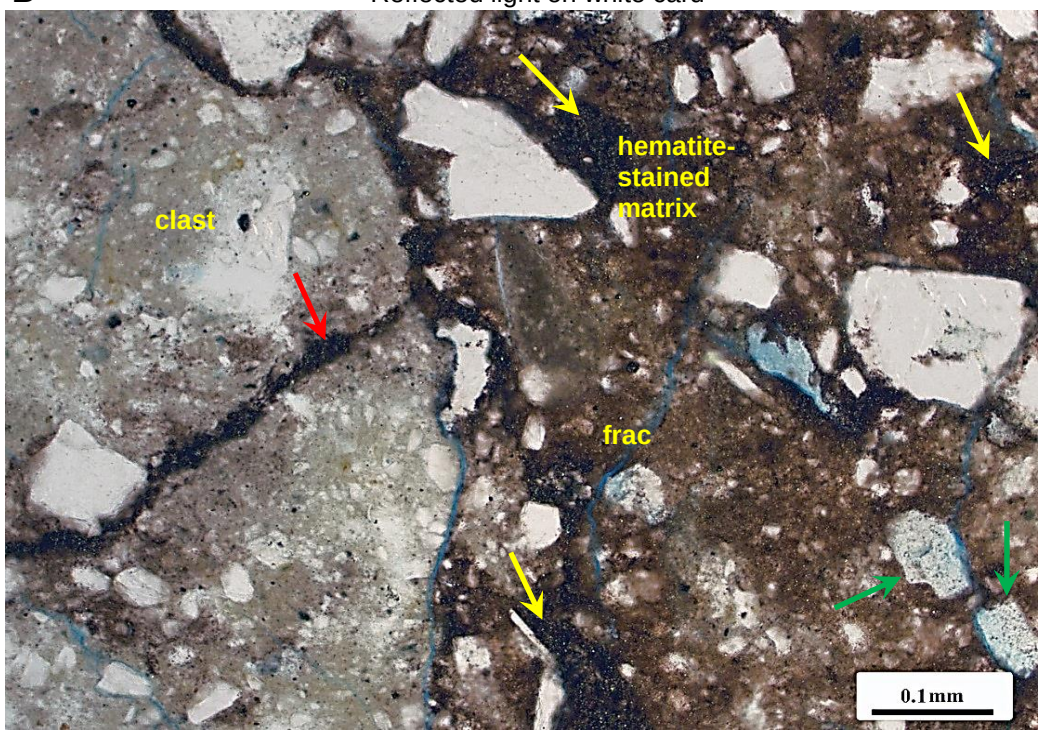
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 725.44
Sample ID: PSH 7

A



B Reflected light on white card



Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

Sample Description

Lithology: sandy hematitic mudstone

Est.Classif. (Folk, 1980): sublitharenite
Grain Size (mm): 0.442 (U. medium sand)
Grn.Sorting: poor

Structures:
massive and chaotic; breccia zones with more hematitic matrix infill

Framework Grains:
abundant quartz; moderate K-feldspar and minor plutonic lithic fragments; minor kaolinite-replaced grains

Accessory Grains:
minor mica; trace heavy minerals

Matrix:
abundant clay matrix

Cements:
pervasive hematite stain of matrix clay

Pore Types:
rare intragranular dissolution pores in feldspar grains

XRD-Whole Rock Mineralogy (Weight %)

Quartz	41.8	Goethite	0.0
K-Feldspar	13.4	Hematite	1.2
Plagioclase	1.0	Pyrite	0.6
Calcite	0.0	Total Clay	42.1

Clay Abundance (Weight %)

Illite / Smectite	24.0	Kaolin*	11.4
Illite & Mica	4.5	Chlorite	2.2

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a massive to chaotic sandy hematitic mudstone breccia with pervasive hematite staining. Photo A shows the poor sorting of grains such as quartz (Q) and K-feldspar (KF). A breccia clast (clast) is also noted. It is distinguishable because it is less hematitic. The dark reddish brown color of the hematite is visible in Photo B, which was taken with the sample resting on a white card, using reflected light. The yellow arrows indicate the most heavily stained matrix. The red arrow indicates a fracture filled with hematite matrix in the clast. Kaolinite detected in XRD is observed in thin section in kaolinite-replaced grains (green arrows).

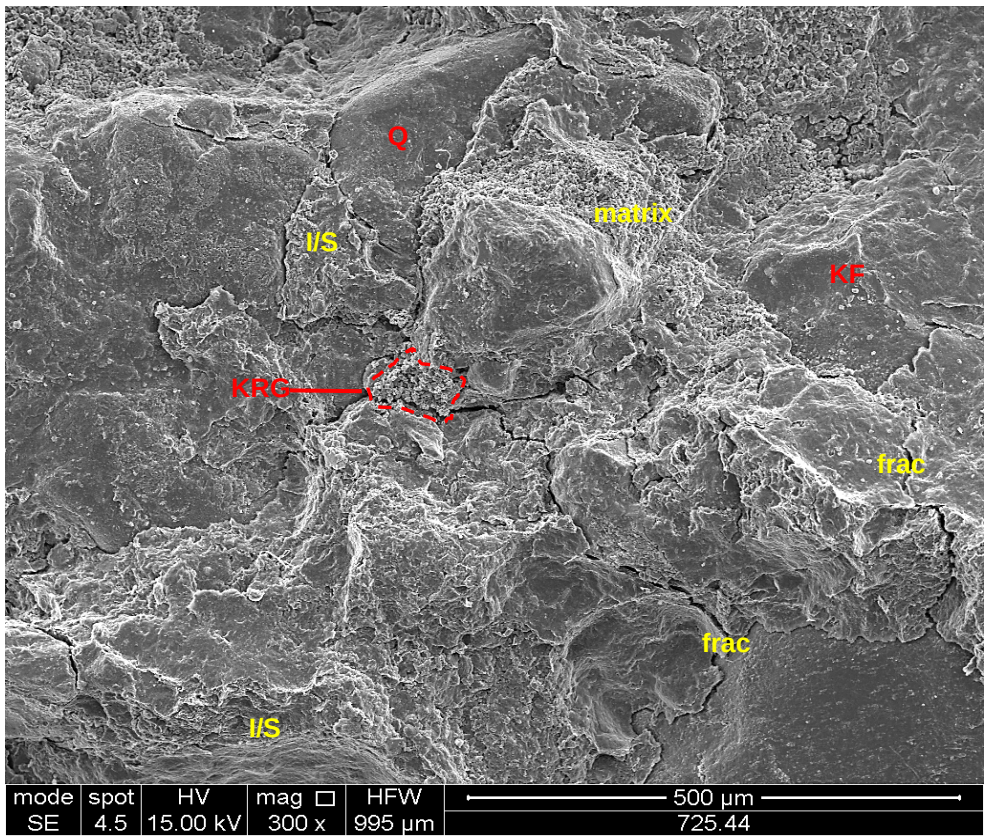
PLATE 3 (cont'd)

Scanning Electron Microscopy

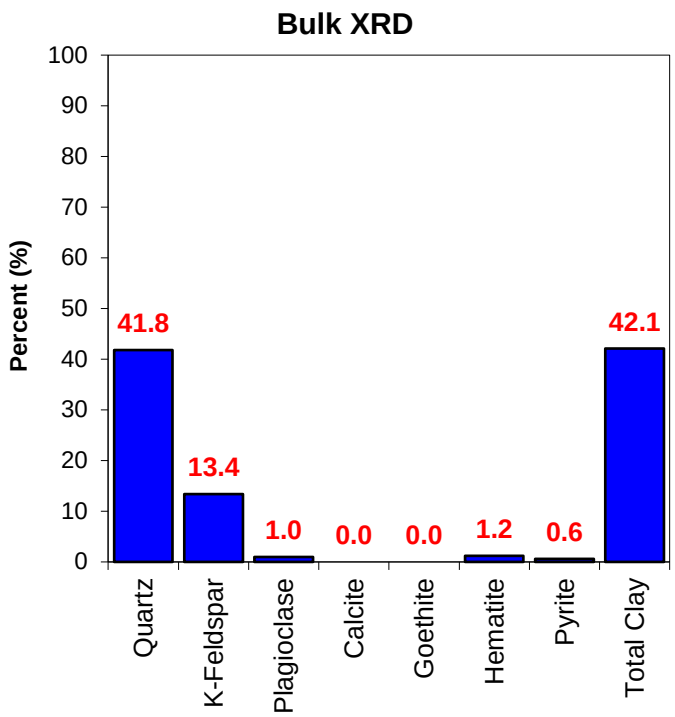
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 725.44
Sample ID: PSH 7

Lithology: sandy hematitic mudstone

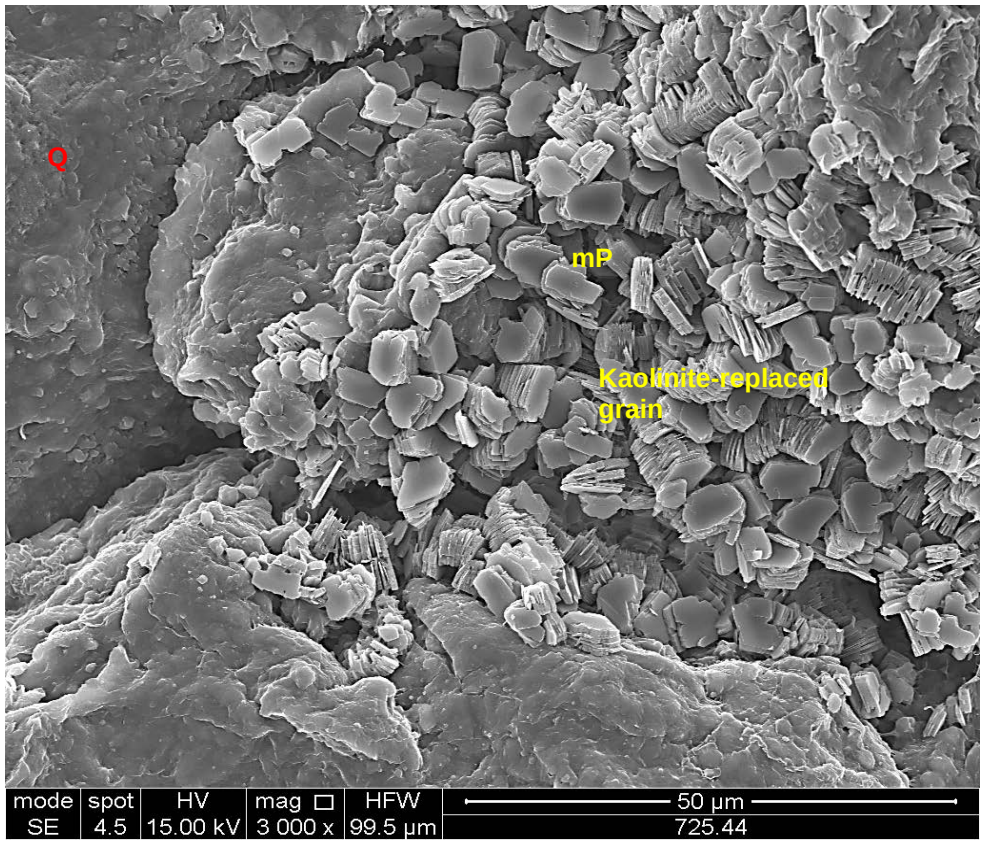
C

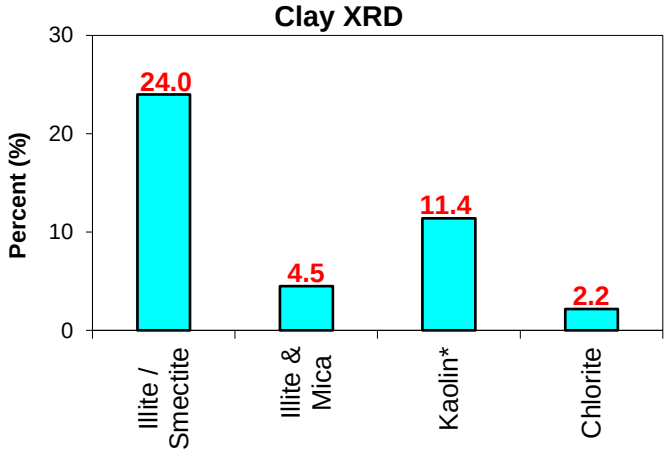


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses show grains including quartz (Q) and K-feldspar (KF) in the abundant clay matrix. Grain-sized patches of kaolinite represent grain-replacement (KRG). XRD analysis indicates that mixed-layer illite/smectite (I/S) is the most abundant matrix clay type, with common kaolinite. Intercrystal micropores are associated with the patches of kaolinite (mP). Fractures in the sample (frac) are induced during sample preparation and are localized in the clay matrix.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

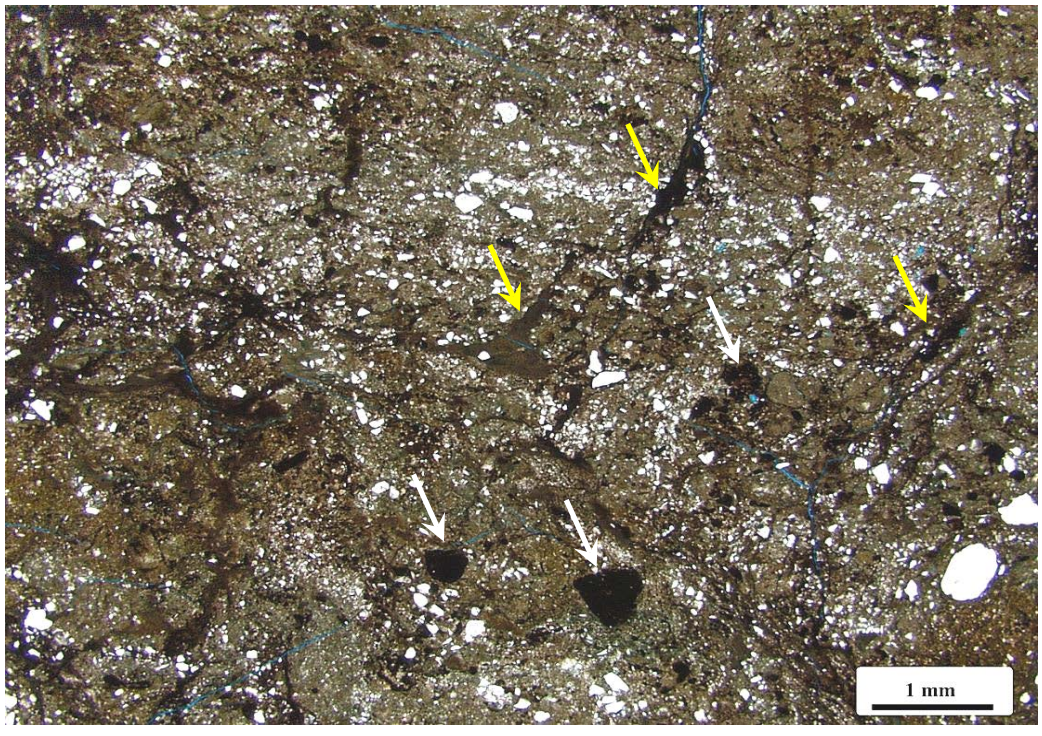
**Core analysis data taken at na psi*

PLATE 4

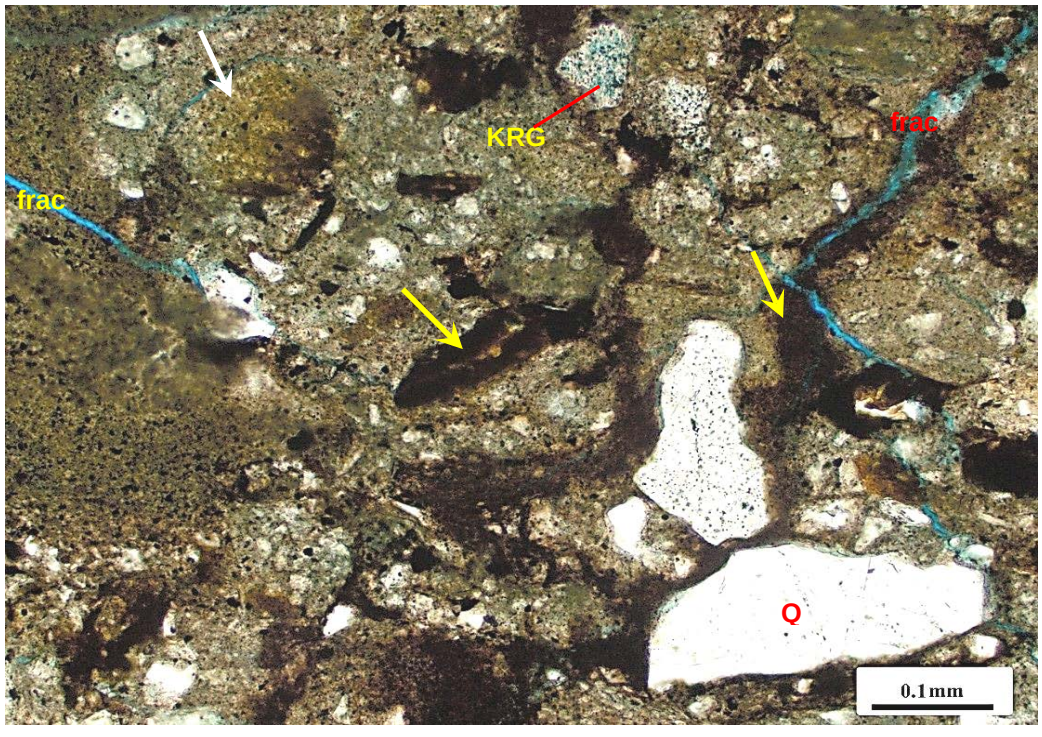
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 740.70
Sample ID: PSH 9

A



B



Sample Description

Lithology: sandy claystone

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.121 (U. very fine sand)
Grn.Sorting: poor

Structures:
crude lamination to chaotic breccia zones; narrow infill zones (vertisol fractures) rich in clay or hematitic matrix

Framework Grains:
abundant quartz; moderate K-feldspar; minor plutonic lithic fragments

Accessory Grains:
trace mica, opaque minerals, heavy minerals including zircon

Matrix:
abundant clay matrix

Cements:
irregular hematite stain of individual clasts and branching zones

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	30.0	Goethite	2.2
K-Feldspar	7.7	Hematite	0.6
Plagioclase	1.0	Pyrite	0.4
Calcite	0.0	Total Clay	57.9

Clay Abundance (Weight %)

Illite / Smectite	33.6	Kaolin*	14.8
Illite & Mica	6.4	Chlorite	3.1

%smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Photo A shows the crude sandy zones with chaotic disruption and crosscutting dark linear to anastomosing zones (yellow arrows). The linear structures may be vertisol fractures infilled with clay sediment, or related to roots. White flecks throughout the sample are mostly quartz grains (Q). Dark intraclasts or rip-up clasts stained by goethite/hematite are indicated with the white arrows. A kaolinite-replaced grain exhibits micropores (KRG; Photo B). The induced fractures (frac) in the sample are a result of the swelling clay components of the matrix.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

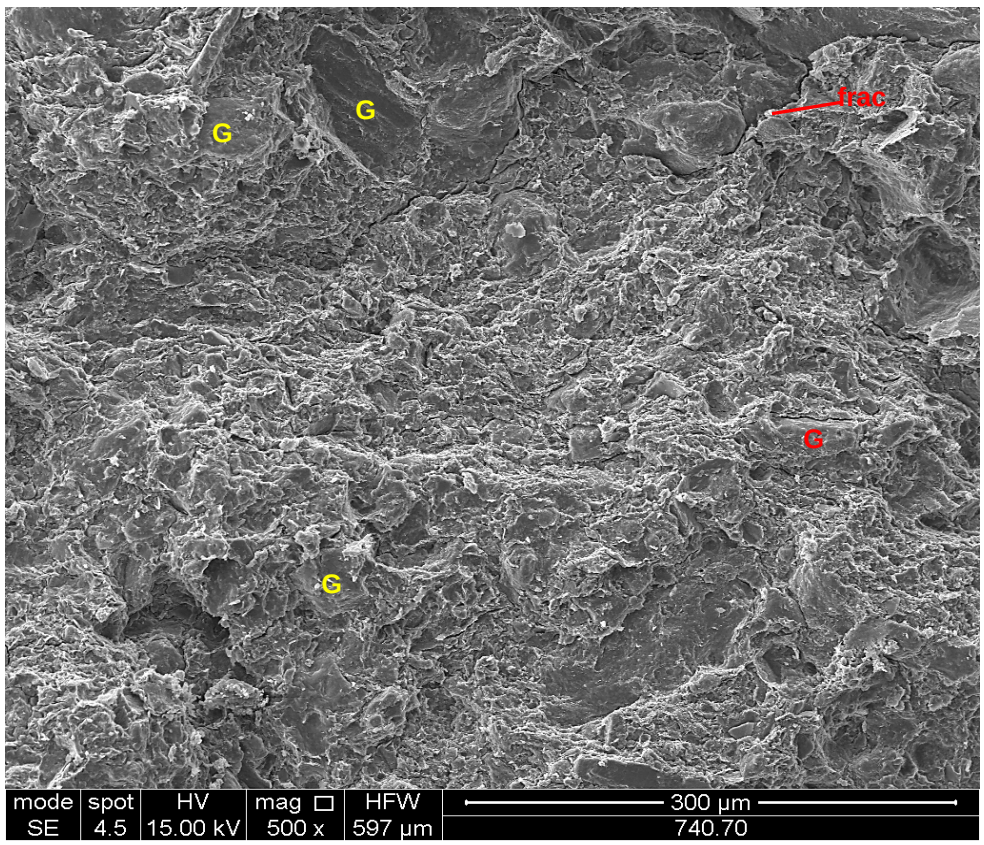
PLATE 4 (cont'd)

Scanning Electron Microscopy

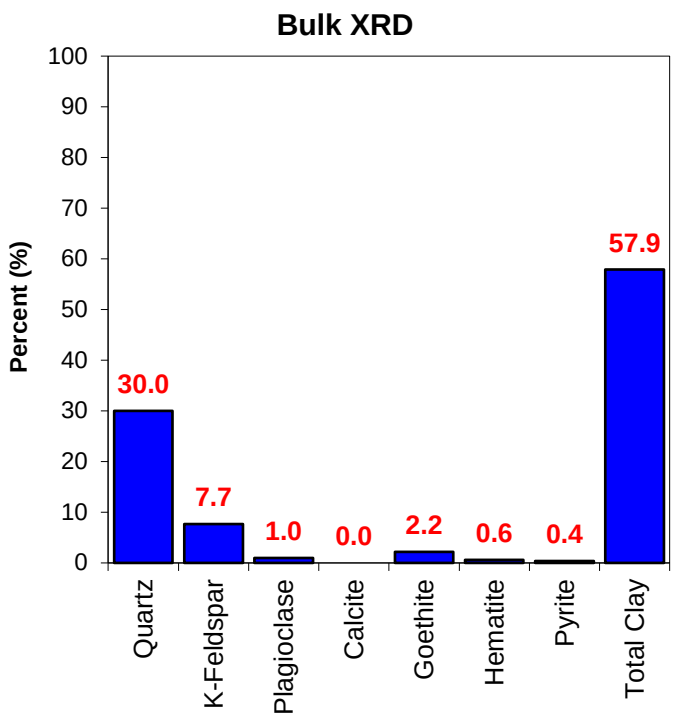
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 740.70
Sample ID: PSH 9

Lithology: sandy claystone

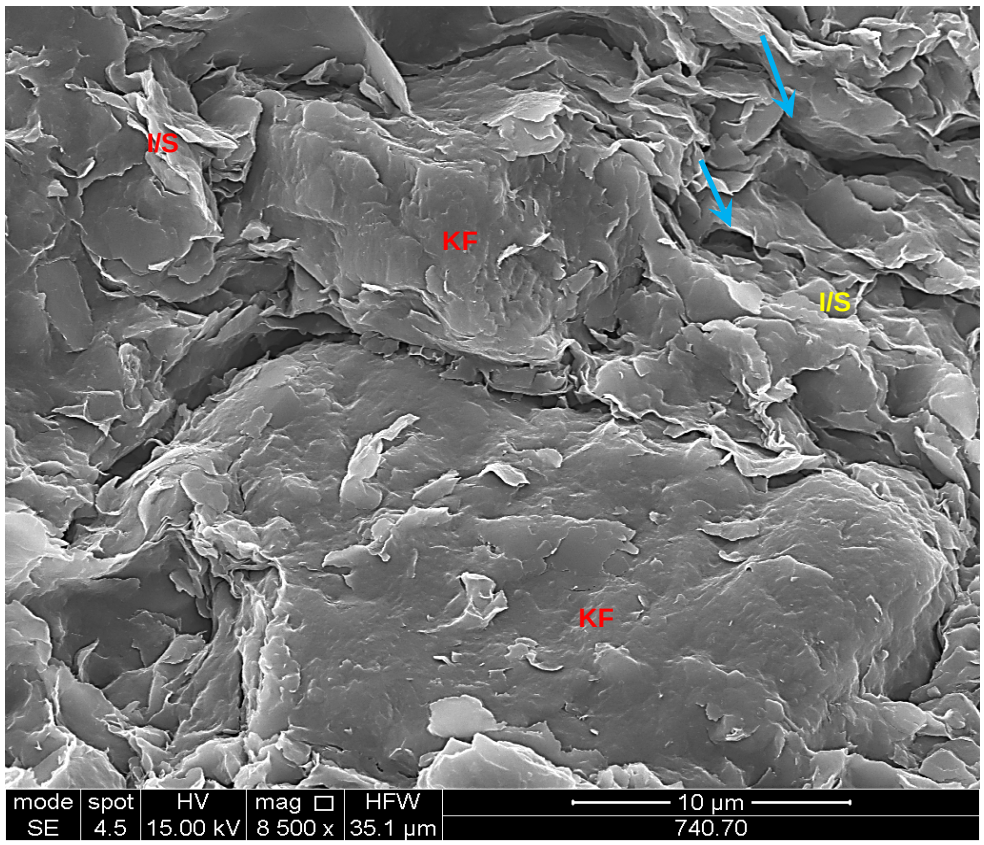
C

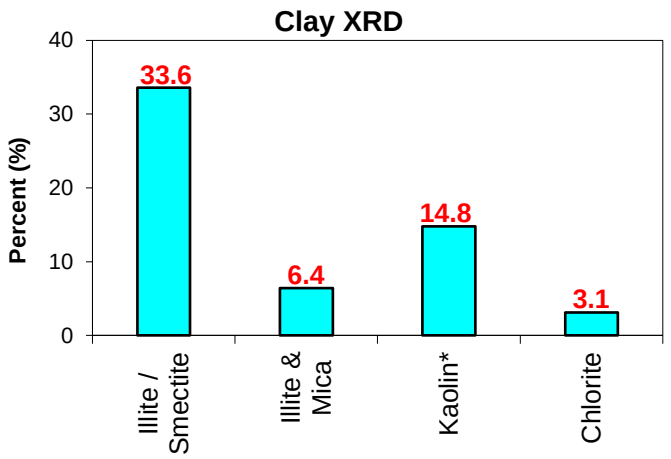


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows grains (G) including K-feldspar (KF) in the abundant clay matrix. XRD analysis indicates that mixed-layer illite/smectite (I/S) is the most abundant matrix clay type. Interparticle micropores are associated with the clay matrix (blue arrows). Fractures in the sample (frac) are induced.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

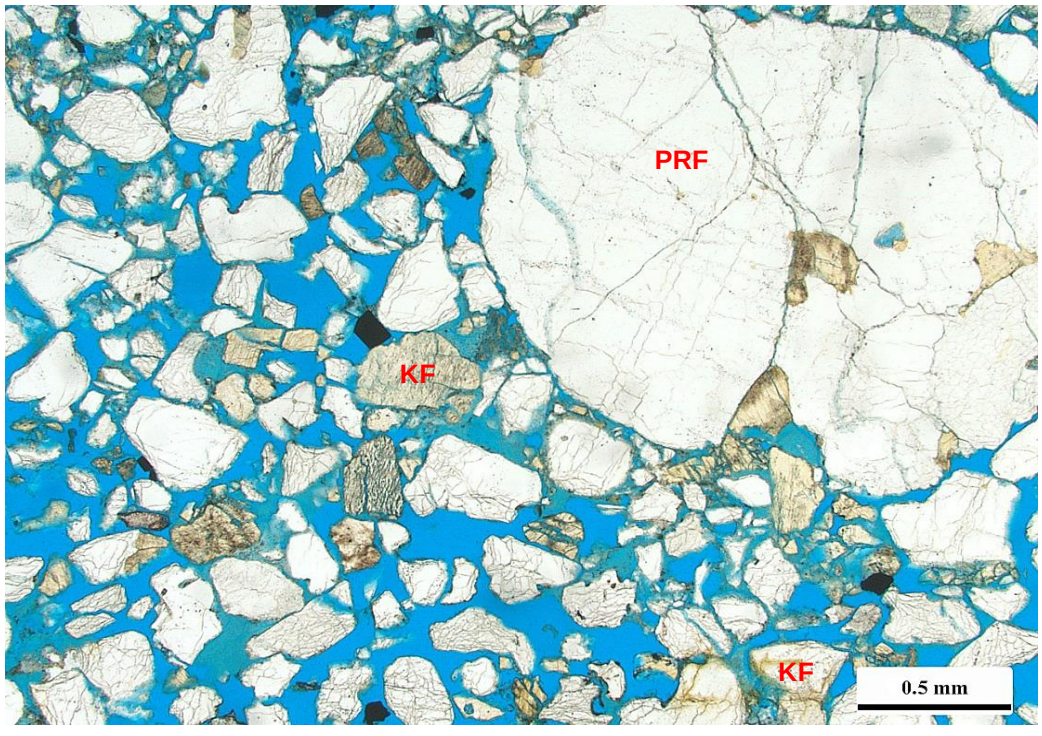
**Core analysis data taken at na psi*

PLATE 5

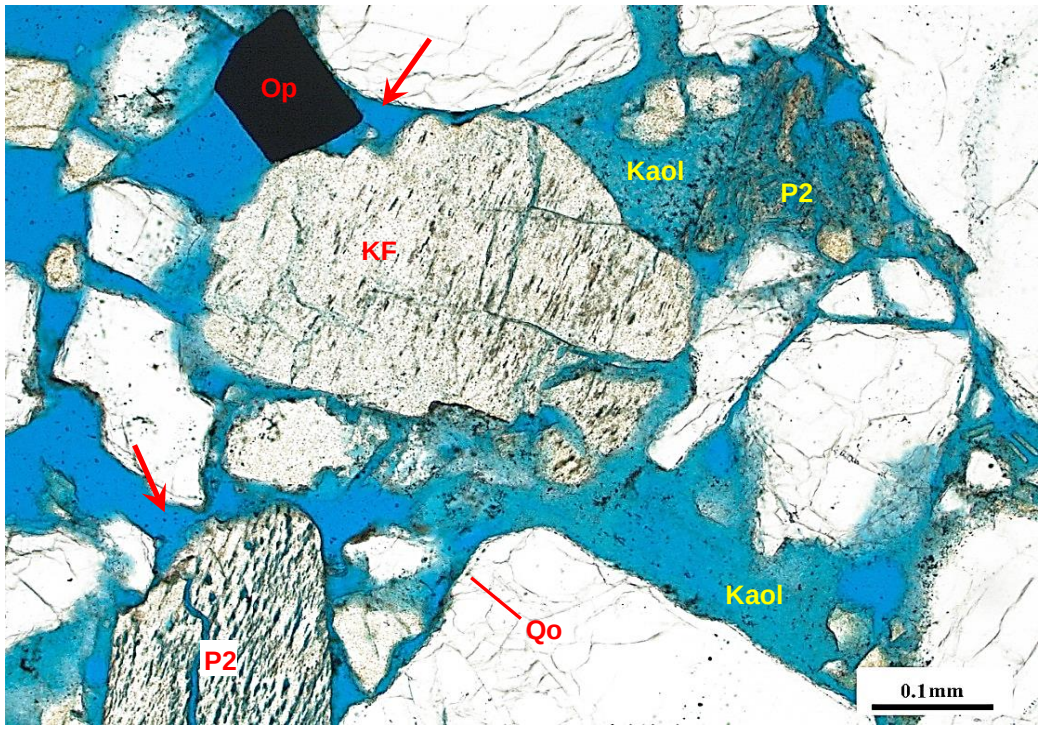
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 760.15
Sample ID: 142

A



B



**The GSWA is currently reviewing the stratigraphy of the southern Perth Basin, including the usage of units originally defined in the northern Perth Basin. Formation names and tops quoted in the DMP's Harvey studies are therefore preliminary and may be subject to change following this review.*

Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 0.608 (Coarse sand)
Grn.Sorting: poor

Structures:
massive; scattered very coarse sand grains

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments; minor altered biotite

Accessory Grains:
minor biotite (mostly altered to kaolinite/dickite), muscovite; trace garnet, opaque minerals

Matrix:
none observed

Cements:
moderate intergranular kaolinite; minor quartz overgrowths visible in thin section and SEM

Pore Types:
common intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	75.8	Goethite	0.0
K-Feldspar	10.8	Hematite	0.0
Plagioclase	0.6	Pyrite	0.0
Calcite	0.0	Total Clay	12.7

Clay Abundance (Weight %)

Illite / Smectite	0.0	Kaolin*	10.2
Illite & Mica	1.0	Chlorite	1.5

%smectite in mixed-layer illite/smectite is na
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a massive, coarse-grained sandstone with abundant quartz grains (Q). K-feldspar (KF; stained yellow) occurs as grains and within plutonic lithic fragments (PRF). Some plutonic grains are very coarse sand-size (Photo A). Opaque minerals occur in trace amounts (Op). Authigenic minerals include thin quartz overgrowths (Qo), and intergranular kaolinite (Kaol). Pore types include intergranular pores (blue epoxy and red arrows), intragranular dissolution pores within K-feldspar grains (P2), and intercrystal micropores associated with kaolinite cement (blue haze coloration within kaolinite).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	29.70
Permeability (md)*:	4420.0
Grain Density (g/cc):	2.64

**Core analysis data taken at 1250 psi*

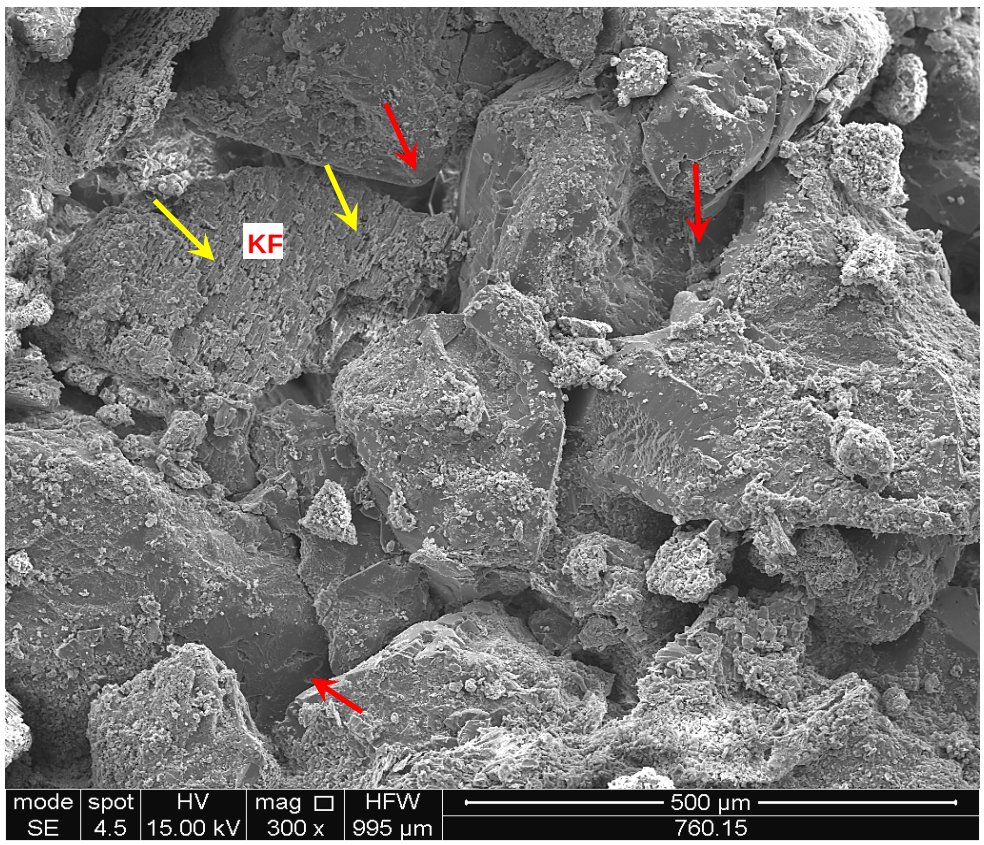
PLATE 5 (cont'd)

Scanning Electron Microscopy

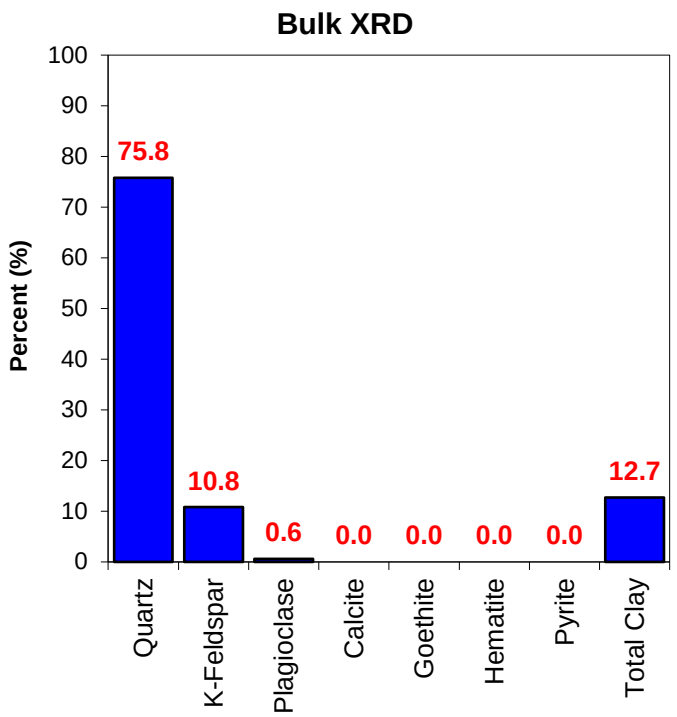
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 760.15
Sample ID: 142

Lithology: sandstone

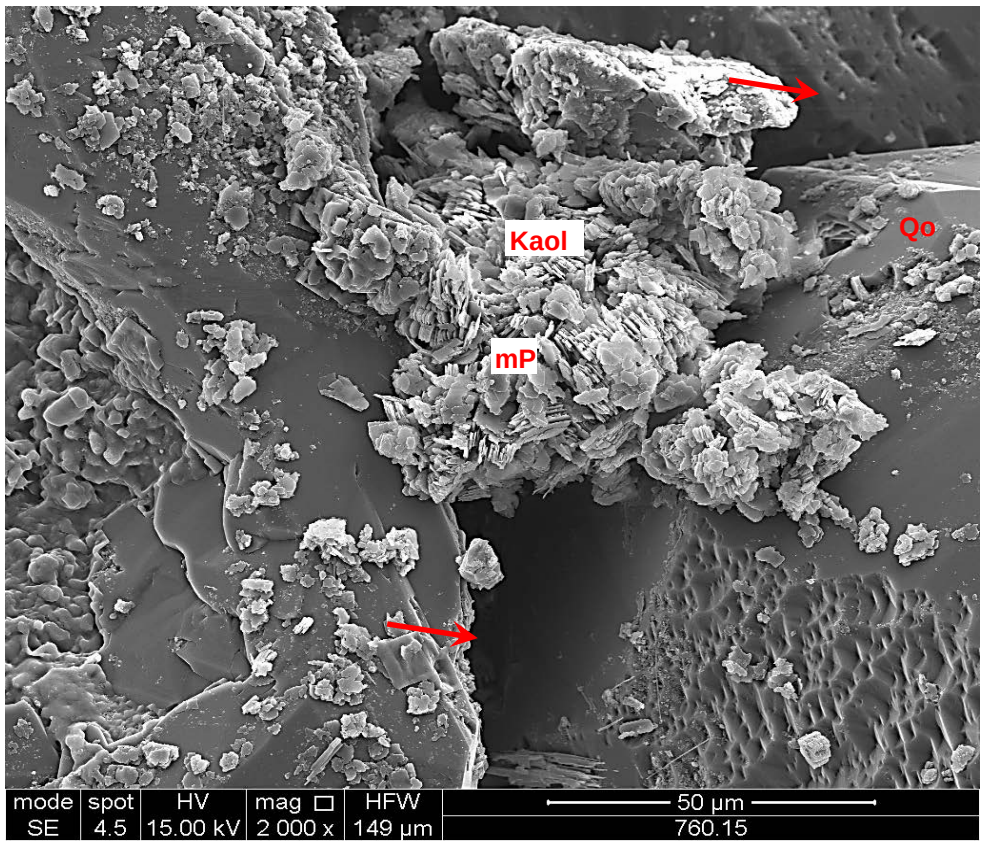
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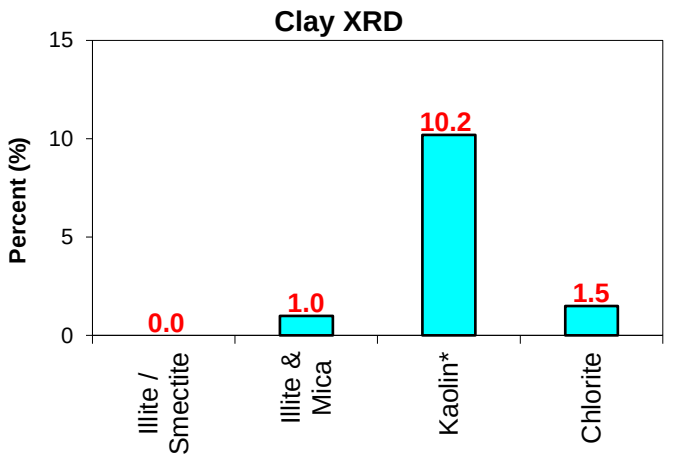


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is na
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis show that the intergranular pores (red arrows) are partly to completely occluded by quartz overgrowths (Qo) or kaolinite (Kaol). Intragranular dissolution pores (yellow arrows) exist in the identified K-feldspar grain (KF).

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	29.70
Permeability (md)*:	4420.0
Grain Density (g/cc):	2.64

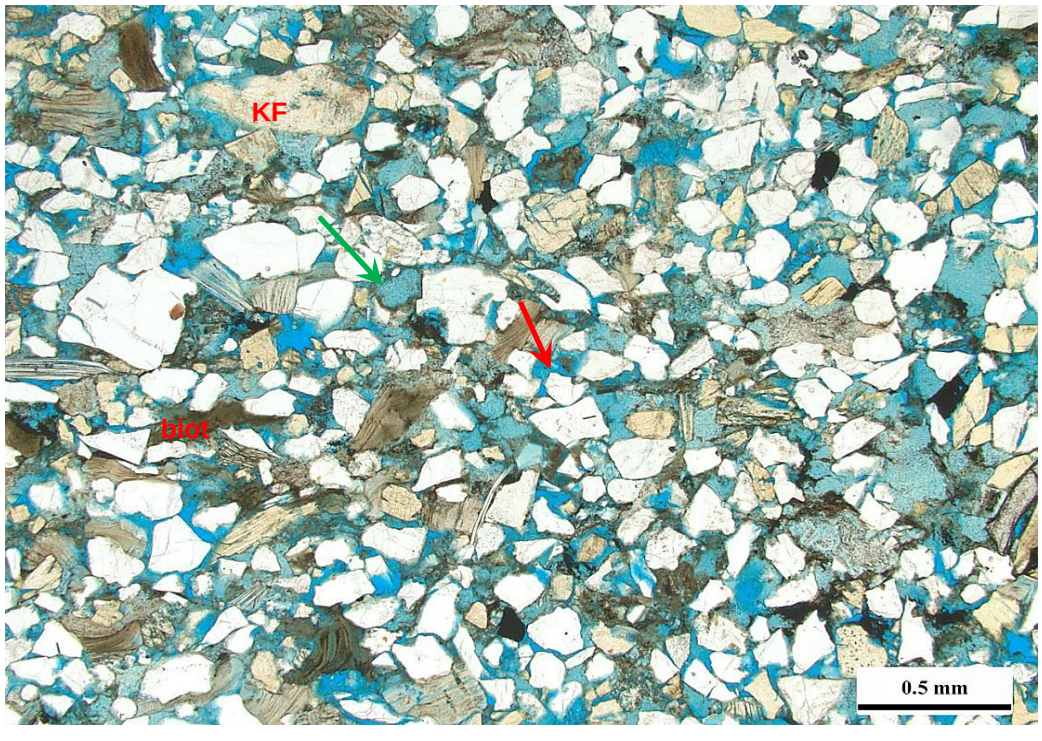
**Core analysis data taken at 1250 psi*

PLATE 6

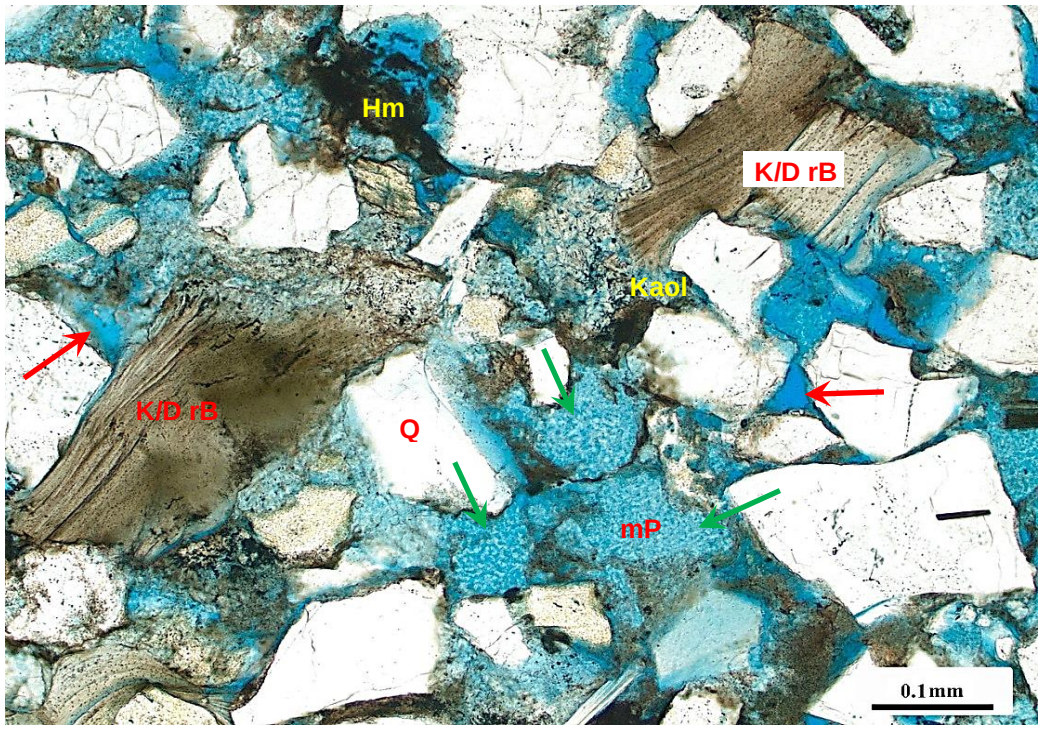
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 863.00
Sample ID: 147

A



B



Sample Description

Lithology: kaolin-rich sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.318 (L. medium sand)
Grn.Sorting: moderately well

Structures:
faint lamination imparted by compactionally aligned mica flakes and slightly more micaceous layers; moderate to heavy compaction

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments; common altered biotite

Accessory Grains:
common biotite - some altered to kaolinite/dickite; trace garnet, opaque minerals

Matrix:
minor mechanically infiltrated clay (cutans)

Cements:
abundant intergranular and intragranular kaolinite; SEM reveals minor quartz and K-feldspar overgrowths

Pore Types:
minor intergranular and intragranular pores; abundant intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	44.8	Goethite	0.0
K-Feldspar	12.6	Hematite	0.0
Plagioclase	0.8	Pyrite	0.0
Calcite	0.0	Total Clay	41.6

Clay Abundance (Weight %)

Illite / Smectite	5.8	Kaolin*	29.5
Illite & Mica	3.8	Chlorite	2.5

%smectite in mixed-layer illite/smectite is 40-50
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a medium-grained sandstone with abundant quartz (Q) and moderate K-feldspar (KF; stained yellow). Biotite (biot) flakes and biotite that is partly to completely replaced by kaolinite/dickite (K/D rB) are common in crude layers that define faint lamination. Heavy minerals occur in trace amounts (Hm). The dark rims on many grains are minor cutans of illitic clay. Authigenic minerals include grain-replacing kaolinite (green arrows) and intergranular kaolinite (Kaol). The high kaolin content detected by XRD includes both the grain-replacing kaolinite and the grain-sized kaolin-replaced biotite. Pore types include intergranular pores (blue epoxy and red arrows) and intercrystal micropores associated with kaolinite cement (blue haze coloration within kaolinite).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	23.40
Permeability (md)*:	18.9
Grain Density (g/cc):	2.64

**Core analysis data taken at 1250 psi*

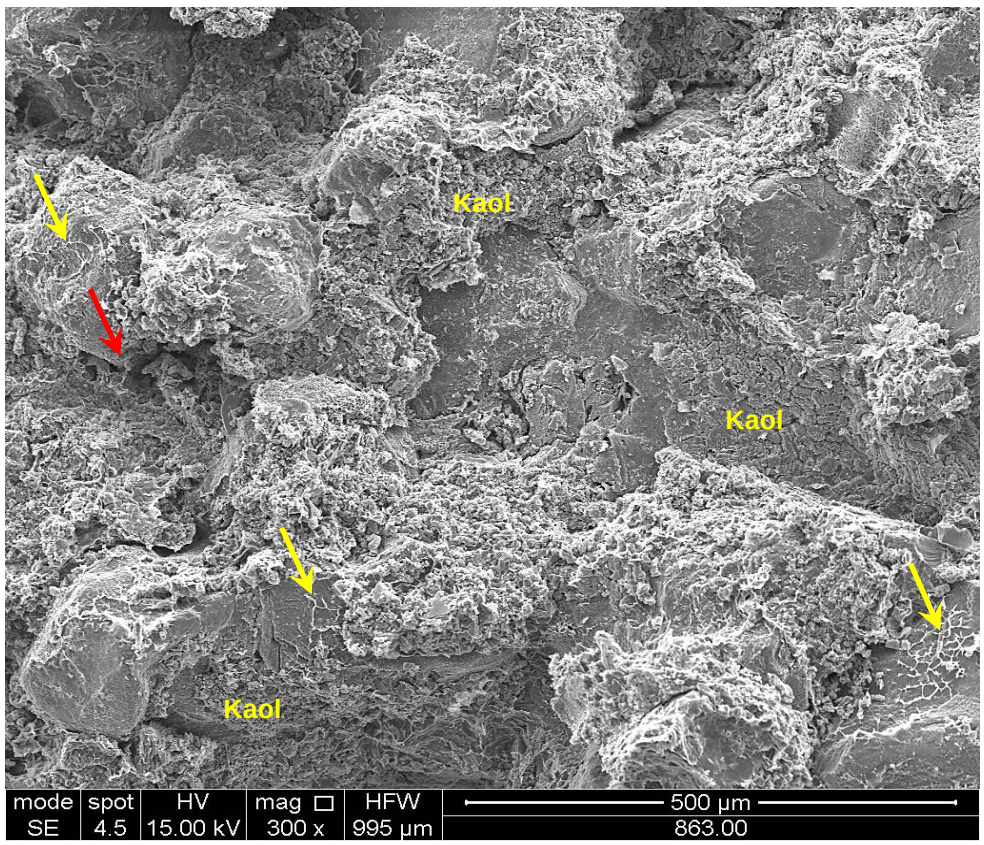
PLATE 6 (cont'd)

Scanning Electron Microscopy

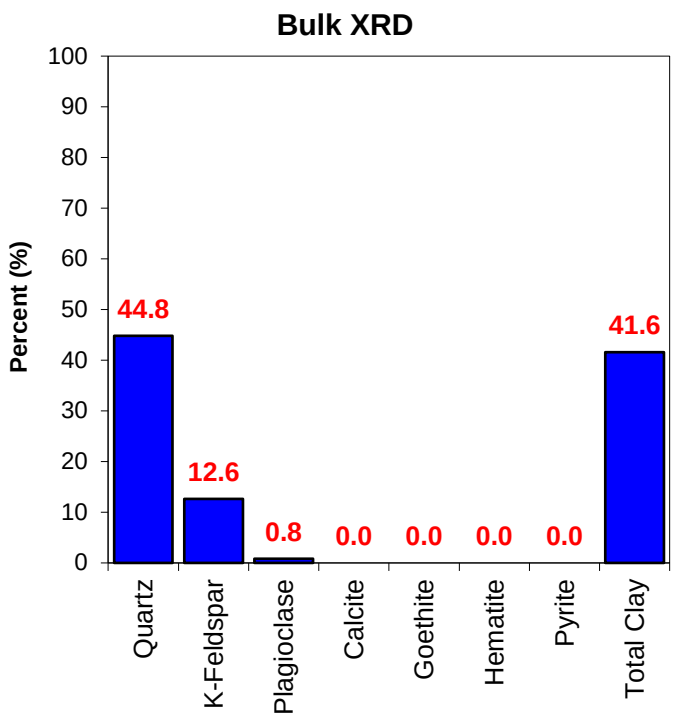
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 863.00
Sample ID: 147

Lithology: kaolin-rich sandstone

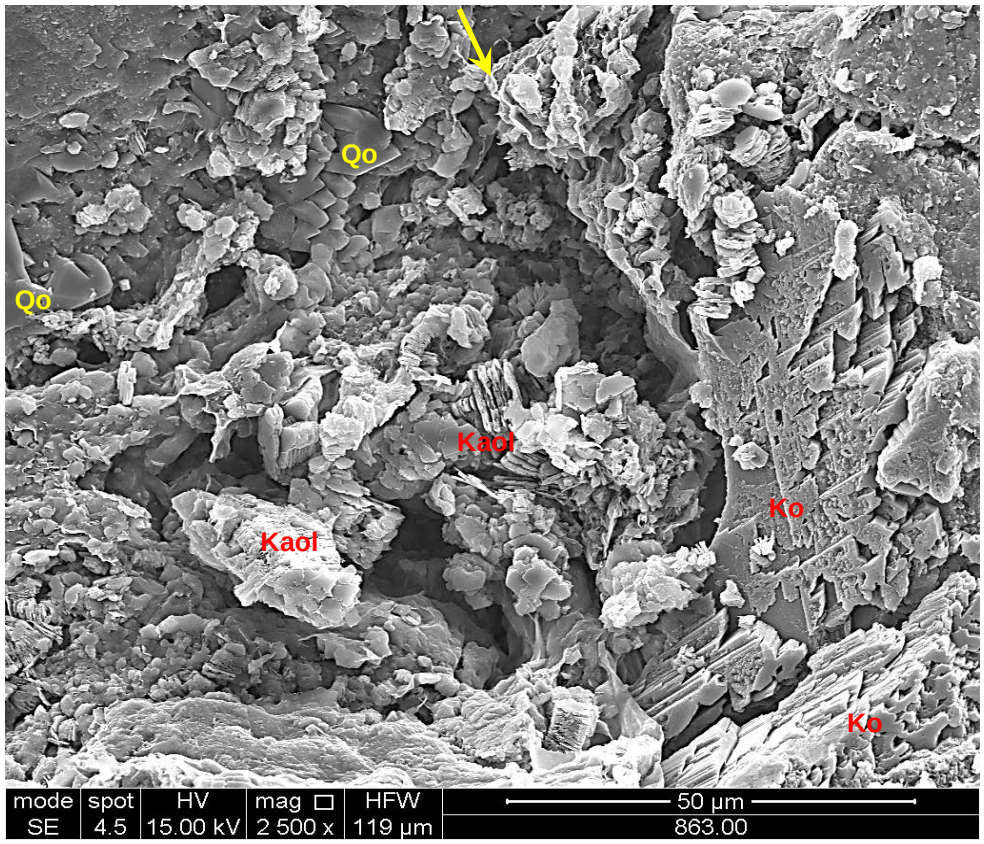
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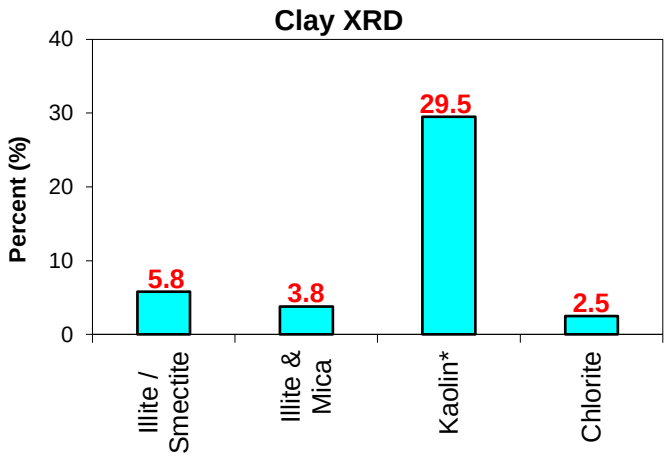


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses of this sandstone show the abundant authigenic kaolinite (Kaol) filling most intergranular areas and replacing grains. The red arrow indicates an intergranular pore. Thin arcuate rims of illitic clay (yellow arrows) appear to be cutans. Image D features authigenic quartz overgrowths (Qo) and K-feldspar overgrowths (Ko). Intercrystal micropores are abundant within the kaolinite.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	23.40
Permeability (md)*:	18.9
Grain Density (g/cc):	2.64

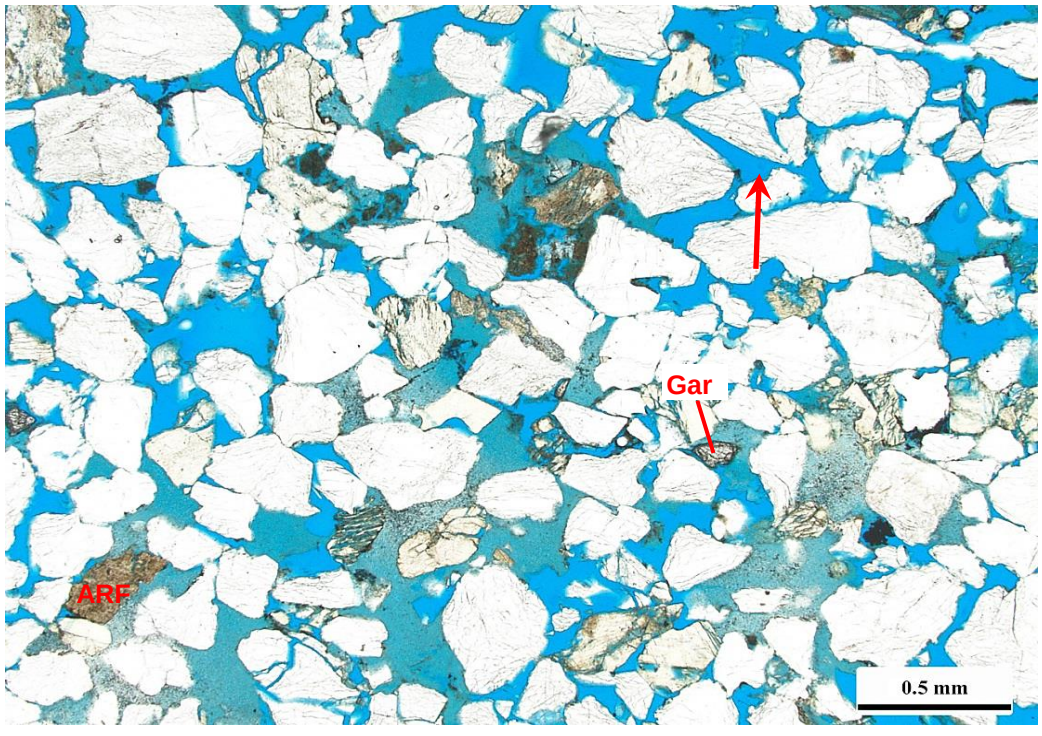
**Core analysis data taken at 1250 psi*

PLATE 7

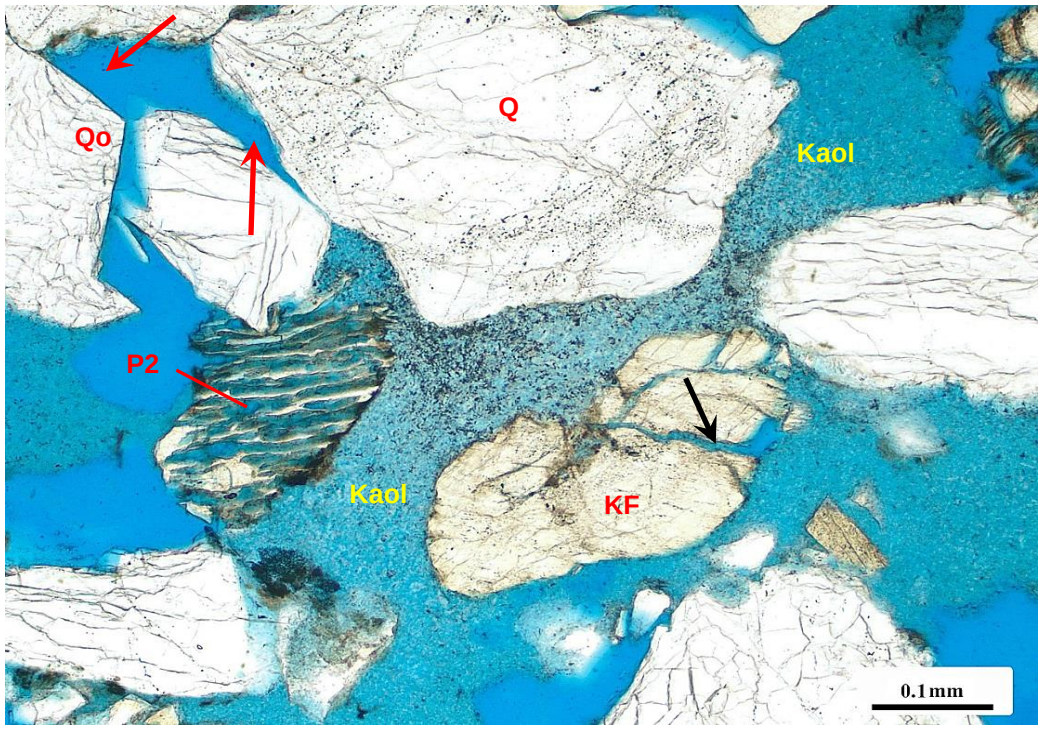
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 919.00
Sample ID: 152

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): sublitharenite
Grain Size (mm): 0.671 (Coarse sand)
Grn.Sorting: moderate

Structures:
faint lamination defined by slight grain size variation with scattered very coarse sand; minor to moderate compaction

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments; minor altered biotite, clay-replaced grains of uncertain origin

Accessory Grains:
minor biotite and muscovite; trace garnet, opaque minerals

Matrix:
trace mechanically infiltrated clay (cutans)

Cements:
patchy intergranular kaolinite; SEM reveals minor quartz overgrowths

Pore Types:
common intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	73.0	Goethite	0.0
K-Feldspar	15.1	Hematite	0.0
Plagioclase	0.6	Pyrite	0.0
Calcite	0.0	Total Clay	11.3

Clay Abundance (Weight %)

Illite / Smectite	1.4	Kaolin*	7.6
Illite & Mica	1.3	Chlorite	1.0

%smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This coarse-grained sandstone is composed of abundant quartz (Q) and lesser K-feldspar (KF) and plutonic lithic fragments. Minor to moderate compaction is indicated by point grain contacts (Photo A). Trace amounts of detrital garnet (Gar) and argillaceous rock fragments (ARF) are observed. Authigenic minerals include quartz overgrowths (Qo) and kaolinite (Kaol). Pore types include intergranular pores (blue epoxy; red arrows), intragranular dissolution pores in K-feldspar (P2), and intercrystal micropores associated with authigenic kaolinite (blue haze coloration). Rarely, K-feldspar grains show intragranular fractures (black arrow).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	28.30
Permeability (md)*:	6610.0
Grain Density (g/cc):	2.63

**Core analysis data taken at 1250 psi*

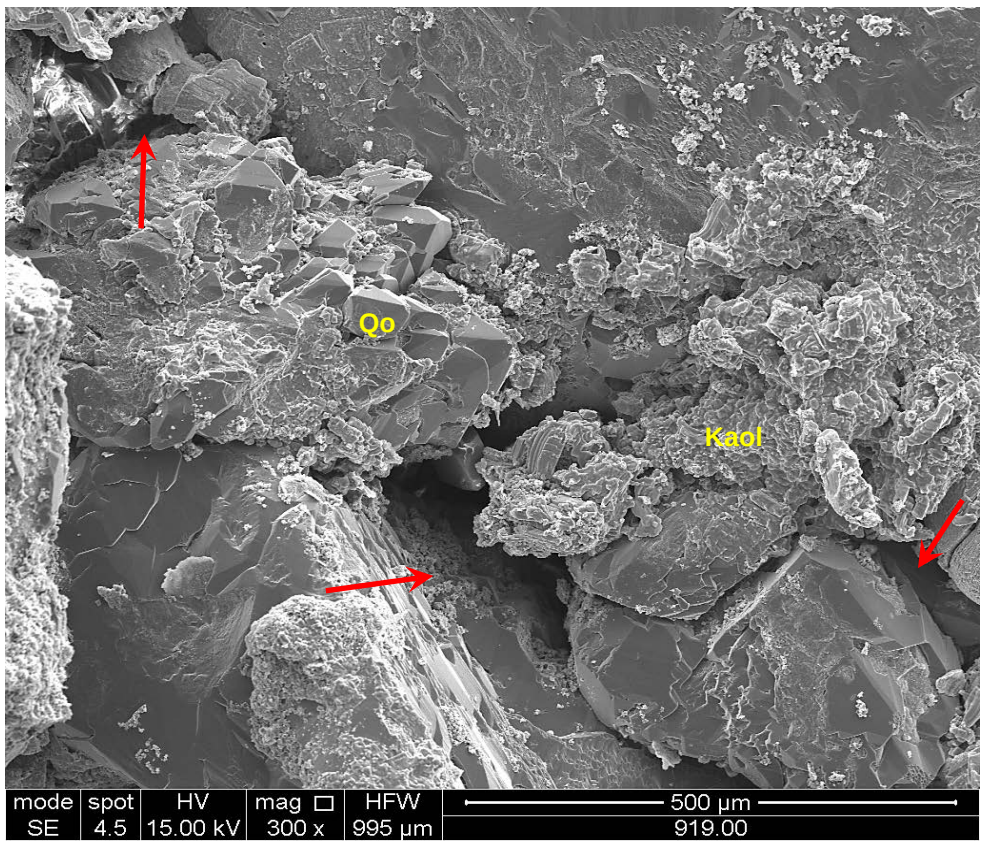
PLATE 7 (cont'd)

Scanning Electron Microscopy

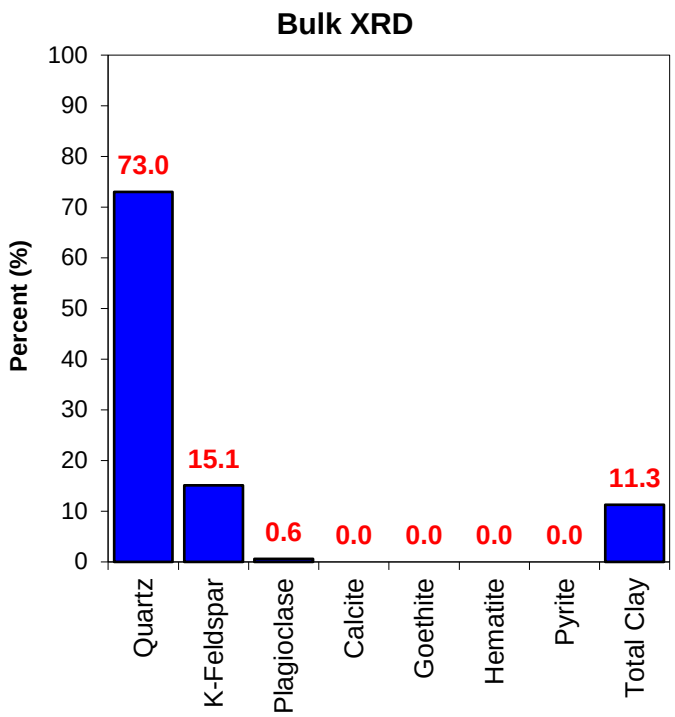
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 919.00
Sample ID: 152

Lithology: sandstone

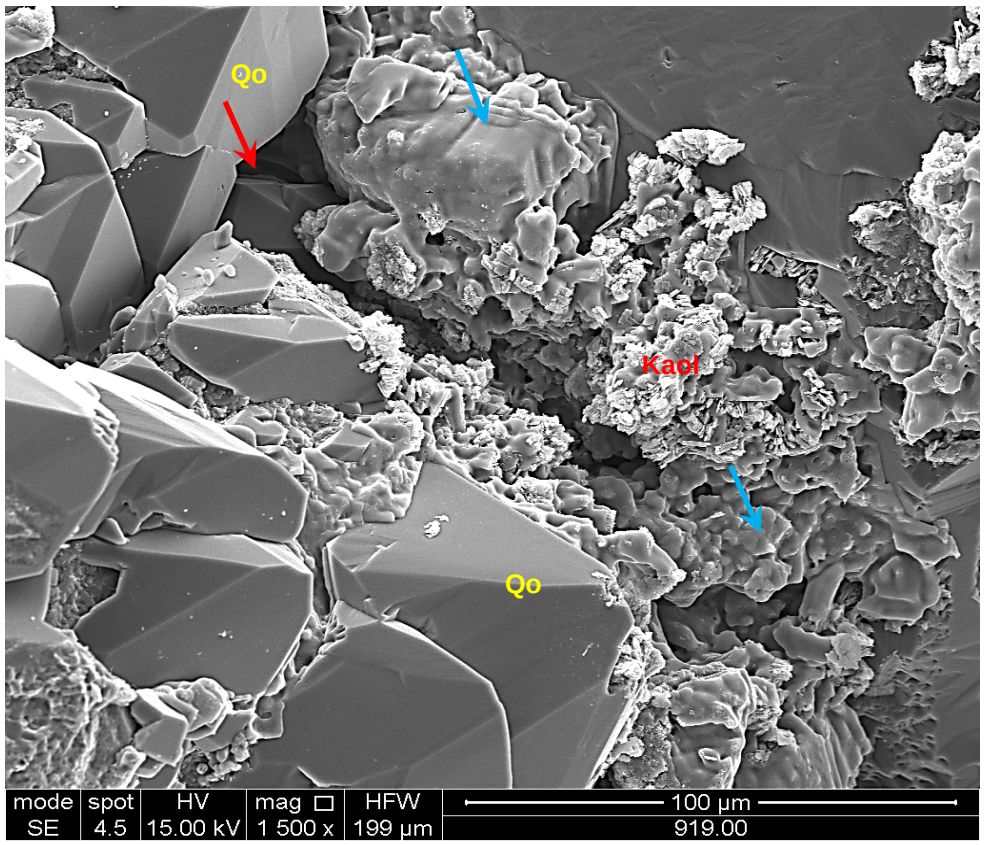
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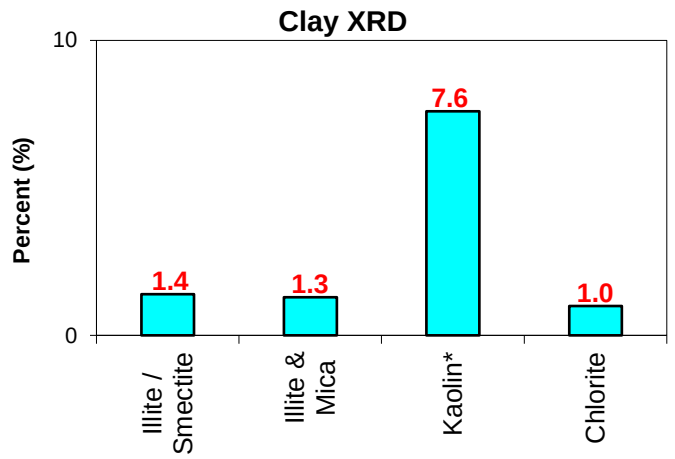


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis show that the intergranular pores (red arrows) are partly to completely occluded by quartz overgrowths (Qo) or kaolinite (Kaol). Some salt (blue arrows) encases the kaolinite, but is only a contaminant.

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	28.30
Permeability (md)*:	6610.0
Grain Density (g/cc):	2.63

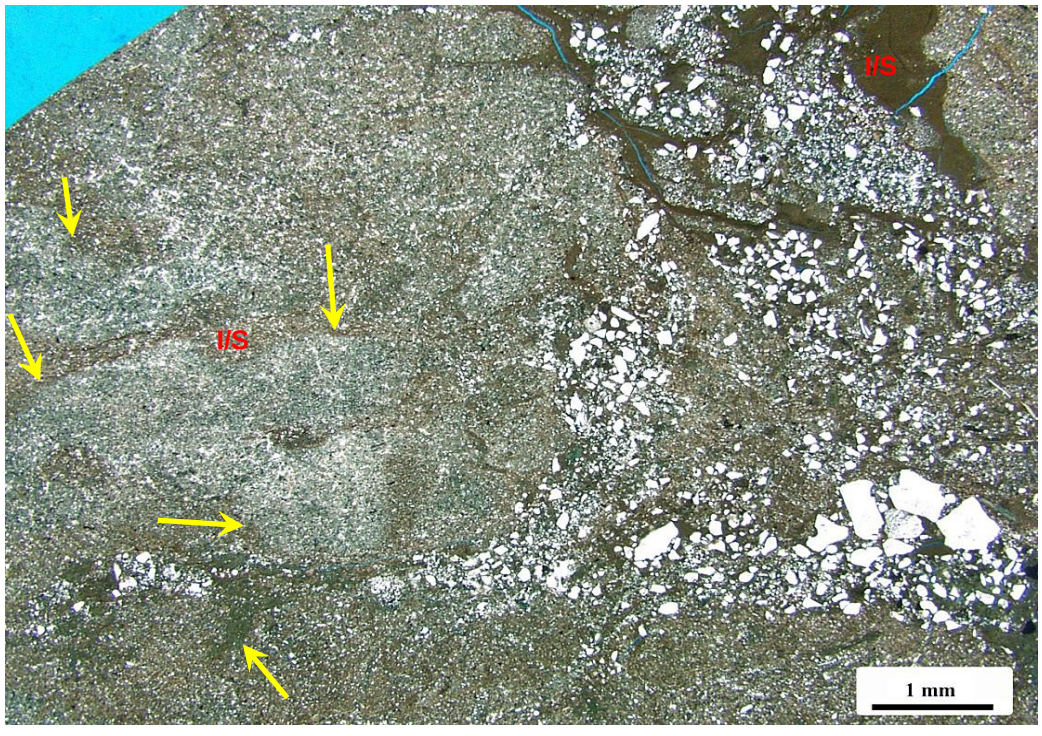
**Core analysis data taken at 1250 psi*

PLATE 8

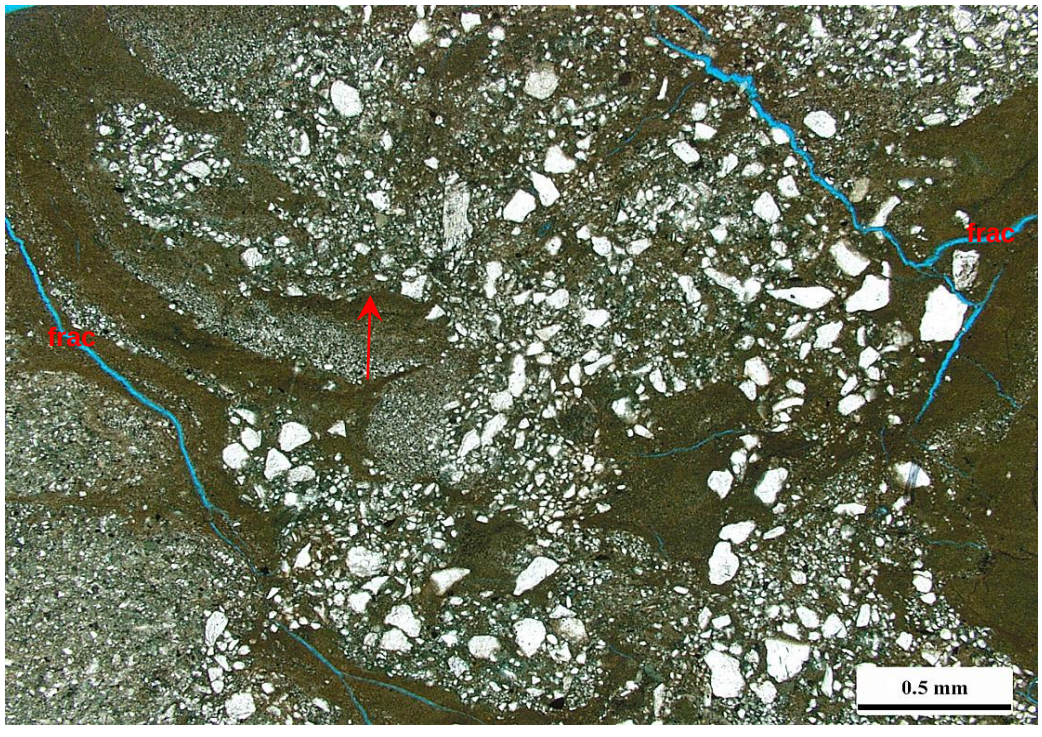
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 965.64
Sample ID: PSH 11

A



B



Sample Description

Lithology: slightly sandy claystone

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.046 (coarse silt)
Grn.Sorting: poor

Structures:
crudely laminated silty claystone is crosscut by chlorite-filled fractures; geopetal infill sediment in irregular fissures that range up to 5 mm wide and nearly 1 cm long; clotted to mottled chlorite-rich domains/clasts

Framework Grains:
localized abundant quartz, minor feldspar in geopetal infill sediment; chlorite-rich intraclasts/rip-up clasts

Accessory Grains:
minor biotite, muscovite; trace chlorite, opaque minerals

Matrix:
abundant matrix clay

Cements:
trace pyrite

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	29.4	Goethite	0.0
K-Feldspar	5.2	Hematite	0.0
Plagioclase	0.5	Pyrite	1.7
Calcite	0.0	Total Clay	63.2

Clay Abundance (Weight %)

Illite / Smectite	17.8	Kaolin*	16.5
Illite & Mica	7.7	Chlorite	21.2

%smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Photo A shows the more sandy portion of the claystone, with poorly sorted grains (angular white grains) and illitic clay (I/S) filling a probable vertisol fracture. The surrounding slightly silty claystone exhibits illite/smectite-rich matrix (I/S); brown) and rounded areas with chloritic matrix (yellow arrows). The thin section observations of this slightly green-colored sample is consistent with the high chlorite content detected by XRD (highest in sample set). Photo B shows a slightly higher magnification view of the infill material. Note that some areas show grading (red arrow). The epoxy-filled fractures (frac) appear to be induced as a consequence of sample drying.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

**Core analysis data taken at na psi*

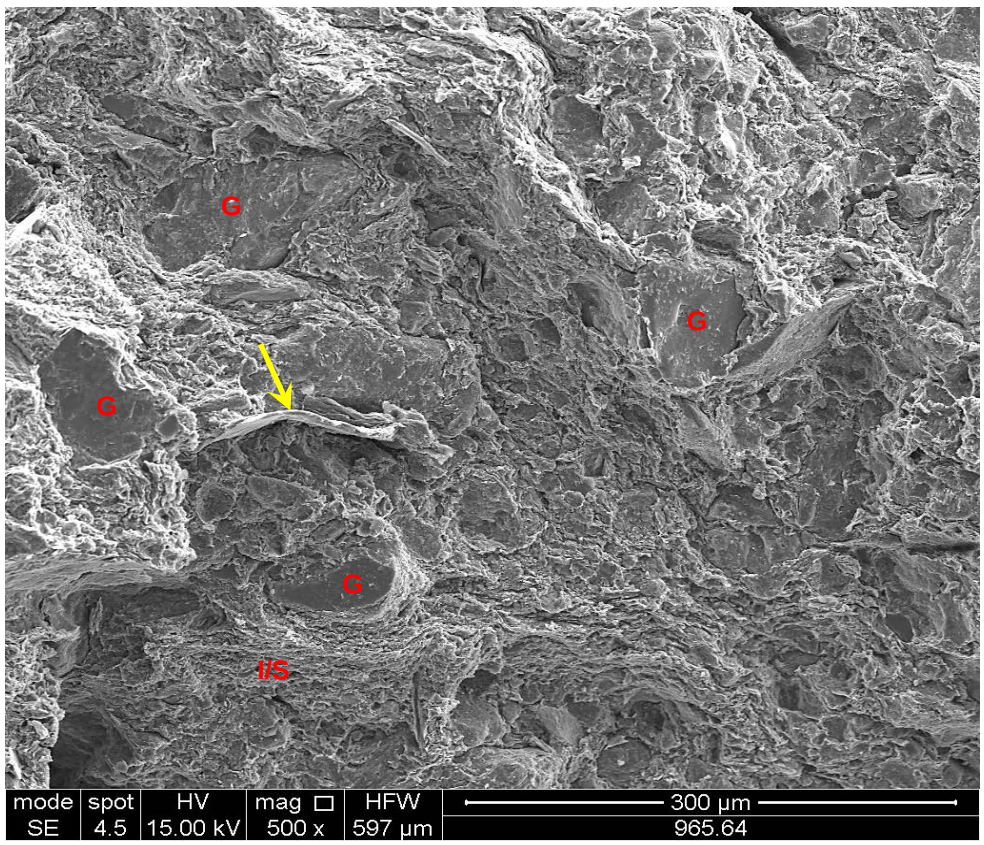
PLATE 8 (cont'd)

Scanning Electron Microscopy

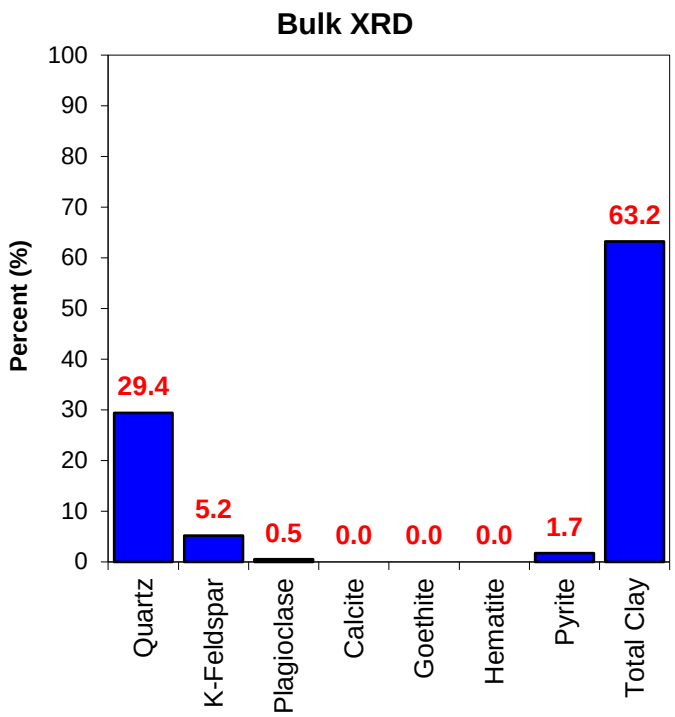
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 965.64
Sample ID: PSH 11

Lithology: slightly sandy claystone

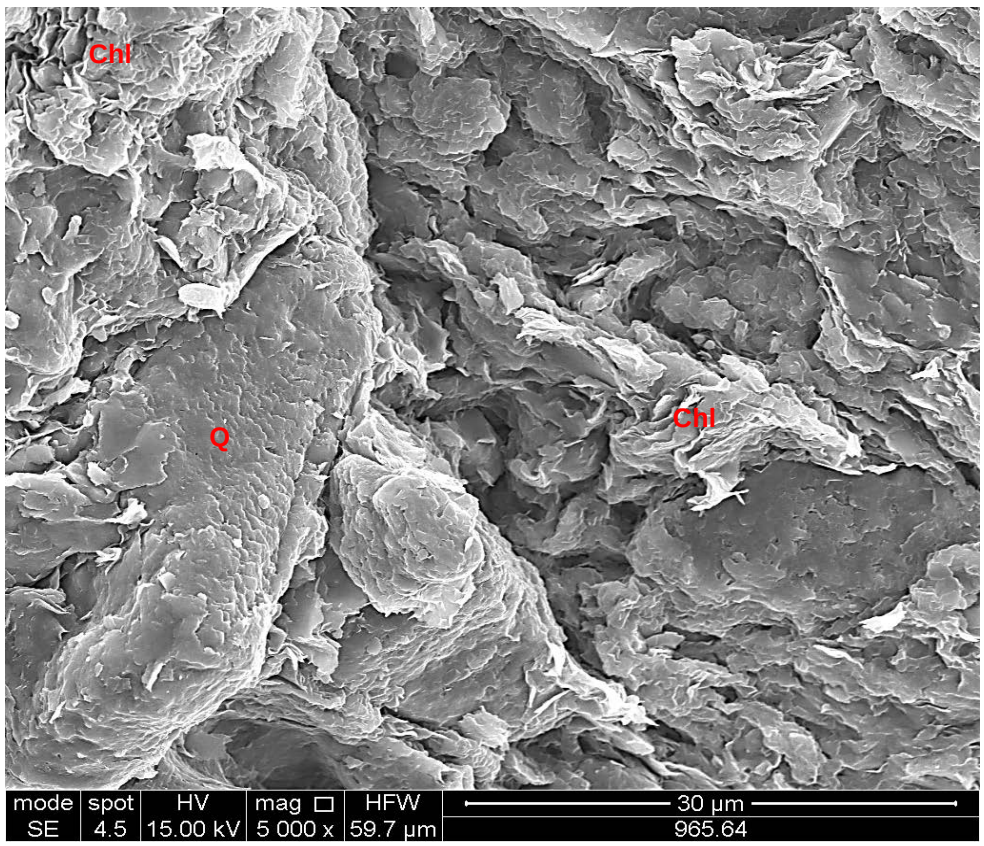
C

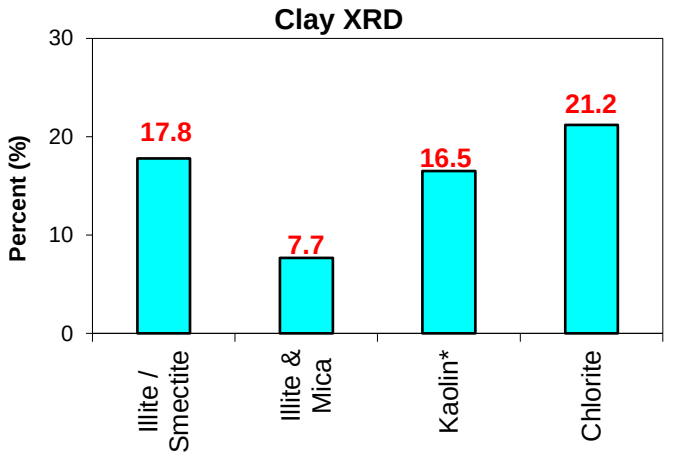


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM images show the abundant clay matrix with scattered detrital grains (G) such as quartz (Q). The yellow arrow indicates a mica flake. EDS analysis of some clay platelets indicates the presence of Fe suggesting that the sample is from the more chlorite-rich matrix domains (compare with Photo A).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

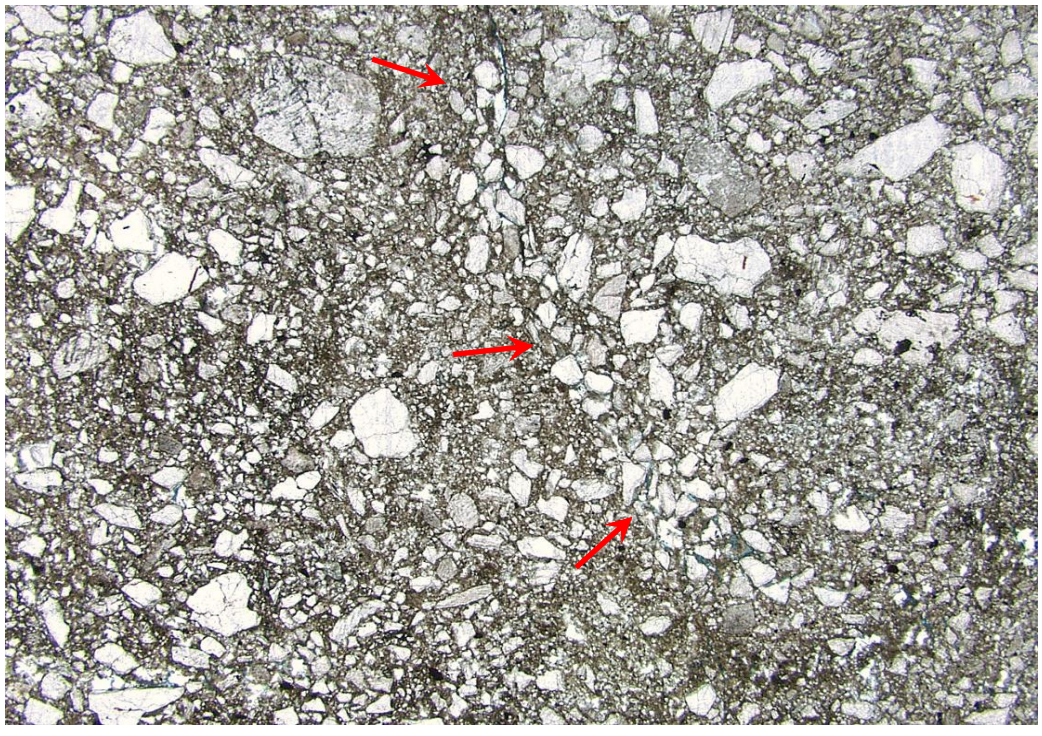
**Core analysis data taken at na psi*

PLATE 9

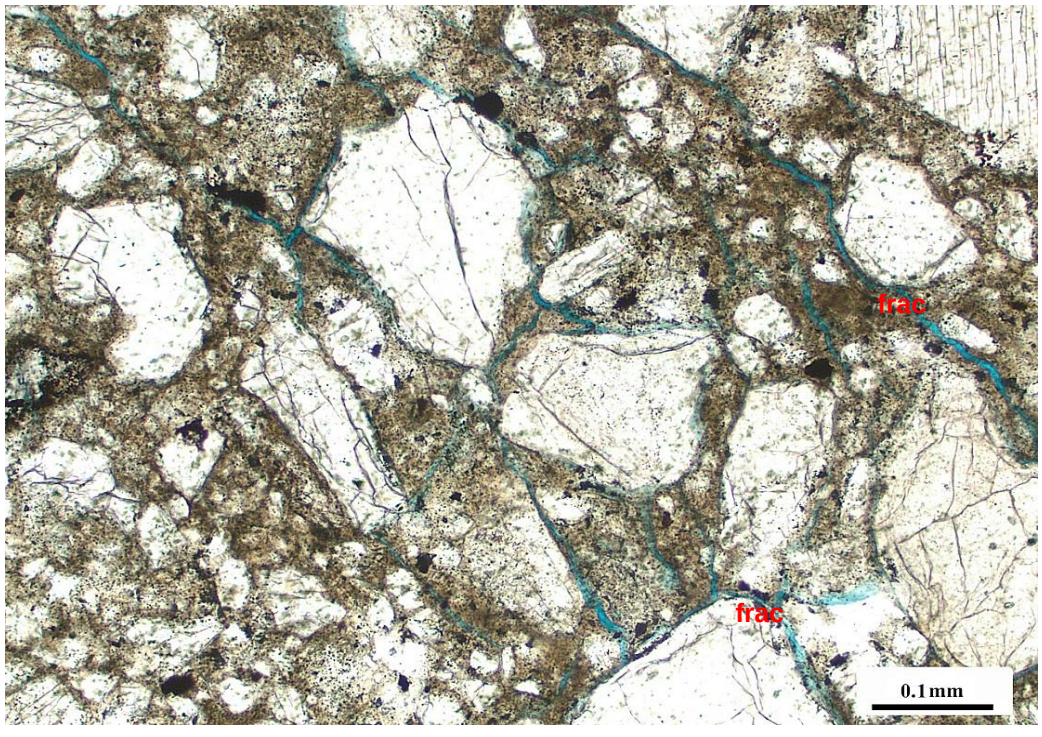
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1079.85
Sample ID: 163

A



B



Sample Description

Lithology: argillaceous sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.327 (L. medium sand)
Grn.Sorting: very poor

Structures:
massive with rare possible microfault

Framework Grains:
abundant quartz; moderate K-feldspar and plagioclase, hematite-stained intraclasts; minor plutonic lithic fragments

Accessory Grains:
trace mica, opaque minerals, heavy minerals

Matrix:
abundant illitic clay supports grains

Cements:
irregular hematite stain of clay matrix

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	46.1	Goethite	0.0
K-Feldspar	10.6	Hematite	0.5
Plagioclase	9.0	Pyrite	0.4
Calcite	0.0	Total Clay	33.4

Clay Abundance (Weight %)

Illite / Smectite	29.3	Kaolin*	1.2
Illite & Mica	2.4	Chlorite	0.5

%smectite in mixed-layer illite/smectite is 50-60
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

Photo A shows massive fabric with a possible microfault structure that crosscuts the sample (red arrows). The slight variation in the color of the matrix reflects irregular hematite staining. The blue epoxy-filled fractures appear induced, a consequence of the presence of swelling clay in the matrix. No macropores are observed.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	9.60
Permeability (md)*:	2.2
Grain Density (g/cc):	2.66

**Core analysis data taken at 1250 psi*

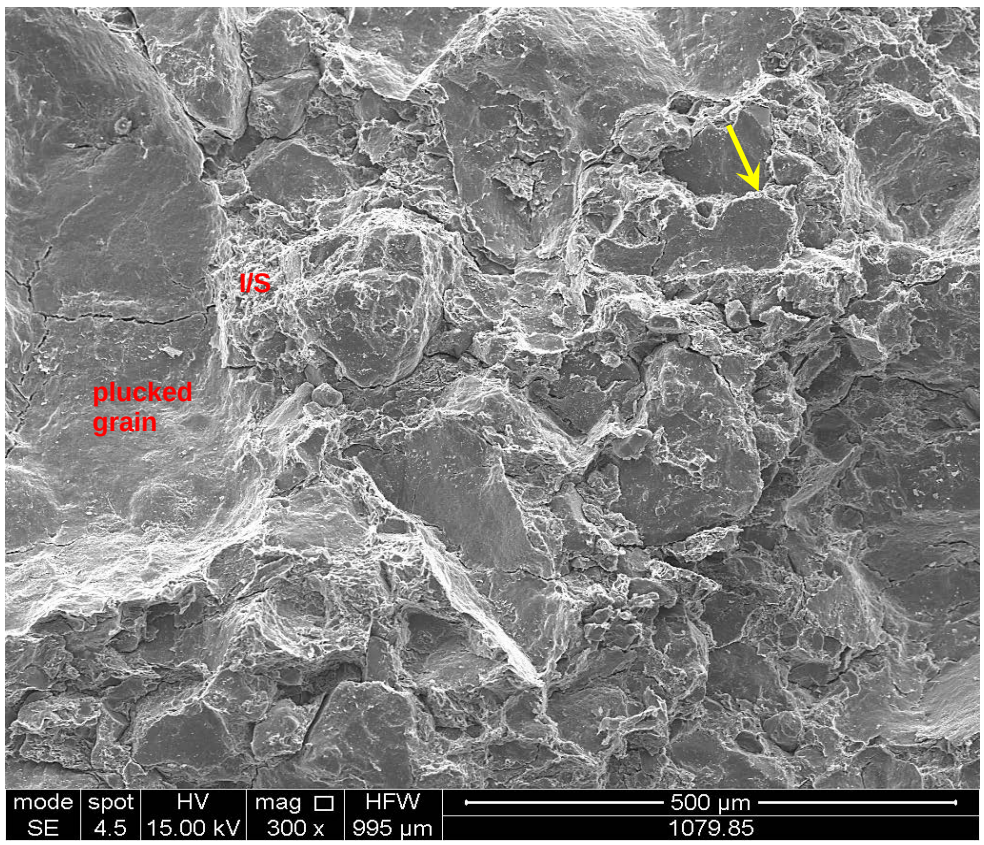
PLATE 9 (cont'd)

Scanning Electron Microscopy

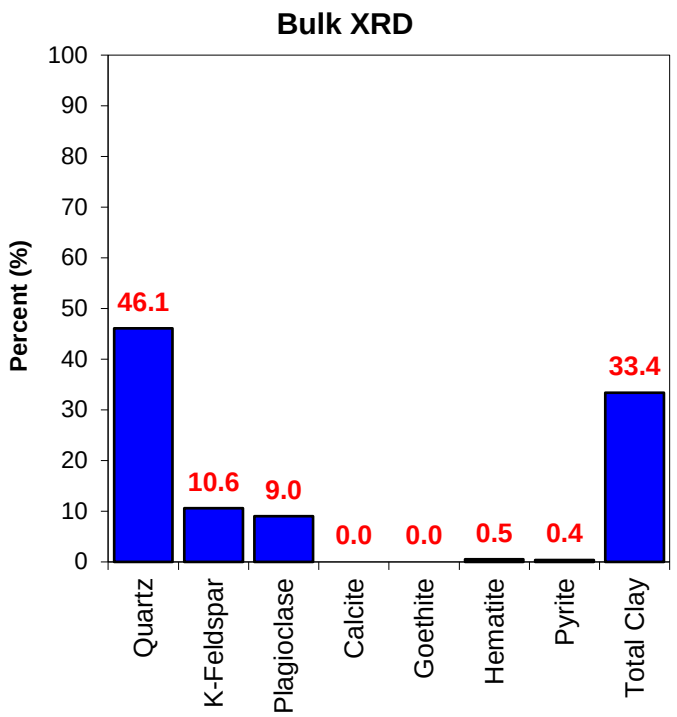
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1079.85
Sample ID: 163

Lithology: argillaceous sandstone

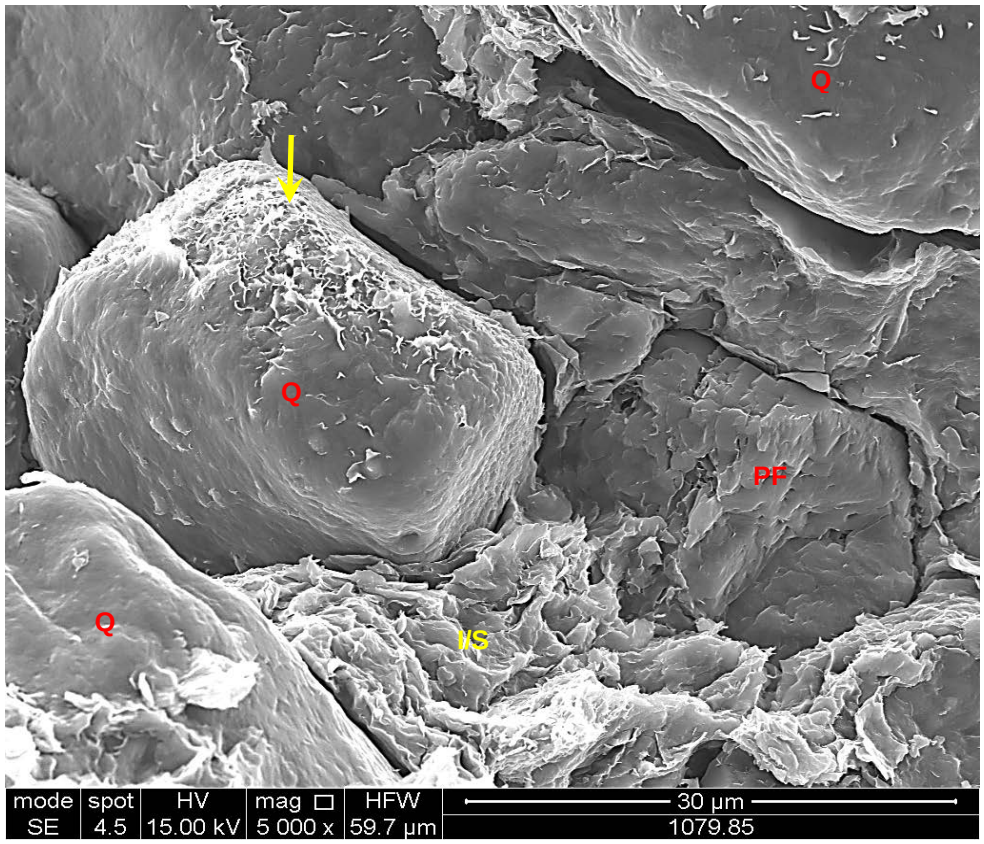
C

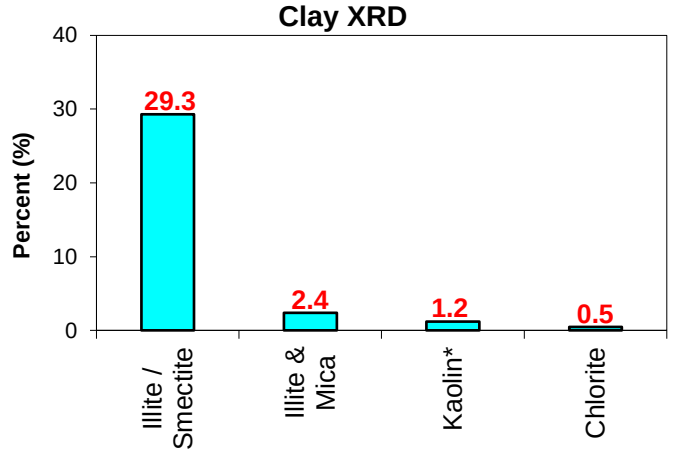


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 50-60
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows that the sample is composed of rounded grains of quartz (Q) and plagioclase (PF) in a matrix of mixed-layer illite/smectite (I/S). Some of the illitic clay forms very thin grain coatings (yellow arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	9.60
Permeability (md)*:	2.2
Grain Density (g/cc):	2.66

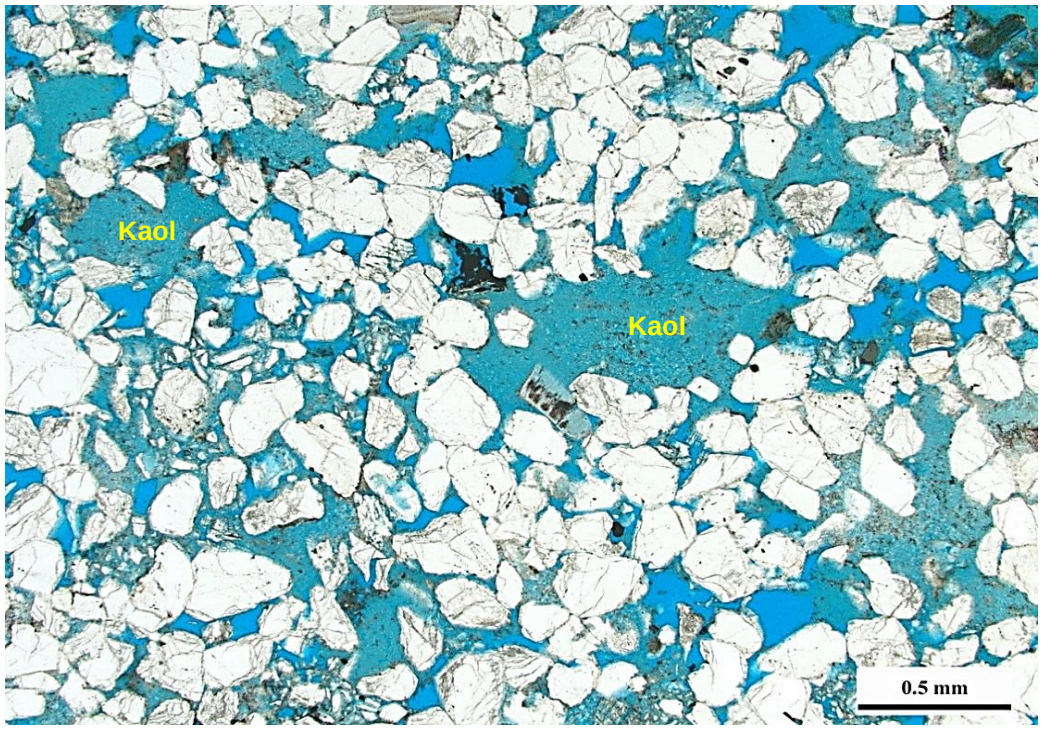
**Core analysis data taken at 1250 psi*

PLATE 10

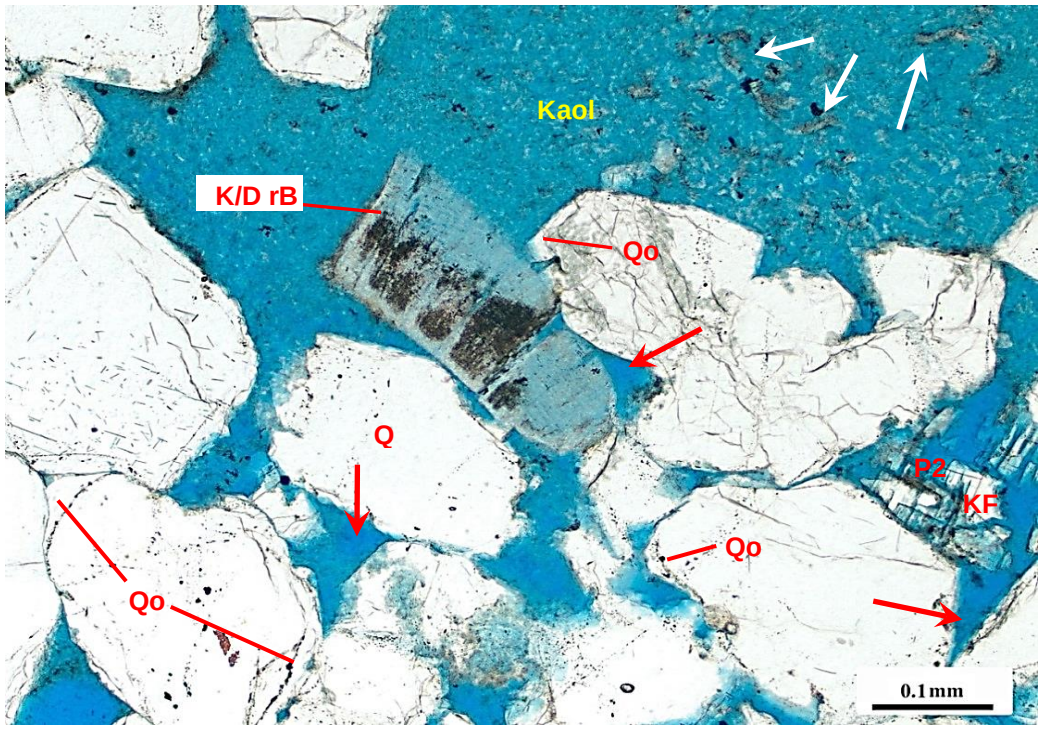
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1179.70
Sample ID: 168

A



B



Sample Description

Lithology: kaolin-rich sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 0.658 (Coarse sand)
Grn.Sorting: moderately well

Structures:
laminated; contact between a well-sorted layer and a moderately sorted layer

Framework Grains:
abundant quartz; minor K-feldspar and plutonic lithic fragments; minor altered biotite

Accessory Grains:
minor micas including biotite altered to kaolinite/dickite; trace garnet, opaque minerals, amphibole

Matrix:
none observed

Cements:
patchy intergranular kaolinite; minor quartz overgrowths; trace pyrite

Pore Types:
common intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	77.2	Goethite	0.0
K-Feldspar	3.8	Hematite	0.0
Plagioclase	0.4	Pyrite	0.3
Calcite	0.0	Total Clay	18.3

Clay Abundance (Weight %)

Illite / Smectite	0.0	Kaolin*	15.4
Illite & Mica	1.0	Chlorite	1.9

%smectite in mixed-layer illite/smectite is na
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Photomicrographs of this sample were taken from the unstained portion of the thin section, although XRD results indicates that K-feldspar is a minor component in the sample. Photo A shows moderately compacted fabric and patchy to oversized areas of kaolinite (Kaol) that characterize this sample. Photo B shows that the oversized patches of kaolinite exhibit distinct curving vermicular stacks of kaolinite (white arrows) whereas the sand-size grains of kaolinite/dickite are replacement of biotite flakes (K/D rB). Minor amounts of intragranular pores (P2) are associated with K-feldspar (KF). Many of the detrital quartz grains (Q) exhibit quartz overgrowths (Qo). The red arrows indicate intergranular pores. The blue coloration of kaolinite indicates it is microporous.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	27.50
Permeability (md)*:	928.0
Grain Density (g/cc):	2.65

**Core analysis data taken at 1250 psi*

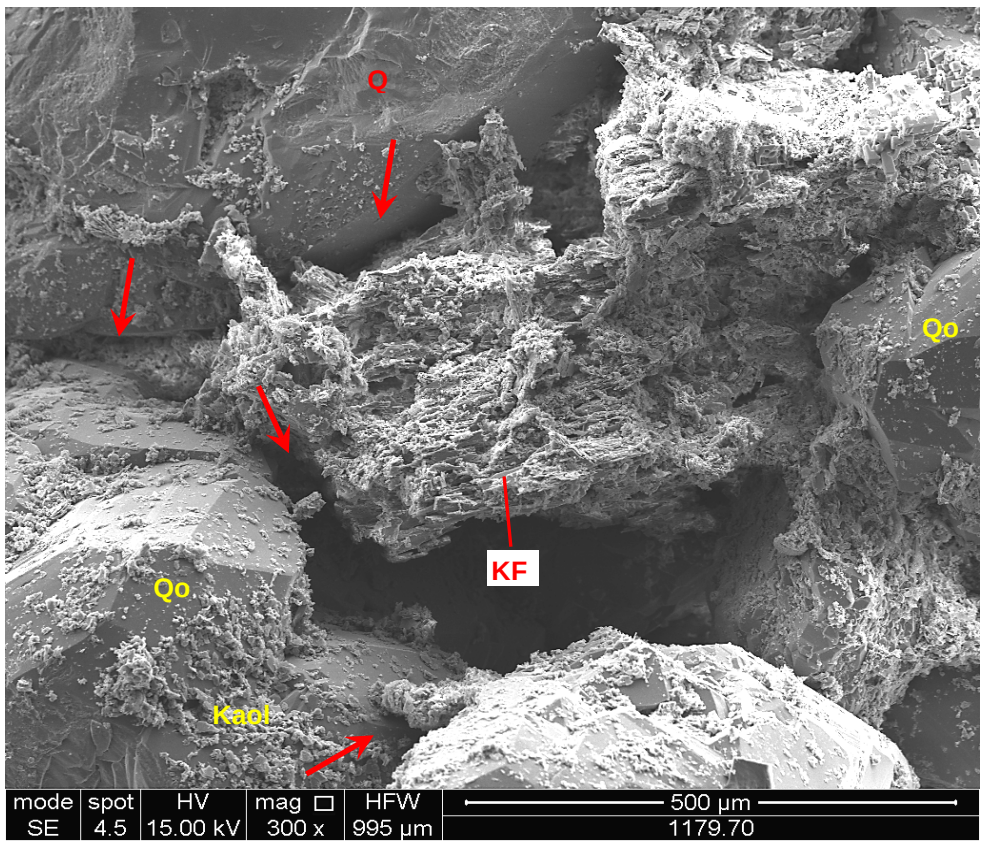
PLATE 10 (cont'd)

Scanning Electron Microscopy

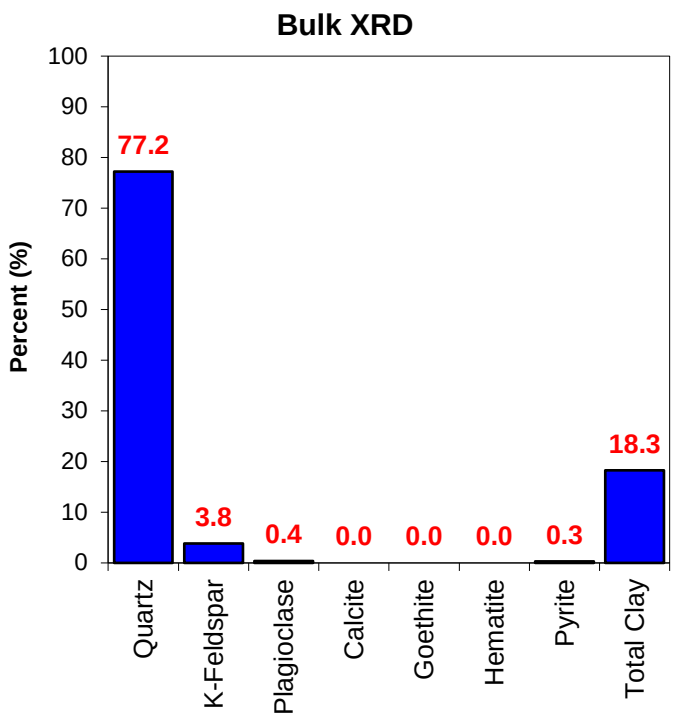
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1179.70
Sample ID: 168

Lithology: kaolin-rich sandstone

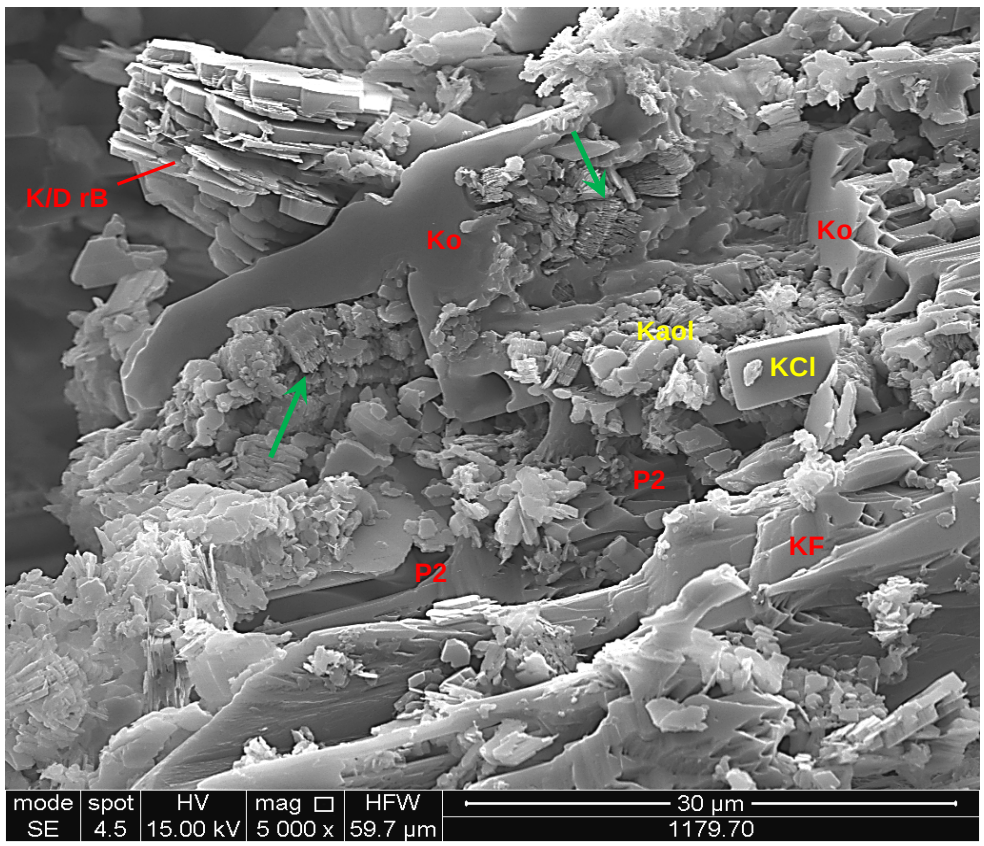
C

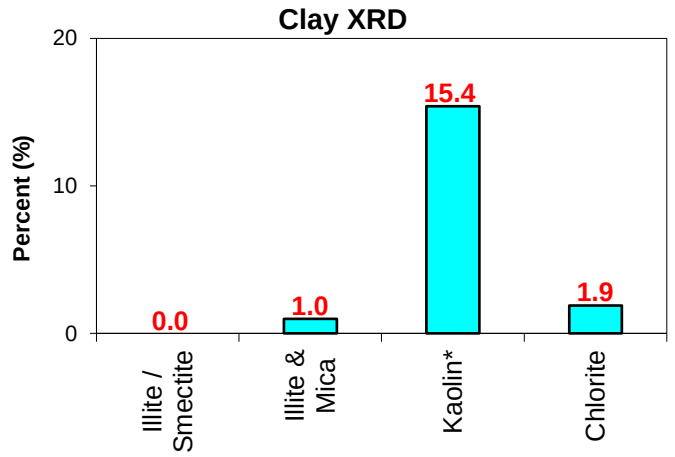


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is na
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses show abundant quartz grains (Q) with quartz overgrowths (Qo) that partly occlude intergranular pores (red arrows). The central K-feldspar grain (KF) is heavily leached and is featured in Image D. The grains shows intragranular pores (P2) that are partly filled with authigenic K-feldspar (Ko) and kaolinite (Kaol). Some of the kaolinite exhibits vermiform booklets (green arrows). Larger booklets of kaolinite also occur replacing a biotite flake (K/D rB). The cubic crystal of sylvite (KCl) is a contaminant.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	27.50
Permeability (md)*:	928.0
Grain Density (g/cc):	2.65

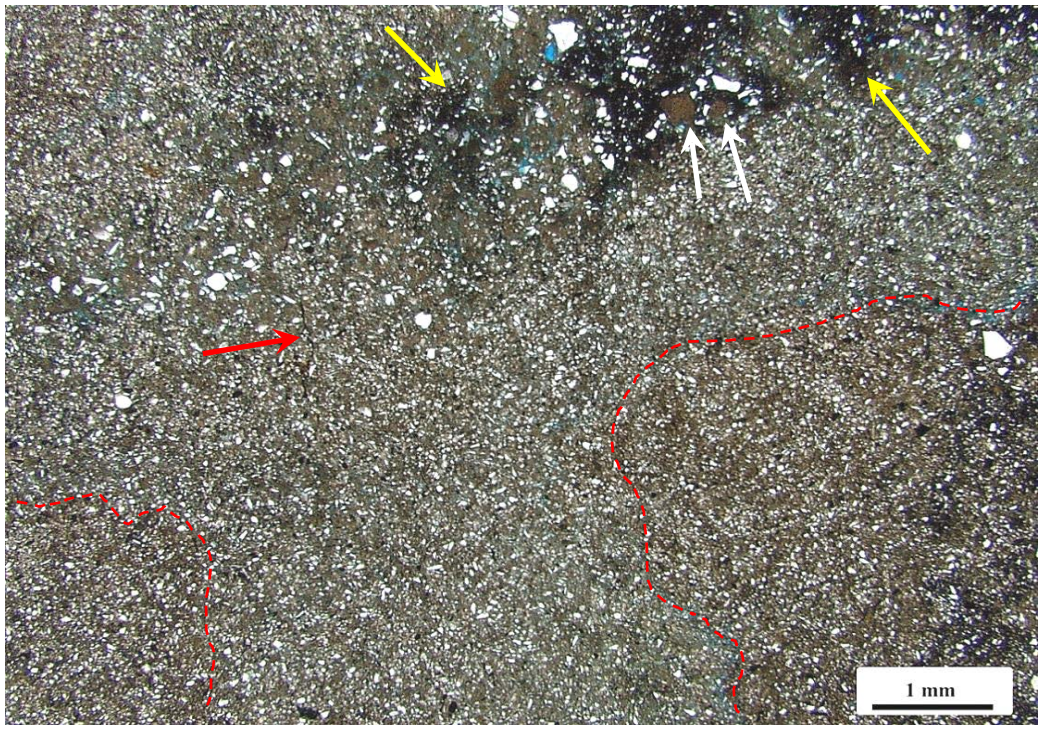
**Core analysis data taken at 1250 psi*

PLATE 11

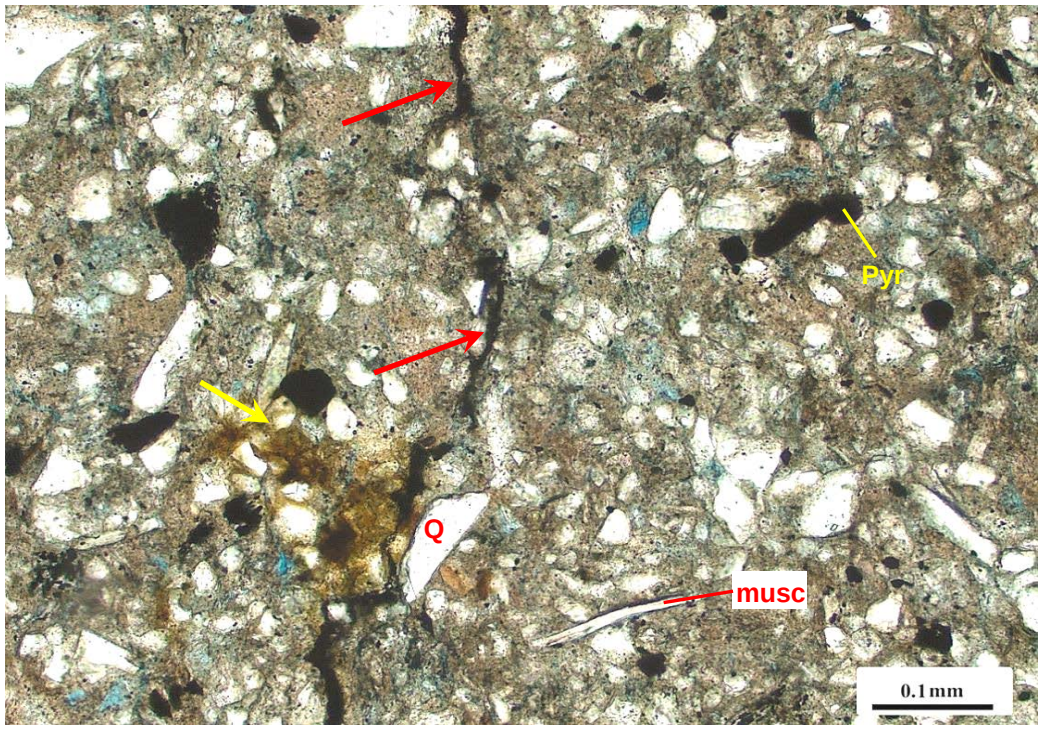
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1226.38
Sample ID: PSH 15

A



B



Sample Description

Lithology: **sandy claystone**

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.078 (L. very fine sand)
Grn.Sorting: moderately well

Structures:
massive; grains supported in clay matrix; sparse possible rooted zones

Framework Grains:
abundant quartz; minor K-feldspar, plagioclase and plutonic lithic fragments; trace argillaceous intraclasts

Accessory Grains:
minor biotite and muscovite, opaque minerals; trace plant fragments

Matrix:
abundant illitic/smectite clay supports grains

Cements:
irregular hematite stain of clay matrix; trace pyrite

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	30.0	Goethite	0.0
K-Feldspar	8.5	Hematite	1.2
Plagioclase	5.2	Pyrite	0.5
Calcite	0.0	Total Clay	54.6

Clay Abundance (Weight %)

Illite / Smectite	37.0	Kaolin*	5.3
Illite & Mica	10.2	Chlorite	2.1

%smectite in mixed-layer illite/smectite is 30-40
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a sandy claystone with evenly dispersed lower very fine sand grains (white flecks). Several areas of the thin section show clay-rich patches with larger quartz (Q) and feldspar grains and a few argillaceous intraclasts (white arrows). Detrital muscovite (musc) and biotite flakes are present. The red arrows indicate a thin slightly organic to pyritic structure interpreted to be a root trace. Authigenic pyrite also occurs as distinct framboids (Pyr). Areas outlined in red exhibit faint staining by limonite. The yellow arrows indicate patches stained by hematite. The faint patches of blue epoxy reflect sample plucking during preparation.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:
Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

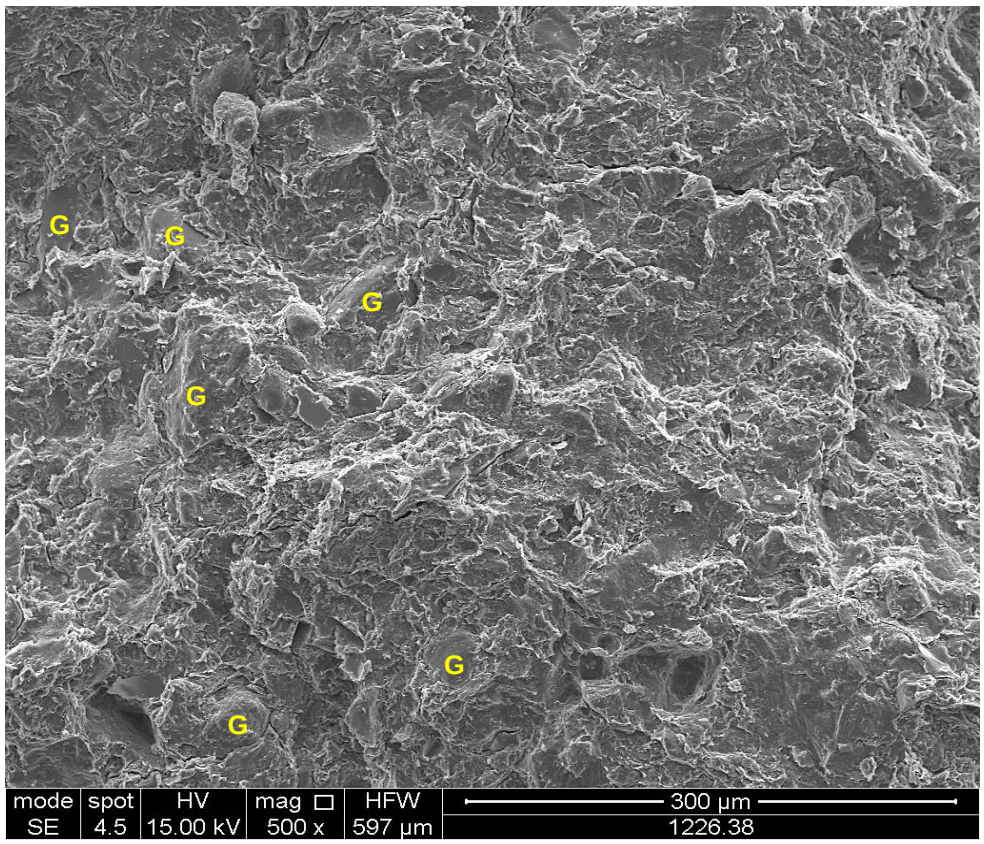
PLATE 11 (cont'd)

Scanning Electron Microscopy

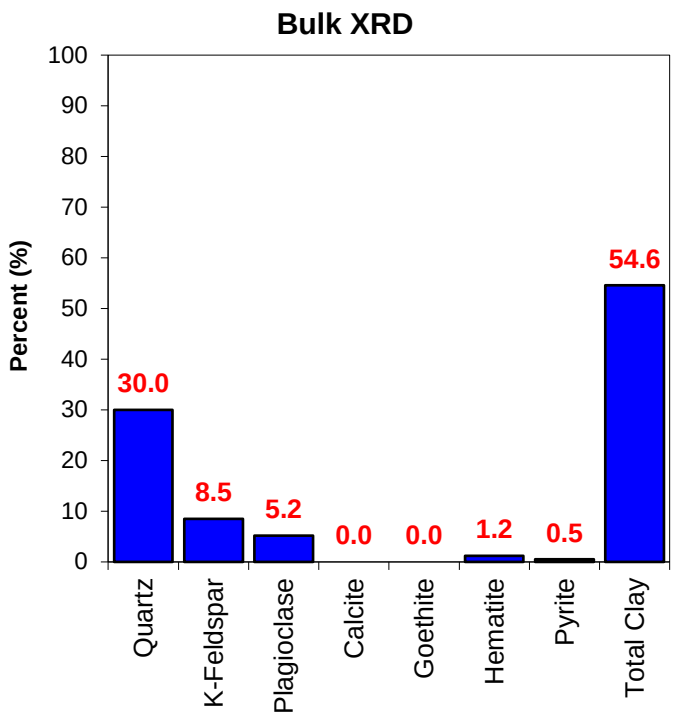
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1226.38
Sample ID: PSH 15

Lithology: sandy claystone

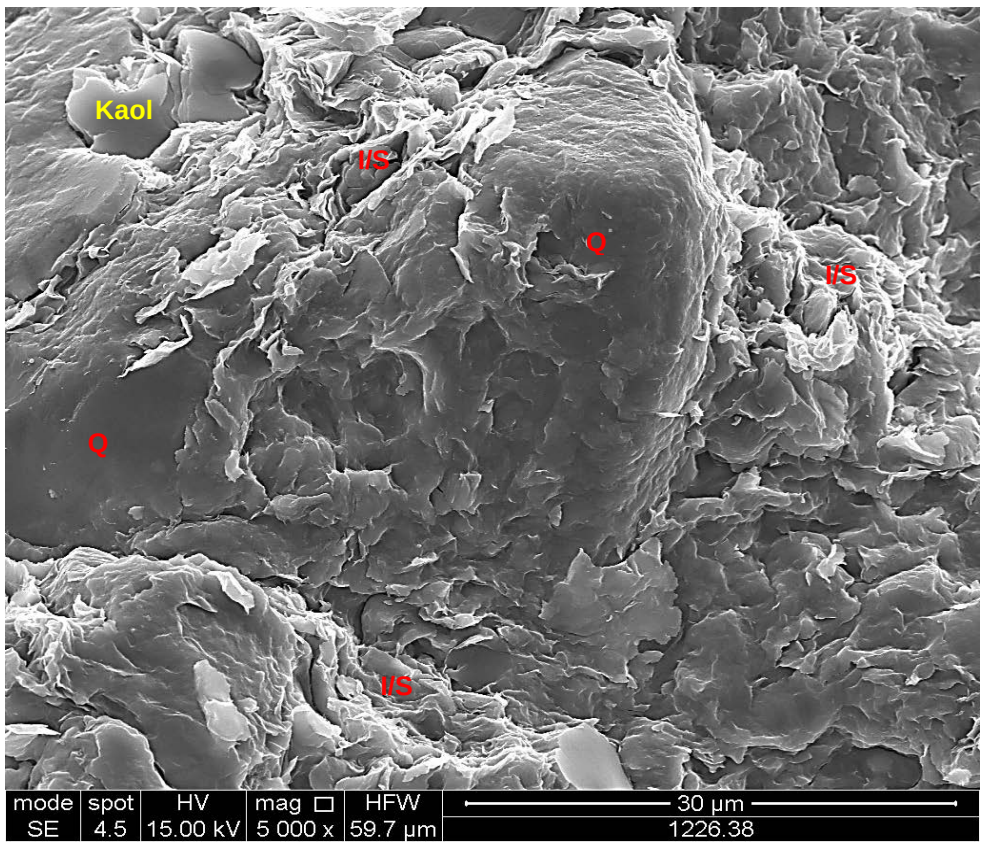
C

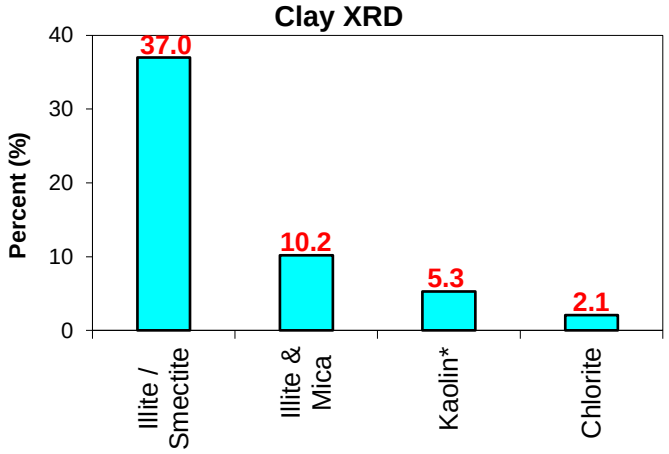


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 30-40
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows the abundant matrix clay (mostly mixed-layer illite/smectite by XRD) and scattered detrital silt and very fine sand grains (G). EDS analysis indicates a quartz grain (Q). Interparticle micropores are associated with the illite/smectite (I/S) matrix clay.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

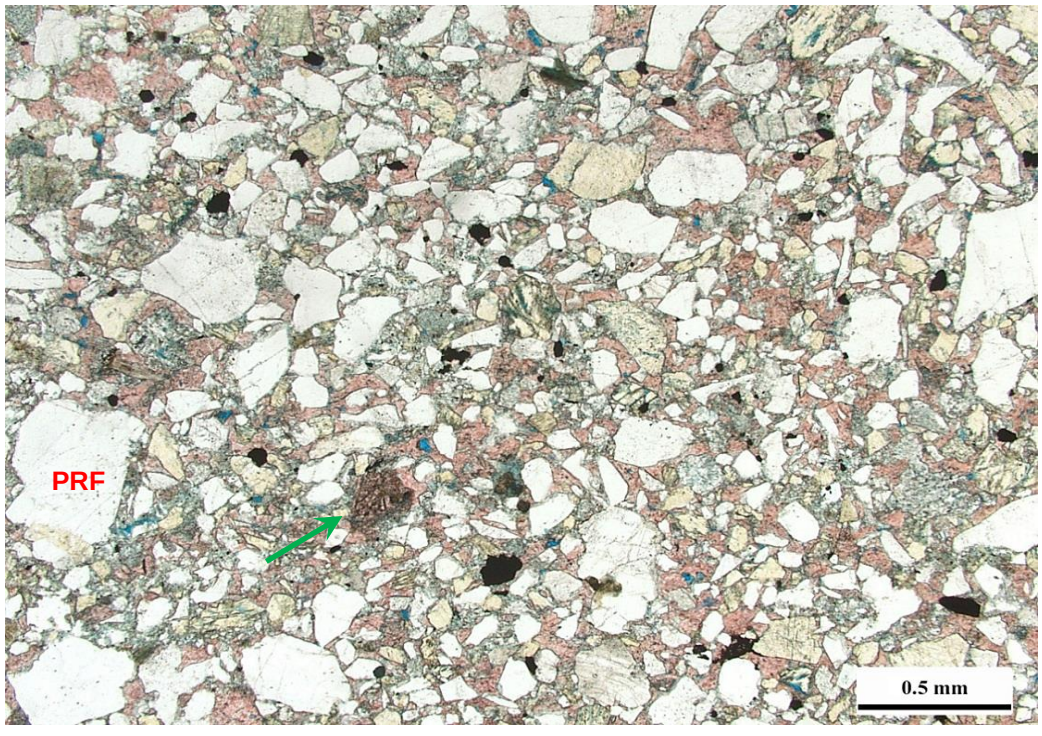
**Core analysis data taken at na psi*

PLATE 12

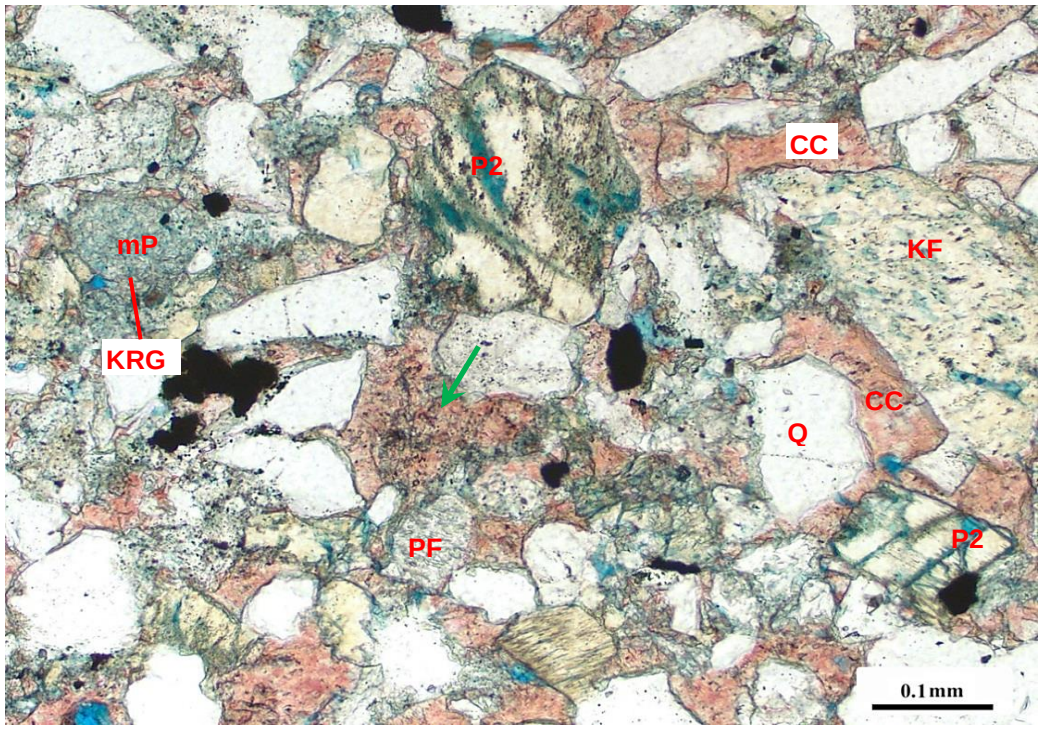
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1258.05
Sample ID: 175

A



B



Sample Description

Lithology: calcite-cemented sandstone

Est.Classif. (Folk, 1980): sublitharenite
Grain Size (mm): 0.346 (L. medium sand)
Grn.Sorting: moderate

Structures:
massive and homogeneous; minor compaction

Framework Grains:
abundant quartz; common K-feldspar, plagioclase and plutonic lithic fragments

Accessory Grains:
trace biotite, opaque minerals, calcite- and kaolinite-replaced grains

Matrix:
none observed

Cements:
abundant intergranular calcite; trace intragranular kaolinite, pyrite

Pore Types:
minor intragranular dissolution pores in feldspars and calcite-replaced grains; trace intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	40.5	Goethite	0.0
K-Feldspar	16.4	Hematite	0.0
Plagioclase	9.8	Pyrite	0.0
Calcite	24.4	Total Clay	8.8

Clay Abundance (Weight %)

Illite / Smectite	5.2	Kaolin*	1.2
Illite & Mica	2.0	Chlorite	0.4

%smectite in mixed-layer illite/smectite is 60-70
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This massive sandstone sample is unique among the sample set. It is the only sample cemented with calcite (CC; stained pink). Framework grains identified include quartz (Q), K-feldspar (KF), plutonic lithic fragments (PRF) and plagioclase (PF). The kaolinite-replaced grains exhibit relics of plagioclase. The green arrows indicate calcite -replaced grains. Most of the black grains are opaque minerals, many of which are altered to hematite or limonite. Intragranular pores (P2) occur within K-feldspar grains, and intercrystal micropores (mP) occur in the authigenic kaolinite.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	5.80
Permeability (md)*:	0.0
Grain Density (g/cc):	2.65

**Core analysis data taken at 1250 psi*

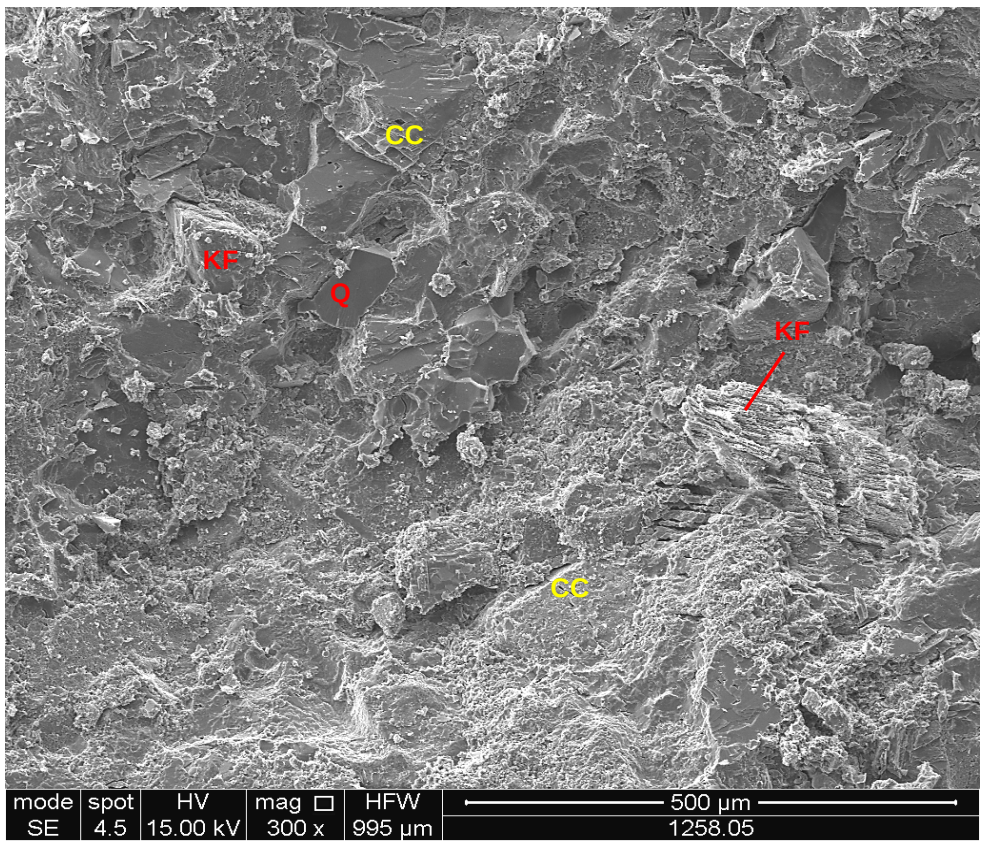
PLATE 12 (cont'd)

Scanning Electron Microscopy

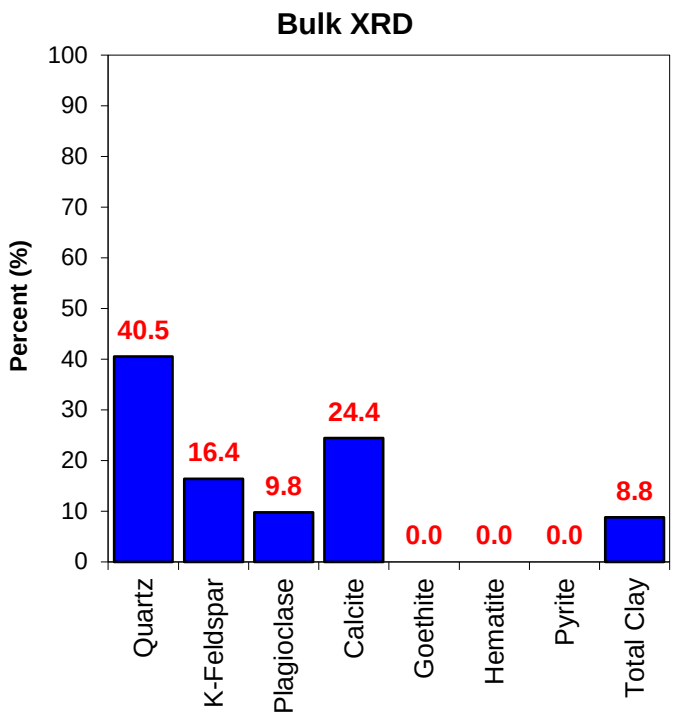
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1258.05
Sample ID: 175

Lithology: calcite-cemented sandstone

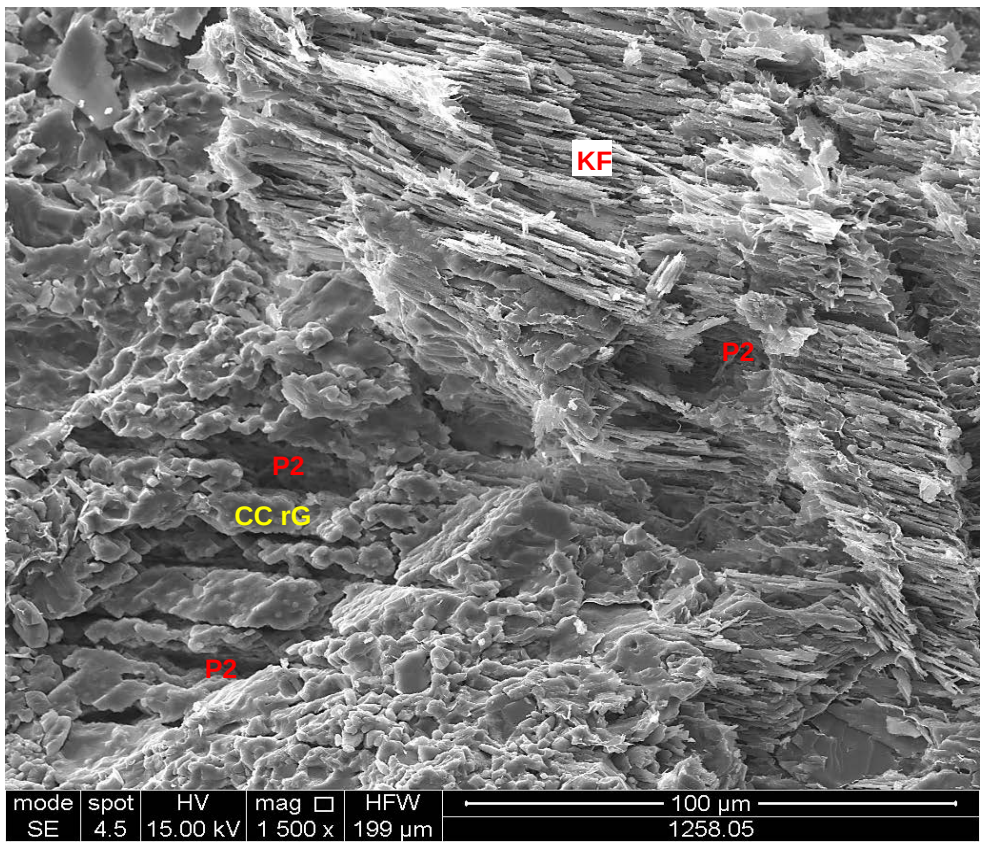
C

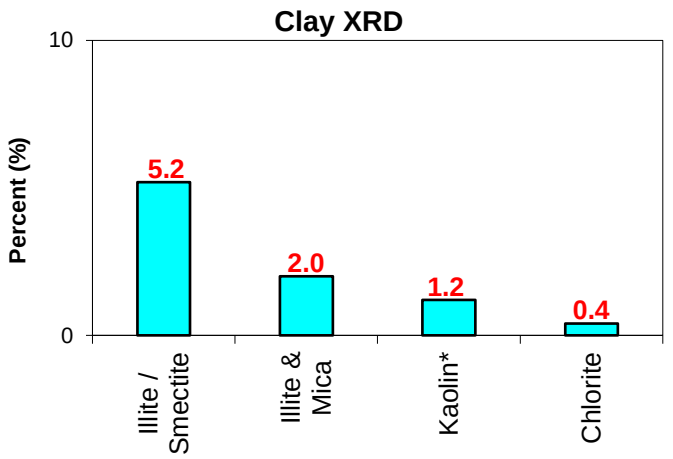


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows grains of K-feldspar (KF) and quartz (Q) cemented by calcite (CC), The only macropores visible are intragranular dissolution pores (P2) associated with K-feldspar and a calcite-replaced grain (CC rG; Image D). Note the distinctly different nature of grain leaching in the K-feldspar and calcite-replaced grains.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	5.80
Permeability (md)*:	0.0
Grain Density (g/cc):	2.65

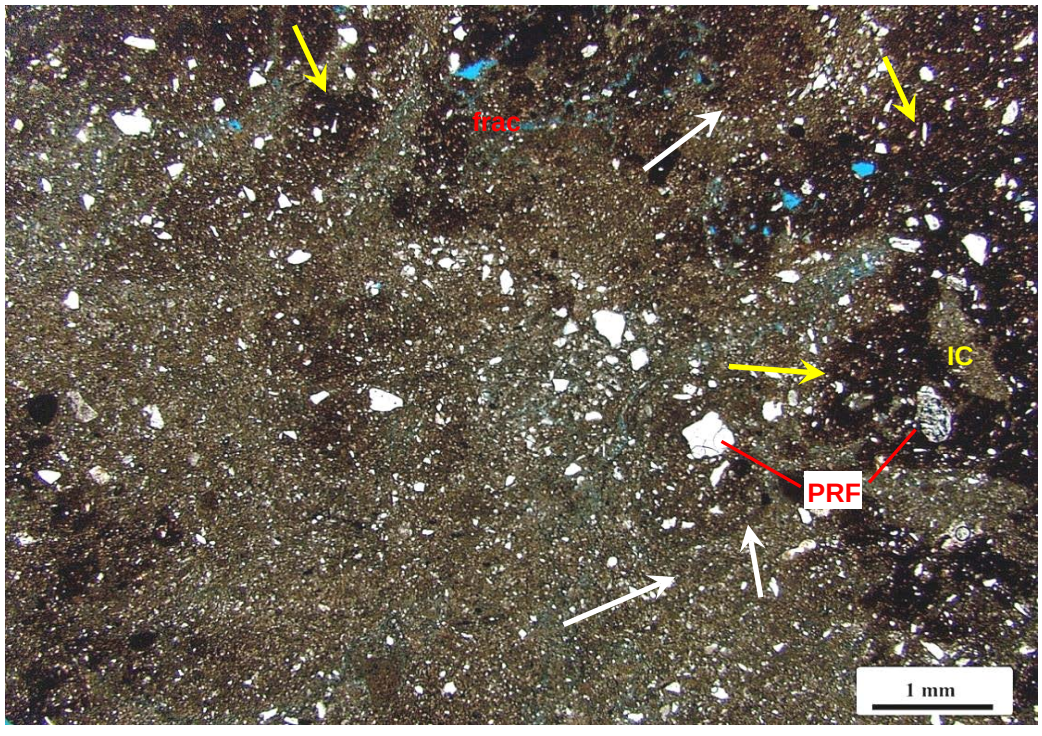
**Core analysis data taken at 1250 psi*

PLATE 13

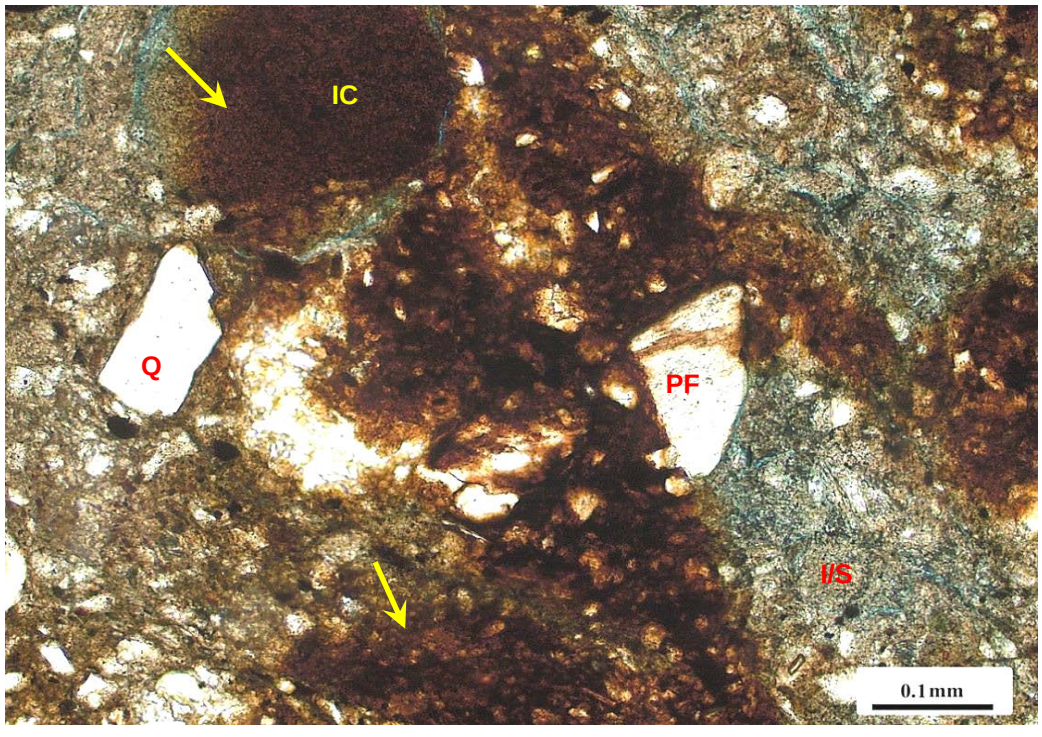
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1291.61
Sample ID: PSH 18

A



B



Sample Description

Lithology: **sandy claystone**

Est.Classif. (Folk, 1980): na
Grain Size range: silt to medium sand
Grn.Sorting: poor

Structures:
mottled with clots of illitic clay; hematitic infiltration sediment with clasts of host mudrock; scattered sand-size grains

Framework Grains:
common quartz; moderate K-feldspar, plagioclase and plutonic lithic fragments; minor argillaceous intraclasts

Accessory Grains:
minor mica; trace heavy minerals

Matrix:
abundant illitic clay supports grains

Cements:
irregular hematite stain of clay matrix; trace pyrite

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	18.1	Goethite	0.0
K-Feldspar	5.6	Hematite	2.6
Plagioclase	9.7	Pyrite	0.0
Calcite	0.0	Total Clay	64.0

Clay Abundance (Weight %)

Illite / Smectite	39.0	Kaolin*	14.5
Illite & Mica	7.8	Chlorite	2.7

%smectite in mixed-layer illite/smectite is 60-70
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a sandy claystone with a mottled fabric and areas containing scattered fine and medium sand grains. The larger grain include quartz (Q), plagioclase (PF) and plutonic lithic fragments (PRF). Argillaceous intraclasts (IC) are noted, and less distinct clasts are indicated with the white arrows. The yellow arrows indicate mottled domains stained by minor hematite. The hematitic sediment may be of infiltration origin. The blue epoxy filled ovals and fractures (frac) reflect the presence of swelling clays in the matrix, which swells during sample preparation.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

**Core analysis data taken at na psi*

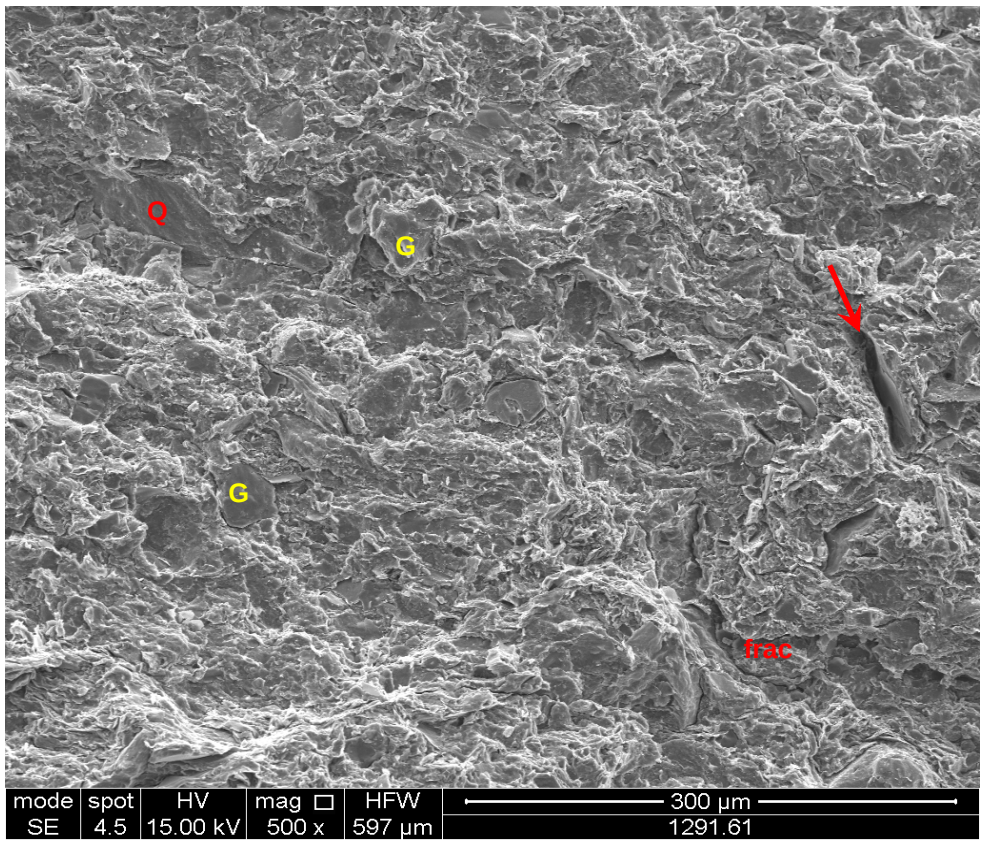
PLATE 13 (cont'd)

Scanning Electron Microscopy

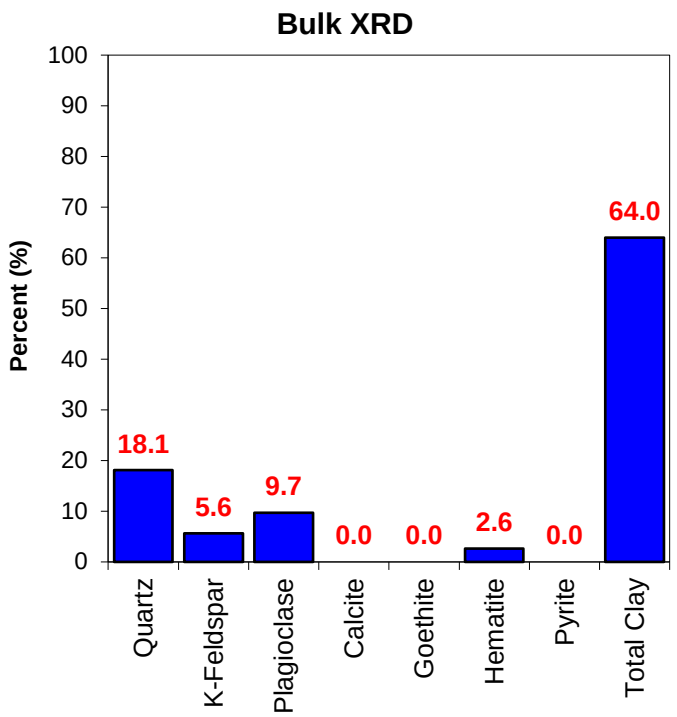
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1291.61
Sample ID: PSH 18

Lithology: sandy claystone

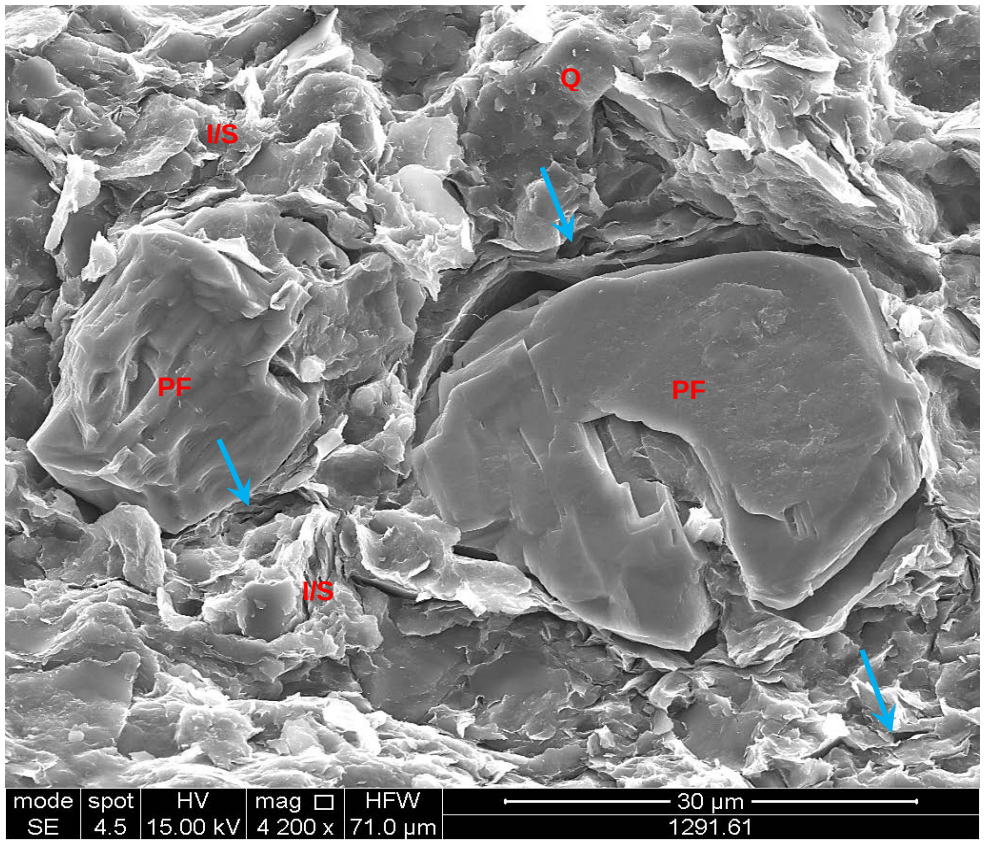
C

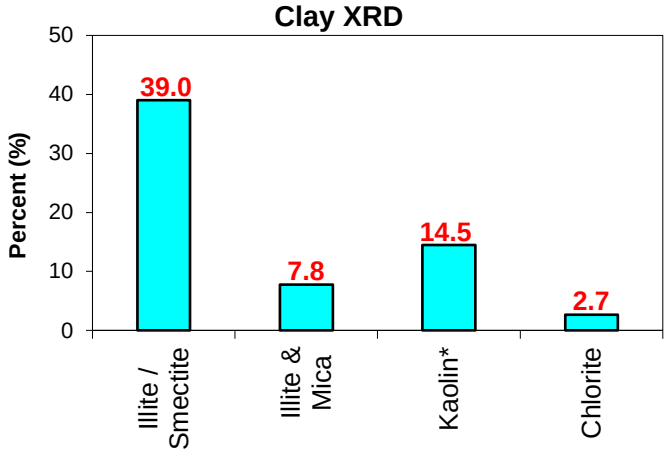


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses show grains (G) including quartz (Q), mica (red arrow), and plagioclase (PF) in the abundant clay matrix. XRD analysis indicates that mixed-layer illite/smectite (I/S) is the most abundant matrix clay type. Interparticle micropores are associated with the clay matrix (blue arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

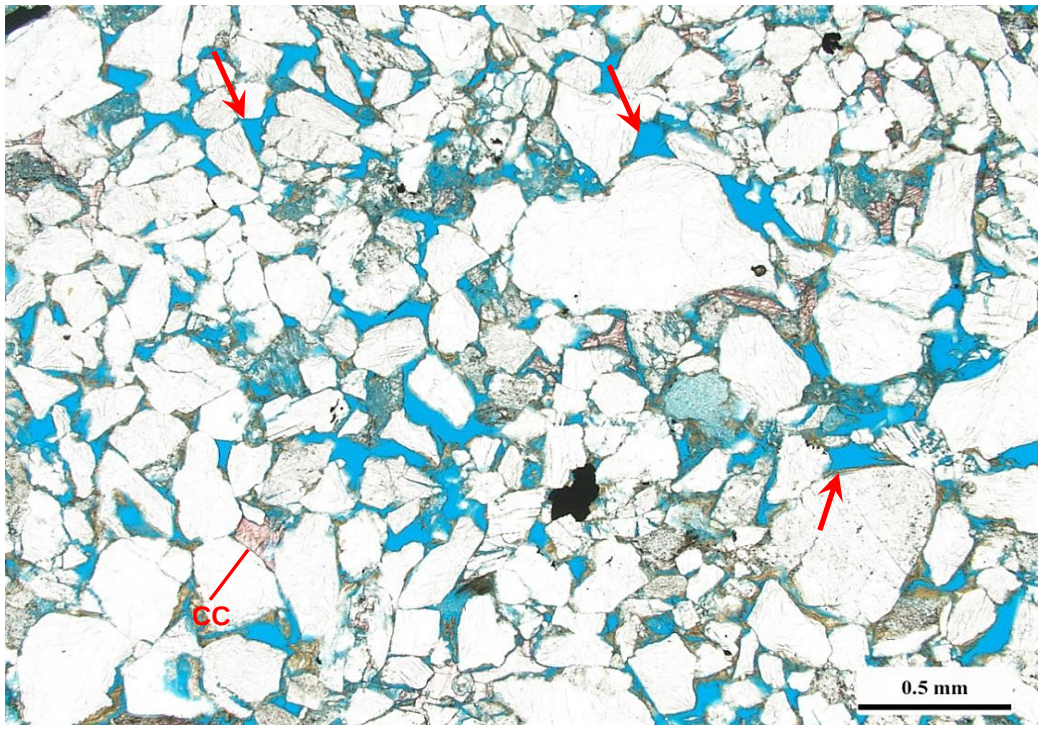
**Core analysis data taken at na psi*

PLATE 14

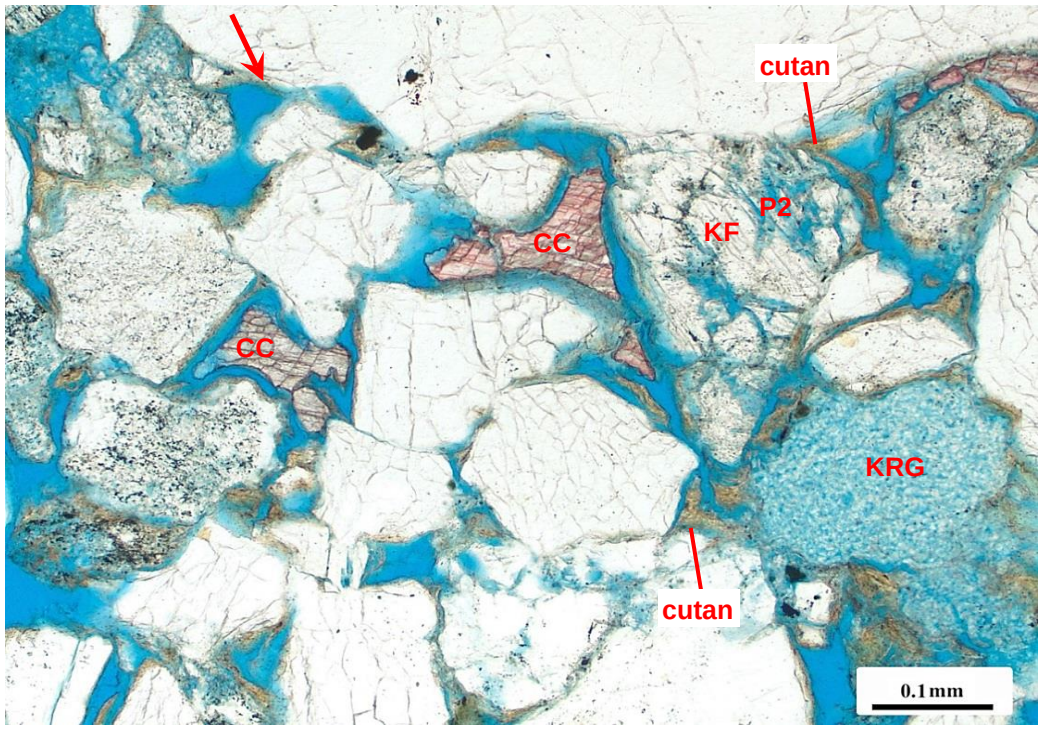
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1335.50
Sample ID: 183

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): sublitharenite
Grain Size (mm): 0.489 (U. medium sand)
Grn.Sorting: well

Structures:
massive; moderate compaction (long grain contacts); feldspars exhibit intragranular fractures

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
minor biotite and muscovite; trace garnet, opaque minerals

Matrix:
common mechanically infiltrated clay (cutans)

Cements:
minor kaolinite replacing grains, patchy intergranular calcite; trace limonite alteration of opaque grains

Pore Types:
common intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	43.7	Goethite	0.0
K-Feldspar	22.6	Hematite	0.0
Plagioclase	13.5	Pyrite	0.0
Calcite	1.8	Total Clay	18.4

Clay Abundance (Weight %)

Illite / Smectite	15.0	Kaolin*	1.1
Illite & Mica	2.0	Chlorite	0.3

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Photomicrographs of this sample were taken from the calcite-stained portion of the thin section, although XRD data indicate that K-feldspar is an abundant component in the sample. Framework grains include abundant quartz, K-feldspar (KF), plagioclase and plutonic lithic fragments. Detrital matrix occurs as pervasive mechanically infiltrated clay cutans (cutans). XRD analysis indicates that the cutans are composed of smectite-rich mixed-layer illite/smectite. Patches of intergranular calcite (CC) occlude some intergranular areas. Kaolinite occurs in kaolinite-replaced grains (KRG). Intercrystal micropores occur between kaolinite platelets. Minor amounts of intragranular pores (P2) are associated with K-feldspar. The red arrows indicate intergranular pores.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.20
Permeability (md)*:	36.4
Grain Density (g/cc):	2.62

**Core analysis data taken at 1250 psi*

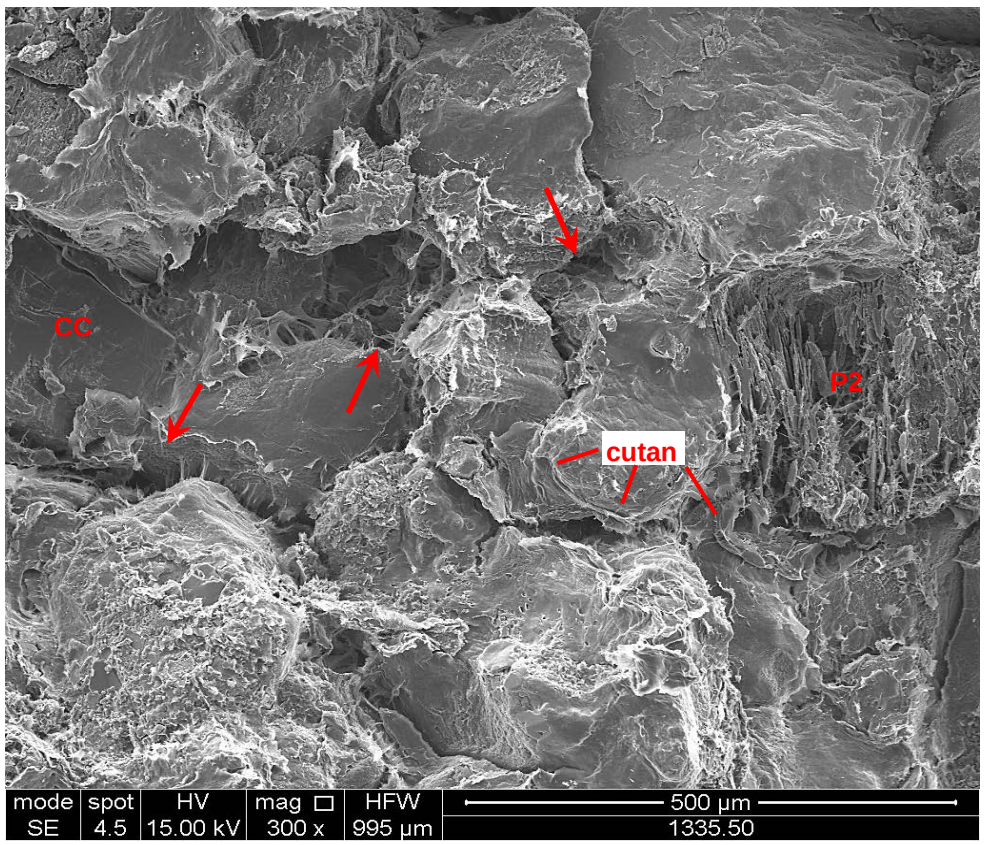
PLATE 14 (cont'd)

Scanning Electron Microscopy

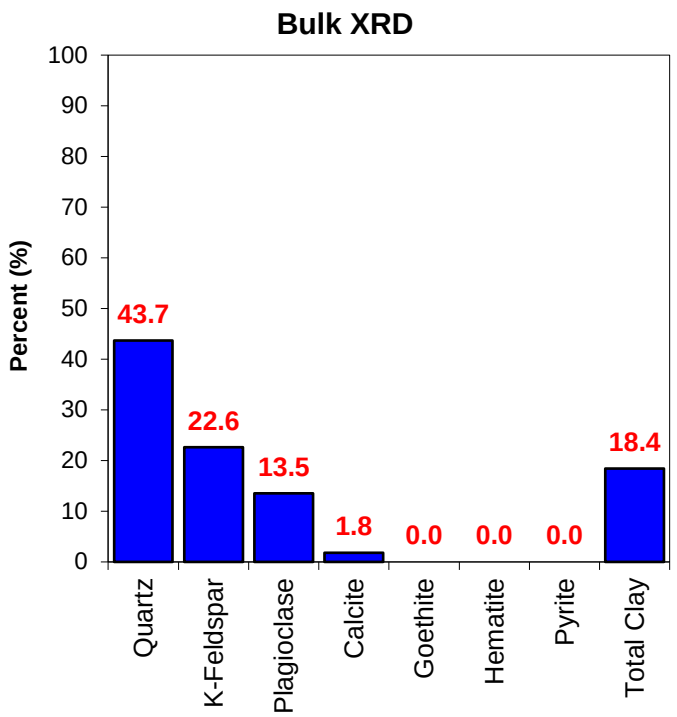
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1335.50
Sample ID: 183

Lithology: sandstone

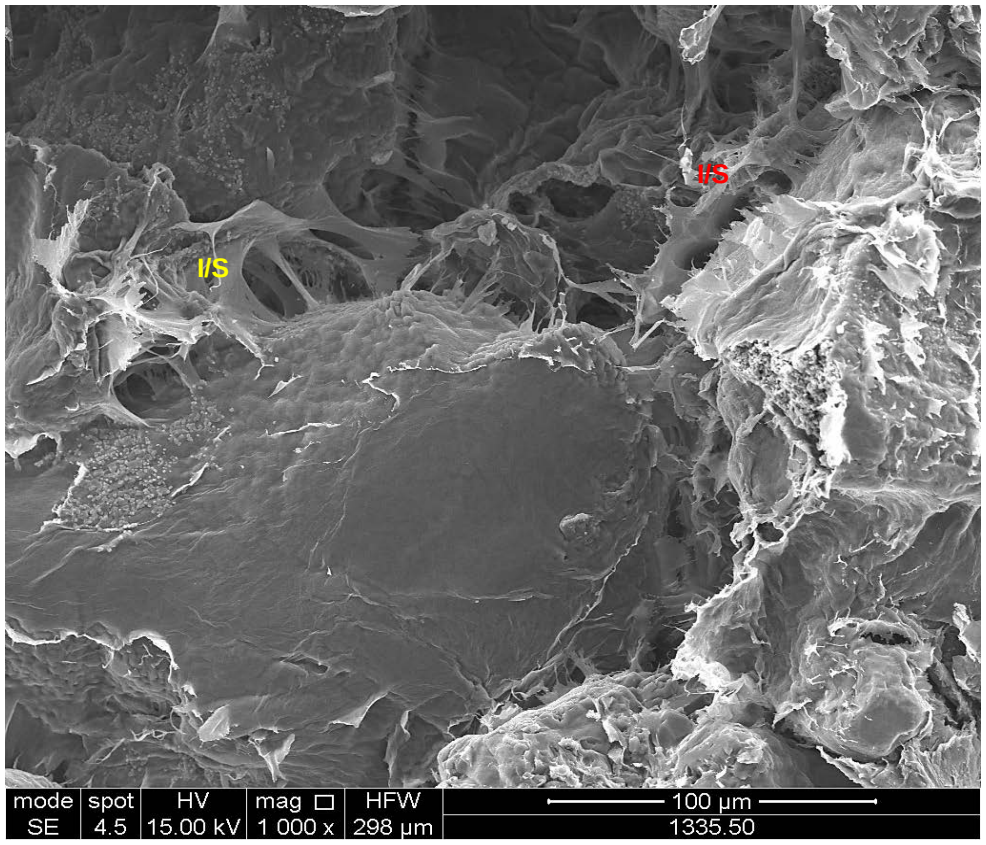
C

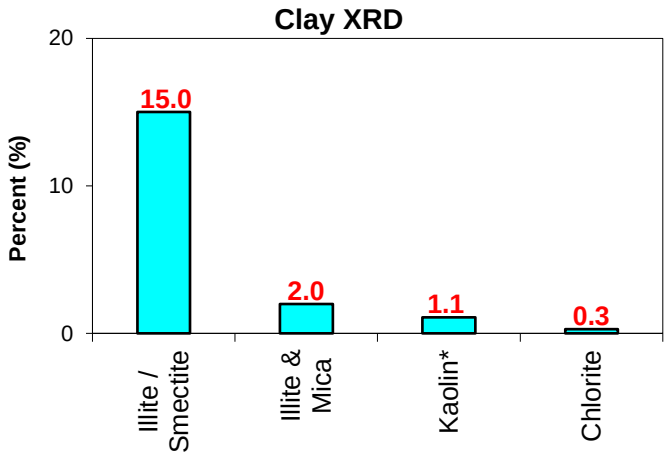


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows that most grains are coated by smectite-rich mixed-layer illite/smectite clay in the form of cutans. The cutans are mechanically-infiltrated clay and the clay platelets are oriented parallel to grain surfaces. Intergranular areas are indicated by the red arrows. Intergranular pores are reduced by patchy calcite (CC) and pore throats are diminished by pore-bridging illite/smectite (I/S). A honeycombed feldspar grain exhibits dissolution pores (P2; Image C).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.20
Permeability (md)*:	36.4
Grain Density (g/cc):	2.62

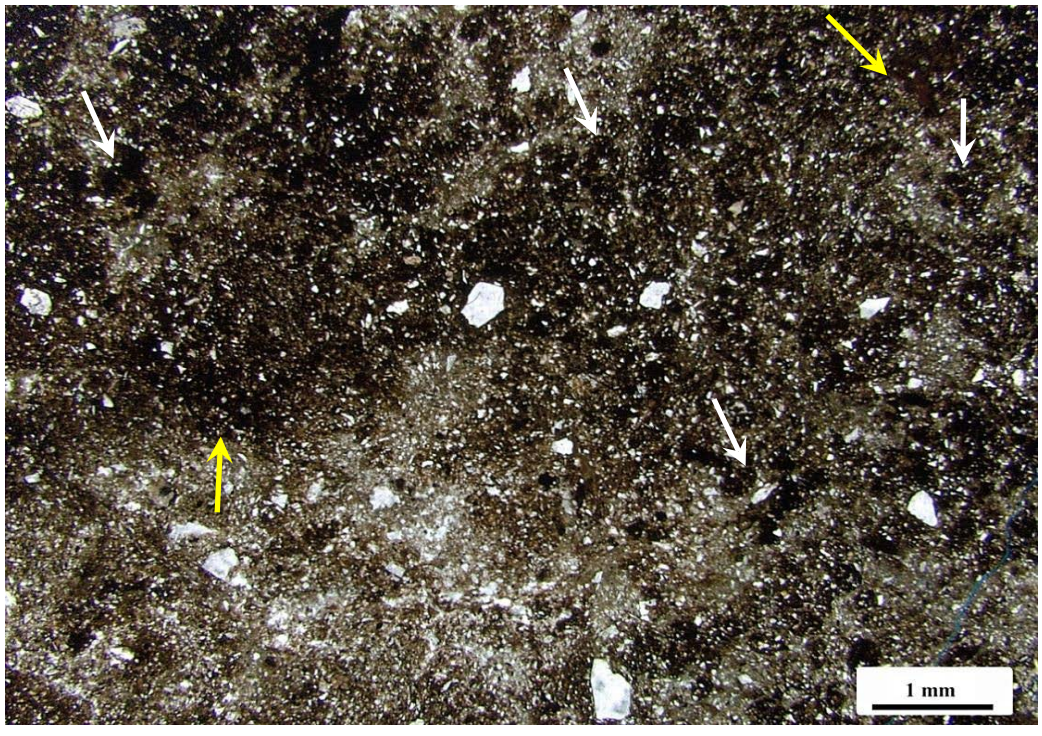
**Core analysis data taken at 1250 psi*

PLATE 15

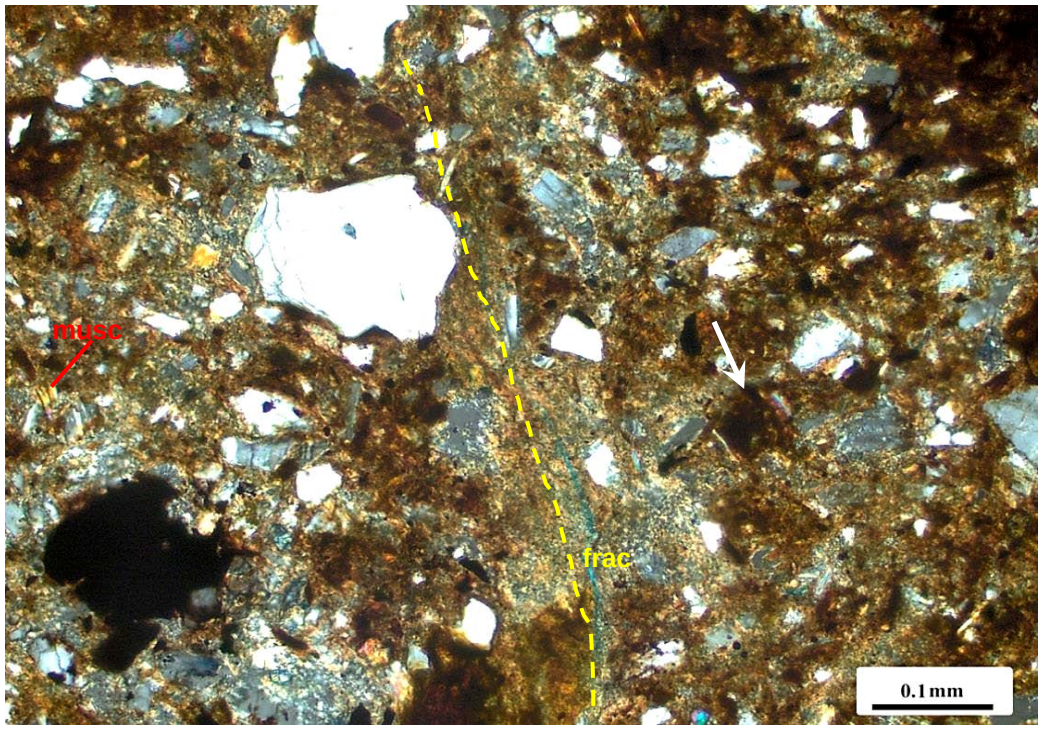
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1353.81
Sample ID: PSH 24

A



B crossed nicols



Sample Description

Lithology: **sandy claystone**

Est.Classif. (Folk, 1980): na
Grain Size range: silt to medium sand
Grn.Sorting: poor

Structures:
mottled with clots of illitic clay and scattered sand grains; hematitic infiltration sediment with clasts of host mudrock

Framework Grains:
common quartz; moderate K-feldspar, plagioclase and plutonic lithic fragments, argillaceous intraclasts (hematite-stained)

Accessory Grains:
minor biotite, muscovite, chlorite; trace epidote, opaque minerals

Matrix:
abundant matrix clay

Cements:
irregular hematite stain of individual clasts and matrix clay

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	18.1	Goethite	1.8
K-Feldspar	8.5	Hematite	0.7
Plagioclase	11.4	Pyrite	0.0
Calcite	0.0	Total Clay	59.5

Clay Abundance (Weight %)

Illite / Smectite	39.7	Kaolin*	9.4
Illite & Mica	7.7	Chlorite	2.7

%smectite in mixed-layer illite/smectite is 40-50
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sandy claystone exhibits a mottled fabric and scattered fine and medium sand grains. The larger grains include quartz, plagioclase, muscovite (musc), and plutonic lithic fragments. Argillaceous intraclasts stained by hematite are noted with the white arrows. The yellow arrows indicate mottled domains stained by minor hematite. The hematitic sediment may be of infiltration origin. Photo B shows a typical zone of well-aligned illite/smectite clay that may represent a vertisol infill structure. Clays in the adjacent areas exhibit a randomized fabric. The fractures (frac) reflect the presence of swelling clays in the matrix, which swells during sample preparation.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

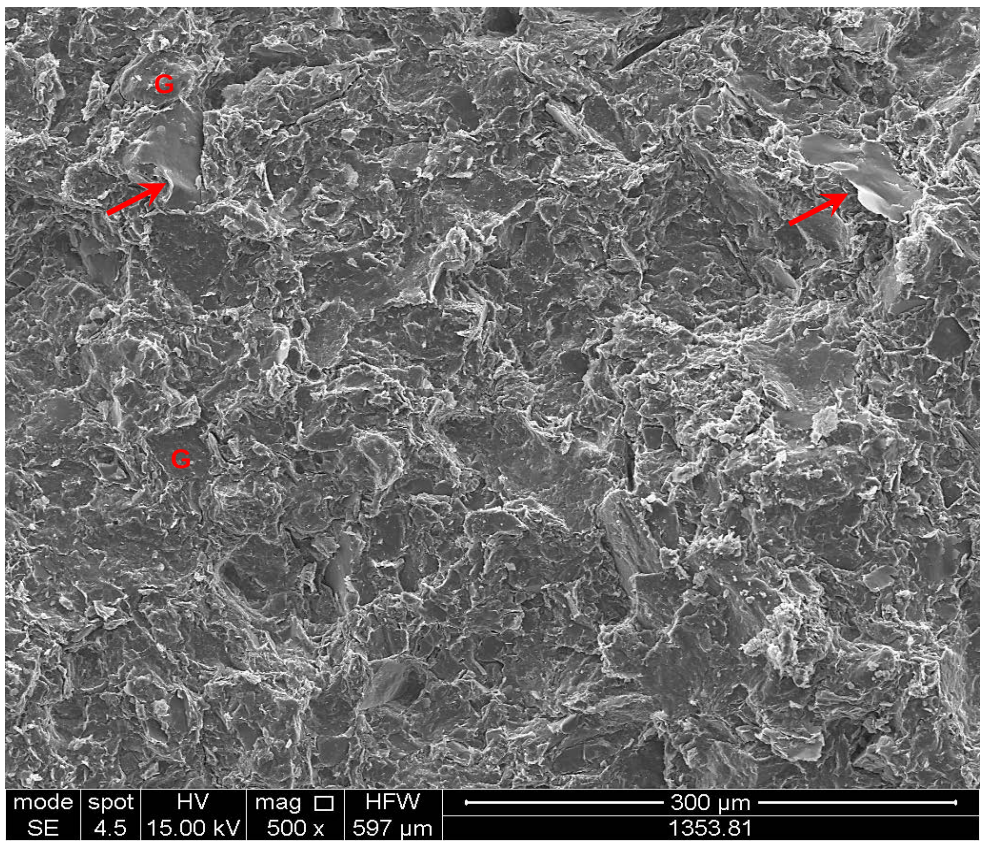
PLATE 15 (cont'd)

Scanning Electron Microscopy

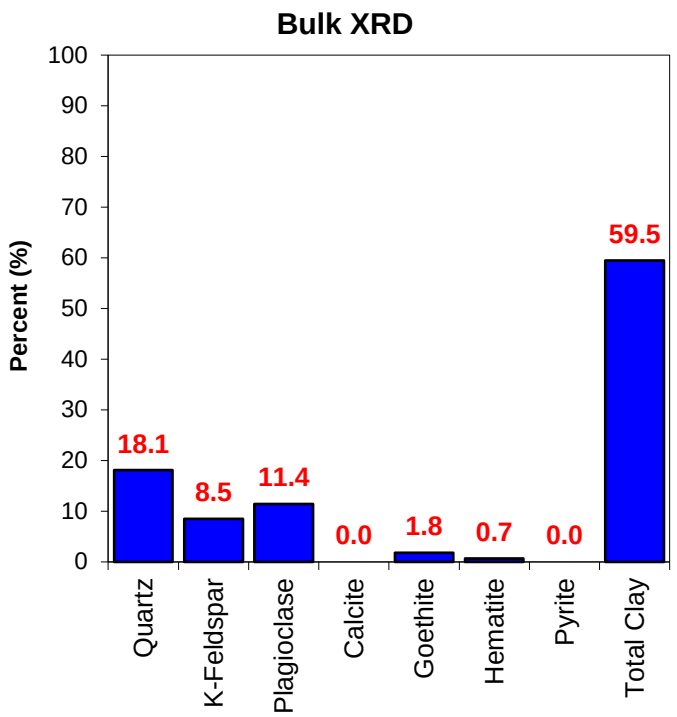
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1353.81
Sample ID: PSH 24

Lithology: sandy claystone

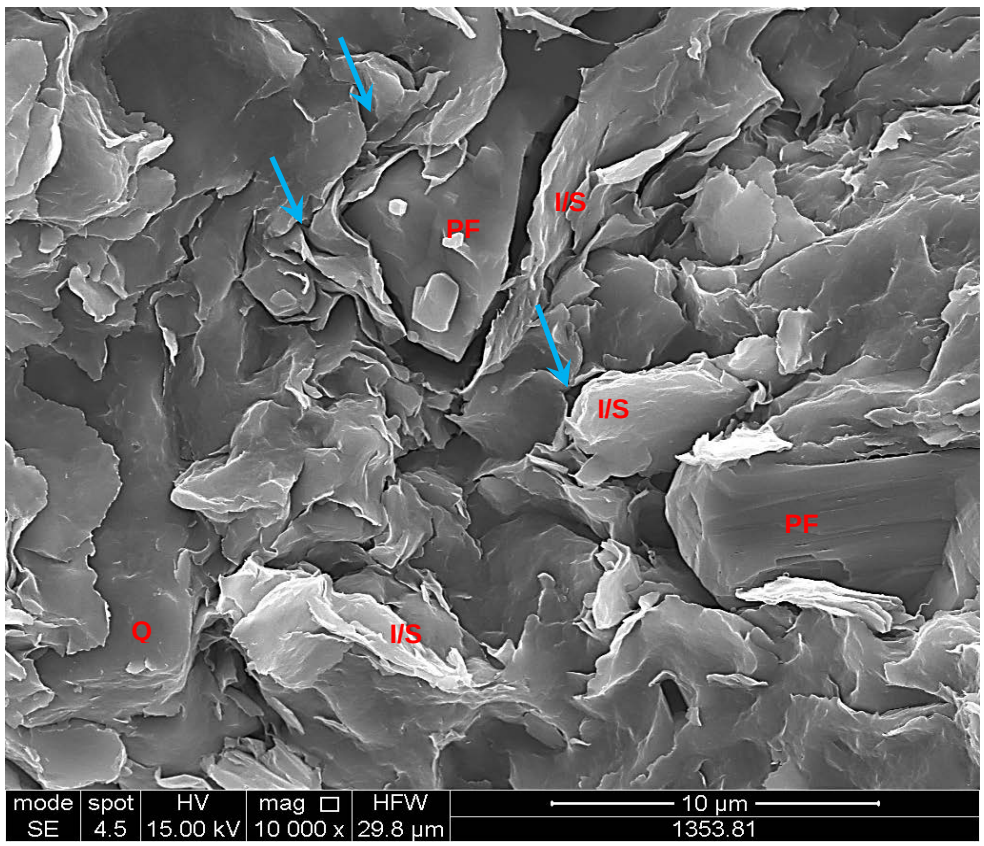
C

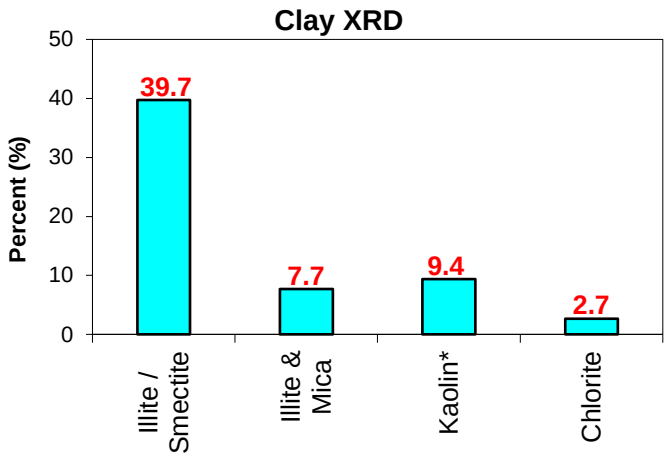


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 40-50
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses show grains (G) including quartz (Q), mica (red arrows), and plagioclase (PF) in the abundant clay matrix. XRD analysis indicates that mixed-layer illite/smectite (I/S) is the most abundant matrix clay type. Interparticle micropores are associated with the clay matrix (blue arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

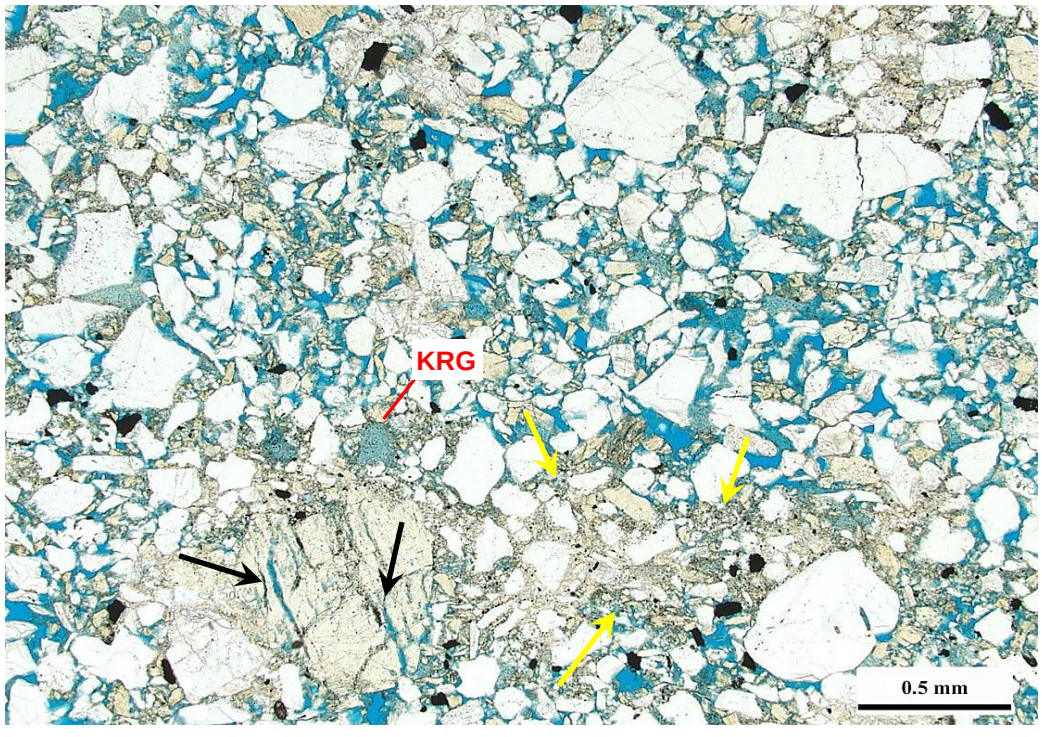
**Core analysis data taken at na psi*

PLATE 16

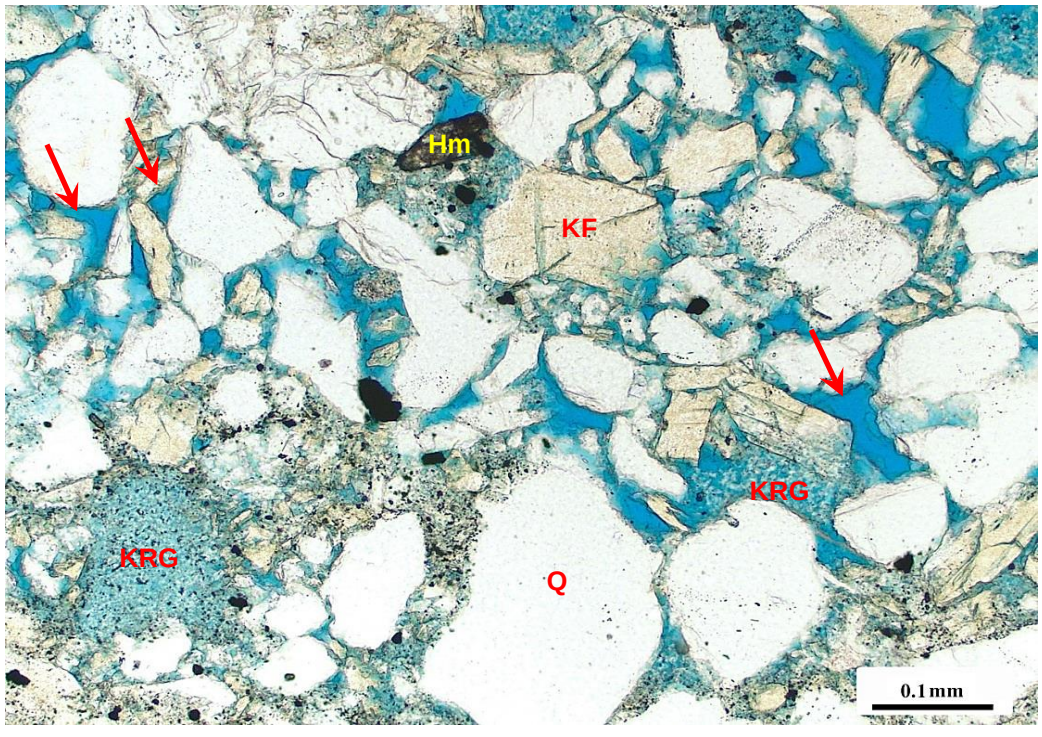
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1394.30
Sample ID: 187

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.276 (L. medium sand)
Grn.Sorting: poor to bimodal

Structures:
massive and homogeneous with scattered coarse sand; moderate compaction; fragmental areas suggesting coring damage

Framework Grains:
abundant quartz; common K-feldspar; minor plutonic lithic fragments

Accessory Grains:
trace zircon, sphene, opaque minerals

Matrix:
trace mechanically infiltrated clay (cutans)

Cements:
patchy intergranular and grain-replacing kaolinite; minor pyrite, quartz overgrowths

Pore Types:
common intergranular pores; minor intragranular pores (in feldspars); moderate intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	69.3	Goethite	0.0
K-Feldspar	19.1	Hematite	0.0
Plagioclase	0.6	Pyrite	0.0
Calcite	0.0	Total Clay	10.9

Clay Abundance (Weight %)

Illite / Smectite	4.3	Kaolin*	4.7
Illite & Mica	1.3	Chlorite	0.6

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a medium-grained sandstone with abundant quartz (Q) and common K-feldspar (KF; stained yellow). Heavy minerals occur in trace amounts (Hm) and include most of the black grains. Irregular areas exhibit highly fragmented grains and kaolinite cement (yellow arrows). Authigenic minerals include grain-replacing kaolinite (KRG). Pore types include intergranular pores (blue epoxy and red arrows) and intercrystal micropores associated with kaolinite cement (blue haze coloration within kaolinite). The black arrows in Photo A indicate intragranular fractures within a K-feldspar grain that appear to be natural.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.10
Permeability (md)*:	17.8
Grain Density (g/cc):	2.63

**Core analysis data taken at 1250 psi*

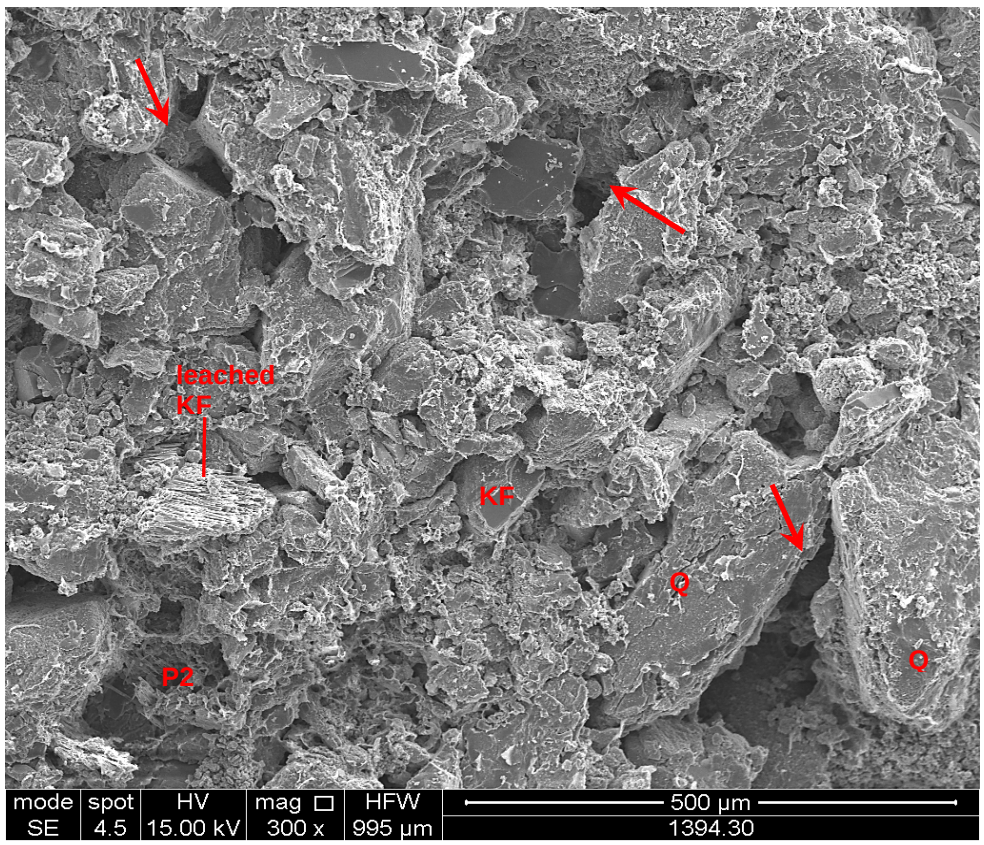
PLATE 16 (cont'd)

Scanning Electron Microscopy

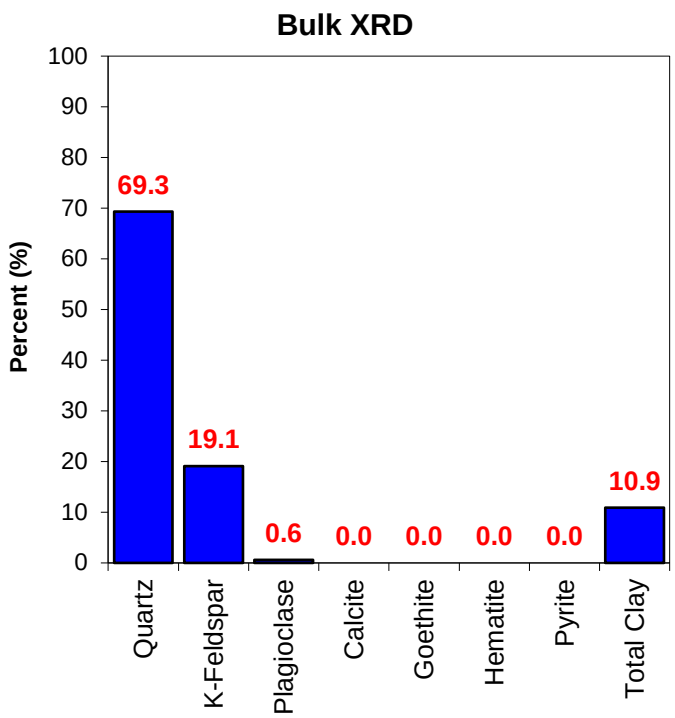
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1394.30
Sample ID: 187

Lithology: sandstone

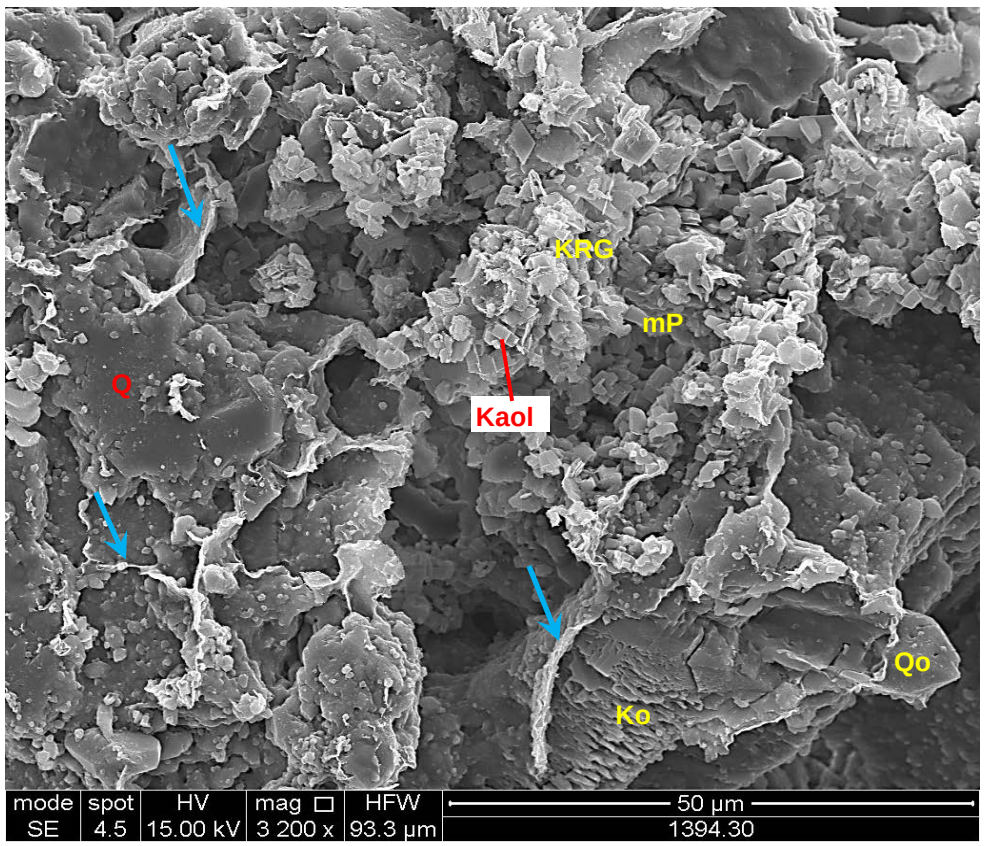
C

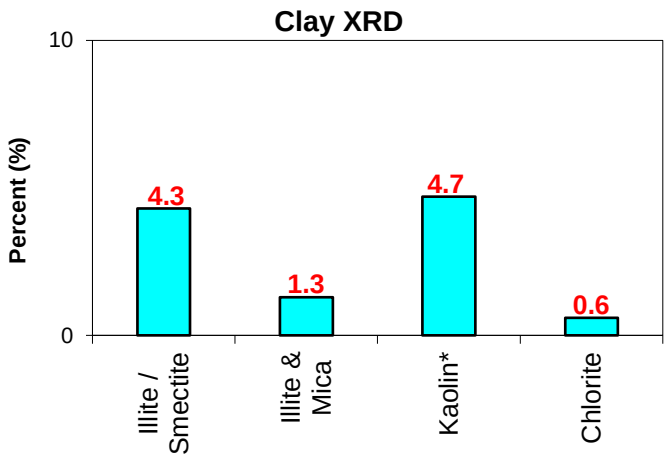


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows the poor sorting of the sandstone, with sand-size grains of quartz (Q) and K-feldspar (KF) identified. The red arrows indicate intergranular pores. Intragranular pores (P2) are associated with leached feldspar. Authigenic minerals induce K-feldspar (Ko) and quartz overgrowths (Qo) and kaolinite (Kaol). Aligned illite/smectite clay with arcuate shapes (blue arrows) suggest disrupted grain-coatings.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.10
Permeability (md)*:	17.8
Grain Density (g/cc):	2.63

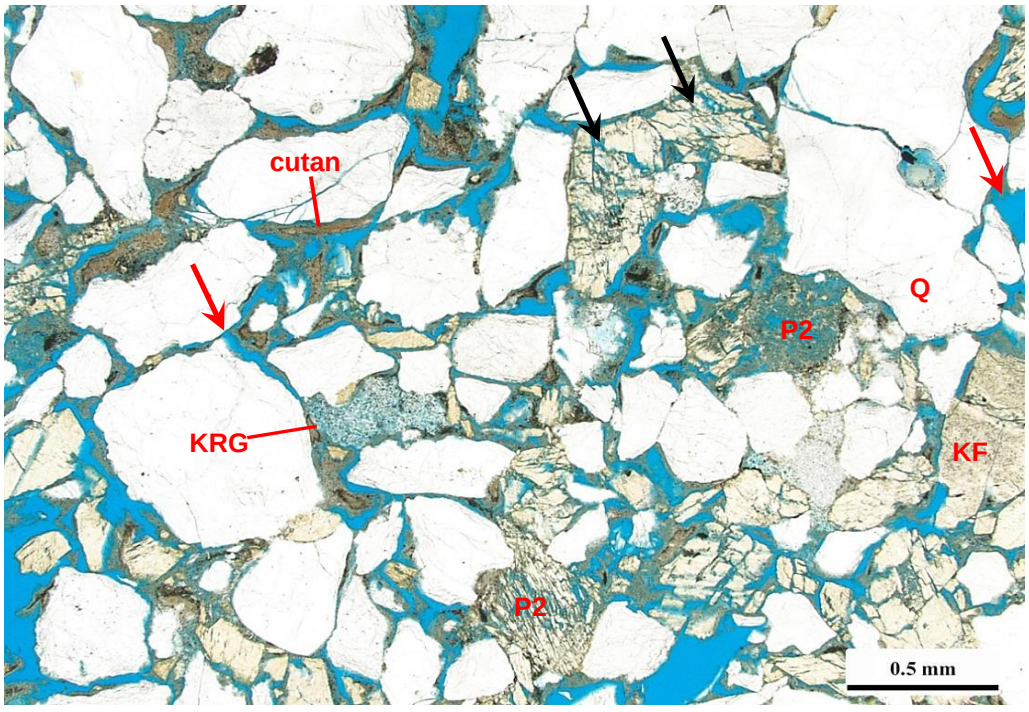
**Core analysis data taken at 1250 psi*

PLATE 17

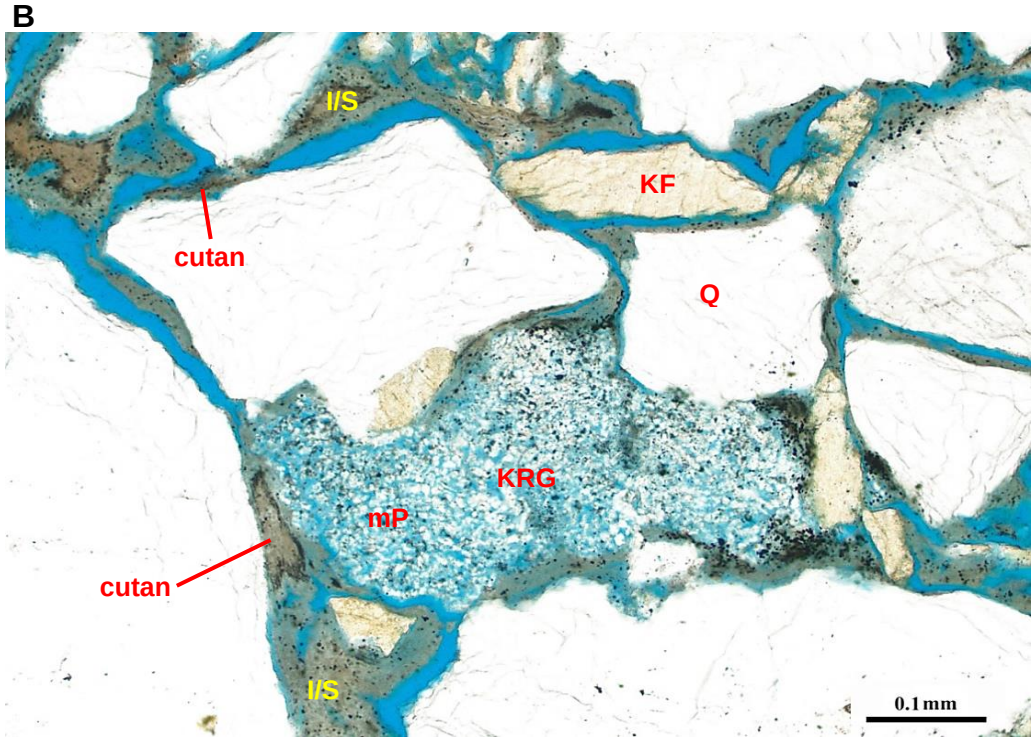
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1395.70
Sample ID: 186

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.688 (Coarse sand)
Grn.Sorting: moderately well

Structures:
massive; moderate compaction (long grain contacts); some feldspar grains exhibit intragranular fractures

Framework Grains:
abundant quartz; common K-feldspar and moderate plutonic lithic fragments

Accessory Grains:
trace opaque minerals, mica

Matrix:
moderate mechanically infiltrated clay (cutans)

Cements:
minor intragranular kaolinite; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); minor intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	67.9	Goethite	0.0
K-Feldspar	18.2	Hematite	0.0
Plagioclase	0.8	Pyrite	0.0
Calcite	0.0	Total Clay	13.1

Clay Abundance (Weight %)

Illite / Smectite	7.4	Kaolin*	2.9
Illite & Mica	2.1	Chlorite	0.7

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

Framework grains in this sandstone include abundant quartz (Q; mostly monocrystalline and minor polycrystalline), K-feldspar (KF), and plutonic lithic fragments that include quartz, microcline and plagioclase. Detrital matrix occurs as pervasive mechanically infiltrated clay cutans (cutans). XRD analysis indicates that the cutans are composed of smectite-rich mixed-layer illite/smectite clay. The minor amount of kaolinite detected by XRD occurs in kaolinite-replaced grains (KRG). Intercrystal micropores occur between kaolinite platelets. Minor amounts of intragranular pores (P2) are associated with K-feldspar (KF). The red arrows indicate intergranular pores. Some K-feldspar grains exhibit intragranular fractures

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.50
Permeability (md)*:	333.0
Grain Density (g/cc):	2.64

**Core analysis data taken at 1250 psi*

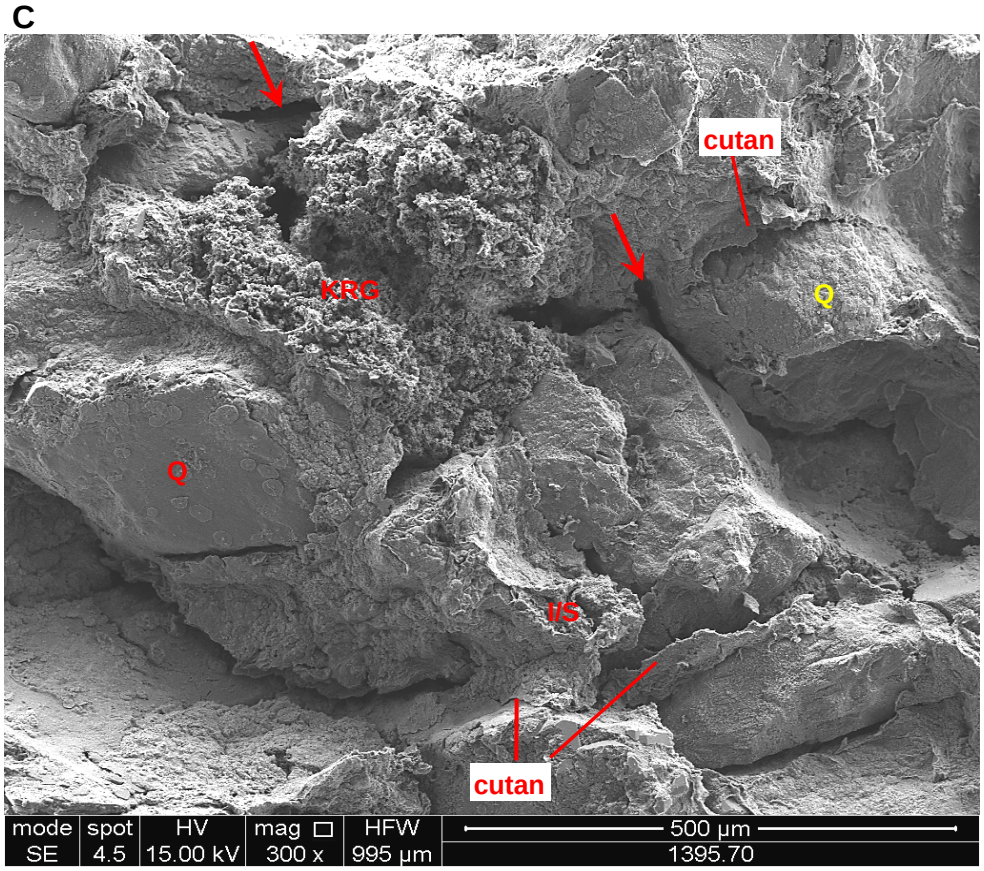
PLATE 17 (cont'd)

Scanning Electron Microscopy

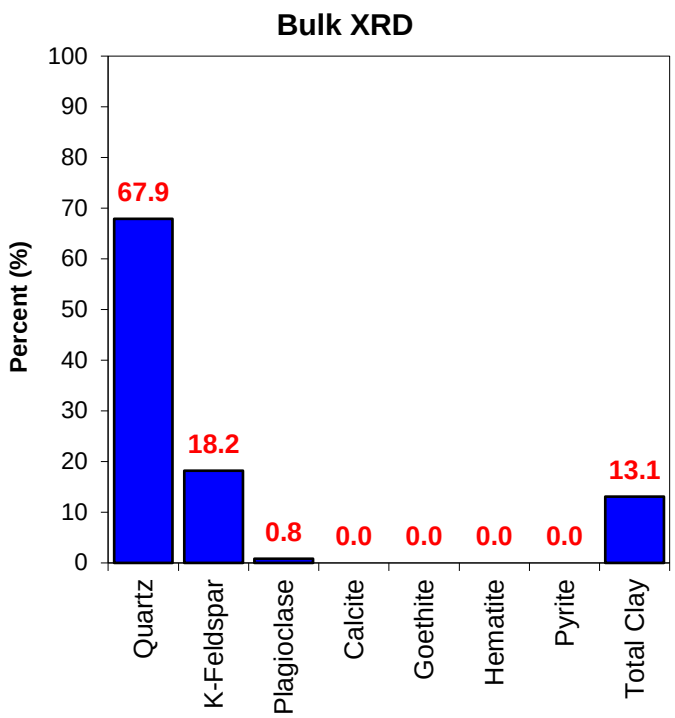
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1395.70
Sample ID: 186

Lithology: sandstone

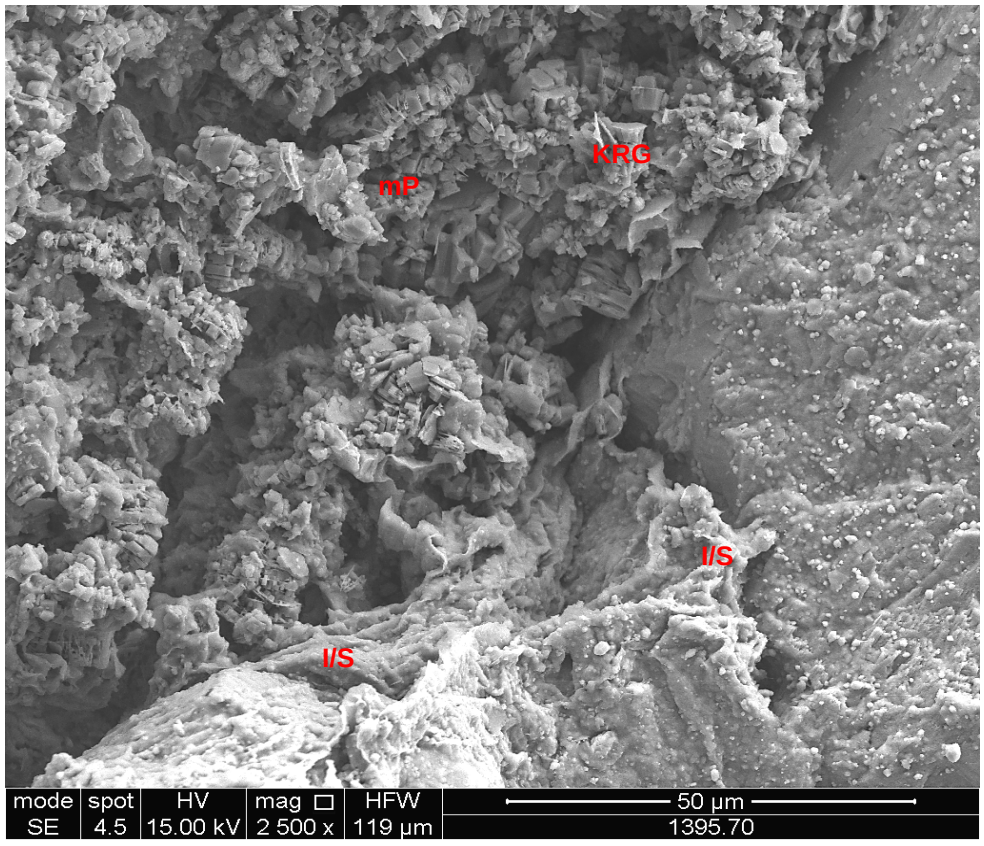
C

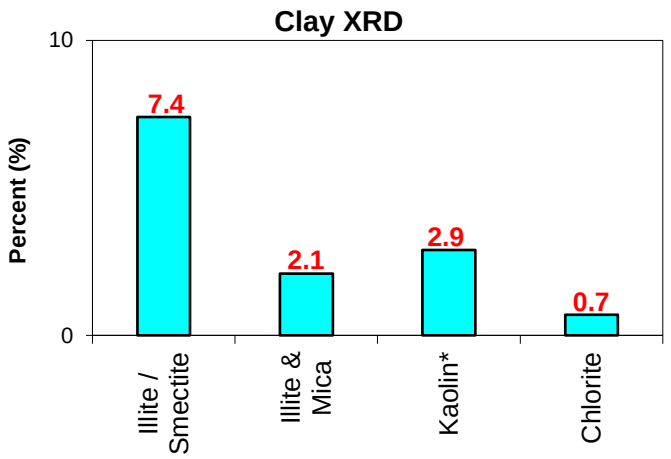


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM images show that this sandstone contains abundant quartz (Q) with some distinctive kaolinite-replaced grains (KRG). Most grains are coated with mixed-layer illite smectite clay (I/S) that occurs as grain-parallel "husks" interpreted to be cutans. Sparse intergranular pores are indicated by the red arrows. Image D features the micropores (mP) within the kaolinite-replaced grain, and well-aligned illite/smectite clay grain coatings.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.50
Permeability (md)*:	333.0
Grain Density (g/cc):	2.64

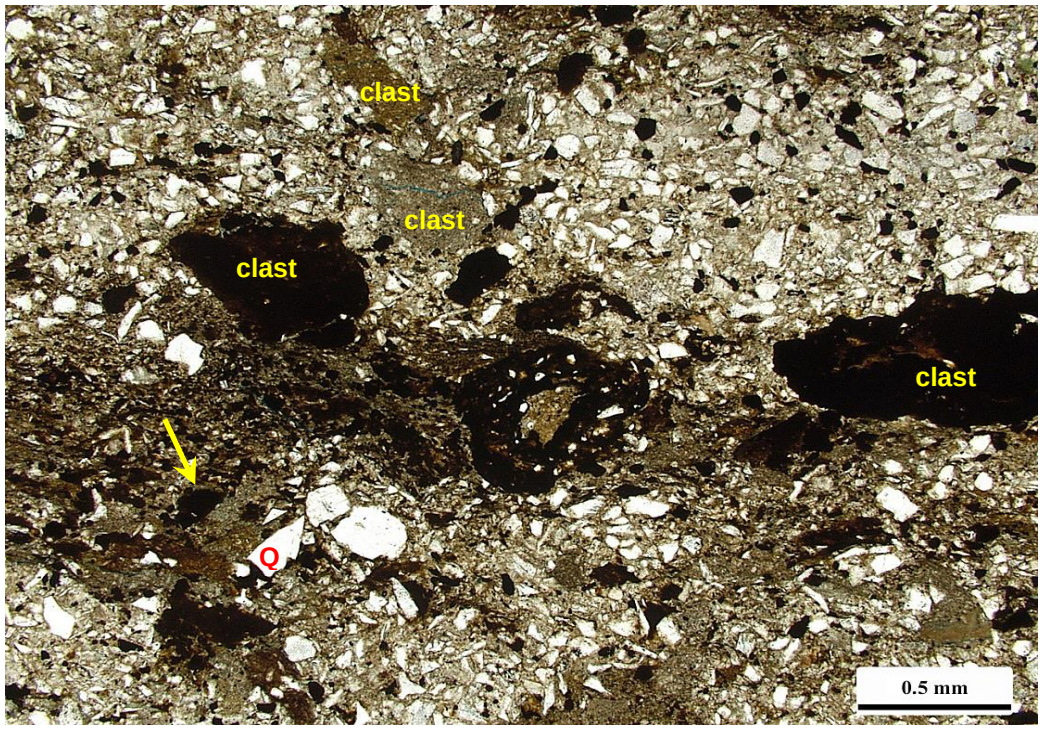
**Core analysis data taken at 1250 psi*

PLATE 18

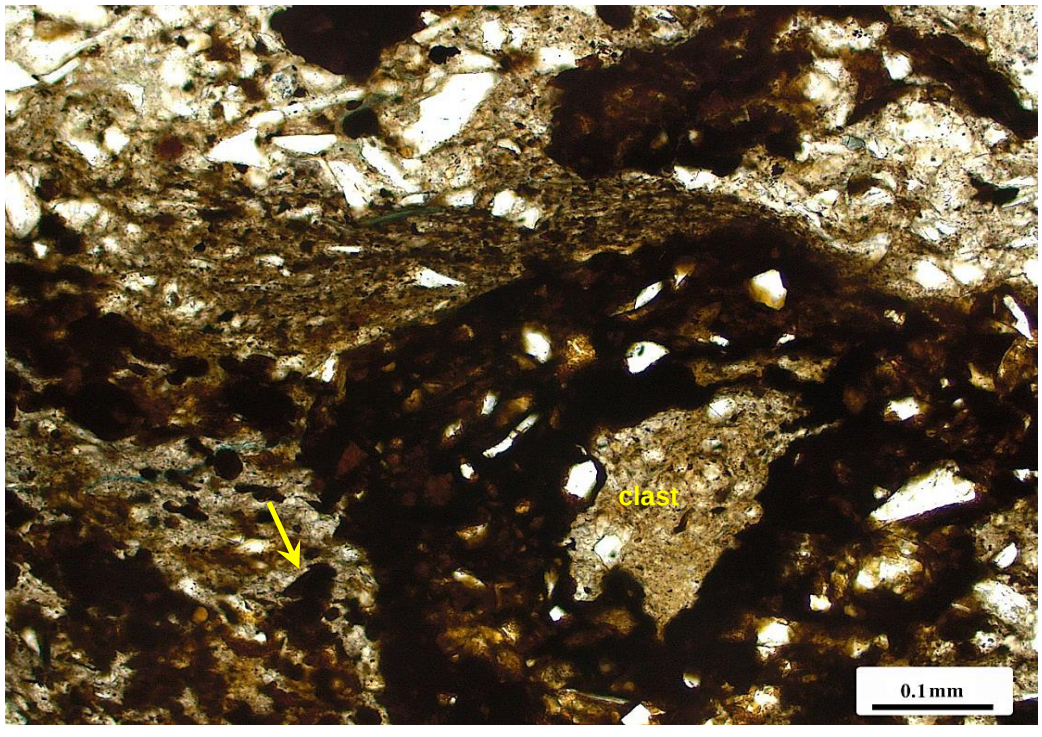
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1406.33
Sample ID: PSH 28

A



B



Sample Description

Lithology: sandy claystone

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.248 (U. fine sand)
Grn.Sorting: moderate

Structures:
laminated to chaotic; rooted structures; argillaceous and hematitic clasts; geopetal sediment infill in linear to anastomosing zones (vertisol)

Framework Grains:
scattered quartz grains (abundant), moderate K-feldspar

Accessory Grains:
minor muscovite, biotite, chlorite; trace epidote, opaque minerals and zircon

Matrix:
abundant clay matrix

Cements:
irregular goethite stain of individual clasts and matrix clay

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	22.7	Goethite	6.3
K-Feldspar	9.8	Hematite	0.0
Plagioclase	1.1	Pyrite	0.0
Calcite	0.0	Total Clay	60.2

Clay Abundance (Weight %)

Illite / Smectite	18.3	Kaolin*	31.2
Illite & Mica	6.4	Chlorite	4.3

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

Photo A shows the crude sandy zones with chaotic disruption and crosscutting dark linear to anastomosing zones (yellow arrows). The linear structures may be vertisol fractures infilled with clay sediment, or rooted zones. White flecks throughout the sample are mostly quartz grains (Q). Dark intraclasts or rip-up clasts are indicated with the yellow arrows. The fractures in the sample are a result of the swelling clay components of the matrix.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

**Core analysis data taken at 18 psi*

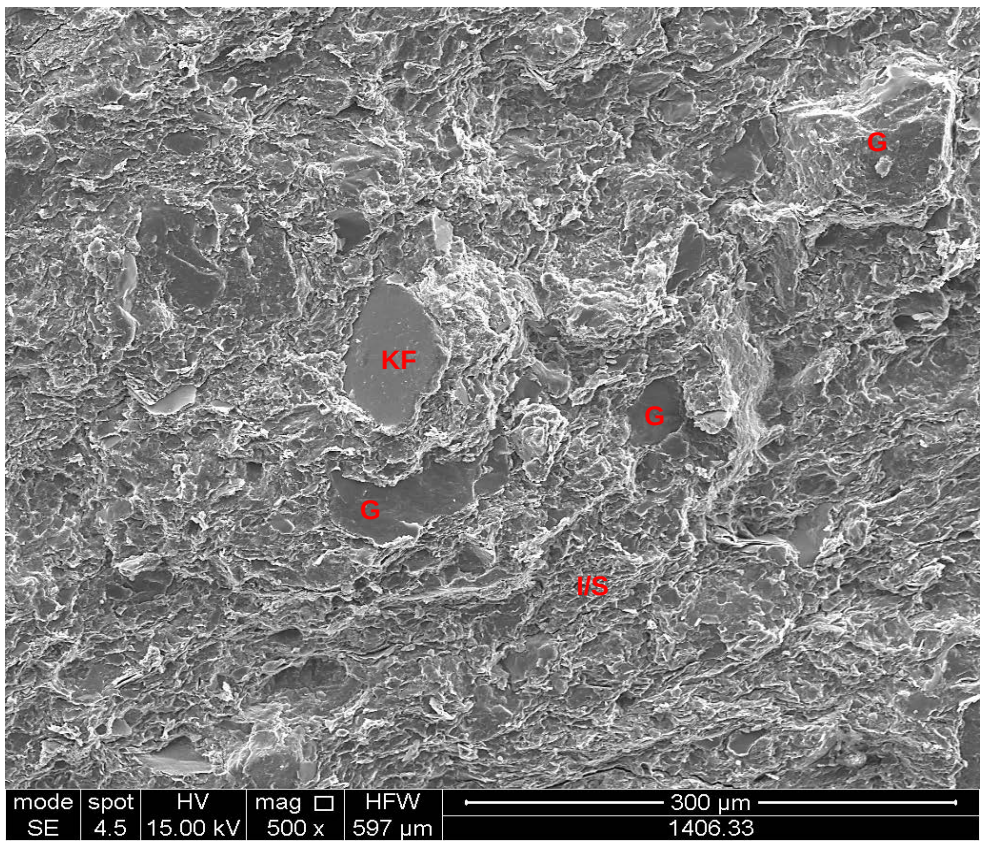
PLATE 18 (cont'd)

Scanning Electron Microscopy

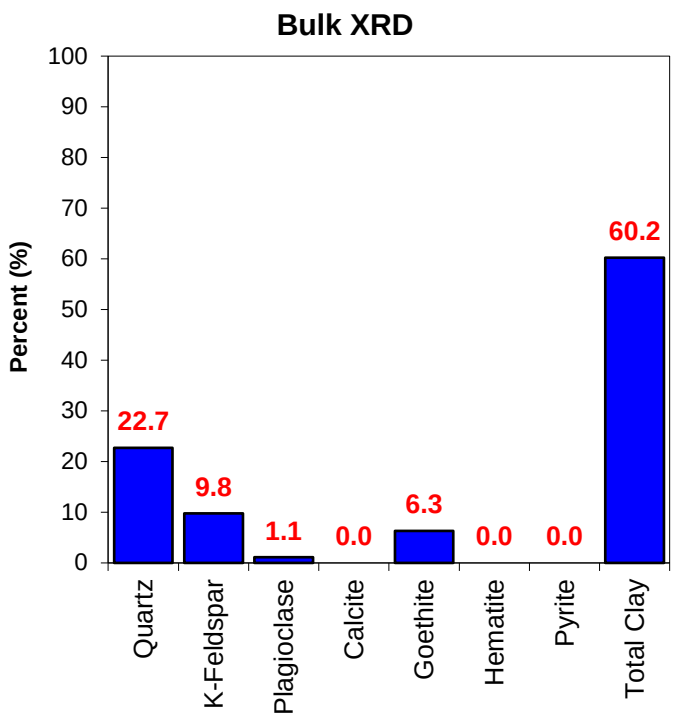
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1406.33
Sample ID: PSH 28

Lithology: sandy claystone

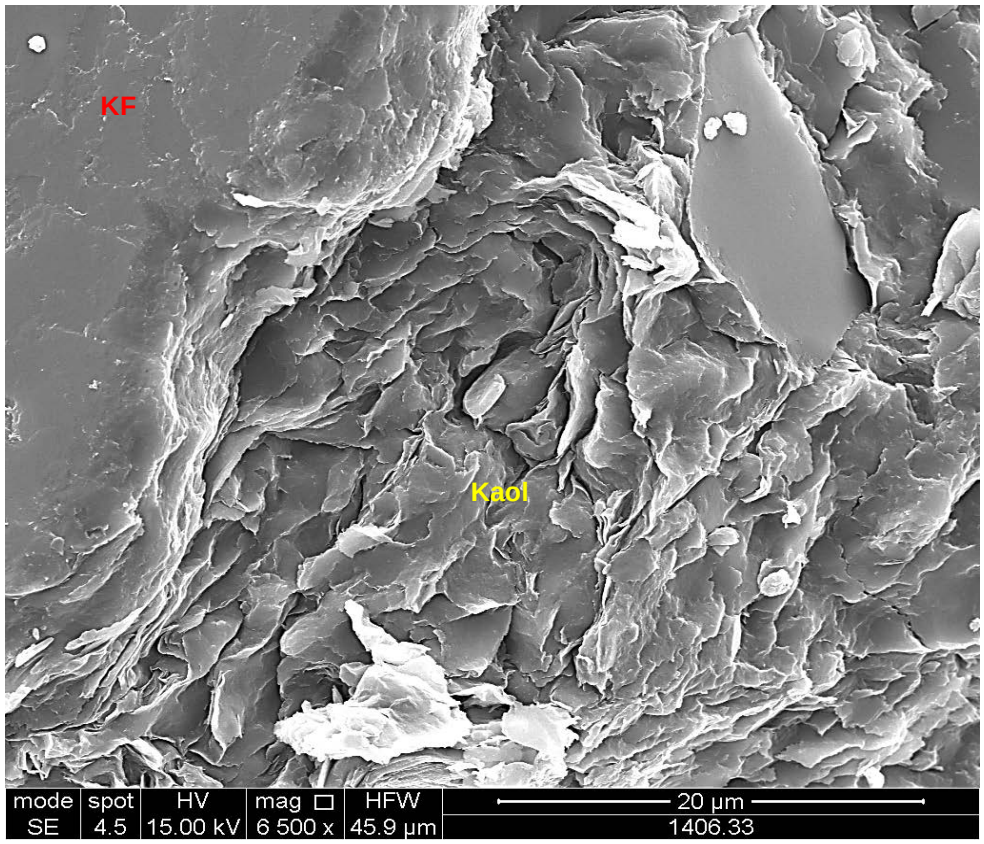
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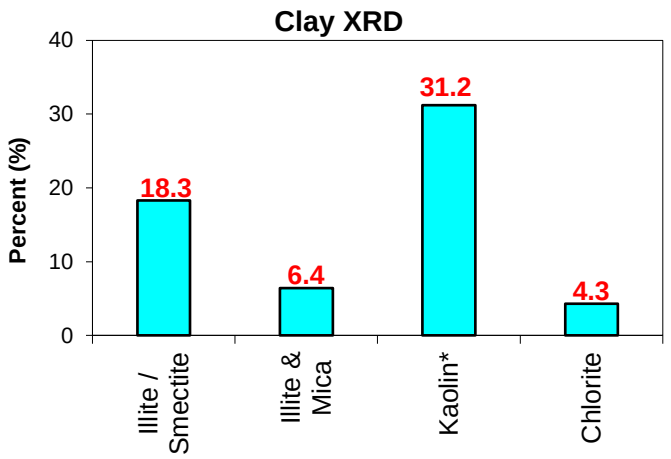


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM Image C shows a massive fabric, with grains (G) supported in an abundant clay matrix. XRD analysis indicates that this sample is composed principally of kaolin (EDS Al=Si) as well as mixed-layer illite/smectite clay. Quartz and K-feldspar (KF) are present as sand-size grains.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

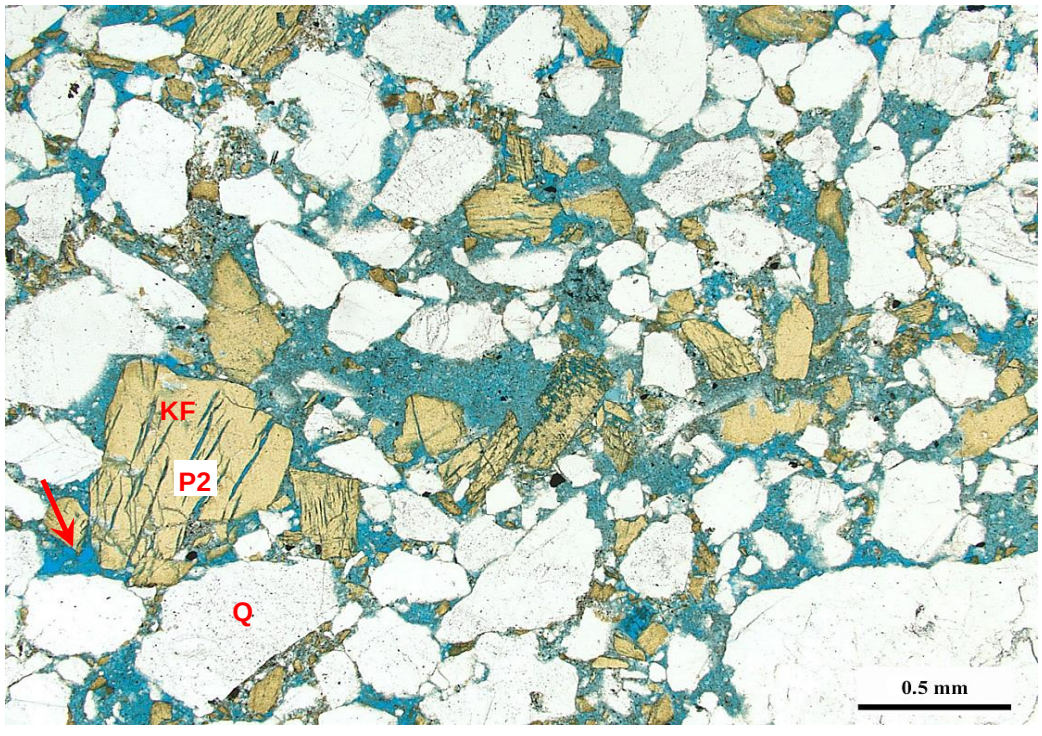
**Core analysis data taken at 18 psi*

PLATE 19

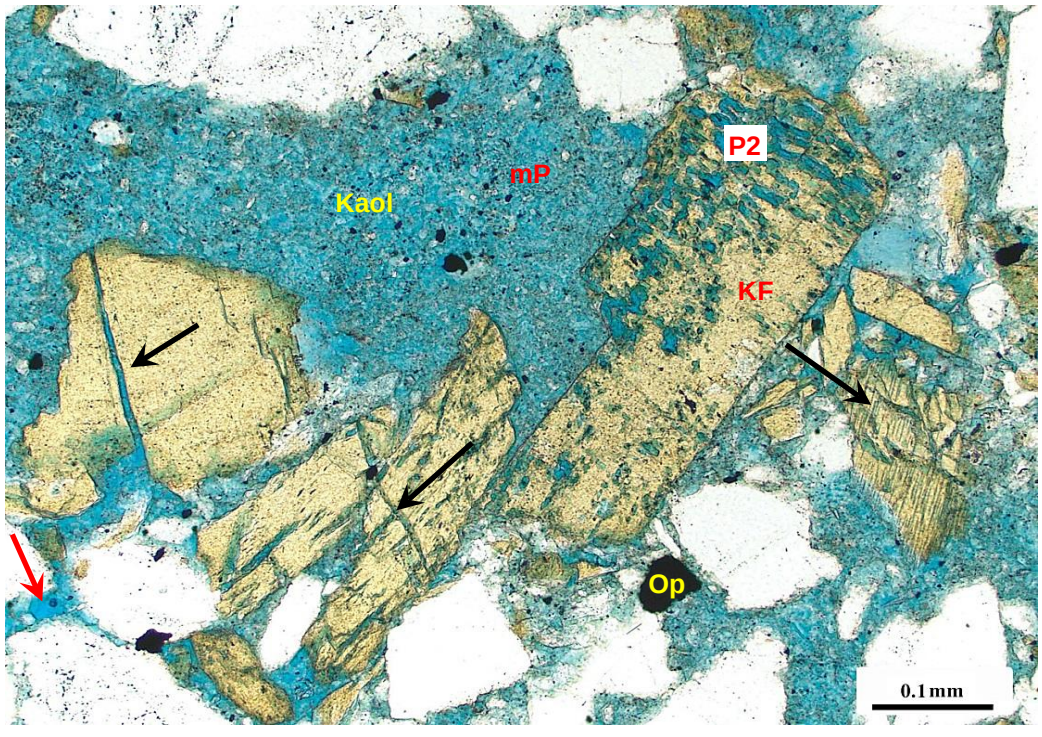
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1414.00
Sample ID: 4

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.567 (Coarse sand)
Grn.Sorting: poor

Structures:
massive; moderate compaction (long grains contacts); scattered very coarse sand grains

Framework Grains:
abundant quartz; common K-feldspar and plutonic lithic fragments

Accessory Grains:
trace opaque minerals, heavy minerals

Matrix:
none observed

Cements:
common intergranular and intragranular kaolinite; trace pyrite

Pore Types:
minor intergranular pores; trace intragranular pores (in feldspars); moderate intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	66.9	Goethite	0.0
K-Feldspar	14.8	Hematite	0.0
Plagioclase	0.6	Pyrite	0.0
Calcite	0.0	Total Clay	17.6

Clay Abundance (Weight %)

Illite / Smectite	2.3	Kaolin*	12.7
Illite & Mica	1.6	Chlorite	1.0

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a coarse-grained sandstone with abundant quartz (Q) and common K-feldspar (KF; stained yellow). Opaque minerals occur in trace amounts (Op). Authigenic minerals include intergranular kaolinite (Kaol), some in oversized patches. Pore types include intergranular pores (blue epoxy and red arrows) and intercrystal micropores associated with kaolinite cement (blue haze coloration within kaolinite). Many of the K-feldspar grains exhibit intragranular dissolution pores (P2) or intragranular fractures (black arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	21.40
Permeability (md)*:	21.2
Grain Density (g/cc):	2.64

**Core analysis data taken at 1250 psi*

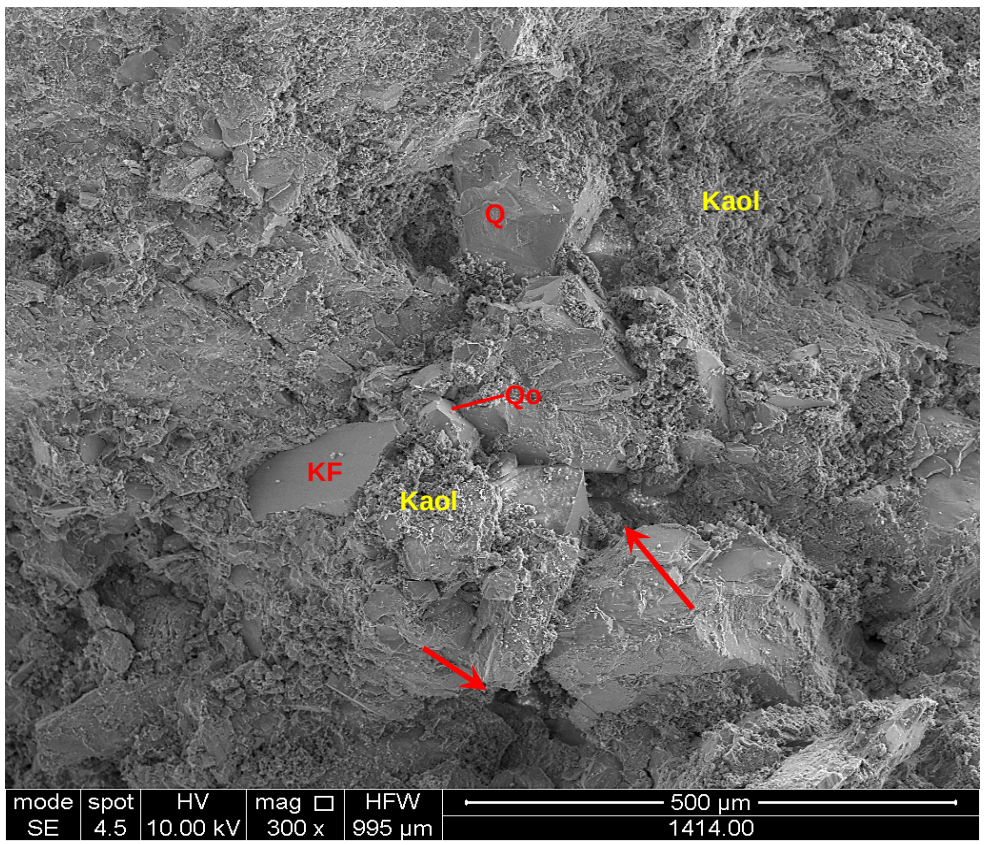
PLATE 19 (cont'd)

Scanning Electron Microscopy

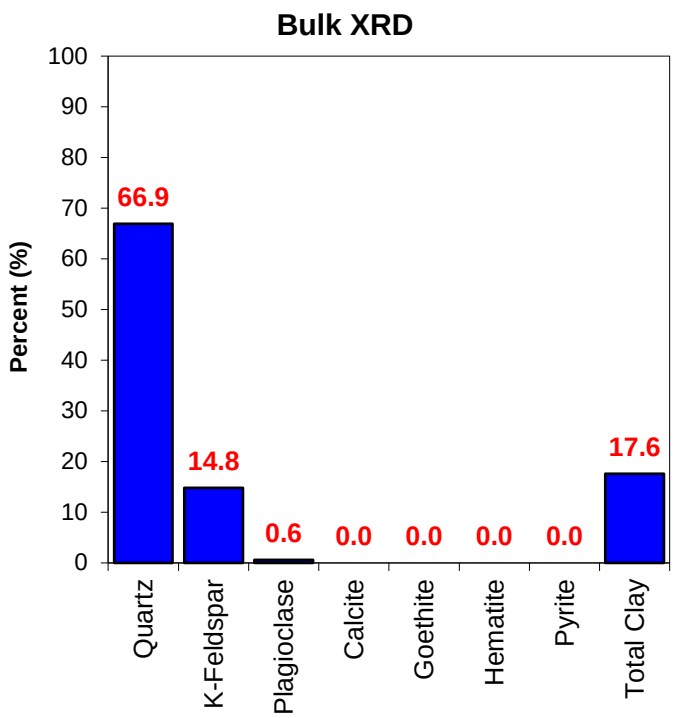
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1414.00
Sample ID: 4

Lithology: sandstone

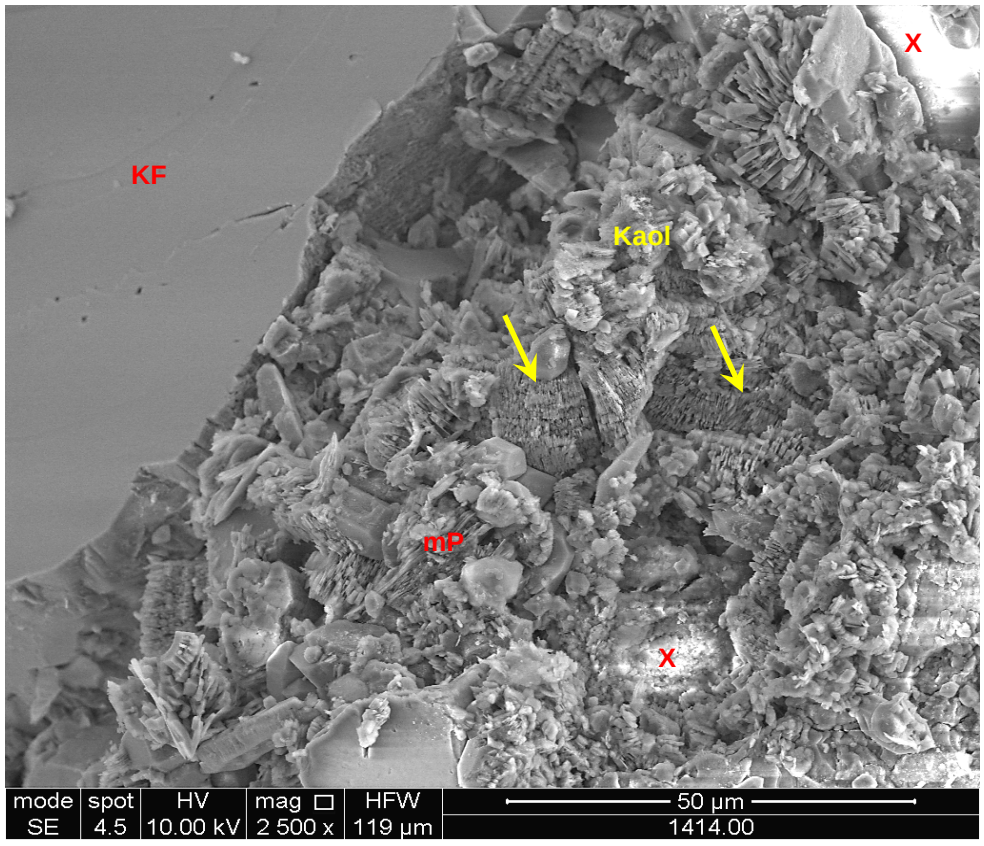
C

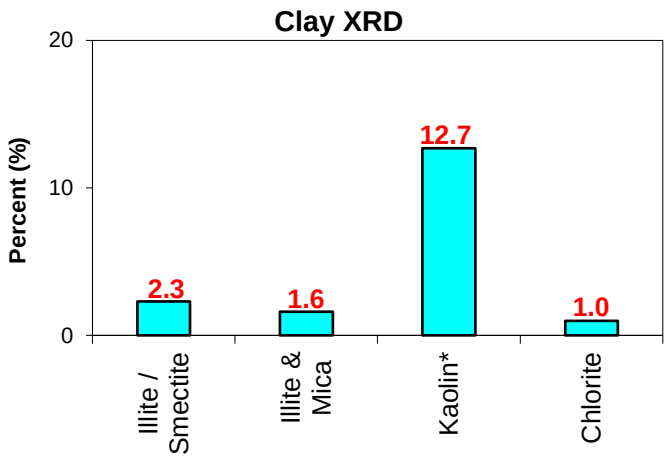


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows common kaolinite (Kaol) and intermixed dickite filling most intergranular areas in this sandstone. Minor quartz overgrowths cement is also noted (Qo), typically lining intergranular pores (red arrows). Grains identified include quartz (Q) and K-feldspar (KF). Image D shows that the kaolin cement contains some vermiform stacks (yellow arrows) and is highly microporous. Areas that are charging under the beam are marked with an "X".

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	21.40
Permeability (md)*:	21.2
Grain Density (g/cc):	2.64

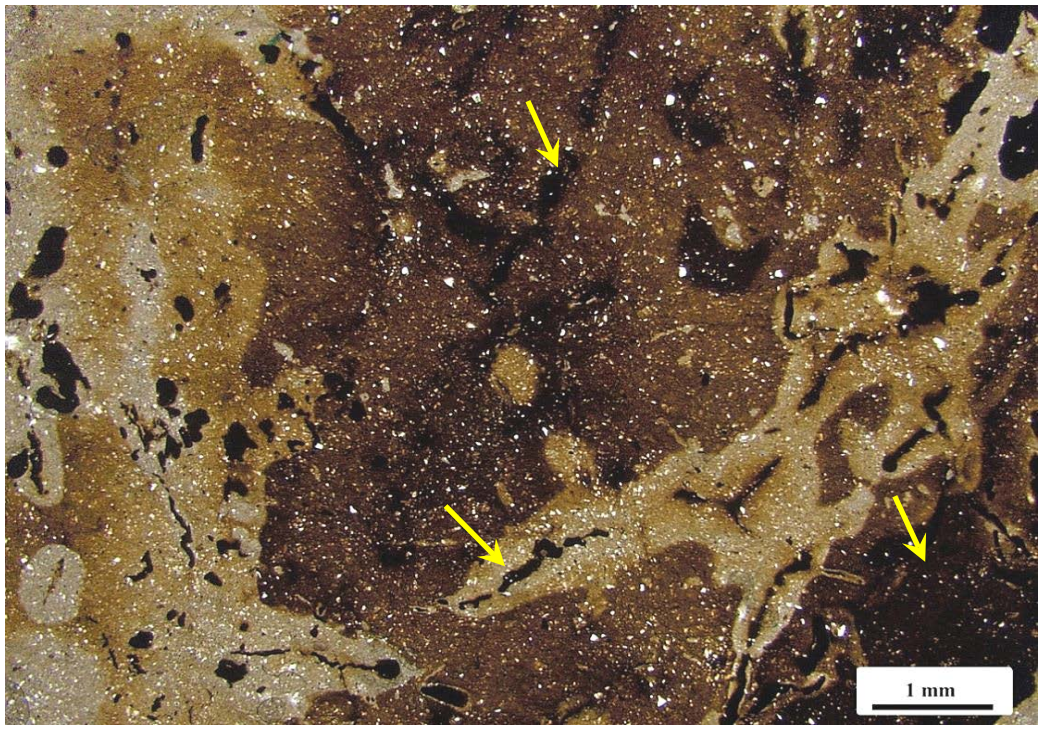
**Core analysis data taken at 1250 psi*

PLATE 20

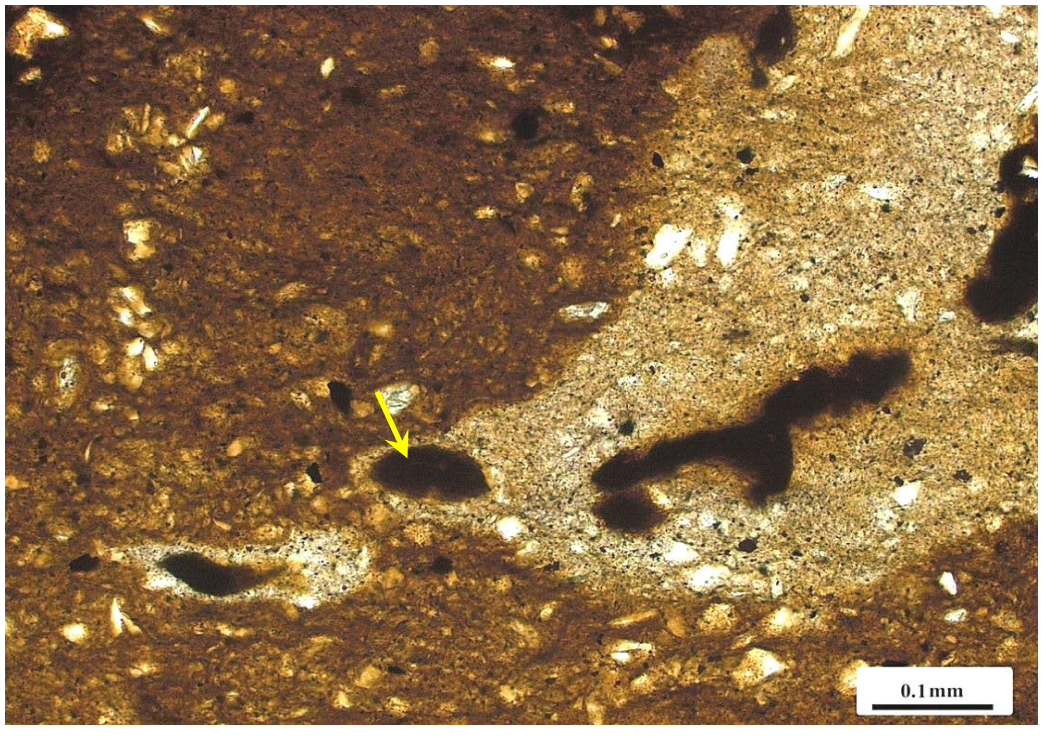
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1416.65
Sample ID: PSH 30

A



B



Sample Description

Lithology: **slightly silty claystone**

Est.Classif. (Folk, 1980): na
Grain Size (mm): 0.000 (medium silt)
Grn.Sorting: well

Structures:
mottled pattern in clay matrix; overprinted by goethite-stained probable rooted zones; sparse root traces; one siltstone-filled vertisol fracture

Framework Grains:
scattered quartz grains, trace K-feldspar

Accessory Grains:
trace mica, chlorite, opaque minerals, heavy minerals

Matrix:
abundant clay matrix

Cements:
irregular goethite stain of individual argillaceous clasts and along branching zones (goethite interpreted to have formed during weathering)

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	13.8	Goethite	9.6
K-Feldspar	2.6	Hematite	0.0
Plagioclase	0.6	Pyrite	0.0
Calcite	0.0	Total Clay	73.3

Clay Abundance (Weight %)

Illite / Smectite	12.9	Kaolin*	49.4
Illite & Mica	5.1	Chlorite	5.9

%smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This slightly silty claystone is composed principally of kaolin and lesser mixed-layer illite/smectite. The sample contains the highest goethite content among the sample set. The abundant clay matrix contains sparse flecks of quartz and minor feldspar. Anastomosing, branching to blob-shaped goethite staining (yellow arrows) resembles possible root traces. No macropores are visible.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

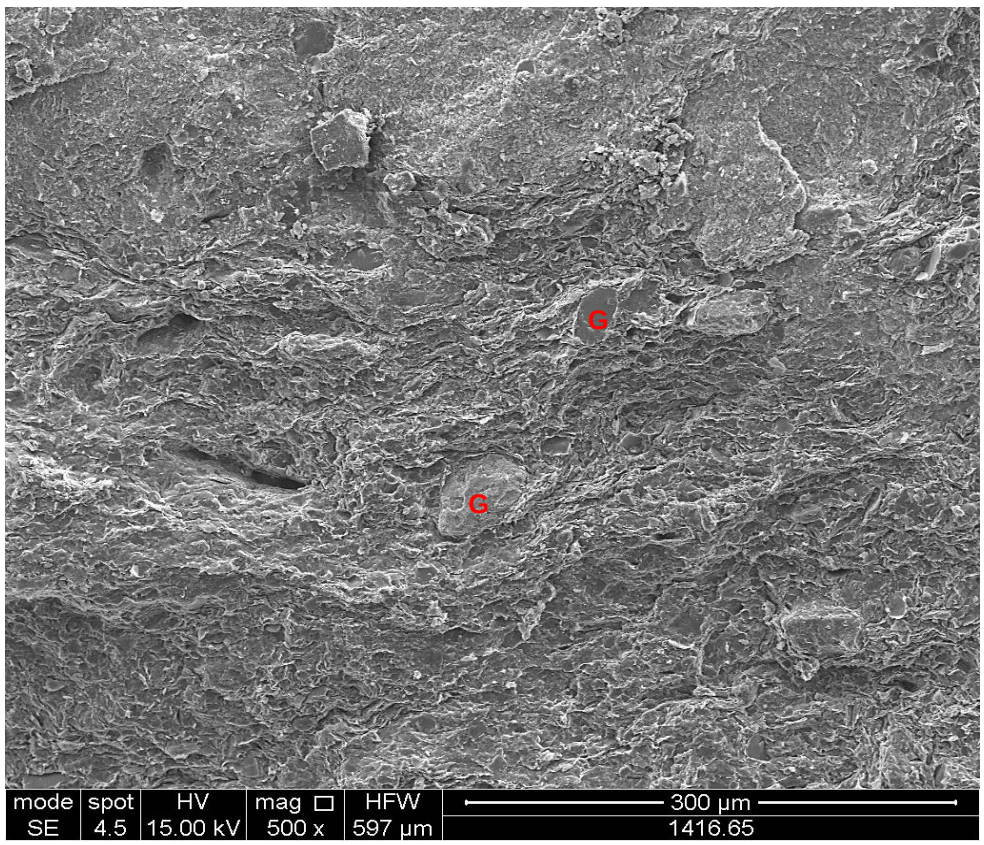
PLATE 20 (cont'd)

Scanning Electron Microscopy

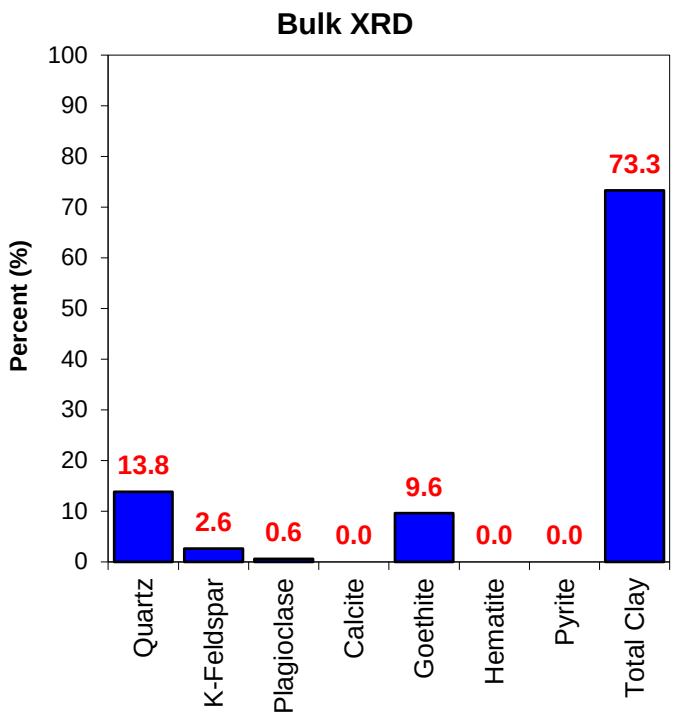
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1416.65
Sample ID: PSH 30

Lithology: slightly silty claystone

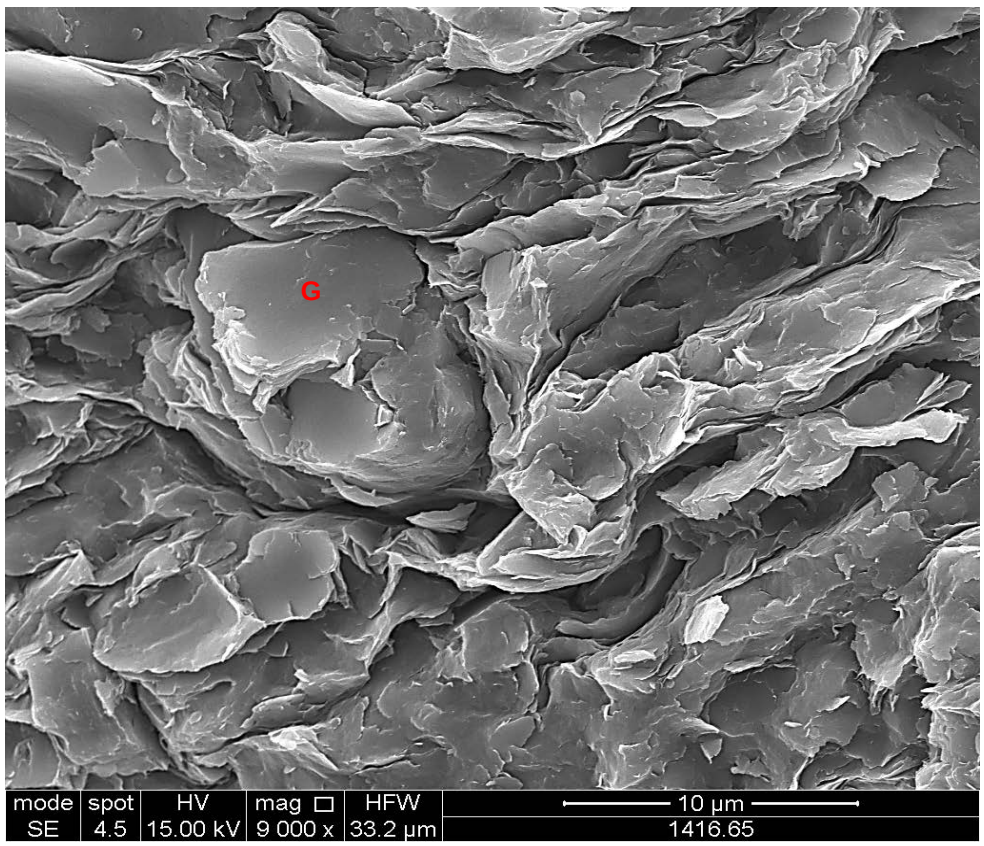
C

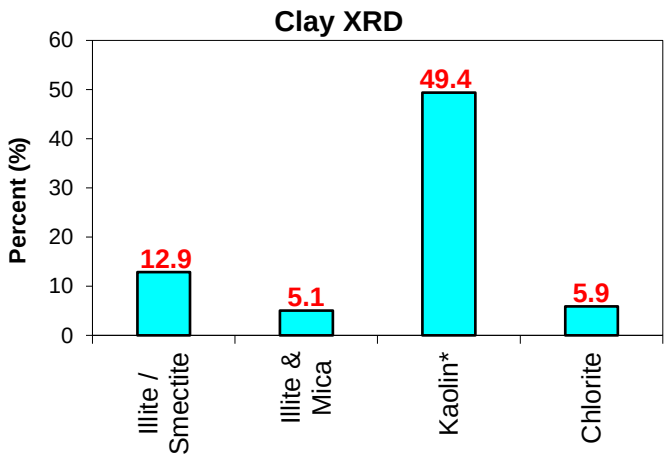


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM Image C shows a massive fabric, with scarce grains (G) supported in an abundant faintly laminated clay matrix. XRD analysis indicates that this sample is composed principally of kaolin with lesser mixed-layer illite/smectite (I/S) clay. EDS analysis of the clays in Image D indicates they are composed kaolin (Si=Al).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

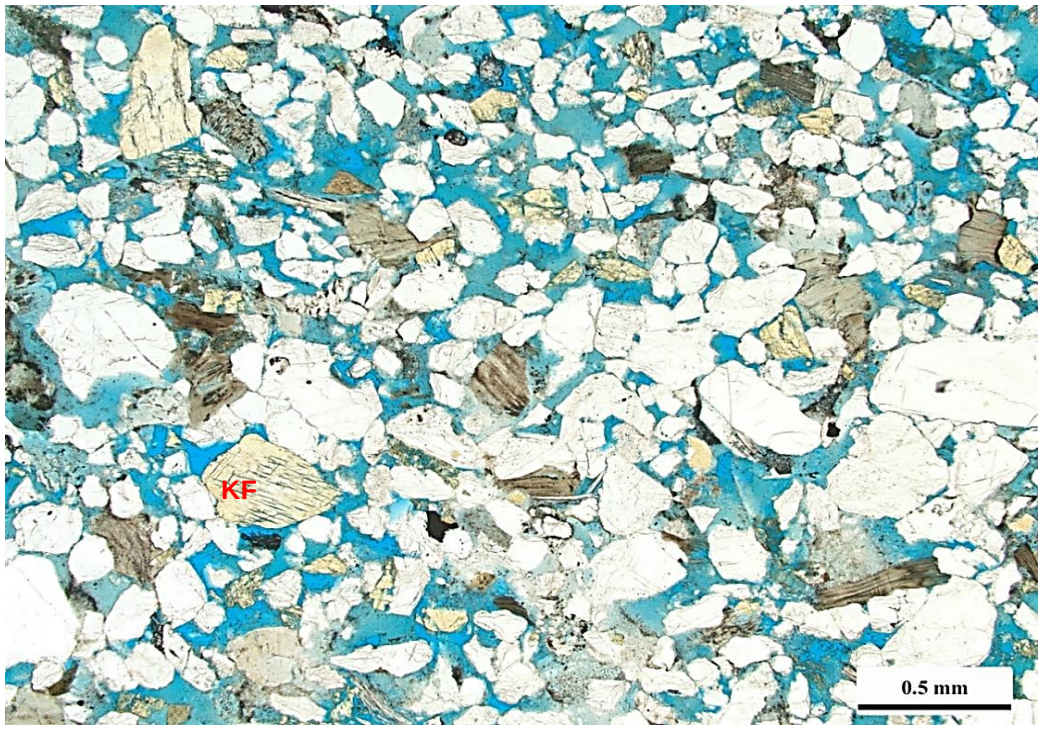
**Core analysis data taken at na psi*

PLATE 21

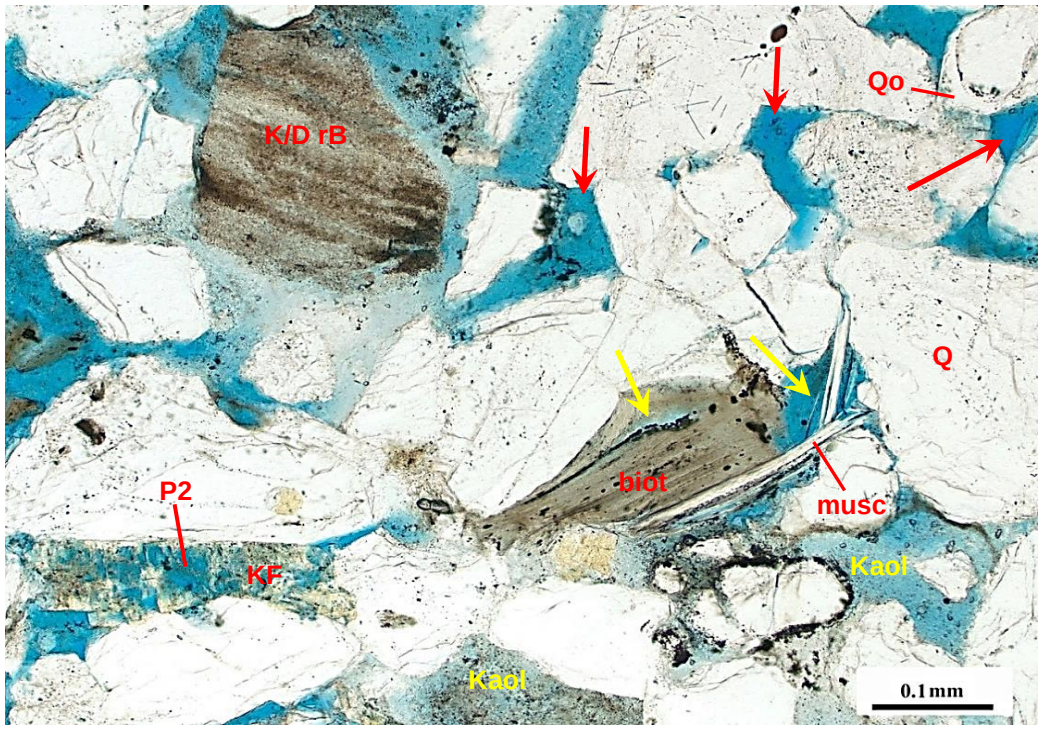
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1420.00
Sample ID: 11

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): sublitharenite
Grain Size (mm): 0.485 (U. medium sand)
Grn.Sorting: moderate

Structures:
thick laminae defined by variable grains sorting and abundance of mica flakes; scattered very coarse sand

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
common biotite (mostly altered to kaolinite/dickite); minor muscovite; trace garnet, opaque minerals, zircon

Matrix:
none observed

Cements:
intergranular and intragranular kaolinite; alteration of biotite to dickite; trace hematite/limonite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	55.4	Goethite	0.0
K-Feldspar	6.0	Hematite	0.0
Plagioclase	0.3	Pyrite	0.0
Calcite	0.0	Total Clay	38.4

Clay Abundance (Weight %)

Illite / Smectite	2.7	Kaolin*	28.1
Illite & Mica	2.8	Chlorite	4.8

%smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a sandstone with faint laminae defined by grain size variation (Photo A). Framework grains identified include quartz (Q), K-feldspar (KF), biotite (biot), muscovite (musc) and replaced biotite flakes (K/D rB). The most important feature of Photo A is the presence of unaltered biotite and muscovite as well as heavily altered biotite flakes. Intermixed kaolinite and dickite are the replacement minerals. Kaolinite also occurs as an intergranular cement (Kaol). Quartz overgrowths (Qo) occur on most quartz grains. Pore types observed include intergranular (red arrows), intragranular pores in K-feldspar (P2), exfoliation pores in deformed mica (yellow arrows), and intercrystal micropores in kaolinite.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	23.20
Permeability (md)*:	35.1
Grain Density (g/cc):	2.64

**Core analysis data taken at 1700 psi*

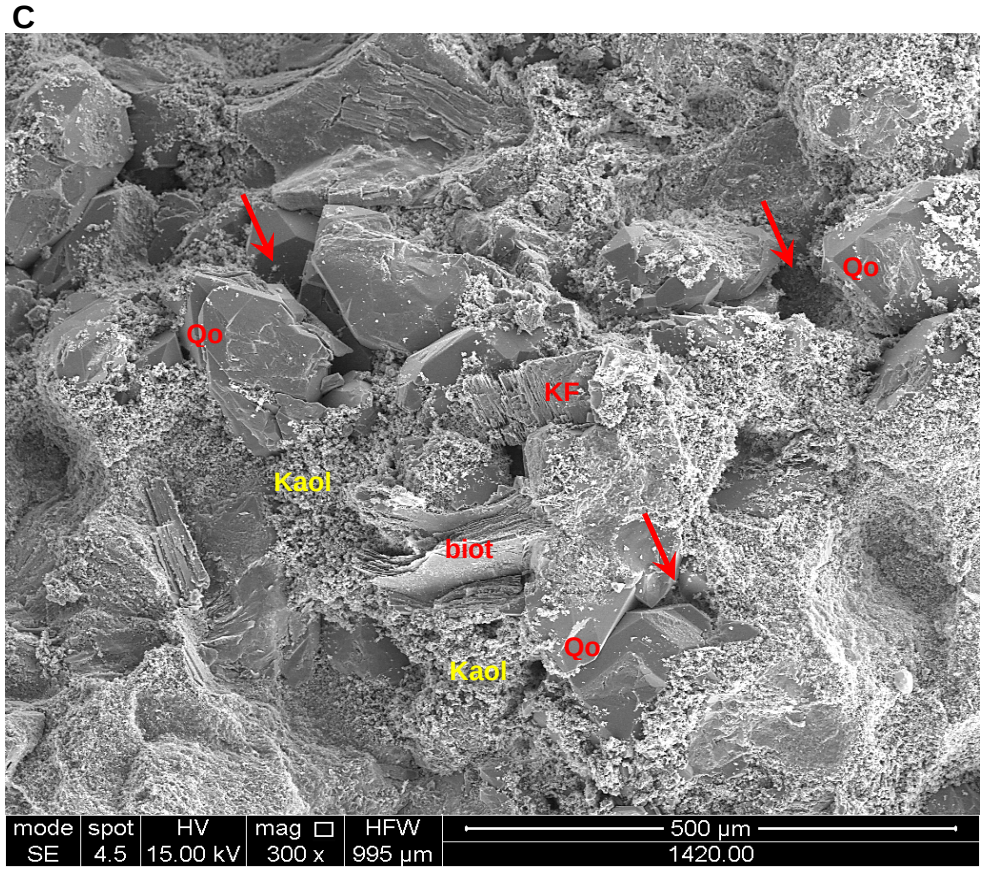
PLATE 21 (cont'd)

Scanning Electron Microscopy

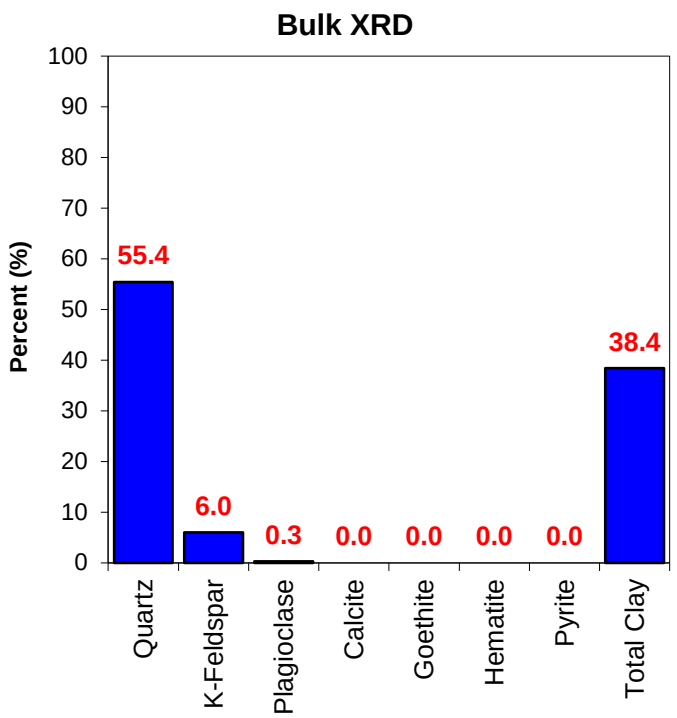
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1420.00
Sample ID: 11

Lithology: sandstone

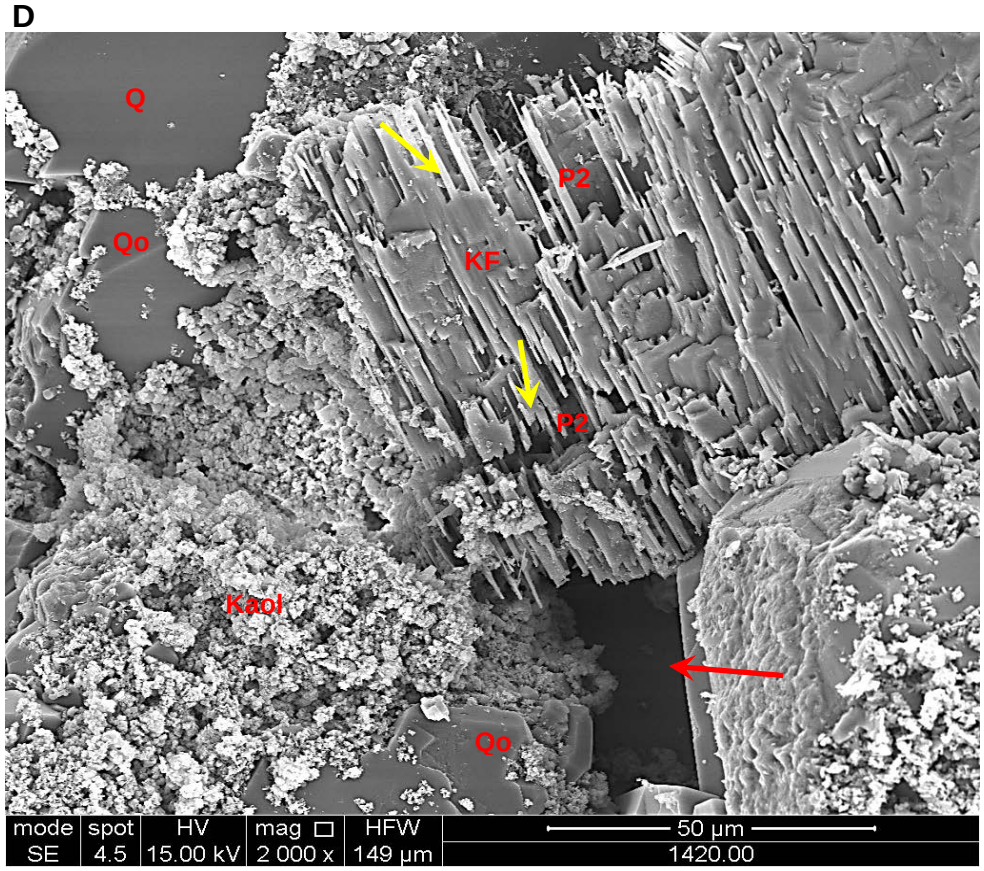
C

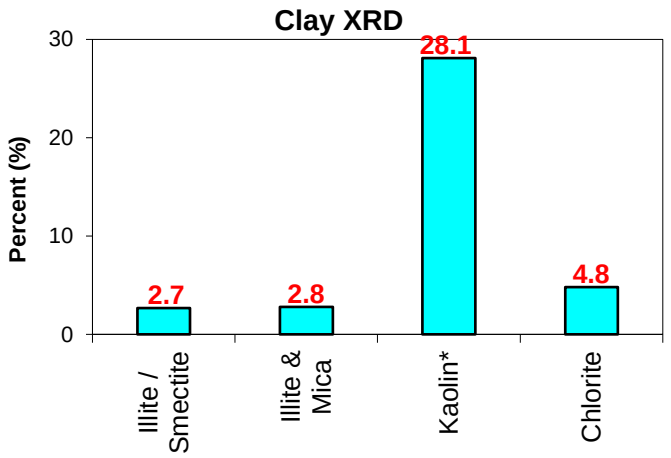


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows grains of quartz (Q) and K-feldspar (KF) and a rare mica flake (biot) surrounded by abundant kaolin matrix (Kaol). The intergranular pores (red arrows) are best recognized by the presence of euhedral quartz overgrowths (Qo) that reduce pore size. The K-feldspar grain featured in Image D is etched with delicate dissolution remnants (yellow arrows) and minor intragranular pores (P2). The abundant kaolinite is highly microporous. Kaolinite and quartz overgrowths are intergrown in some areas such as the upper left corner of Image D.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	23.20
Permeability (md)*:	35.1
Grain Density (g/cc):	2.64

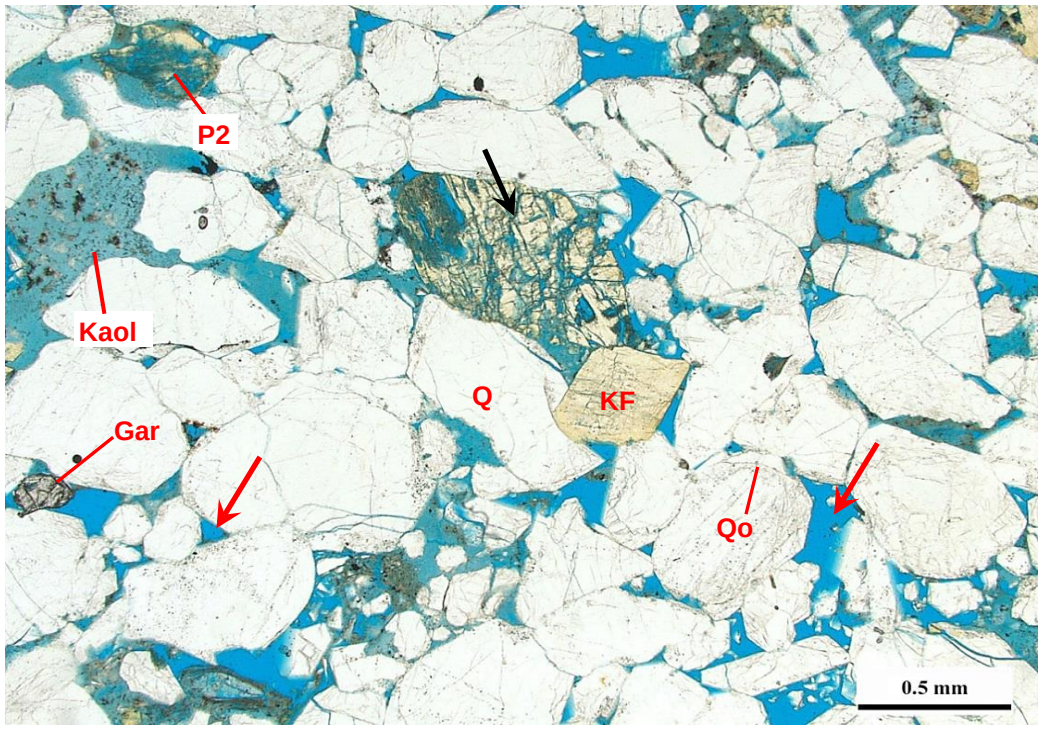
**Core analysis data taken at 1700 psi*

PLATE 22

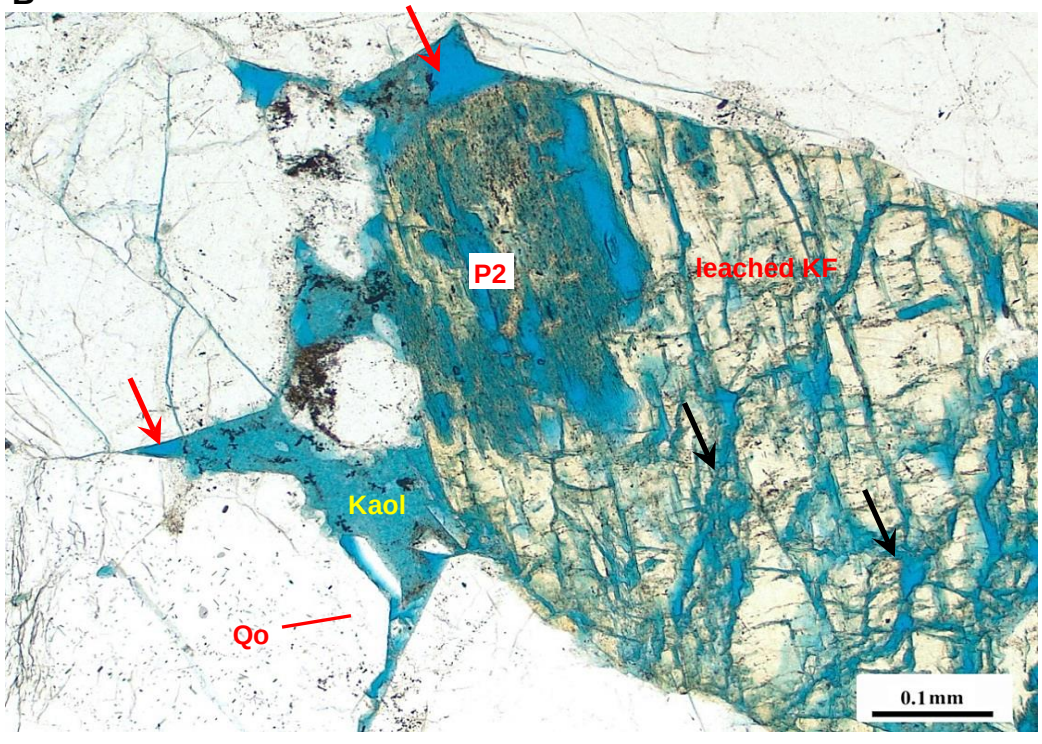
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1444.00
Sample ID: 35

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.735 (Coarse sand)
Grn.Sorting: moderate

Structures:
massive; moderate compaction (long grain contacts); some feldspar grains exhibit intragranular fractures; long grain contacts suggest moderate compaction

Framework Grains:
abundant quartz; common K-feldspar and plutonic lithic fragments

Accessory Grains:
minor muscovite, biotite; trace garnet, zircon

Matrix:
none observed

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths, dickite replacing biotite flakes; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	71.1	Goethite	0.0
K-Feldspar	13.5	Hematite	0.0
Plagioclase	0.4	Pyrite	0.0
Calcite	0.0	Total Clay	14.9

Clay Abundance (Weight %)

Illite / Smectite	1.5	Kaolin*	10.7
Illite & Mica	1.7	Chlorite	1.0

%smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a coarse-grained sandstone with a massive fabric. Framework grains include quartz (Q), plutonic lithic fragments, K-feldspar (KF) and accessory garnet (Gar).. Intergranular kaolinite (Kaol) occurs in grain-sized patches and within intergranular areas. The red arrows indicate intergranular pores reduced in size by authigenic quartz overgrowths (Qo). Some of the feldspar grains exhibit intragranular dissolution pores (P2) or intragranular fractures (black arrow). The "blue haze" coloration of the kaolinite cement indicates that it is microporous.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.00
Permeability (md)*:	582.0
Grain Density (g/cc):	2.63

**Core analysis data taken at 1700 psi*

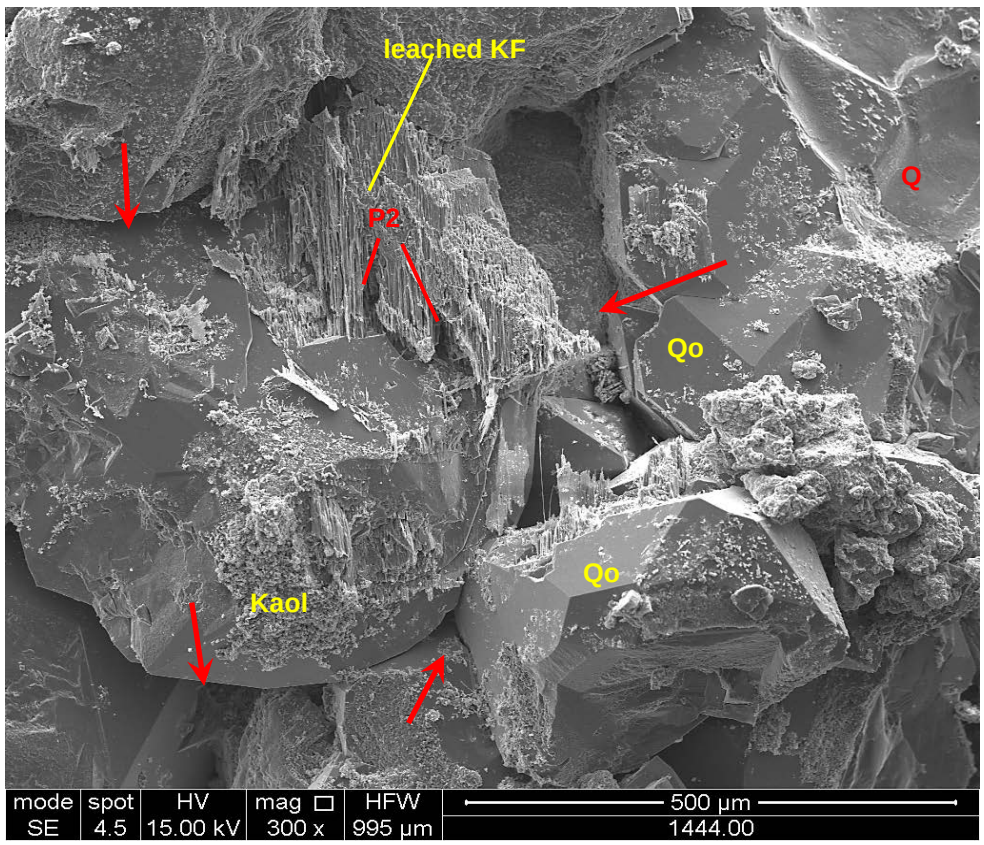
PLATE 22 (cont'd)

Scanning Electron Microscopy

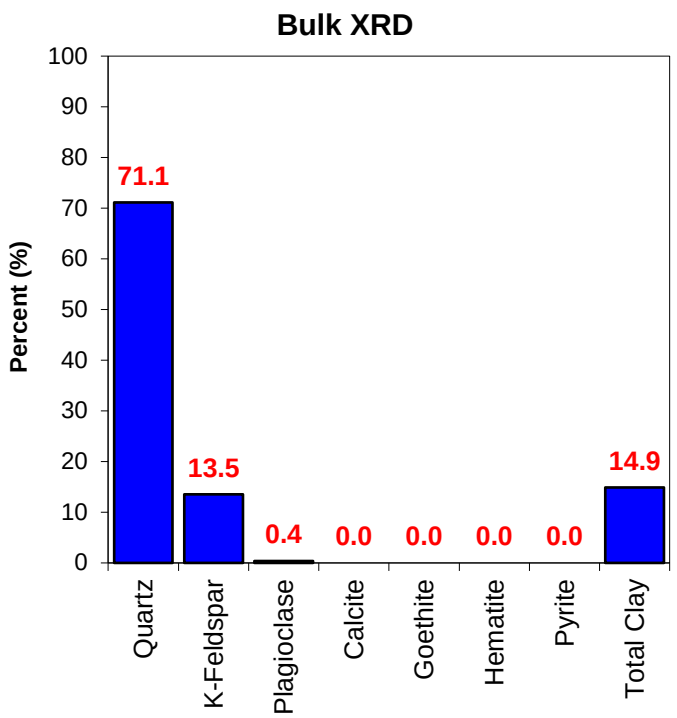
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1444.00
Sample ID: 35

Lithology: sandstone

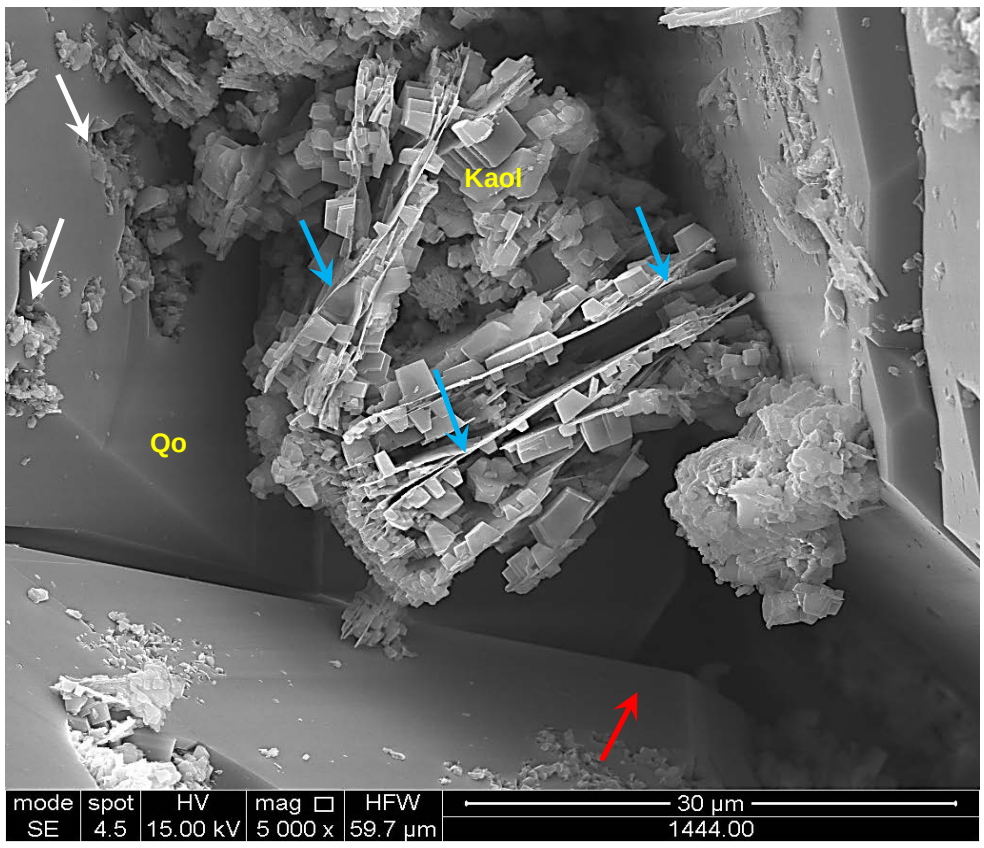
C

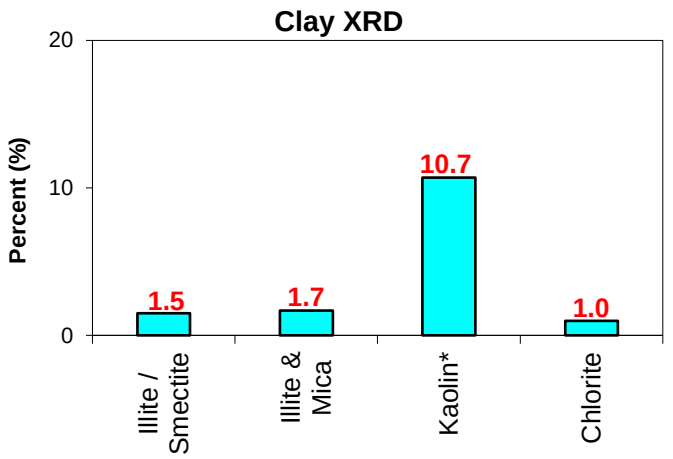


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM images show that intergranular pores (red arrows) are bounded by euhedral quartz overgrowths (Qo), and partly filled by minor amounts of authigenic kaolinite (Kaol). Blocky kaolinite occupies the intercrystal areas in a heavily exfoliated altered biotite (blue arrows). Kaolinite crystals are engulfed by quartz overgrowths (white arrows), indicating they formed concurrently.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.00
Permeability (md)*:	582.0
Grain Density (g/cc):	2.63

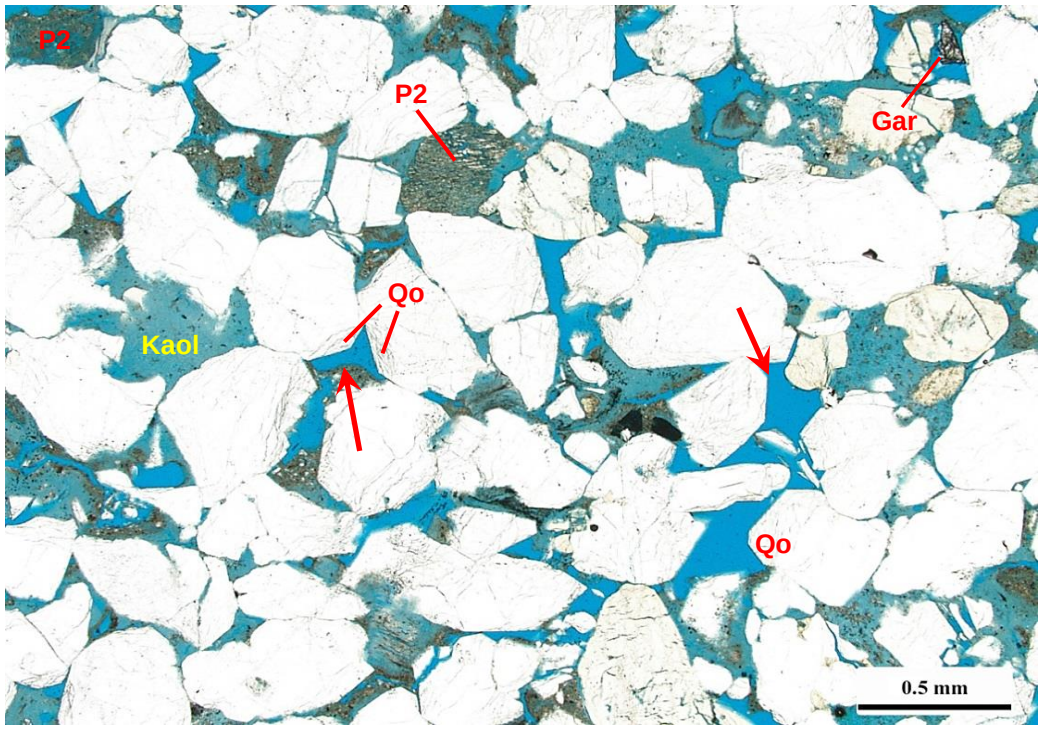
**Core analysis data taken at 1700 psi*

PLATE 23

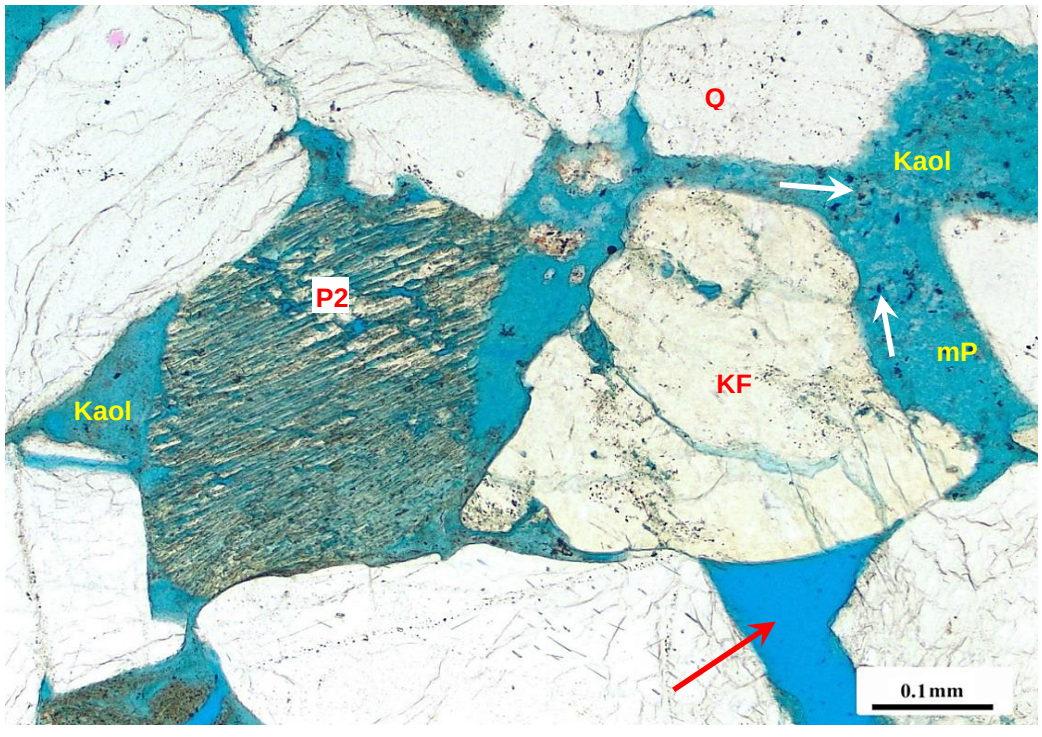
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1462.00
Sample ID: 53

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 0.861 (Coarse sand)
Grn.Sorting: moderately well

Structures:
massive; moderate compaction (long grain contacts); some feldspar grains exhibit intragranular fractures

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
trace micas, garnet, opaque minerals

Matrix:
none observed

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	75.7	Goethite	0.0
K-Feldspar	13.0	Hematite	0.0
Plagioclase	0.5	Pyrite	0.3
Calcite	0.0	Total Clay	10.4

Clay Abundance (Weight %)

Illite / Smectite	1.9	Kaolin*	6.2
Illite & Mica	1.2	Chlorite	1.1

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This coarse-grained sandstone is composed of abundant quartz (Q) and moderate K-feldspar (KF) and plutonic lithic fragments. Moderate compaction is indicated by long and point grain contacts (Photo A). Trace amounts of detrital garnet (Gar) is observed. Authigenic minerals include quartz overgrowths (Qo) and kaolinite (Kaol). Pore types include intergranular pores (blue epoxy; red arrows), intragranular dissolution pores in K-feldspar (P2), and intercrystal micropores (mP) associated with authigenic kaolinite (blue haze coloration). The white arrows indicate faintly visible vermicular stacks of kaolinite.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	19.80
Permeability (md)*:	1030.0
Grain Density (g/cc):	2.63

**Core analysis data taken at 1700 psi*

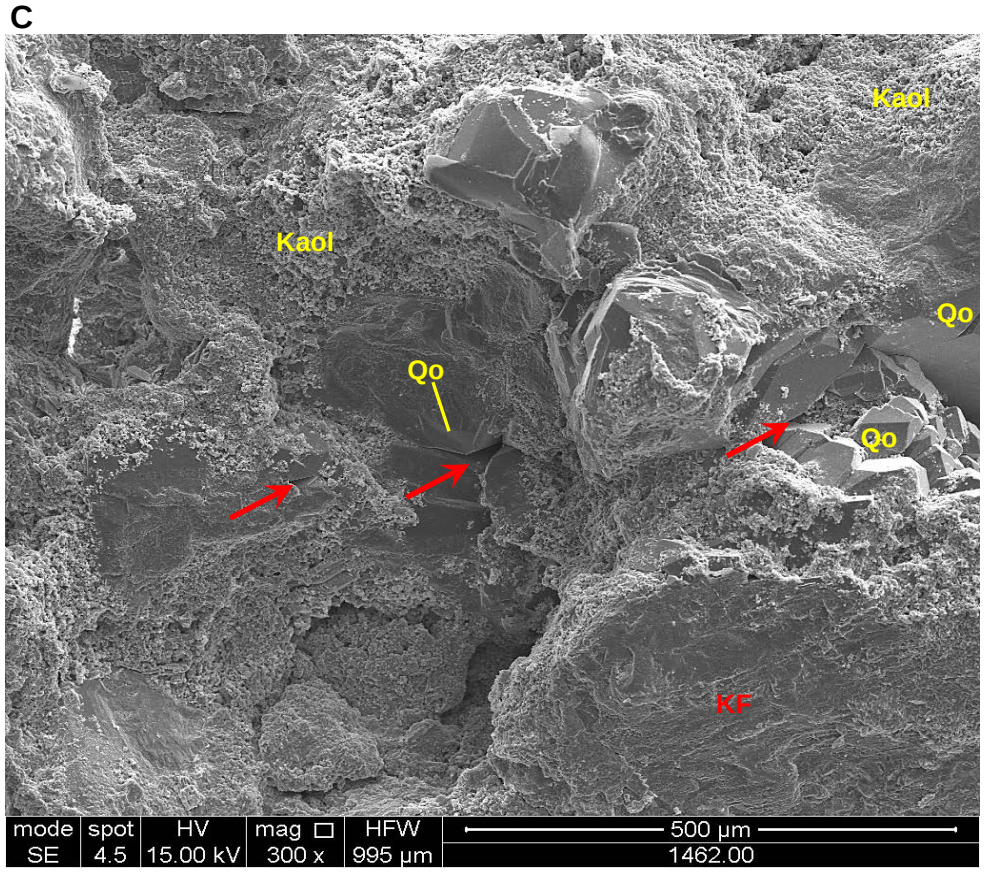
PLATE 23 (cont'd)

Scanning Electron Microscopy

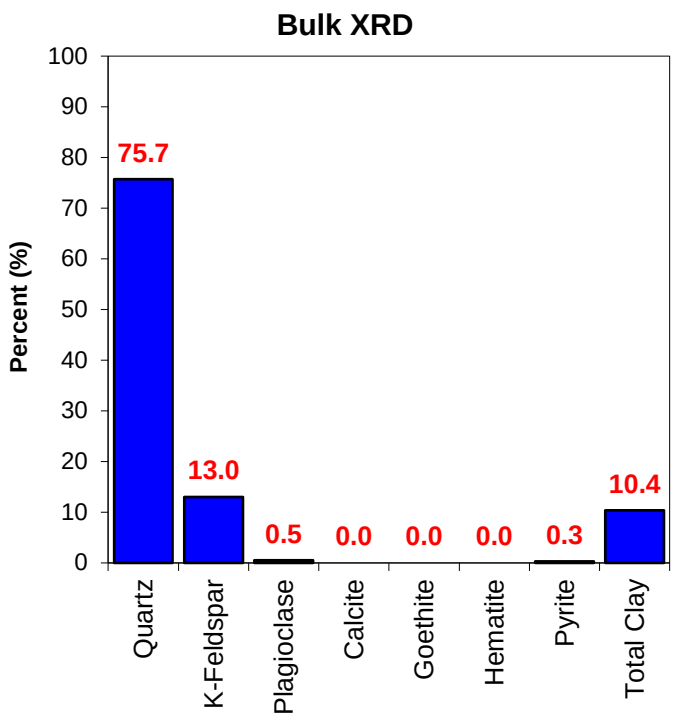
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1462.00
Sample ID: 53

Lithology: sandstone

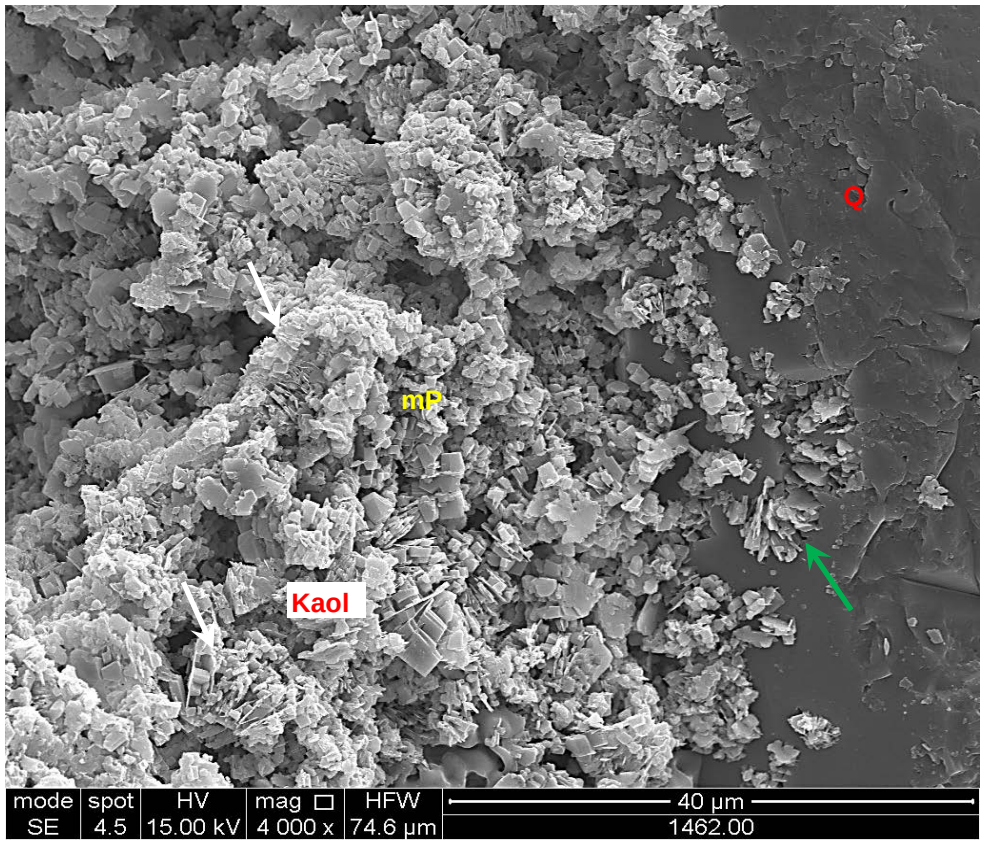
C

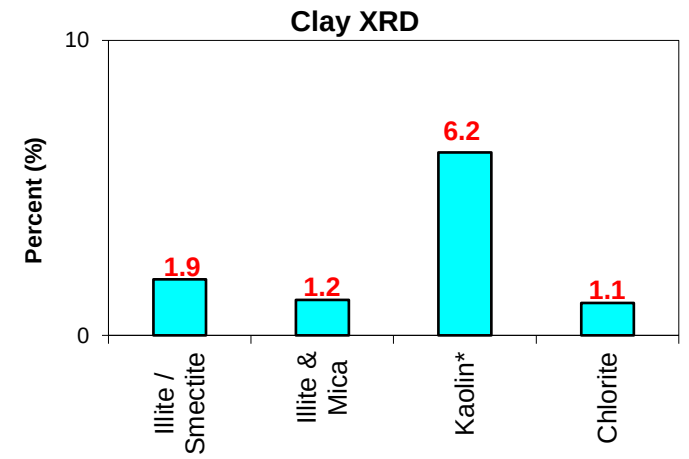


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses show that the intergranular pores (red arrows) are partly to completely occluded by quartz overgrowths (Qo) or kaolinite (Kaol). The highly reduced intergranular pores are typically bounded by euhedral quartz overgrowth crystal faces. Identified grains include quartz (Q) and K-feldspar (KF). Image D features the abundant intercrystal micropores (mP) in the kaolinite cement. This explains why the kaolinite appears bluish in thin section. The white arrows indicate faintly visible vermicular stacks of kaolinite. Kaolinite engulfed by quartz overgrowths (green arrow) indicates the cements grew concurrently.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	19.80
Permeability (md)*:	1030.0
Grain Density (g/cc):	2.63

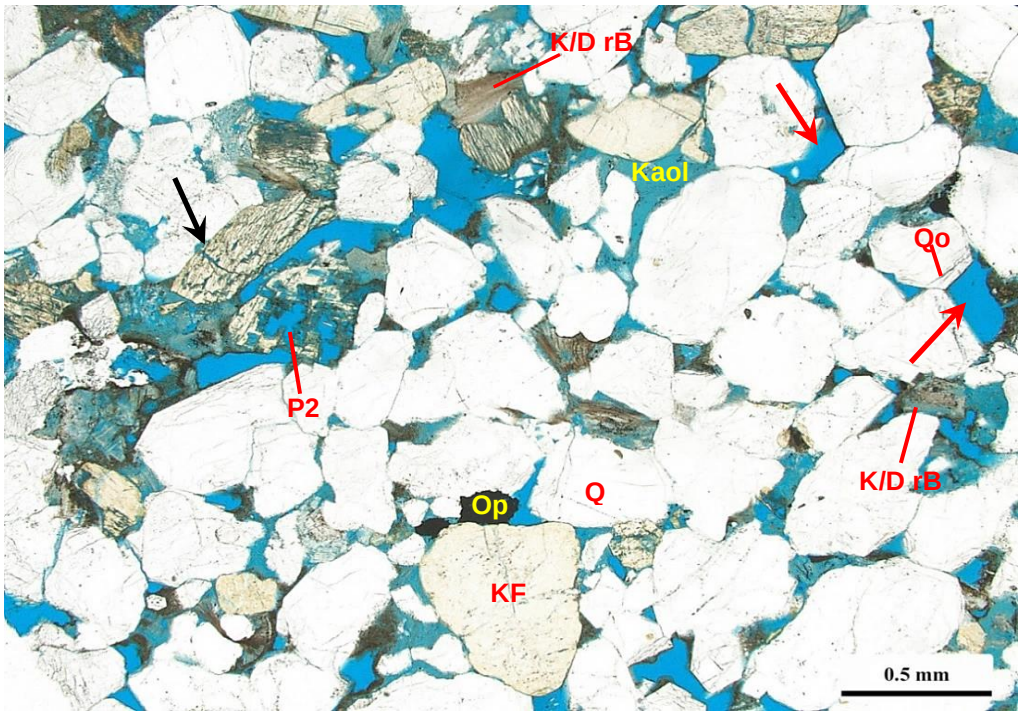
**Core analysis data taken at 1700 psi*

PLATE 24

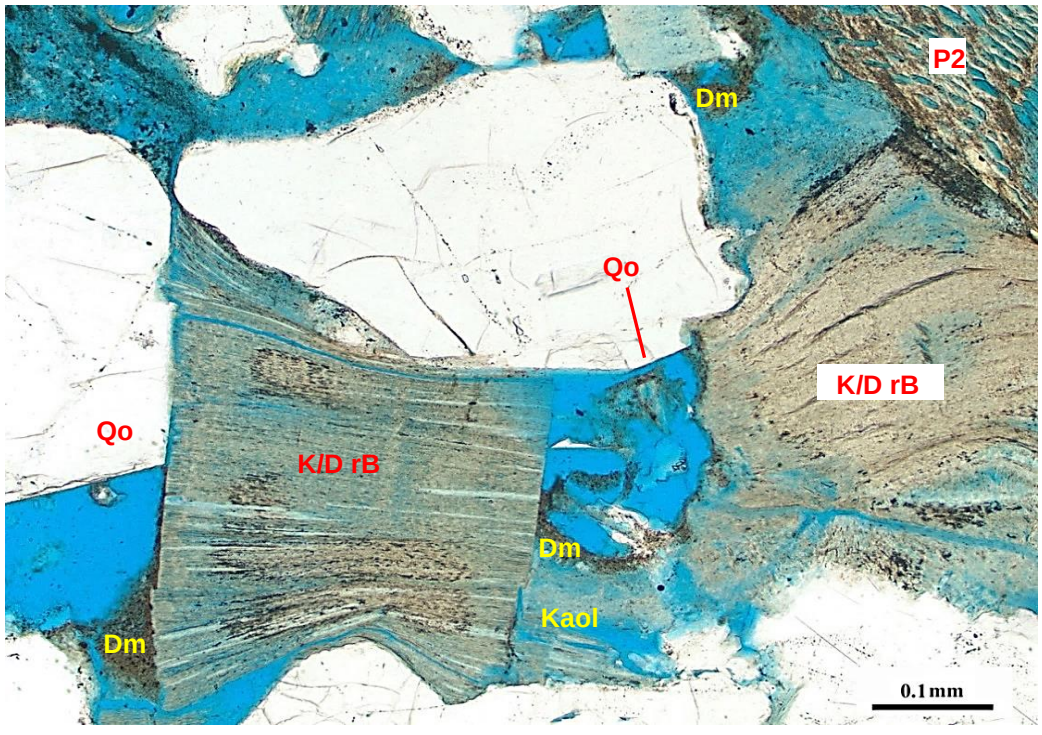
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1479.00
Sample ID: 70

A



B



Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.50
Permeability (md)*:	309.0
Grain Density (g/cc):	2.64

**Core analysis data taken at 1700 psi*

Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 0.884 (Coarse sand)
Grn.Sorting: well

Structures:
massive; moderate compaction (long grain contacts); some feldspar grains exhibit intragranular fractures

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments; minor altered biotite

Accessory Grains:
minor muscovite, biotite altered to kaolinite/dickite; trace garnet

Matrix:
none observed

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths, dickite replacing biotite flakes; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	73.5	Goethite	0.0
K-Feldspar	8.3	Hematite	0.0
Plagioclase	0.2	Pyrite	0.0
Calcite	0.0	Total Clay	18.0

Clay Abundance (Weight %)

Illite / Smectite	1.7	Kaolin*	12.8
Illite & Mica	1.6	Chlorite	1.9

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a coarse-grained sandstone with abundant quartz (Q) and moderate K-feldspar (KF; stained yellow). Distinctive sand-size kaolinite/dickite- replaced biotite flakes (K/D rB) are evenly dispersed in this massive sandstone. Opaque minerals occur in trace amounts (Op). Authigenic minerals include minor amounts of intergranular kaolinite (Kaol) and quartz overgrowths (Qo). Pore types include intergranular pores (blue epoxy; red arrows) and intercrystal micropores associated with kaolinite cement (blue haze coloration within kaolinite). The dark material on the edges of some pore-filling kaolinite is drilling mud (Dm). Many of the K-feldspar grains exhibit intragranular dissolution pores (P2) or intragranular fractures (black arrow).

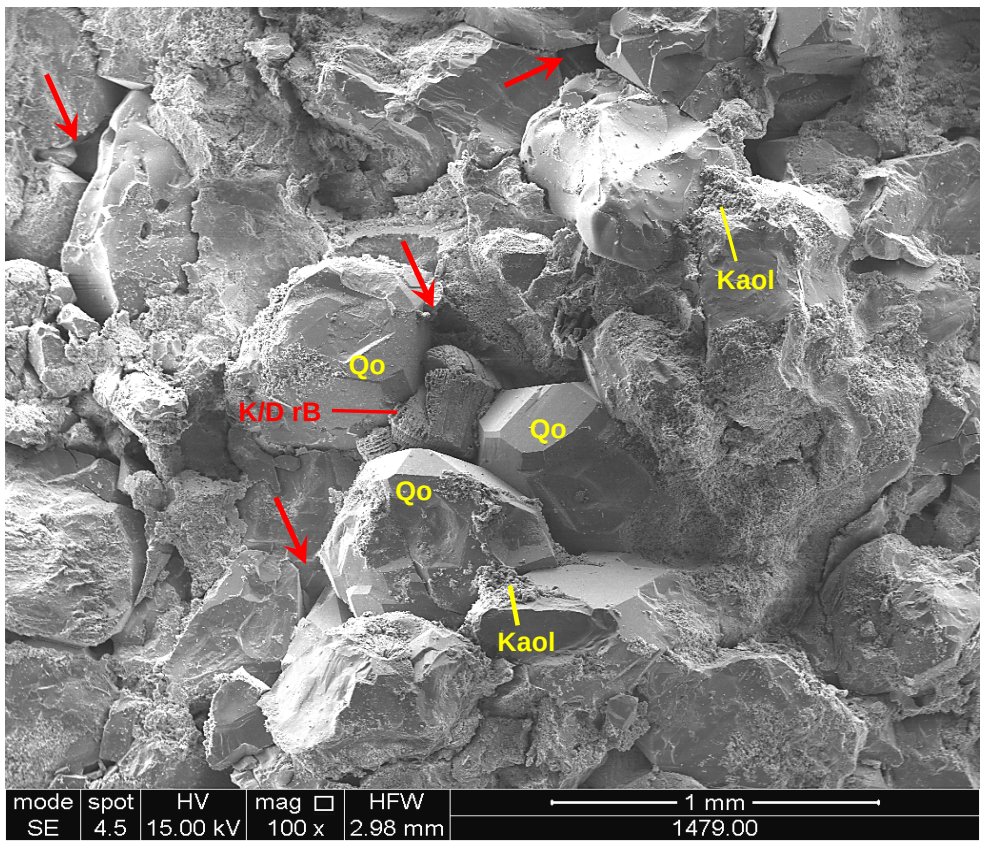
PLATE 24 (cont'd)

Scanning Electron Microscopy

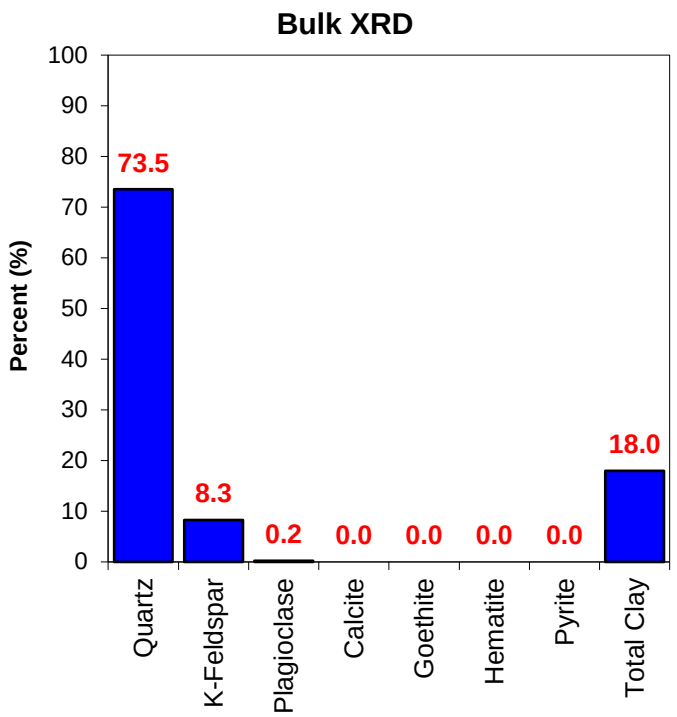
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1479.00
Sample ID: 70

Lithology: sandstone

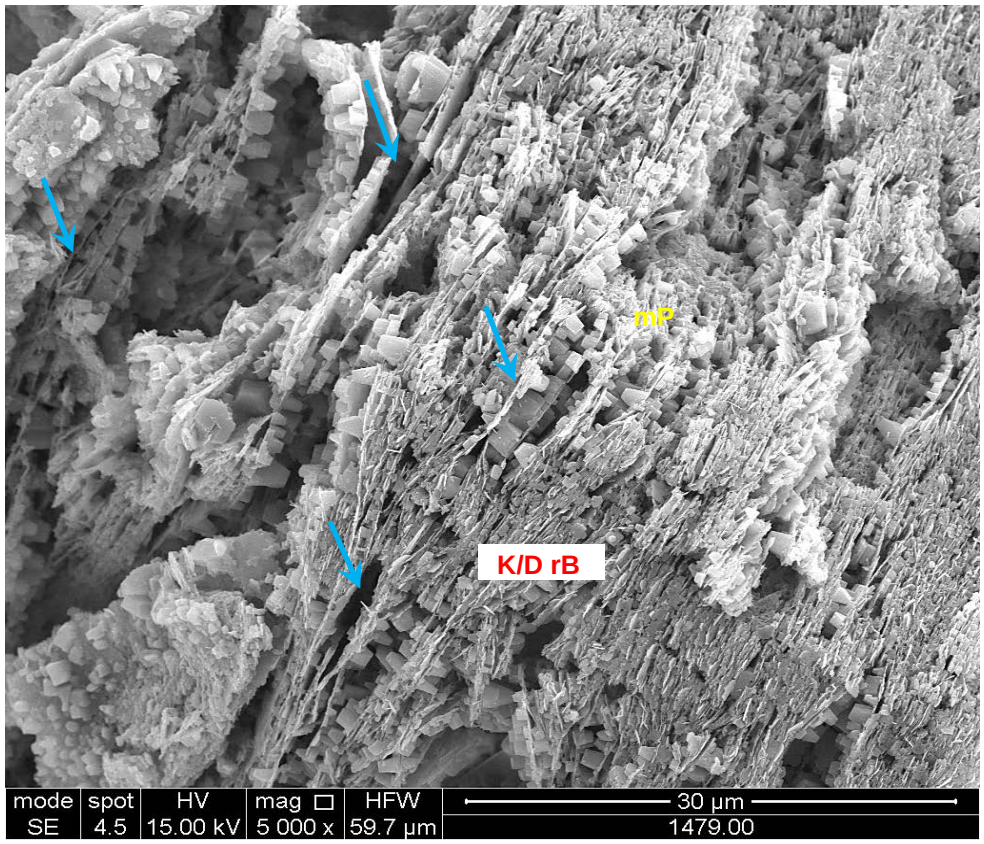
C

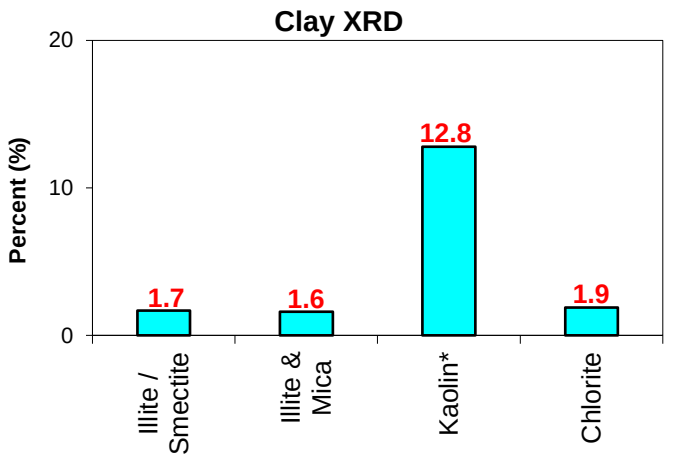


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis show that the intergranular pores (red arrows) are partly to completely occluded by quartz overgrowths (Qo) or pore-filling kaolinite (Kaol). Note the kaolinite/dickite replaced biotite flake (K/D rB) in the center of the image. Image D features the intercrystal micropores (mP) in the replaced biotite flake. The blue arrows indicate exfoliation pores between the original biotite sheets.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.50
Permeability (md)*:	309.0
Grain Density (g/cc):	2.64

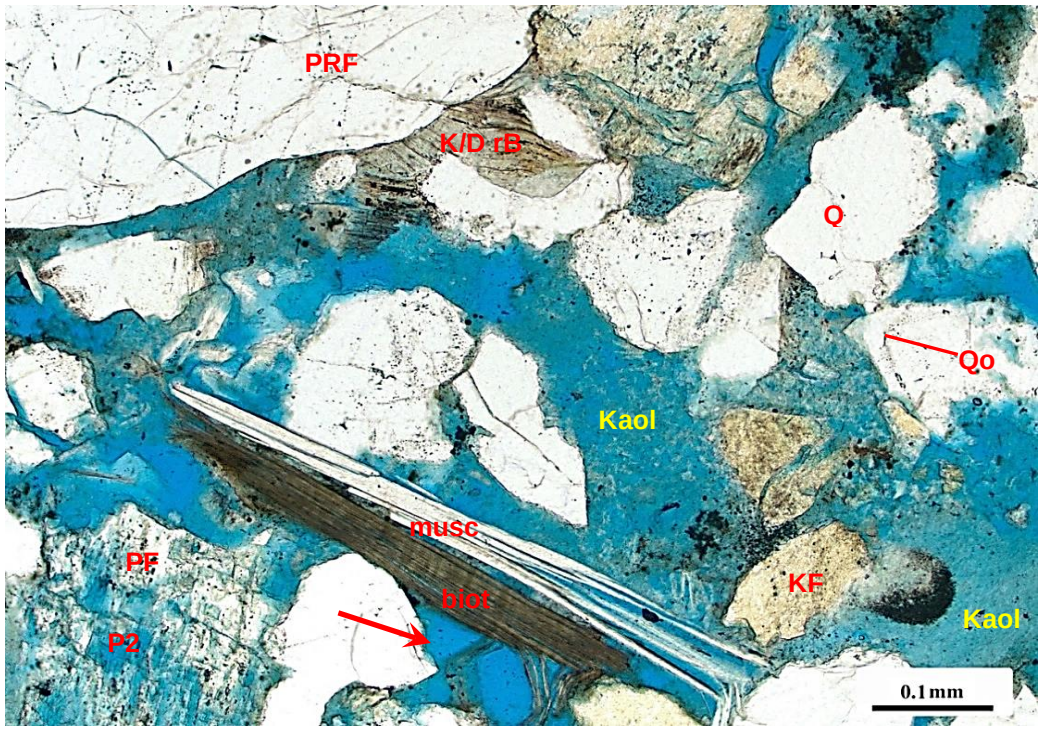
**Core analysis data taken at 1700 psi*

PLATE 25

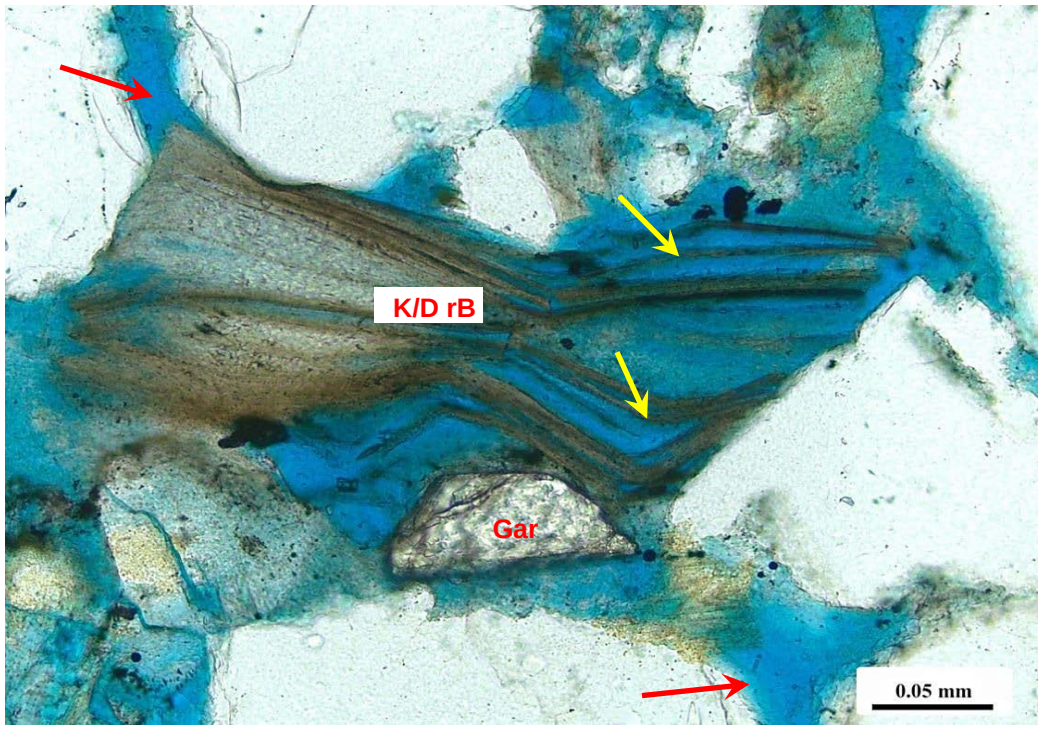
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1500.00
Sample ID: 91

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 0.965 (Coarse sand)
Grn.Sorting: bimodal

Structures:
massive; moderate compaction (both point and long contacts); scattered very coarse sand grains

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
minor muscovite, biotite altered to kaolinite/dickite; trace garnet

Matrix:
none observed

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths, dickite replacing biotite flakes; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	63.5	Goethite	0.0
K-Feldspar	9.1	Hematite	0.0
Plagioclase	0.6	Pyrite	0.0
Calcite	0.0	Total Clay	26.9

Clay Abundance (Weight %)

Illite / Smectite	2.1	Kaolin*	17.2
Illite & Mica	2.2	Chlorite	5.4

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a sandstone with bimodal sorting (Photo A), with plutonic lithic fragments (PRF) most commonly occurring as the larger grains. Other grains identified include quartz (Q) , plagioclase (PF), K-feldspar (KF) and garnet (Gar). The most important feature of Photo A is the presence of unaltered biotite (biot) and muscovite (musc) as well as heavily altered biotite flakes (K/D rB). Kaolinite and dickite are the replacement minerals. Kaolinite also occurs as an intergranular cement (Kaol) Pore types observed include intergranular (red arrows), intragranular pores in plagioclase (P2), exfoliation pores in deformed mica (yellow arrows), and intercrystal micropores in kaolinite.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.30
Permeability (md)*:	18.2
Grain Density (g/cc):	2.65

**Core analysis data taken at 1700 psi*

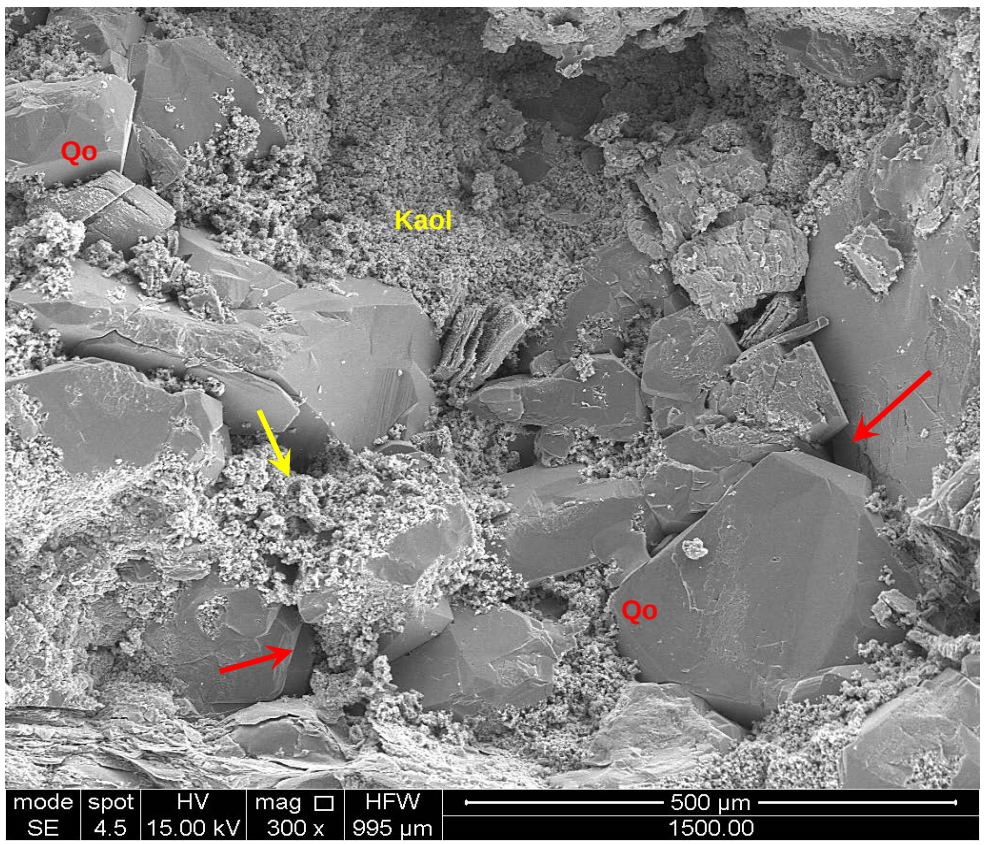
PLATE 25 (cont'd)

Scanning Electron Microscopy

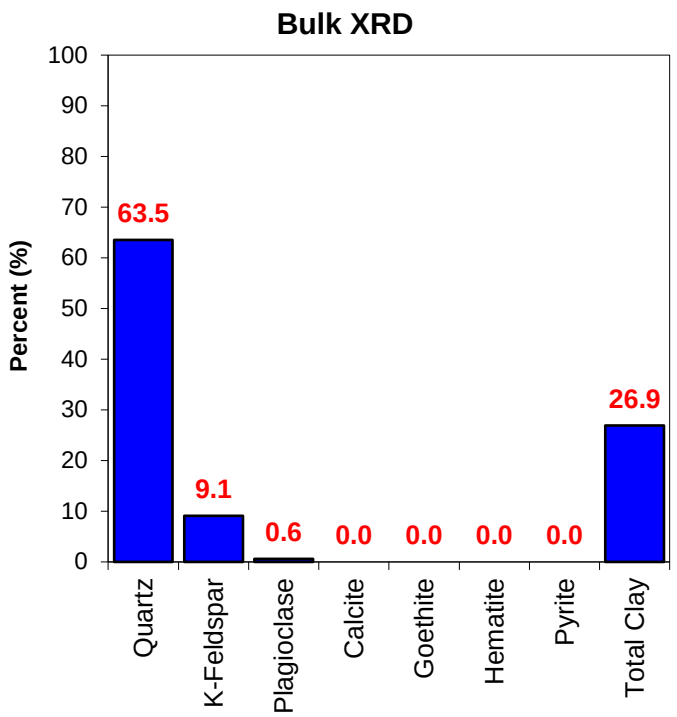
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1500.00
Sample ID: 91

Lithology: sandstone

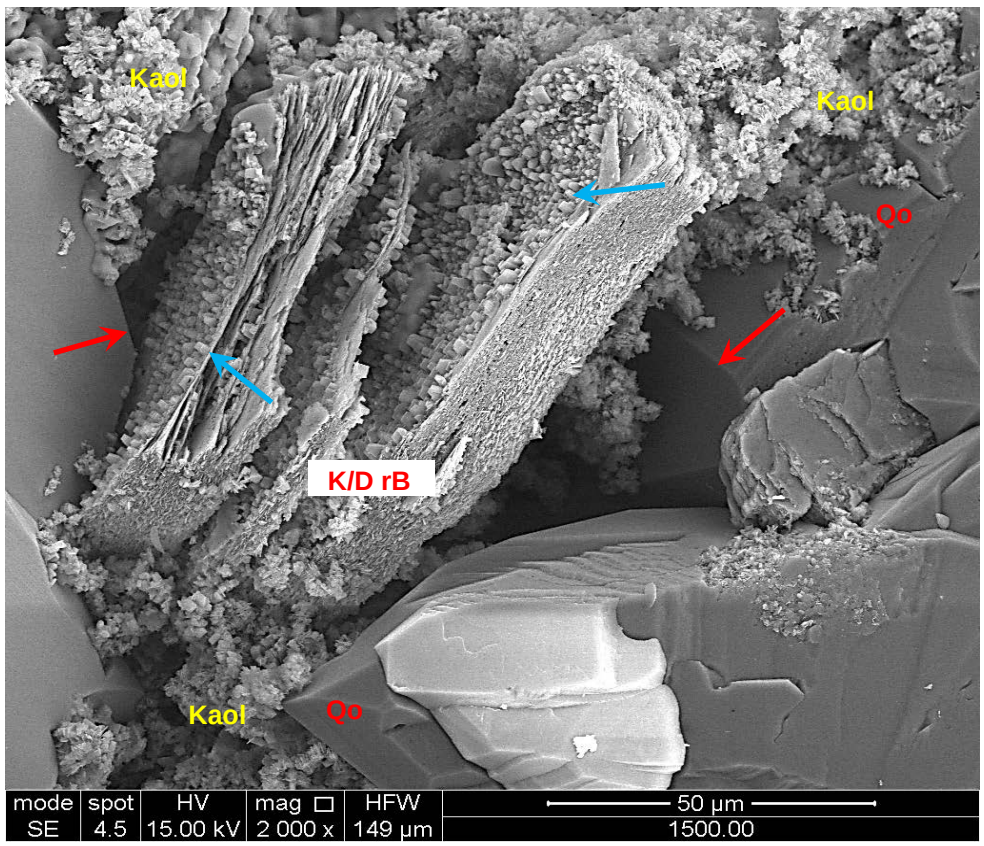
C

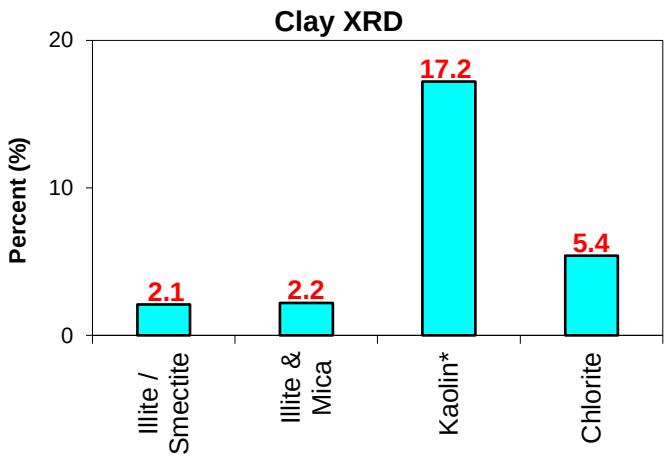


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

XRD analysis indicates that kaolin clay is the most abundant clay type. Kaolin includes both kaolinite (Kaol) and dickite, both visible in these SEM images. The kaolinite occurs as finely crystalline pore-filling cement with sparse curving vermicular stacks barely visible (yellow arrow). In Image D the kaolinite is intergrown with quartz overgrowth (Qo) cement indicating that they formed concurrently. The central grain featured in Image D is a detrital biotite flake the replacement dickite growing along the faces of mica flakes (blue arrows). The red arrows indicate intergranular macropores. The intergranular kaolinite is microporous.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.30
Permeability (md)*:	18.2
Grain Density (g/cc):	2.65

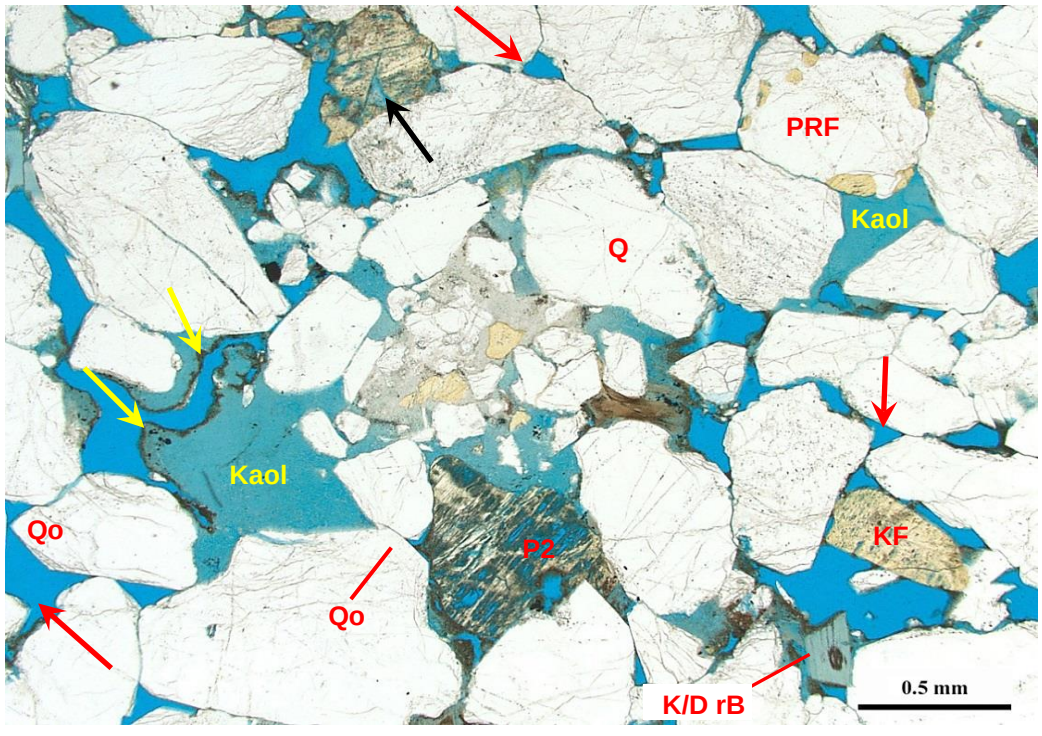
**Core analysis data taken at 1700 psi*

PLATE 26

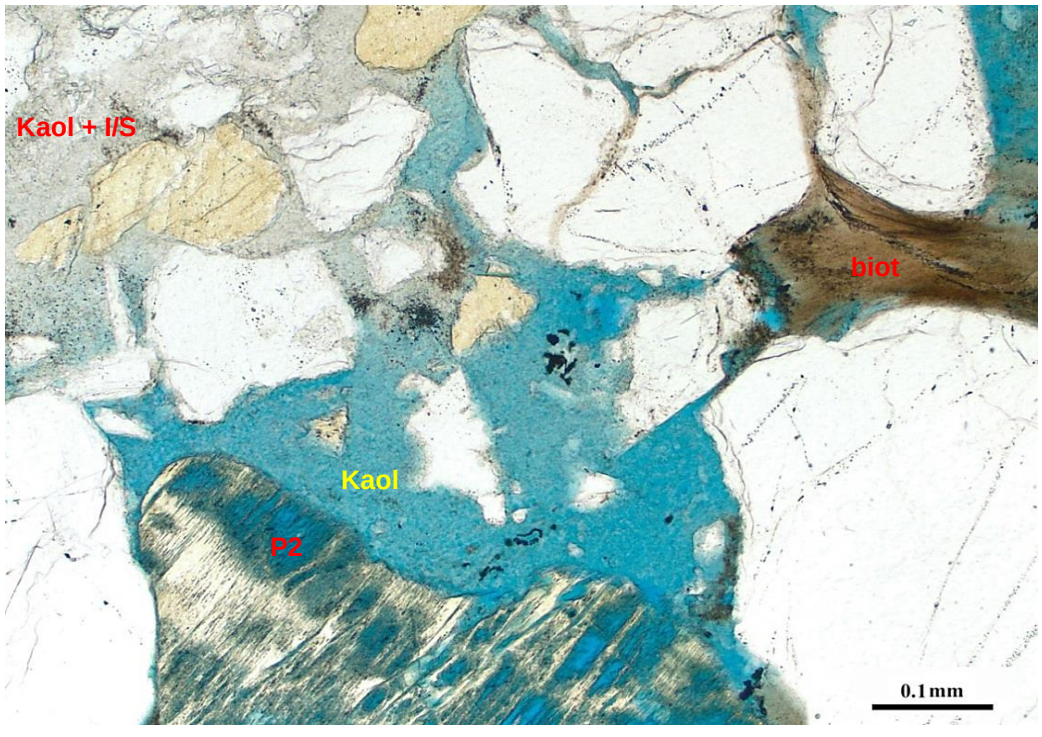
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1519.00
Sample ID: 110

A



B



Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	17.90
Permeability (md)*:	2070.0
Grain Density (g/cc):	2.63

**Core analysis data taken at 1700 psi*

Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 1.536 (Coarse sand)
Grn.Sorting: well

Structures:
massive; moderate compaction (long grain contacts)

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
minor muscovite, biotite altered to kaolinite/dickite; trace garnet

Matrix:
none observed

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths, dickite replacing biotite flakes; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); common intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	85.9	Goethite	0.0
K-Feldspar	7.1	Hematite	0.0
Plagioclase	0.2	Pyrite	0.0
Calcite	0.0	Total Clay	6.8

Clay Abundance (Weight %)

Illite / Smectite	1.6	Kaolin*	3.8
Illite & Mica	0.8	Chlorite	0.6

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a coarse-grained sandstone with a massive fabric. Identified framework grains include quartz (Q), plutonic lithic fragments (PRF), and K-feldspar (KF). Biotite flakes (biot) and highly altered biotite that has been replaced by kaolinite/or dickite (K/D rB) are also noted. Intergranular kaolinite (Kaol) is indicated. The dark rims on some grains and within kaolinite are drilling mud (yellow arrows). The red arrows indicate intergranular pores reduced in size by authigenic quartz overgrowths (Qo). Some of the feldspar grains exhibit intragranular dissolution pores (P2) or intragranular fractures (black arrow). The "blue haze" coloration of the kaolinite cement indicates that it is microporous.

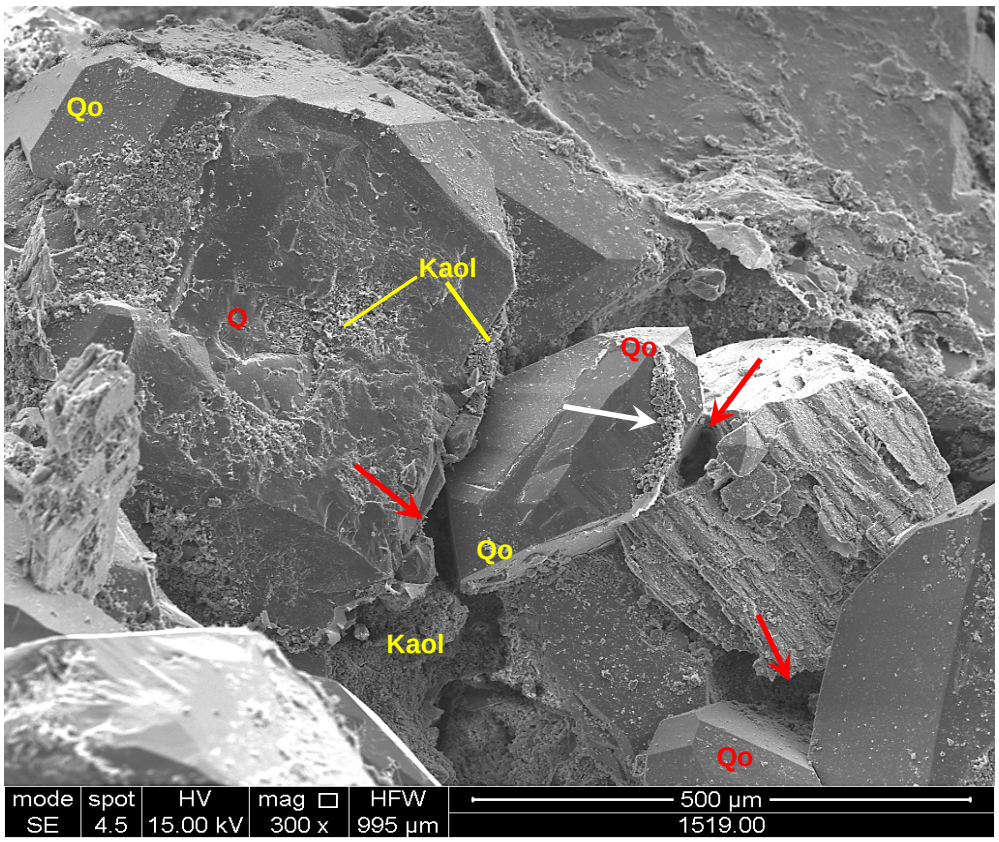
PLATE 26 (cont'd)

Scanning Electron Microscopy

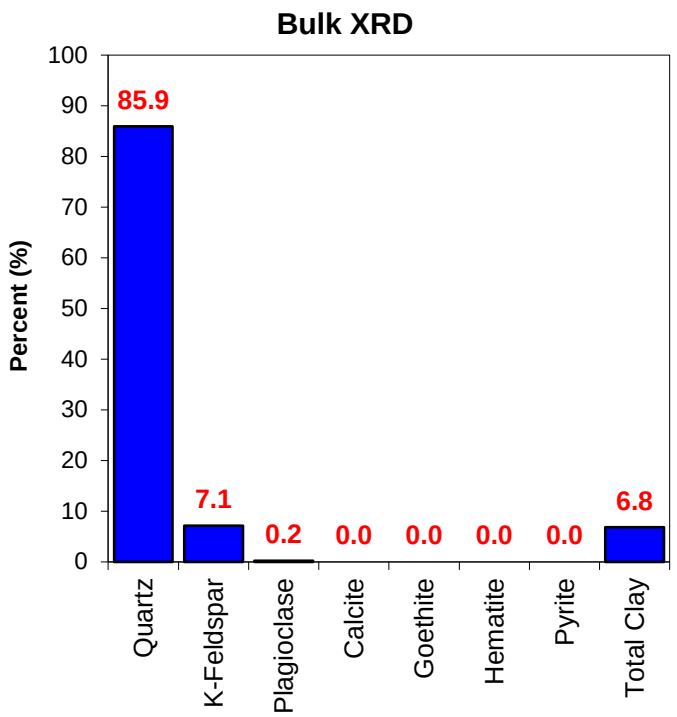
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1519.00
Sample ID: 110

Lithology: sandstone

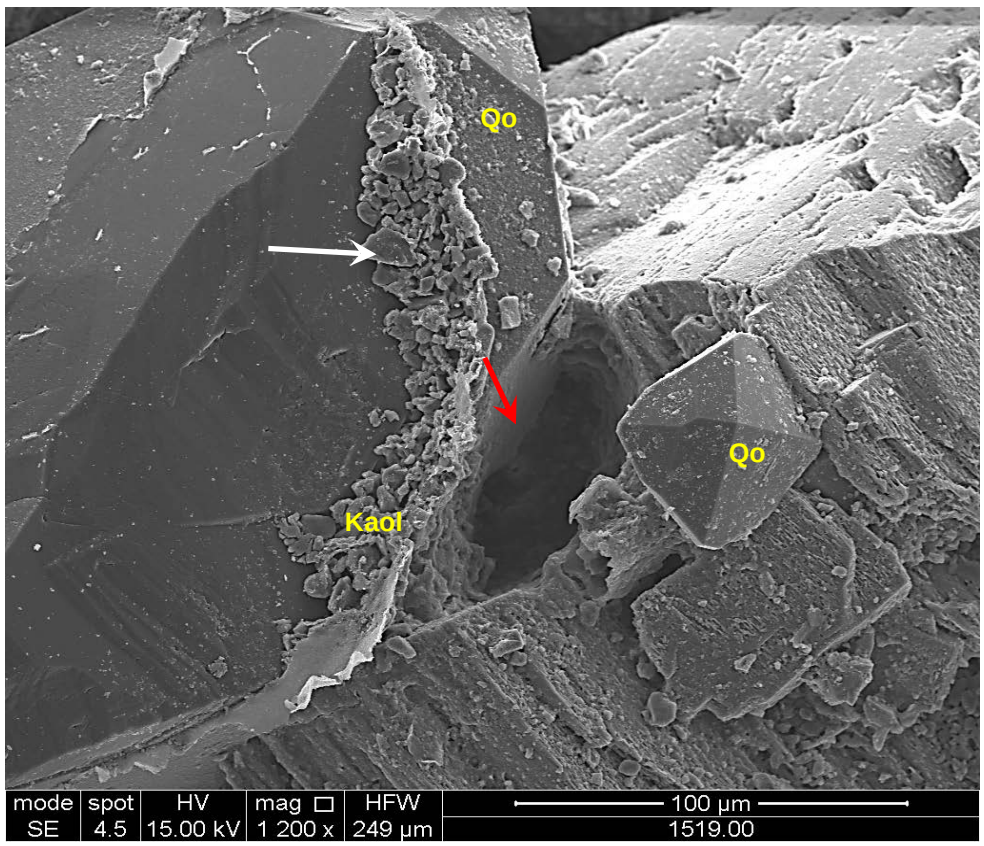
C

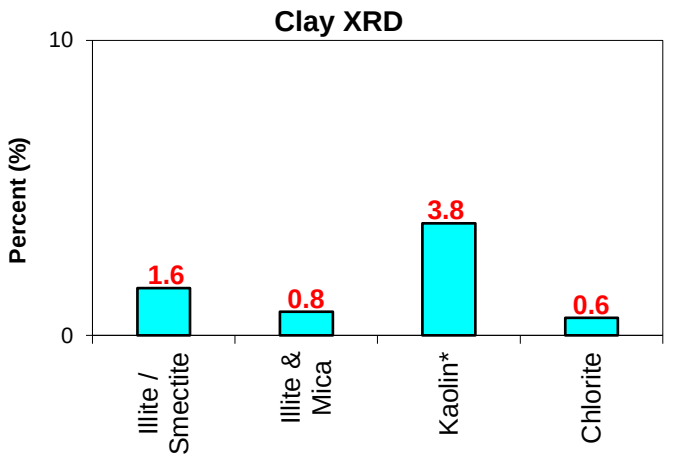


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows that this coarse sandstone is composed of abundant quartz grains (Q) with well-formed syntaxial quartz overgrowths (Qo). Intergranular pores (red arrows) are reduced by the quartz overgrowths. Minor kaolinite (Kaol) is observed within intergranular areas and clinging to grain surfaces (white arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	17.90
Permeability (md)*:	2070.0
Grain Density (g/cc):	2.63

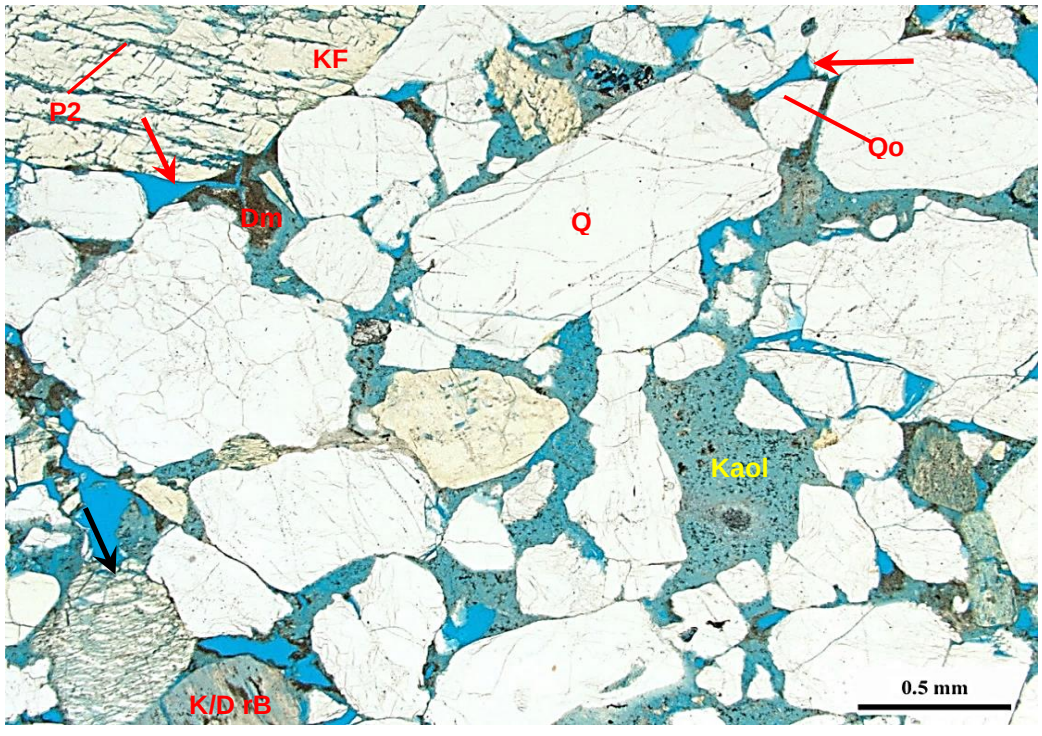
**Core analysis data taken at 1700 psi*

PLATE 27

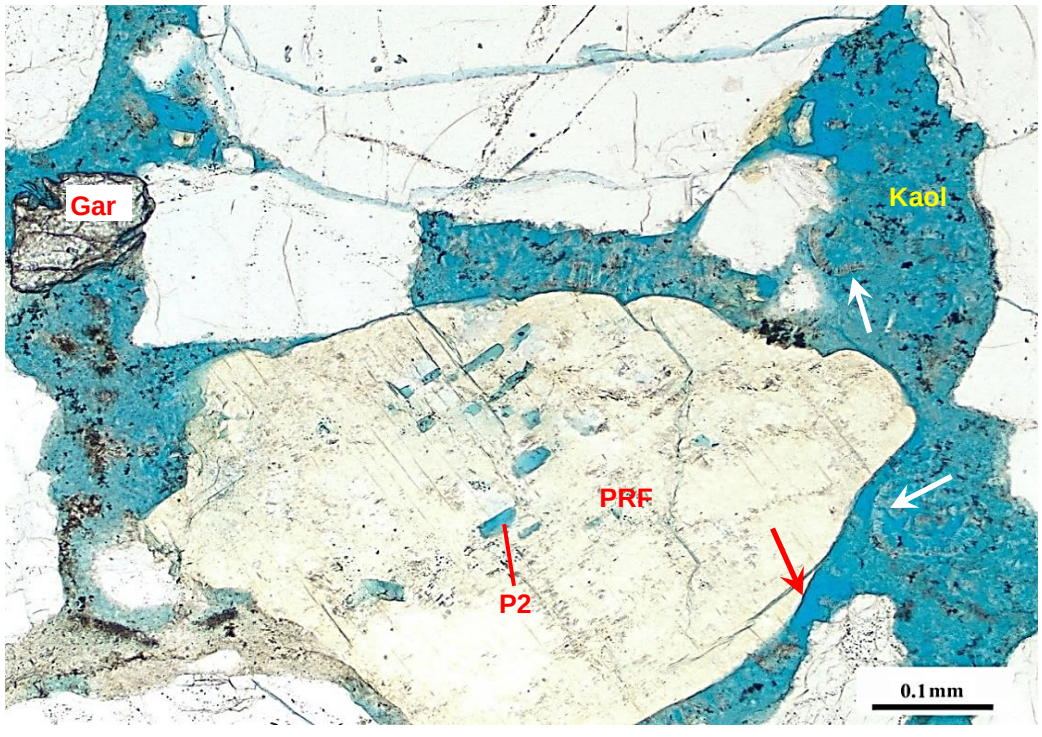
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1544.00
Sample ID: 135

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 1.086 (Coarse sand)
Grn.Sorting: moderate

Structures:
massive; moderate compaction (long grain contacts); some feldspar grains exhibit intragranular fractures

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
minor muscovite, biotite altered to kaolinite/dickite; trace garnet, opaque minerals

Matrix:
trace mechanically infiltrated clay (cutans)

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths, dickite replacing biotite flakes; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); moderate intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	79.8	Goethite	0.0
K-Feldspar	13.3	Hematite	0.0
Plagioclase	0.5	Pyrite	0.0
Calcite	0.0	Total Clay	6.4

Clay Abundance (Weight %)

Illite / Smectite	1.0	Kaolin*	3.7
Illite & Mica	0.7	Chlorite	1.0

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a coarse-grained sandstone with a massive fabric. Identified framework grains include quartz (Q), K-feldspar (KF) and plutonic lithic fragments (PRF). One biotite flake altered to kaolinite/dickite is present (K/D rB). Accessory garnet (Gar) occurs in trace amounts. Intergranular kaolinite (Kaol) cement and vermicular stacks of kaolinite booklets (white arrows) are identified. Note that some areas of kaolinite are oversized. The red arrows indicate intergranular pores reduced in size by the presence of quartz overgrowths (Qo). Some of the feldspar grains exhibit intragranular dissolution pores (P2) or intragranular fractures (black arrow). Feldspar dissolution and fractures follow cleavages. The blue coloration of the kaolinite cement indicates that it is microporous. The dark material is drilling mud (Dm) contamination.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.40
Permeability (md)*:	633.0
Grain Density (g/cc):	2.64

**Core analysis data taken at 1700 psi*

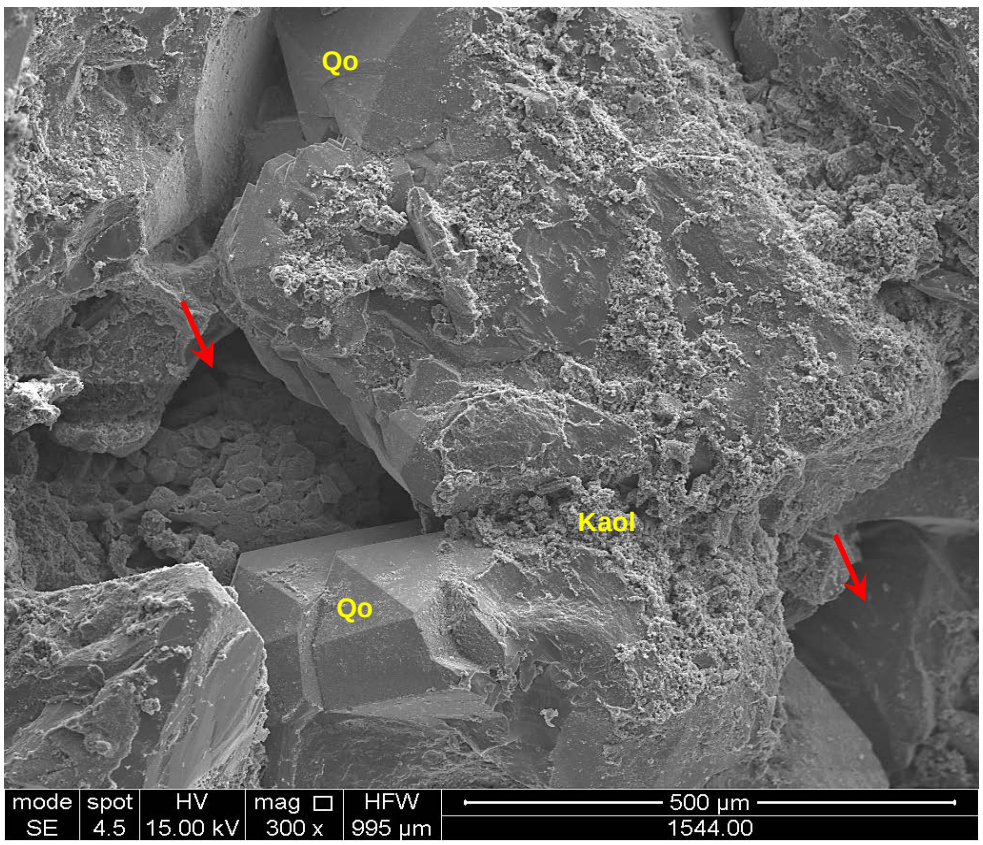
PLATE 27 (cont'd)

Scanning Electron Microscopy

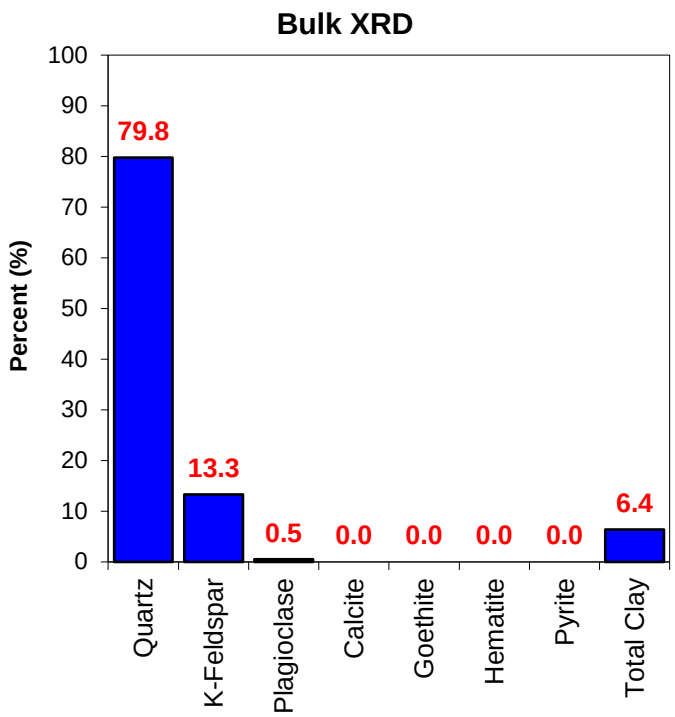
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1544.00
Sample ID: 135

Lithology: sandstone

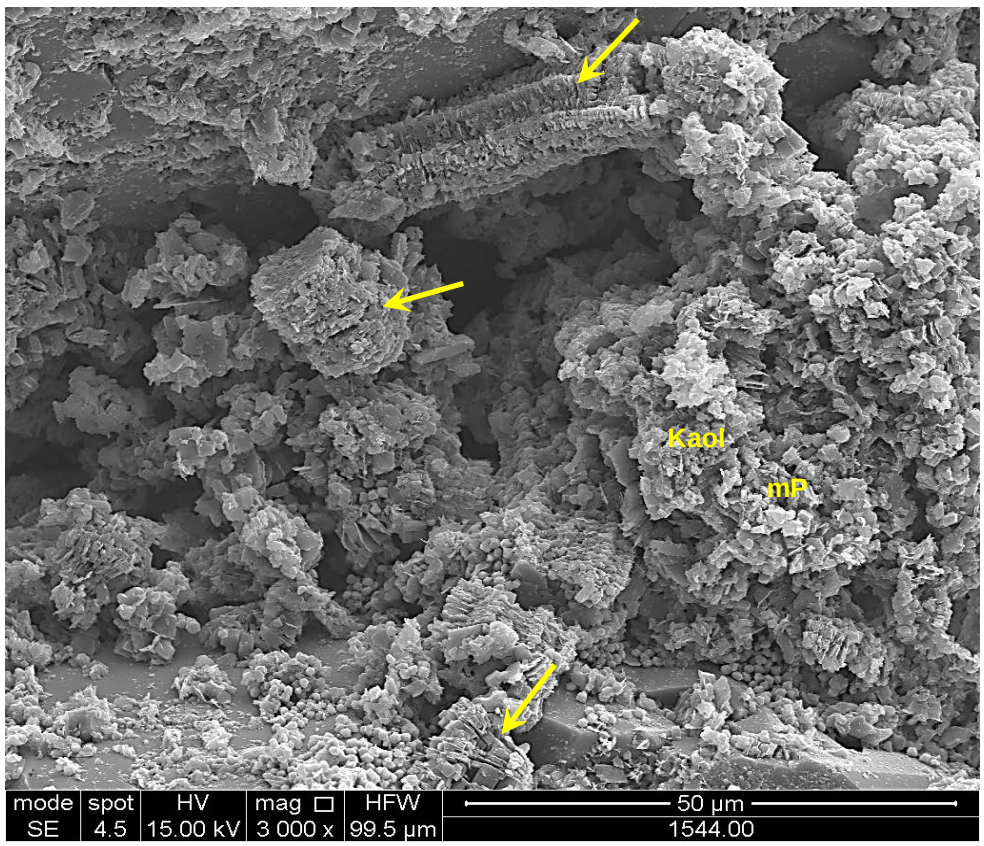
C

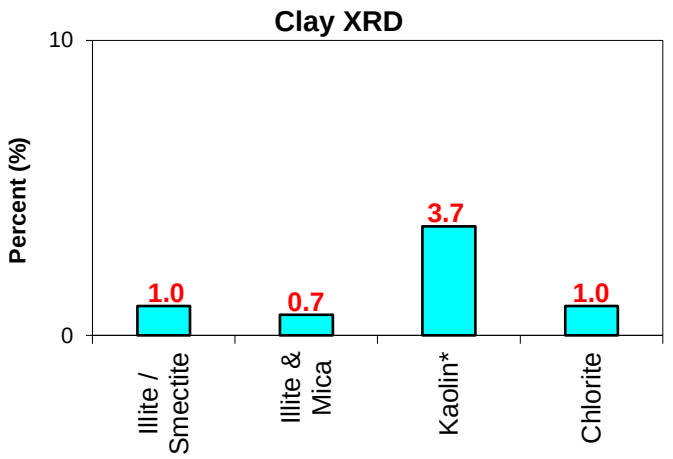


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM images show that intergranular pores (red arrows) are bounded by euhedral quartz overgrowths (Qo), and partly filled by minor amounts of intermixed authigenic kaolinite (Kaol) and dickite. Curving vermicular stacks of kaolinite booklets are featured in image D (yellow arrows). The kaolin exhibits intercrystal micropores (mP).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.40
Permeability (md)*:	633.0
Grain Density (g/cc):	2.64

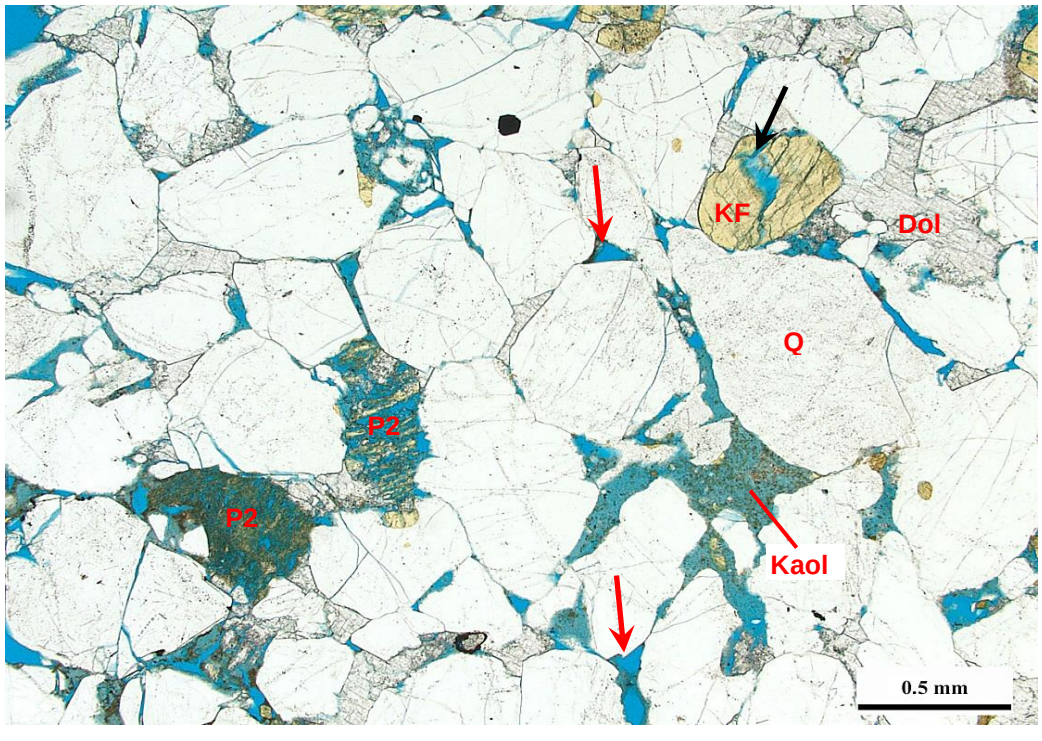
**Core analysis data taken at 1700 psi*

PLATE 28

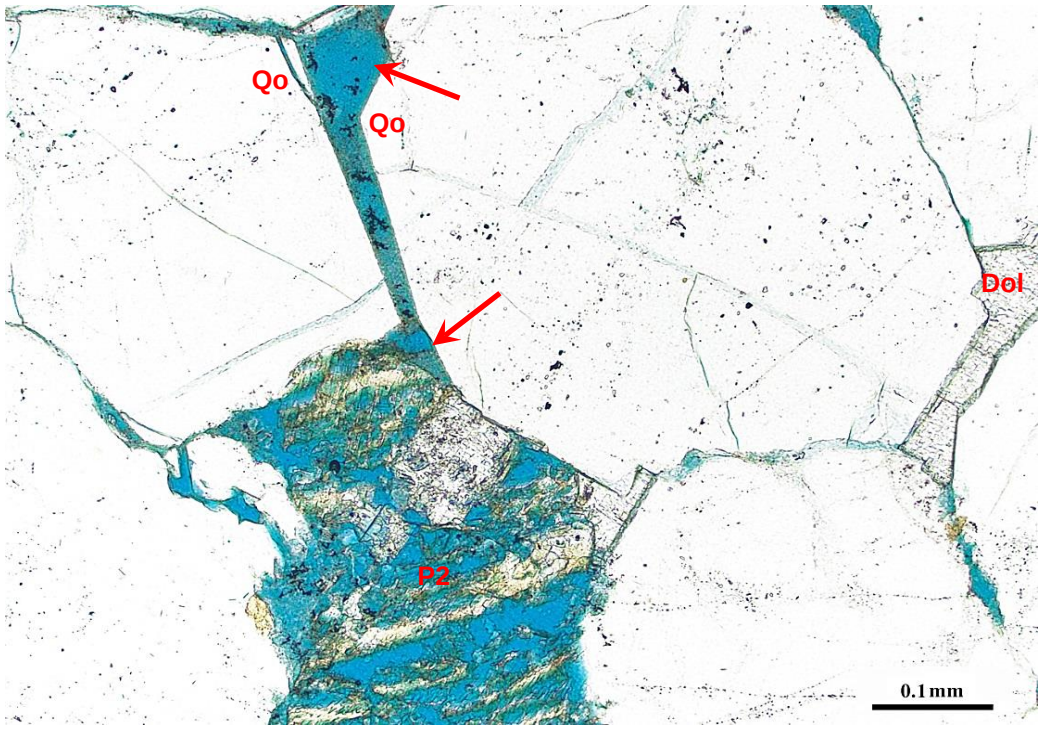
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1549.00
Sample ID: 140

A



B



Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.50
Permeability (md)*:	3700.0
Grain Density (g/cc):	2.68

**Core analysis data taken at 1700 psi*

Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 0.764 (Coarse sand)
Grn.Sorting: well

Structures:
massive; moderate compaction (both point and long contacts); some feldspar grains exhibit intragranular fractures; long to concavo-convex grain contacts indicate moderate to strong compaction

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments

Accessory Grains:
trace epidote, magnetite

Matrix:
none observed

Cements:
patchy intergranular and intragranular kaolinite; minor quartz overgrowths, dickite replacing biotite flakes, one patch of intergranular dolomite; trace pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); moderate intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	85.8	Goethite	0.0
K-Feldspar	7.1	Hematite	0.0
Plagioclase	0.4	Pyrite	0.0
Calcite	0.0	Total Clay	6.7

Clay Abundance (Weight %)

Illite / Smectite	2.2	Kaolin*	3.0
Illite & Mica	1.0	Chlorite	0.5

%smectite in mixed-layer illite/smectite is 25-35
*Kaolin includes both kaolinite and dickite

Photomicrograph Caption

This sample is a coarse-grained sandstone with a massive fabric. Identified framework grains include quartz (Q) and K-feldspar (KF). The red arrows indicate intergranular pores reduced in size by the presence of quartz overgrowths (Qo). Patchy dolomite (Dol) is observed in one area of the thin section, and completely occludes pores. The XRD split for this sample did not contain the dolomite cement. Intergranular kaolinite is also indicated in Photo A. Some of the feldspar grains exhibit intragranular dissolution pores (P2) or intragranular fractures (black arrow).

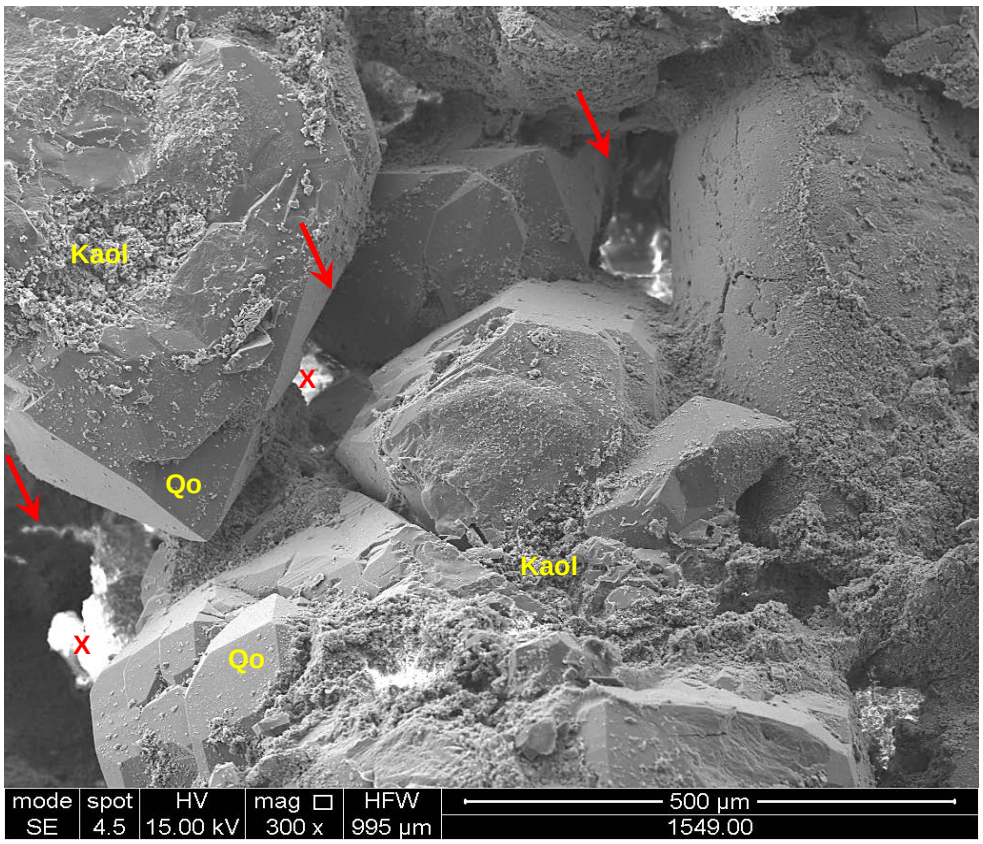
PLATE 28 (cont'd)

Scanning Electron Microscopy

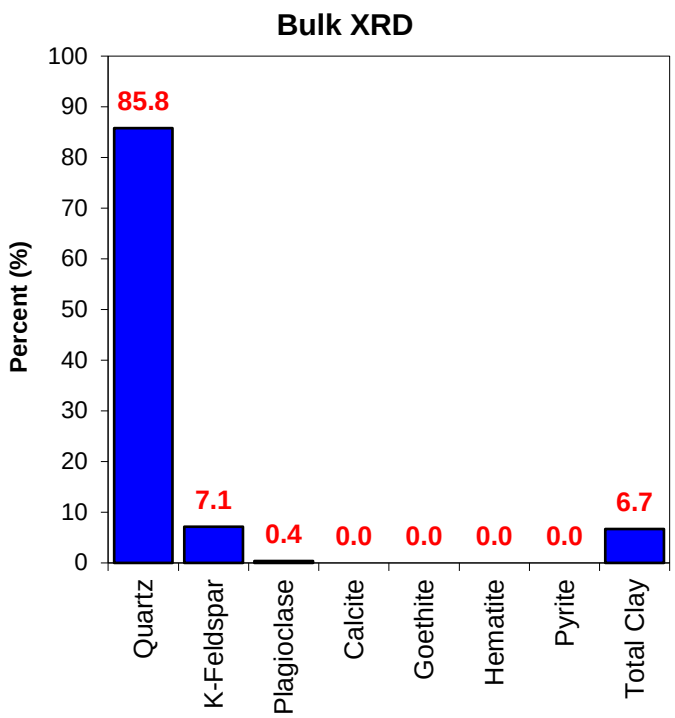
Company: Australia Department of Mines and Petroleum
Well: Harvey-3
Location: Perth Basin, Australia
Formation*: Wonnerup Mbr.
Depth (m): 1549.00
Sample ID: 140

Lithology: sandstone

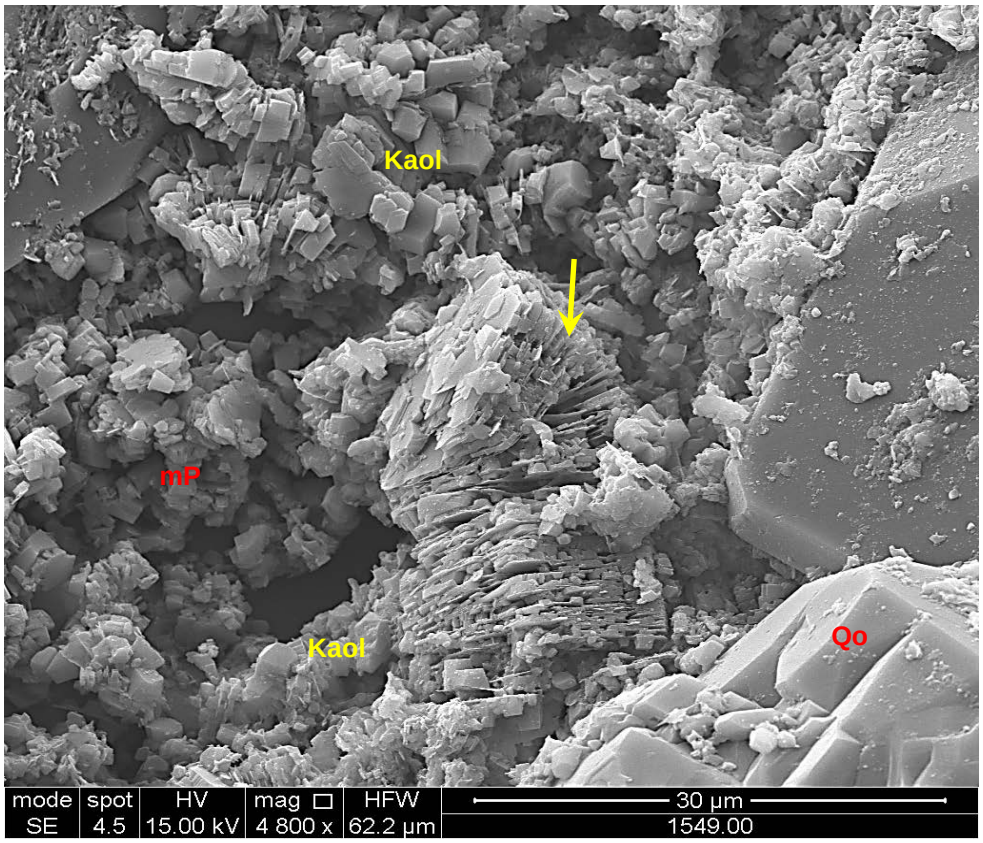
C

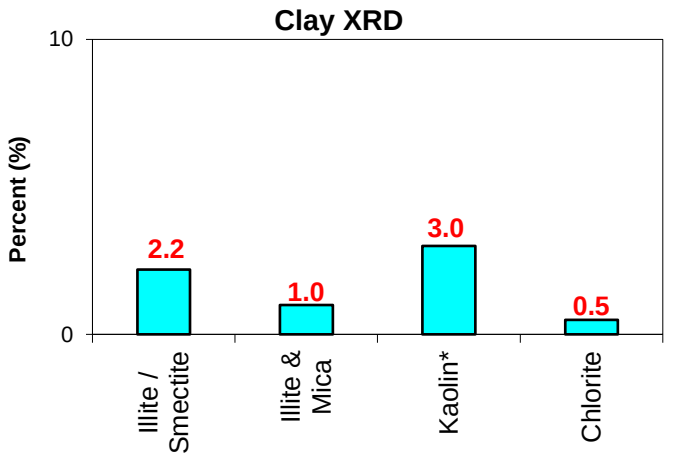


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM images show that intergranular pores (red arrows) are bounded by euhedral quartz overgrowths (Qo), and partly filled by minor amounts of intermixed authigenic kaolinite (Kaol) and dickite. A curving vermiform stack of kaolinite booklets is featured in image D (yellow arrow). Dickite or blocky kaolinite appears to be occupying some intercrystal areas in the kaolinite stack. The kaolin exhibits intercrystal micropores (mP). Charging of the sample under the beam is indicated by "X".

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	18.50
Permeability (md)*:	3700.0
Grain Density (g/cc):	2.68

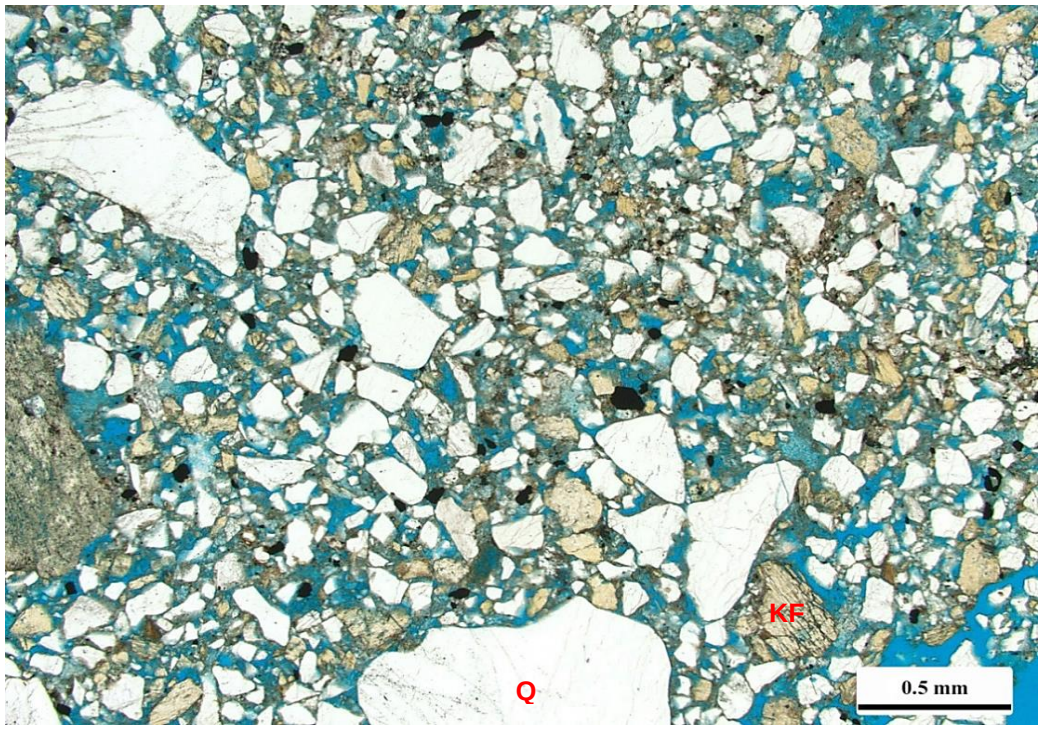
**Core analysis data taken at 1700 psi*

PLATE 29

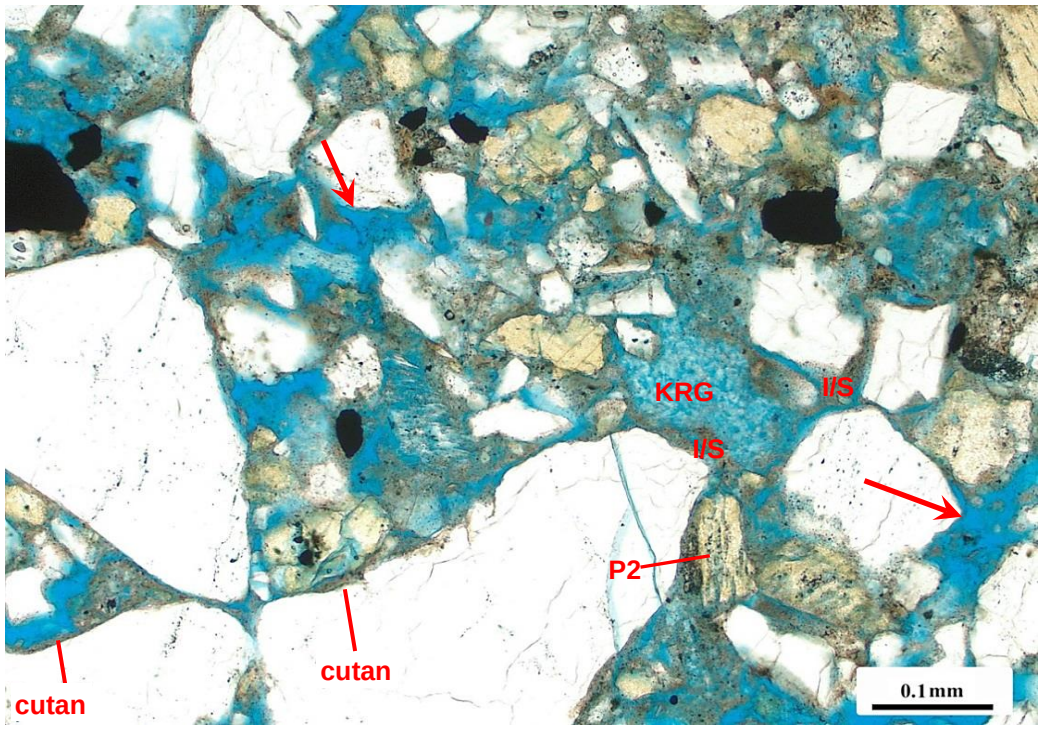
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 893.04
Sample ID: PSH 1

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.152 (L. fine sand)
Grn.Sorting: moderately well

Structures:
massive with one slightly coarser layer and a few scattered coarse sand grains

Framework Grains:
abundant quartz; moderate K-feldspar; minor plagioclase and plutonic lithic fragments

Accessory Grains:
minor opaque minerals; trace heavy minerals

Matrix:
moderate disrupted mechanically infiltrated clay (cutans)

Cements:
patchy intergranular and intragranular kaolinite; trace quartz overgrowths, pyrite

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); moderate intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	60.8	Goethite	0.0
K-Feldspar	14.2	Hematite	0.0
Plagioclase	3.5	Pyrite	0.0
Calcite	0.0	Total Clay	21.5

Clay Abundance (Weight %)

Illite / Smectite	7.9	Kaolin*	10.6
Illite & Mica	1.7	Chlorite	1.3

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Framework grains in this sandstone include abundant quartz (Q; mostly monocrystalline and minor polycrystalline), K-feldspar (KF), and plutonic lithic fragments composed of quartz, microcline and plagioclase. Scattered opaque grains (black) are present. Detrital matrix occurs as pervasive mechanically infiltrated clay cutans (cutan) composed of illite/smectite clay (I/S). The cutans in this sample are not as well preserved as in other samples. The kaolinite detected by XRD occurs in kaolinite replaced grains (KRG). Intercrystal micropores occur between kaolinite platelets. Minor amounts of intragranular pores (P2) are associated with K-feldspar. The red arrows indicate intergranular pores.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

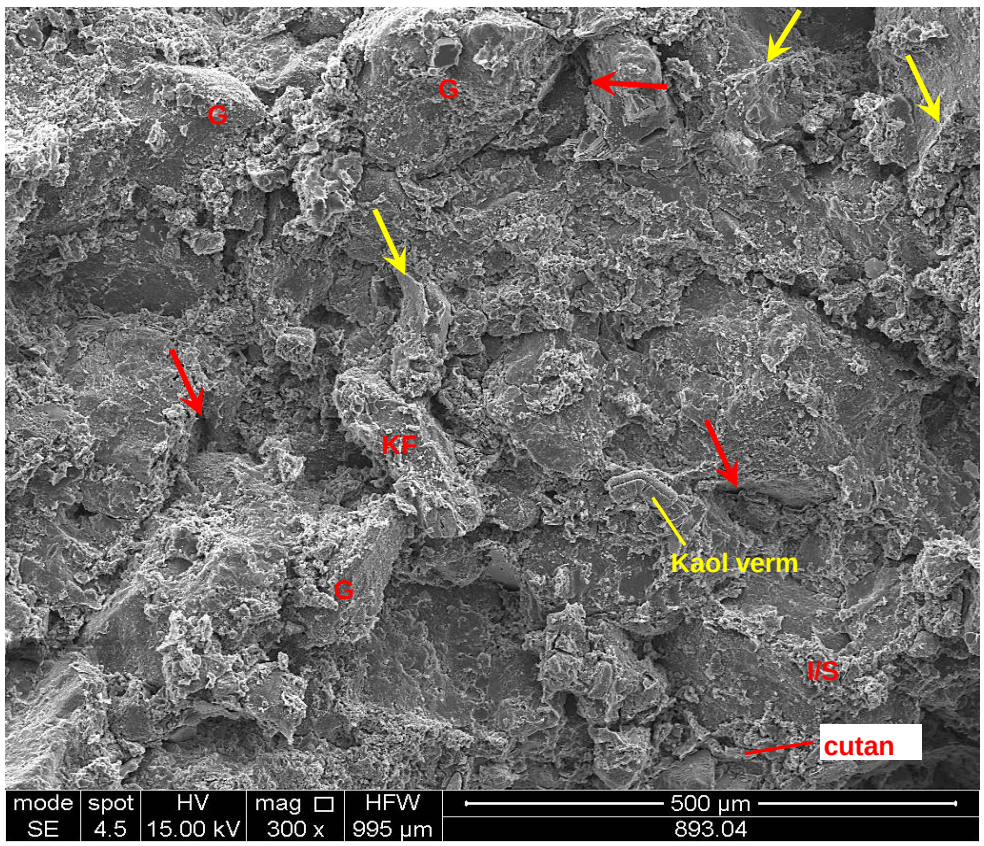
PLATE 29 (cont'd)

Scanning Electron Microscopy

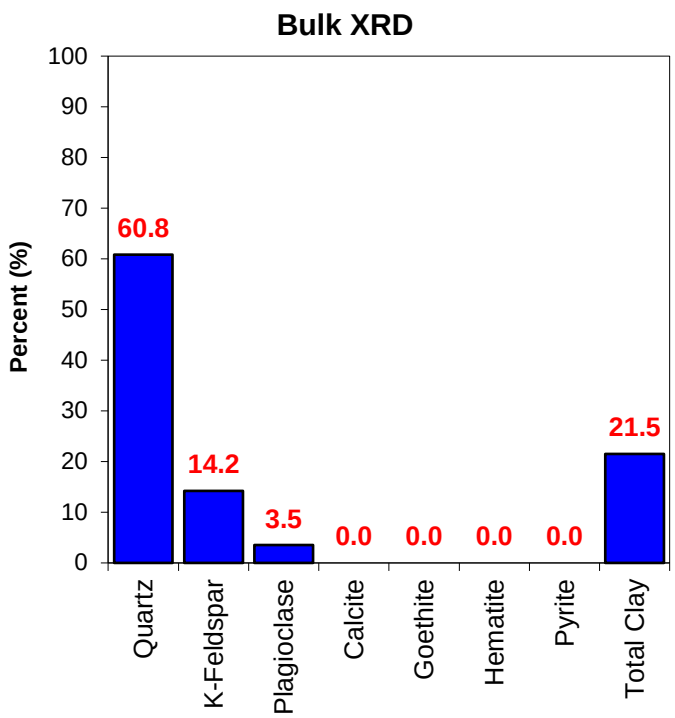
Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 893.04
Sample ID: PSH 1

Lithology: sandstone

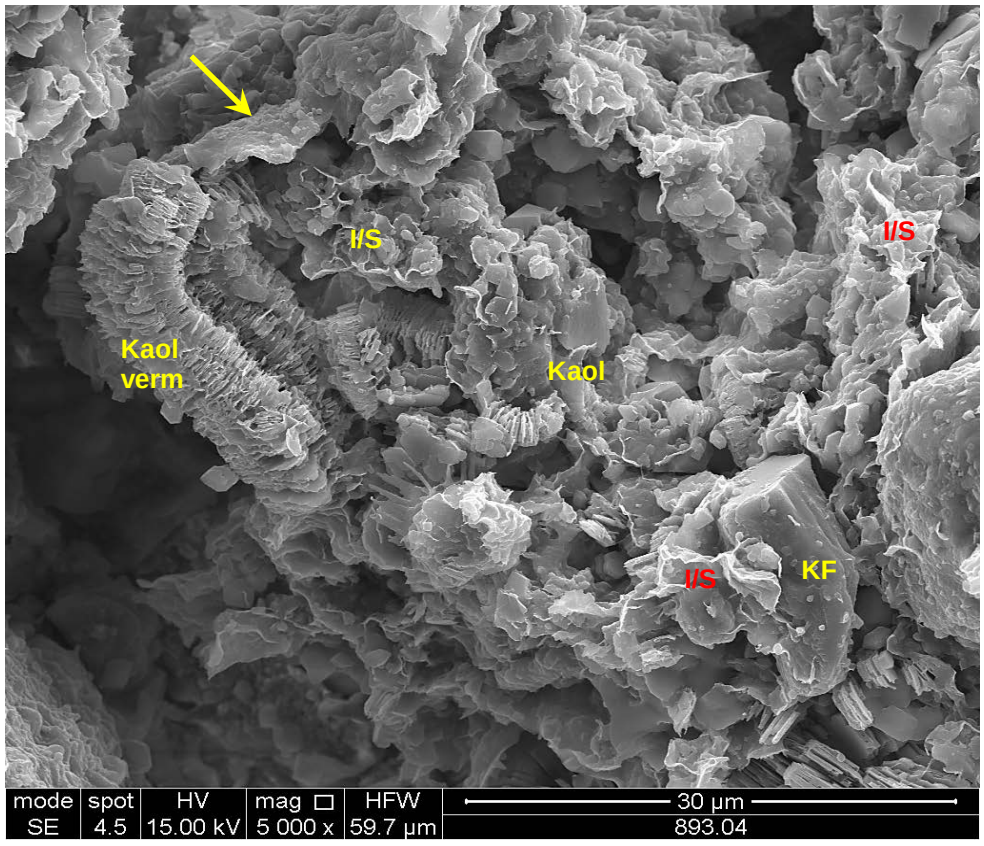
C

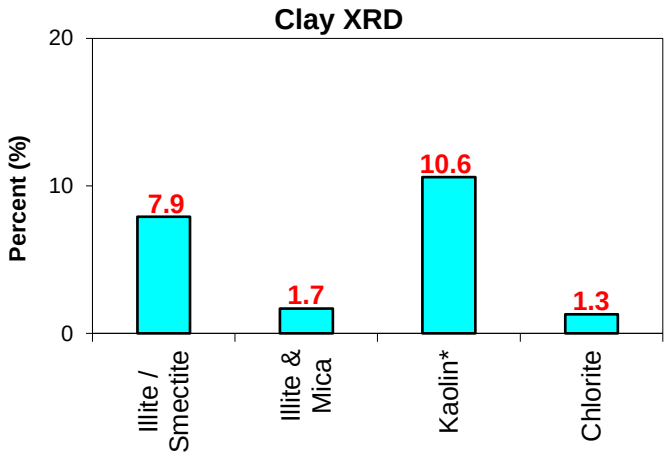


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analyses show sand-size grains (G) of mostly quartz and K-feldspar (KF). The red arrows indicate intergranular pores. Authigenic minerals include kaolinite (Kaol), with some well-formed vermicular stacks (Kaol verm). Aligned illite/smectite clay with arcuate shapes (yellow arrows) suggest disrupted grain-coating cutans. Illite/smectite (I/S) clay is also associated with pore-filling kaolinite (Image D).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

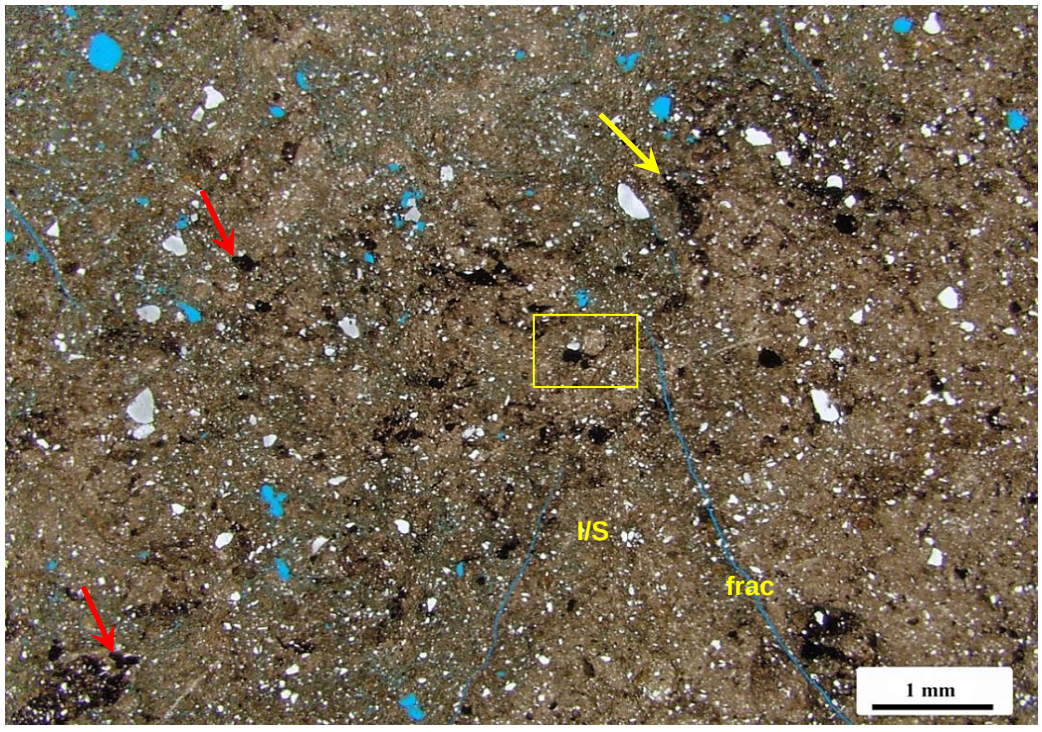
**Core analysis data taken at na psi*

PLATE 30

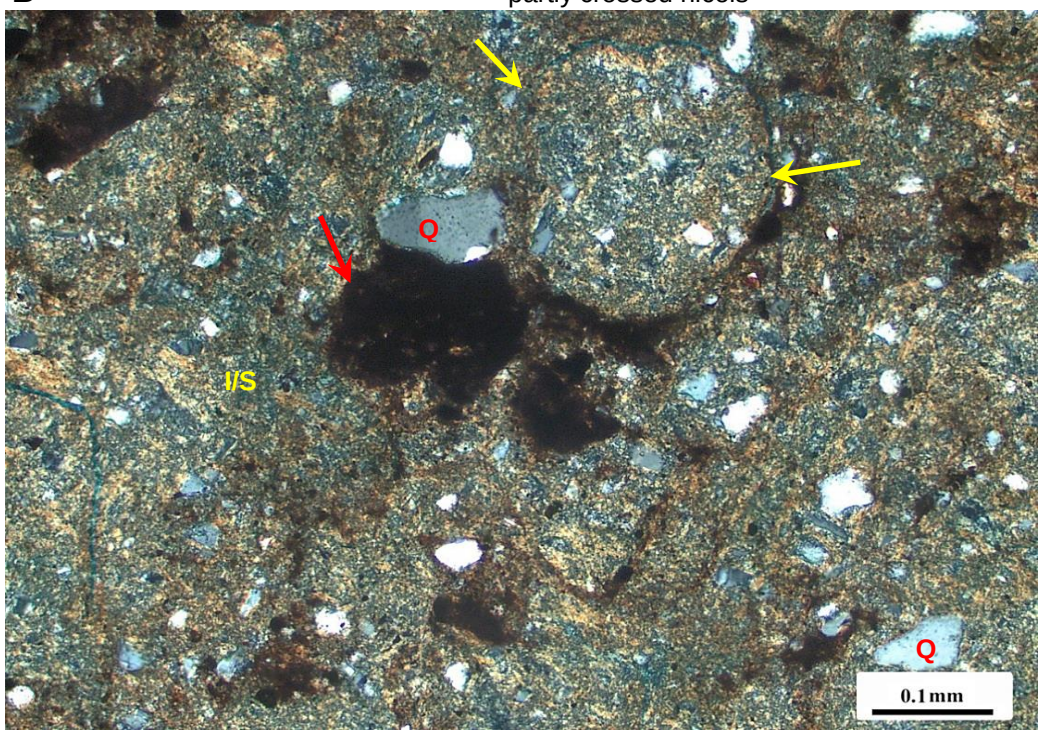
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 899.12
Sample ID: PSH 5

A



B partly crossed nicols



Sample Description

Lithology: **slightly sandy claystone**

Est.Classif. (Folk, 1980): na
Grain size range: silt - medium sand
Grn.Sorting: poor

Structures:
massive to mottled with clay globules and sparse scattered sand grains; hematitic clasts and matrix

Framework Grains:
common quartz; minor K-feldspar, plagioclase and plutonic lithic fragments, argillaceous intraclasts (hematite-stained)

Accessory Grains:
trace heavy minerals

Matrix:
abundant clay matrix

Cements:
irregular hematite stain of clay matrix and some clay clasts

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	20.9	Goethite	0.0
K-Feldspar	3.0	Hematite	0.9
Plagioclase	1.2	Pyrite	0.0
Calcite	0.0	Total Clay	73.9

Clay Abundance (Weight %)

Illite / Smectite	57.4	Kaolin*	10.1
Illite & Mica	3.1	Chlorite	3.3

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a slightly sandy claystone. Sand and silt grains are poorly sorted and supported in the mixed-layer illite/smectite (I/S) clay matrix. The fractures (frac) and oval "plucks" visible in Photo A are an artifact of the high smectite content of the matrix clay. Quartz is the most common grains type (Q). The yellow box in Photo A shows the location of Photo B. The clay matrix exhibits circular domains of aligned clay (yellow arrows) that are interpreted to reflect the presence of rooted zones, and the sample is interpreted to be a vertisol. Hematite (red arrows) stains some clay clasts.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*: na
Permeability (md)*: na
Grain Density (g/cc): na
**Core analysis data taken at na psi*

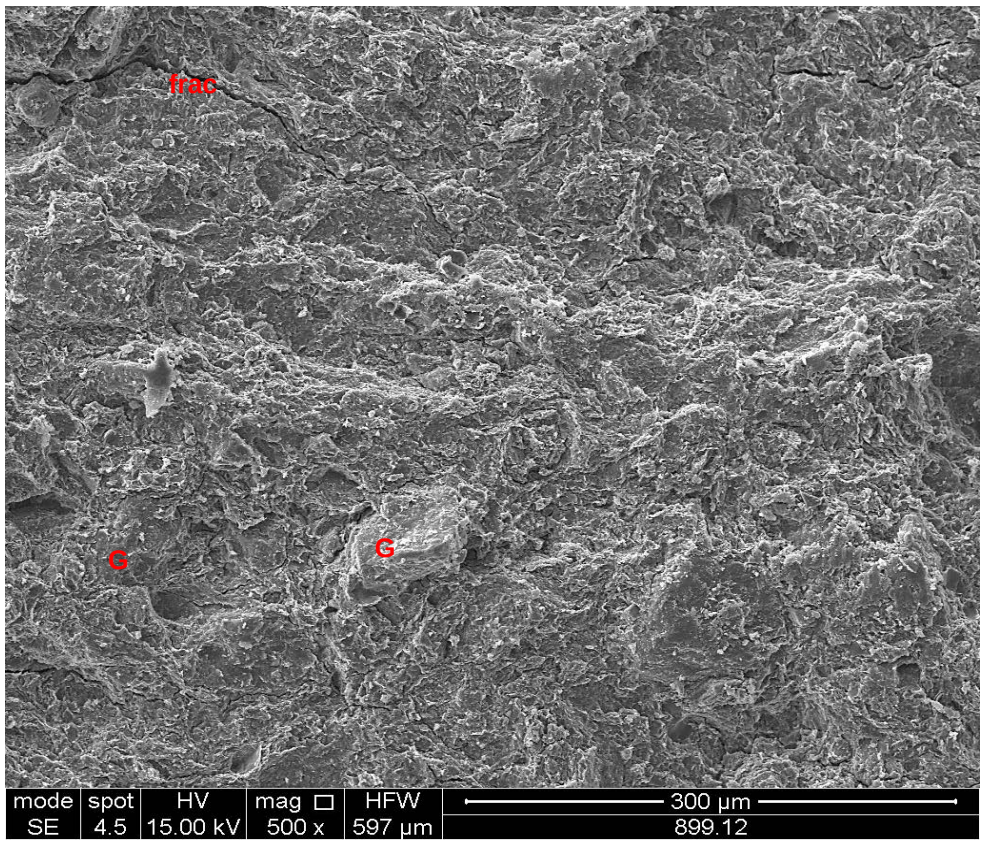
PLATE 30 (cont'd)

Scanning Electron Microscopy

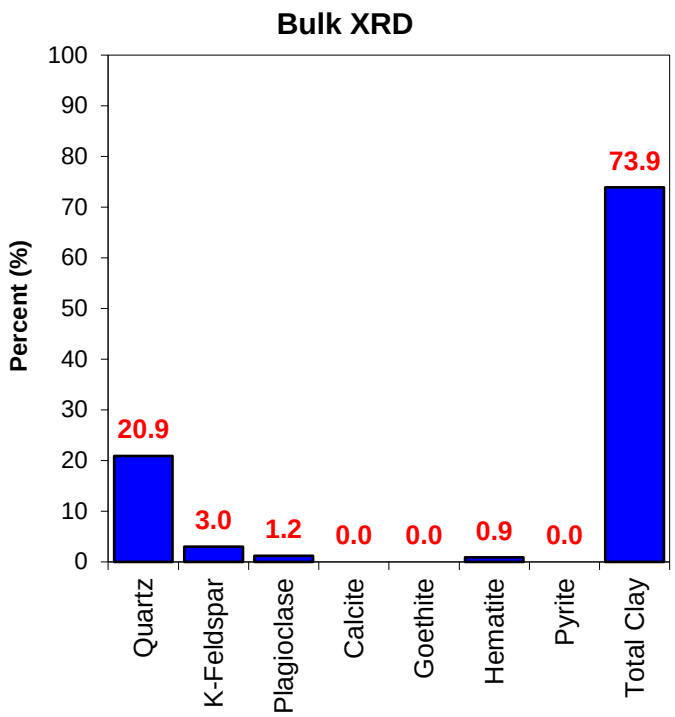
Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 899.12
Sample ID: PSH 5

Lithology: slightly sandy claystone

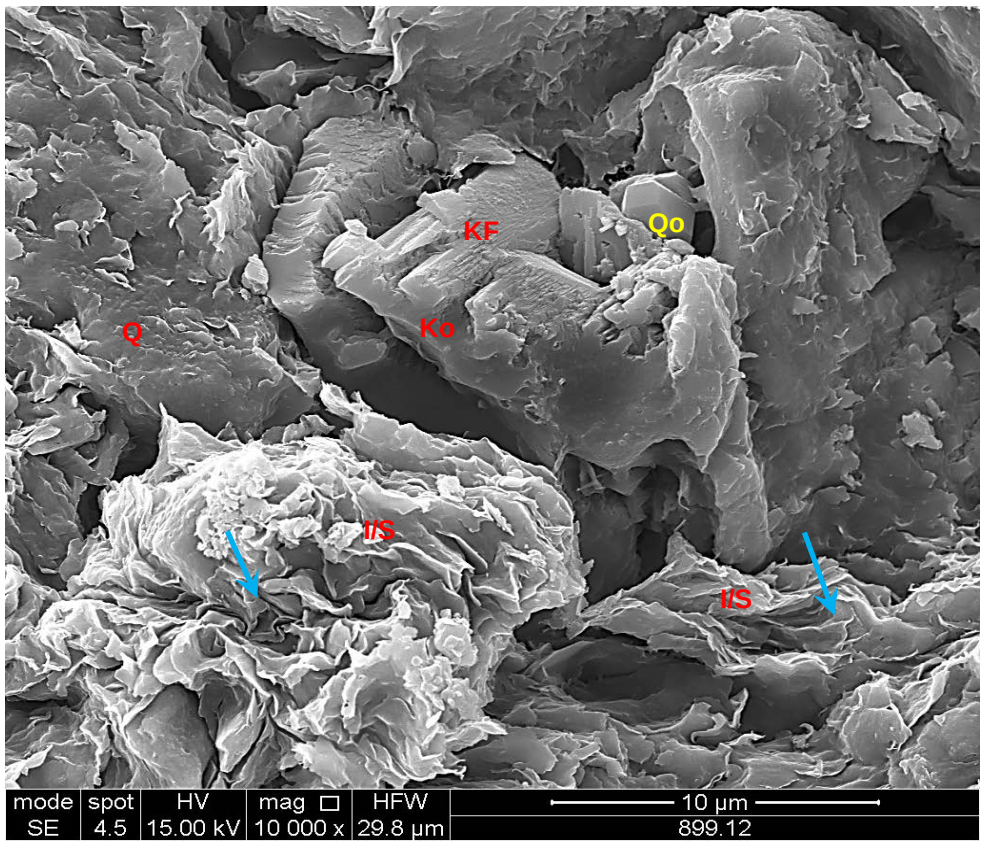
C

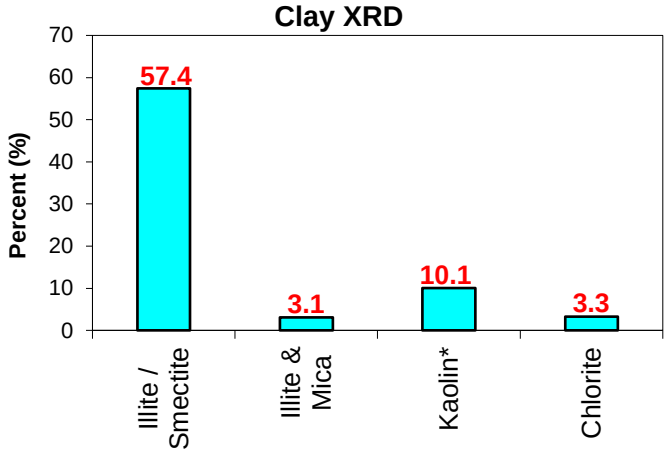


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

This slightly sandy claystone is composed principally of smectite-rich mixed-layer illite/smectite (I/S) clay. The fracture (frac) is induced, from the swelling clay. Quartz is the second most abundant mineral by XRD and one grain is identified in Image D. K-feldspar grains are also present (KF). SEM Image C shows very few grains (G) in the clay matrix. The high magnification image of the clay matrix indicates the illite/smectite (I/S) matrix clay is microporous (blue arrows). Authigenic minerals include quartz overgrowths (Qo) and K-feldspar overgrowths (Ko).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

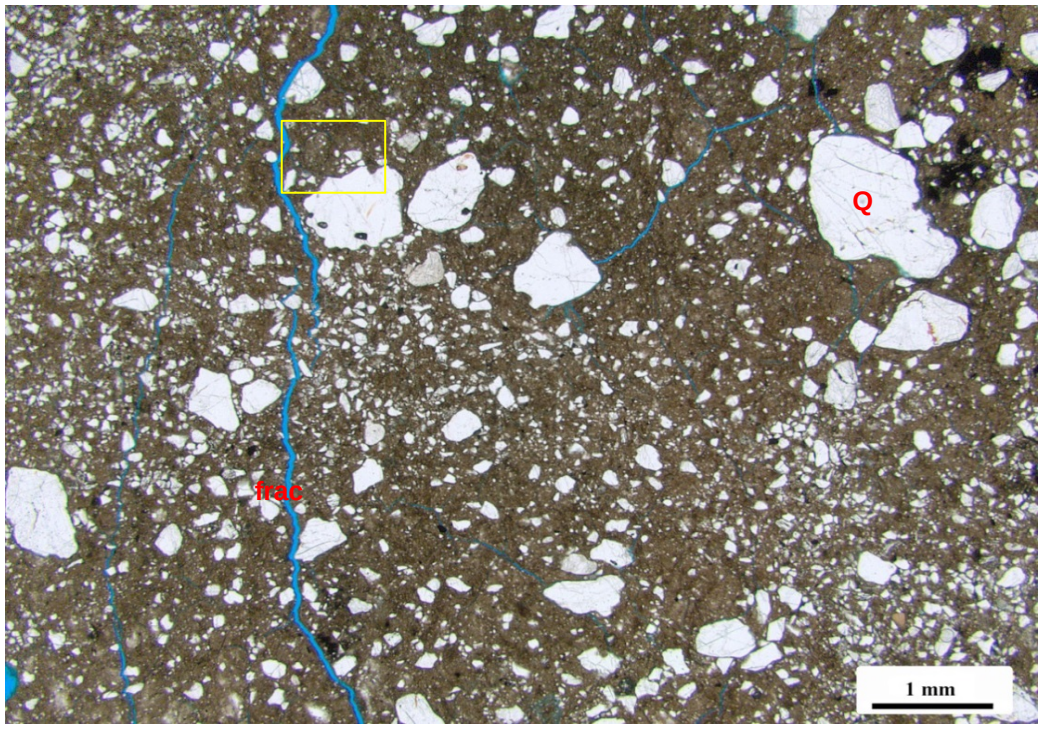
**Core analysis data taken at na psi*

PLATE 31

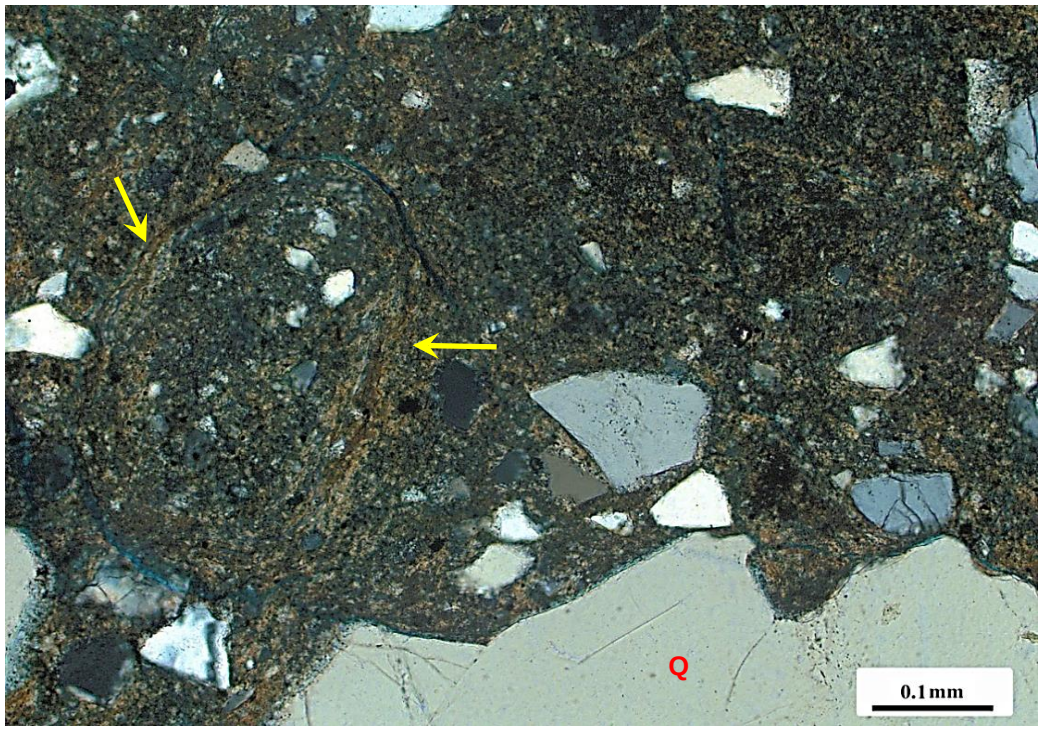
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 902.78
Sample ID: PSH 7

A



B crossed nicols



Sample Description

Lithology: **sandy claystone**

Est.Classif. (Folk, 1980): quartzarenite
Grain size range: silt-very coarse sand
Grn.Sorting: poor

Structures:
massive; grains are clay matrix supported; vague fracture (vertisol) overprint with hematite-stained fracture-fill

Framework Grains:
abundant quartz, minor plutonic lithic fragments and K-feldspar

Accessory Grains:
minor opaque minerals; trace heavy minerals

Matrix:
abundant clay matrix

Cements:
irregular hematite stain of clay matrix and along microfractures or root traces

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	43.1	Goethite	0.0
K-Feldspar	3.9	Hematite	1.5
Plagioclase	1.9	Pyrite	0.0
Calcite	0.0	Total Clay	49.6

Clay Abundance (Weight %)

Illite / Smectite	39.2	Kaolin*	4.2
Illite & Mica	4.0	Chlorite	2.2

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This sample is a sandy claystone. Sand and silt grains are poorly sorted and supported in the clay matrix. The fractures visible in Photo A are an artifact of the high smectite content of the claystone. Quartz is the most common grain type (Q). The yellow box in A shows the location of Photo B. The clay matrix exhibits circular domains of aligned clay (yellow arrows) that are interpreted to reflect the presence of rooted zones, and the sample is interpreted to be a vertisol.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

**Core analysis data taken at na psi*

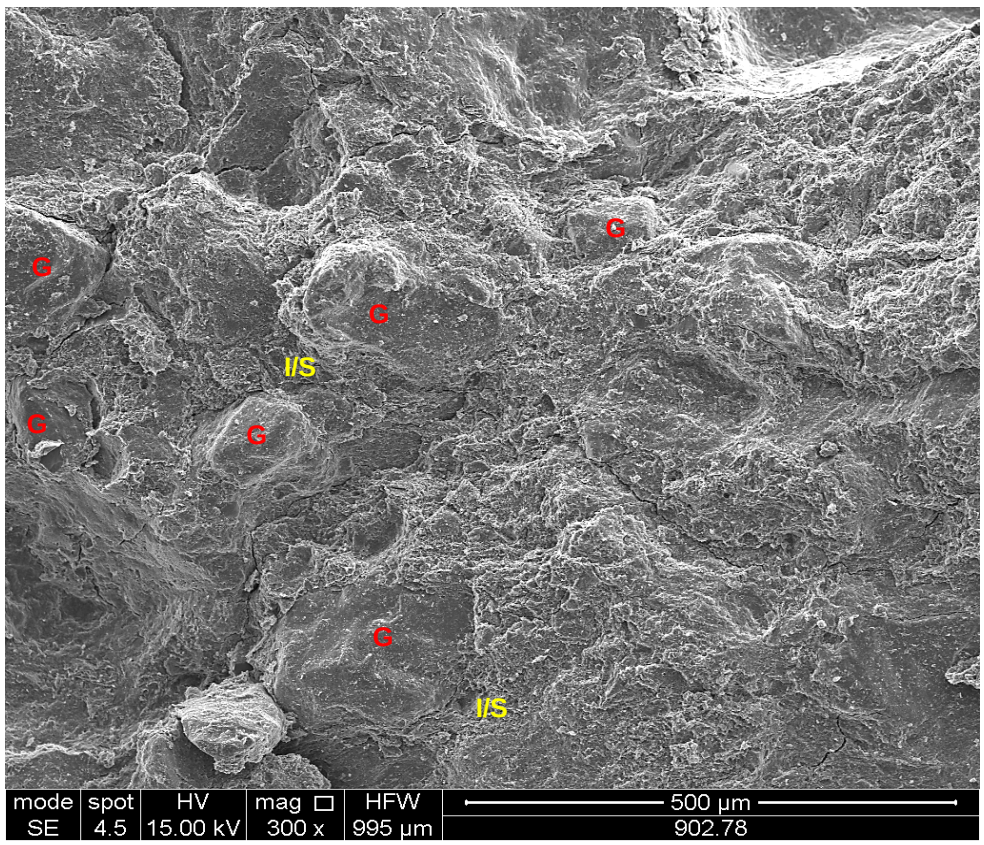
PLATE 31 (cont'd)

Scanning Electron Microscopy

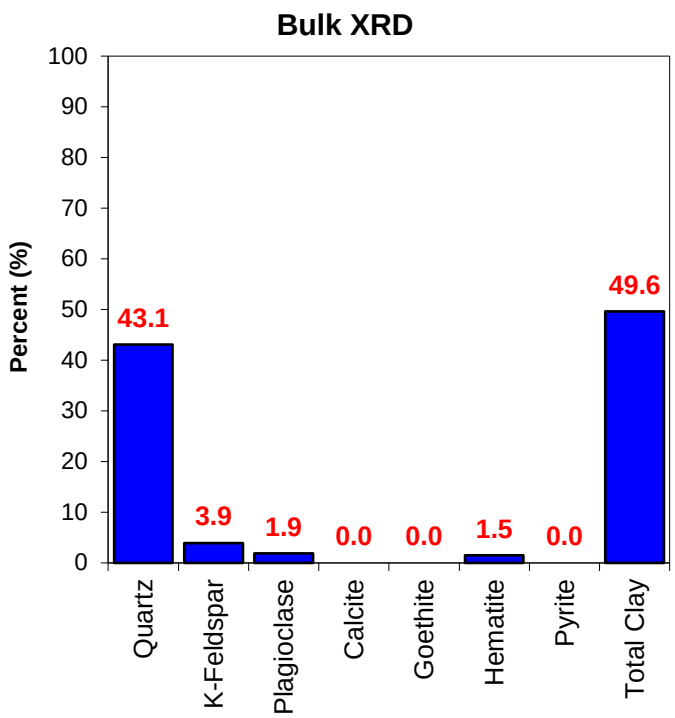
Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 902.78
Sample ID: PSH 7

Lithology: sandy claystone

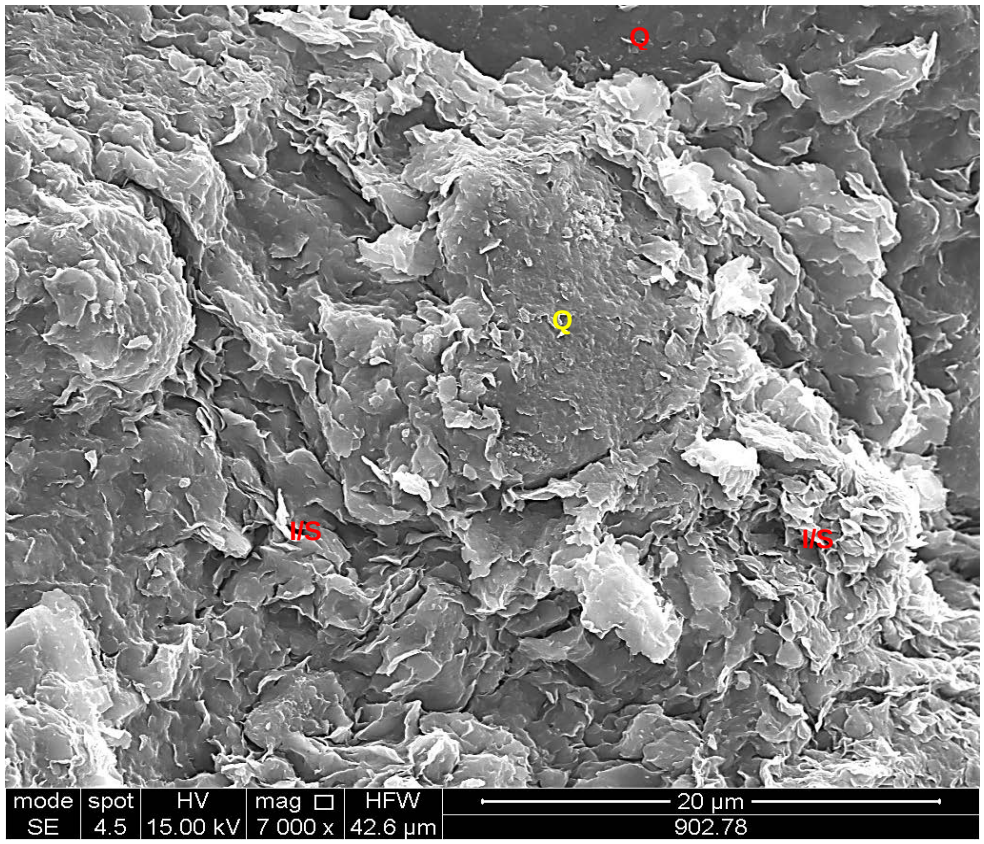
C

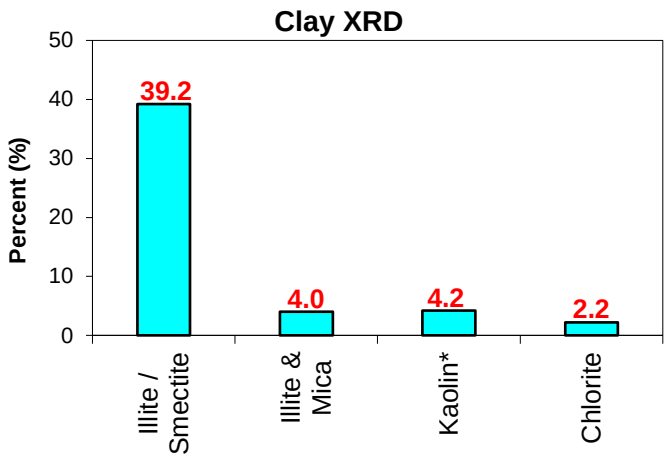


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM image C shows the massive fabric, with grains (G) supported in an abundant clay matrix (I/S). XRD analysis indicates that this sample is composed principally of smectite-rich mixed-layer illite/smectite (I/S) clay. Quartz (Q) is the second most abundant mineral and EDS analysis shows the location of several grains in Image D. The clay matrix exhibits interparticle micropores.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

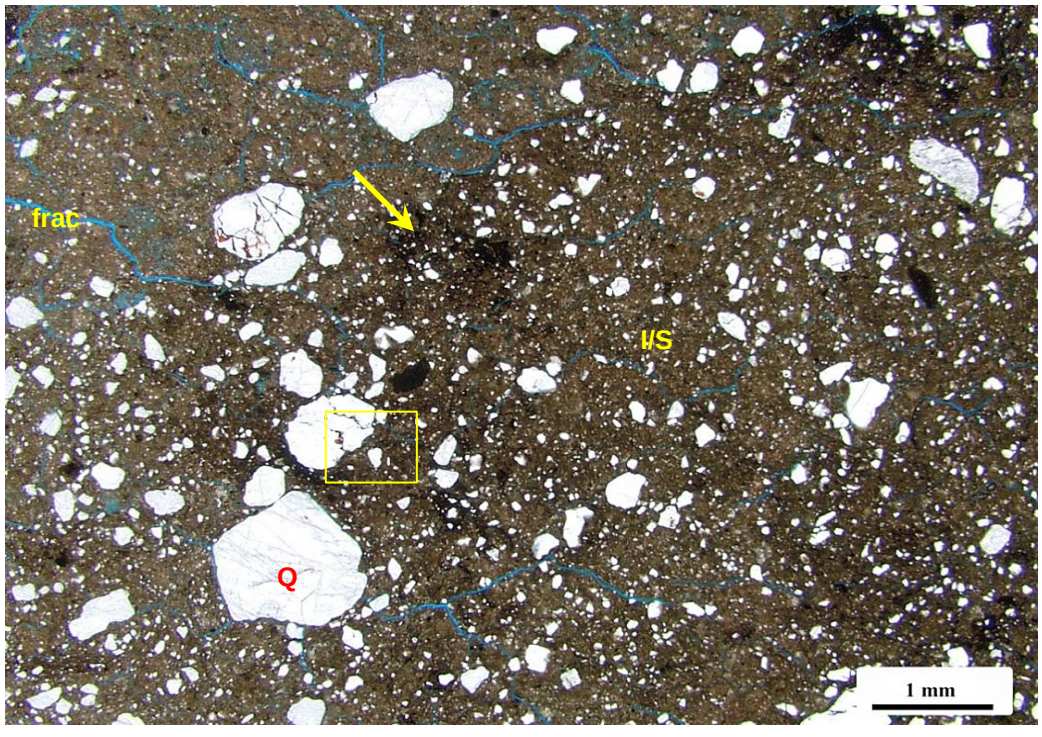
**Core analysis data taken at na psi*

PLATE 32

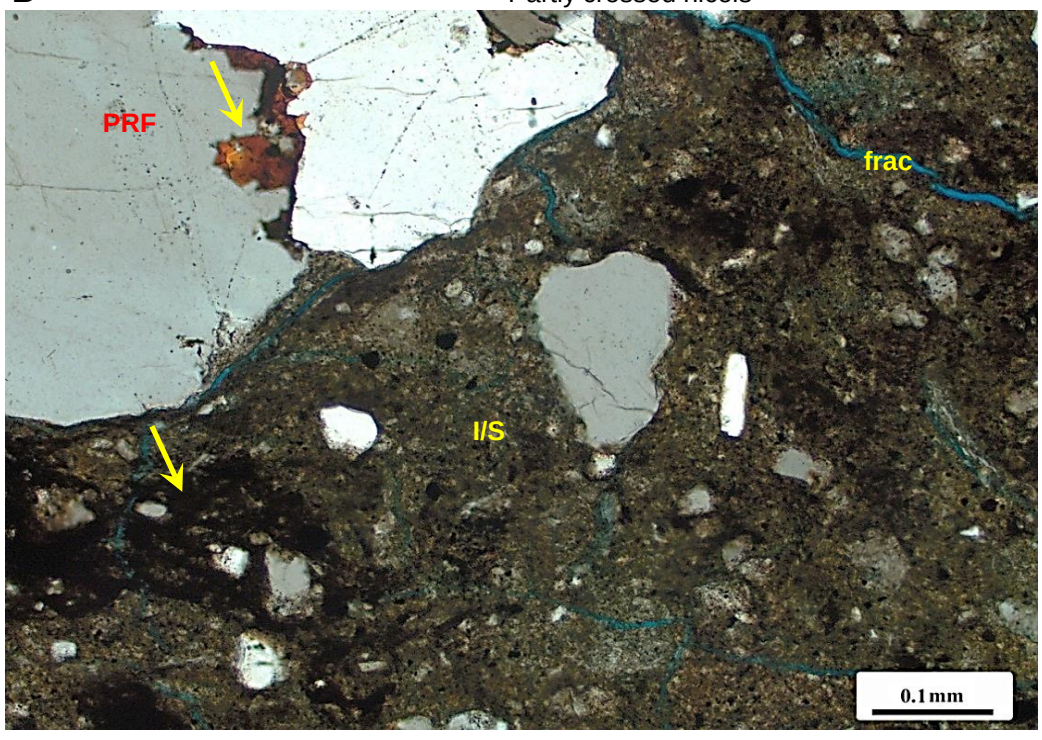
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 906.33
Sample ID: PSH 10

A



B Partly crossed nicols



Sample Description

Lithology: **sandy claystone**

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): silt-very coarse sand
Grn.Sorting: poor

Structures:
massive; grains are clay matrix supported; vague fracture (vertisol) overprint with hematite-stained fracture-fill

Framework Grains:
abundant quartz, minor plutonic lithic fragments and K-feldspar

Accessory Grains:
trace heavy minerals

Matrix:
abundant clay matrix

Cements:
irregular hematite stain of clay matrix and along microfractures or root traces

Pore Types:
no macropores observed

XRD-Whole Rock Mineralogy (Weight %)

Quartz	31.4	Goethite	0.0
K-Feldspar	2.4	Hematite	0.4
Plagioclase	1.3	Pyrite	0.0
Calcite	0.0	Total Clay	64.5

Clay Abundance (Weight %)

Illite / Smectite	50.9	Kaolin*	8.0
Illite & Mica	3.1	Chlorite	2.5

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Photo A shows the abundant mixed-layer illite/smectite clay matrix (I/S) and scattered, poorly sorted grains that characterize this sandy claystone. XRD analysis indicates that the mixed-layer clay is highly smectitic. The blue epoxy-filled fractures (frac) are induced: a consequence of the abundant swelling clay. Grains identified include quartz (Q) and plutonic lithic fragments (PRF). The yellow arrows indicate traces of hematite along crystal boundaries and staining the matrix.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

**Core analysis data taken at na psi*

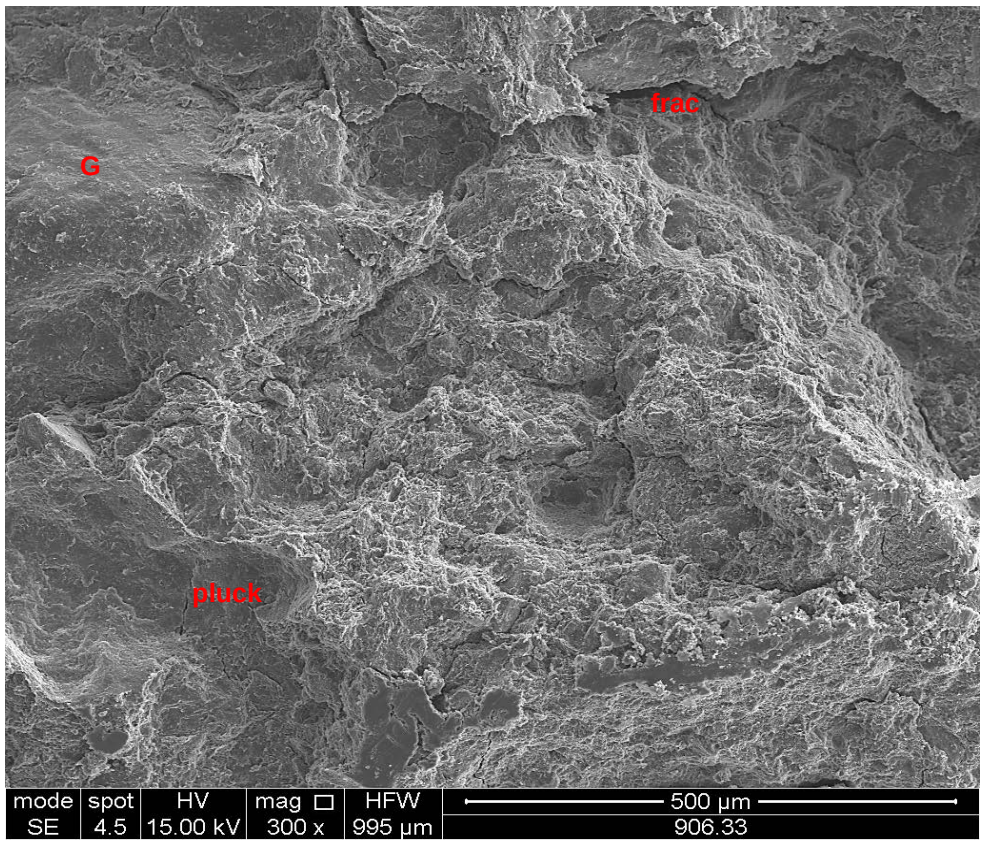
PLATE 32 (cont'd)

Scanning Electron Microscopy

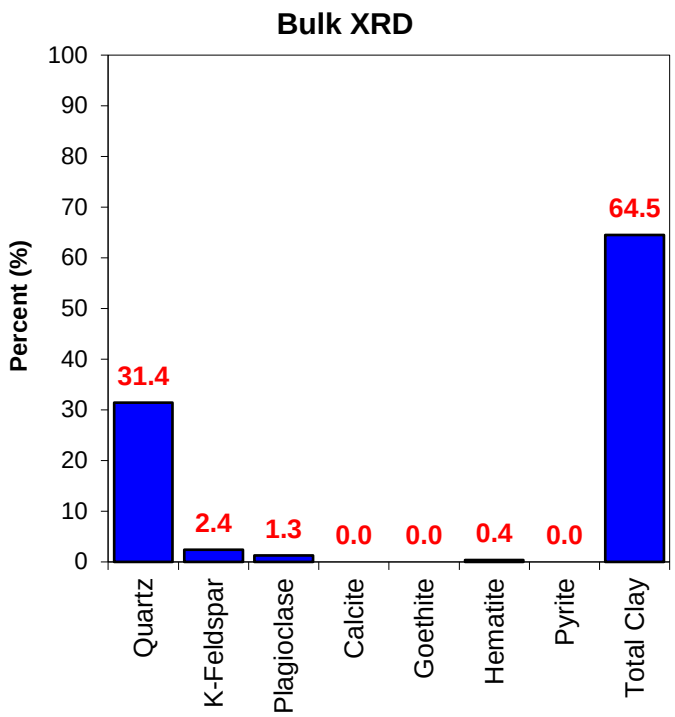
Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Eneabba shale
Depth (m): 906.33
Sample ID: PSH 10

Lithology: sandy claystone

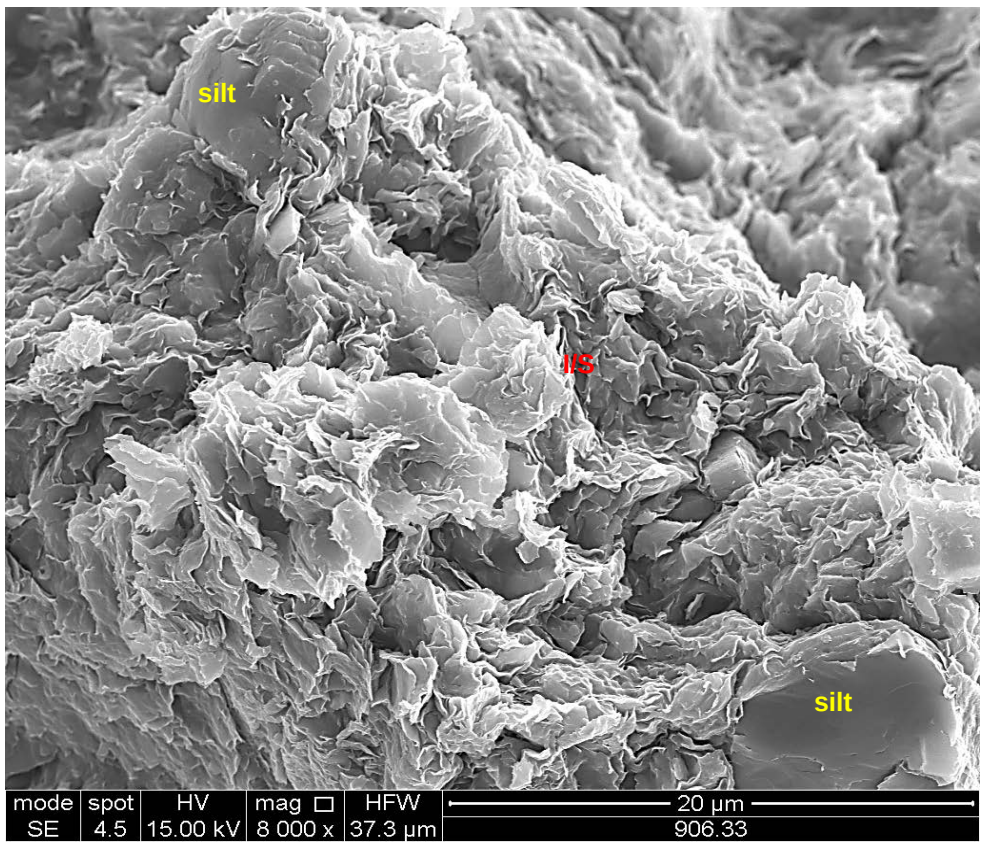
C

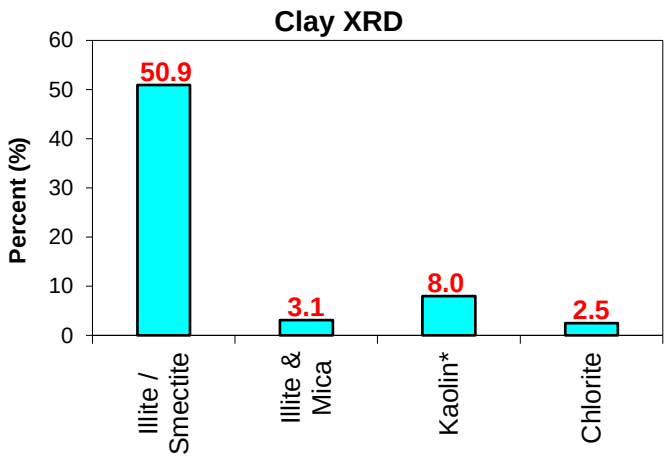


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

This sandy claystone is composed principally of smectite-rich mixed-layer illite/smectite (I/S) clay. Quartz is the second most abundant mineral by XRD. SEM image C shows areas with grains (G) and plucked grains (pluck) in the clay matrix. The fracture (frac) is induced, from the swelling clay. The high magnification image of the clay matrix indicates the matrix clay is microporous.

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	na
Permeability (md)*:	na
Grain Density (g/cc):	na

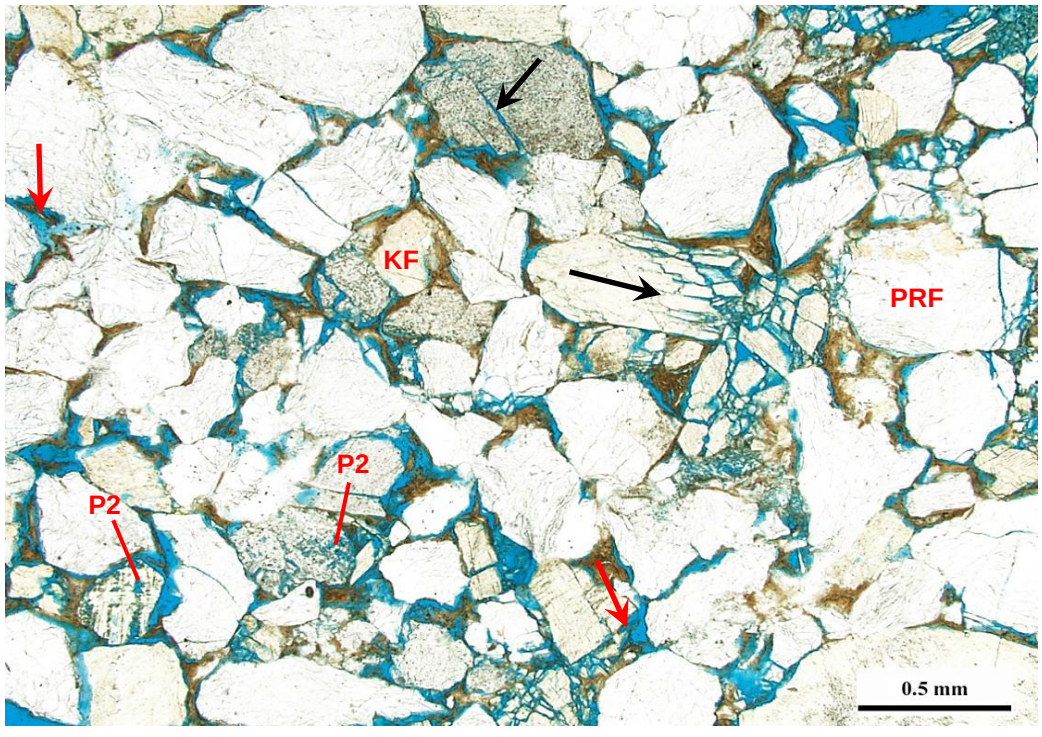
**Core analysis data taken at na psi*

PLATE 33

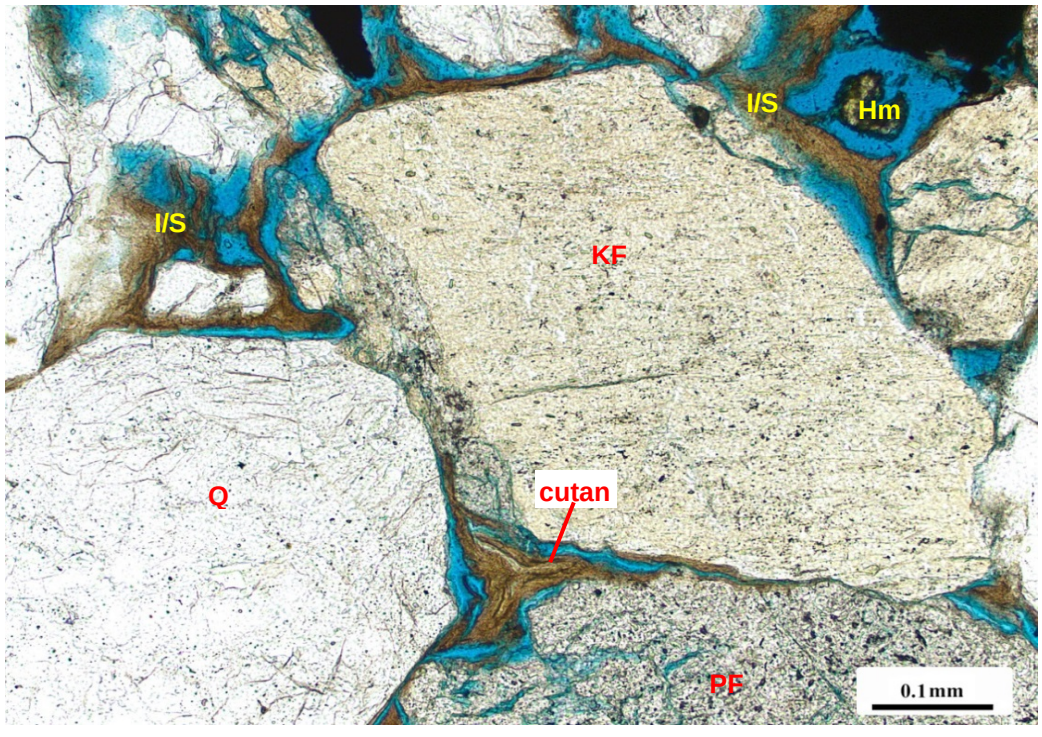
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1326.25
Sample ID: 1A

A



B



Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): subarkose
Grain Size (mm): 0.607 (Coarse sand)
Grn.Sorting: moderately well

Structures:
massive; moderate compaction (long grain contacts); some feldspar grains exhibit intragranular fractures

Framework Grains:
abundant quartz; common K-feldspar; moderate plutonic lithic fragments and plagioclase

Accessory Grains:
trace magnetite, epidote, garnet

Matrix:
common mechanically infiltrated clay (cutans)

Cements:
trace intragranular kaolinite, pyrite

Pore Types:
minor intergranular and intragranular dissolution pores in feldspars; trace intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	44.3	Goethite	0.0
K-Feldspar	25.7	Hematite	0.0
Plagioclase	13.8	Pyrite	0.0
Calcite	0.0	Total Clay	16.2

Clay Abundance (Weight %)

Illite / Smectite	12.8	Kaolin*	0.7
Illite & Mica	2.4	Chlorite	0.3

%smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

Framework grains include abundant quartz (Q; mostly monocrystalline and minor polycrystalline), K-feldspar (KF; stained yellow), plagioclase (PF), and plutonic lithic fragments (PRF) that include quartz, microcline and plagioclase. A heavy mineral grain (Hm) shows partial dissolution. The matrix occurs as pervasive mechanically infiltrated clay cutans (cutan). XRD analysis indicates that the cutans are composed of smectite-rich mixed-layer illite/smectite (I/S) clay. Minor amounts of intragranular pores (P2) are associated with K-feldspar (KF). The red arrows indicate intergranular pores. Some K-feldspar grains show intragranular fractures (black arrows).

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.00
Permeability (md)*:	371.0
Grain Density (g/cc):	2.63

**Core analysis data taken at 1250 psi*

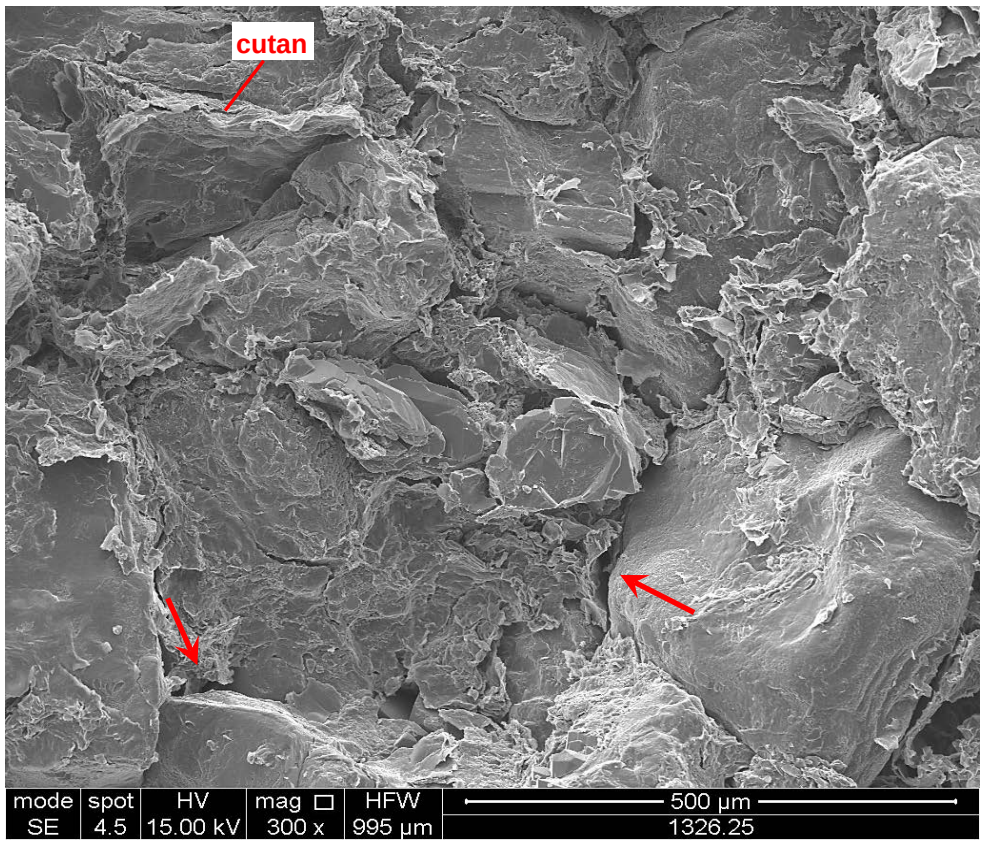
PLATE 33 (cont'd)

Scanning Electron Microscopy

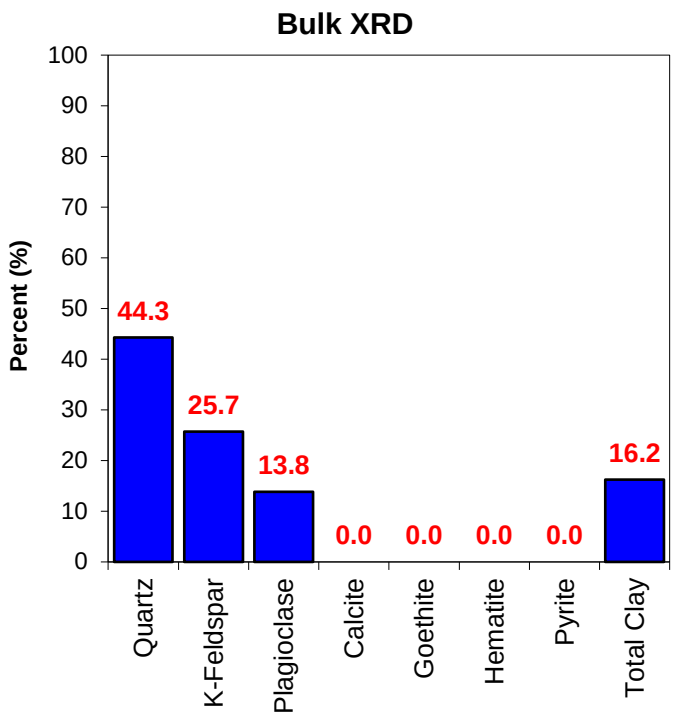
Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1326.25
Sample ID: 1A

Lithology: sandstone

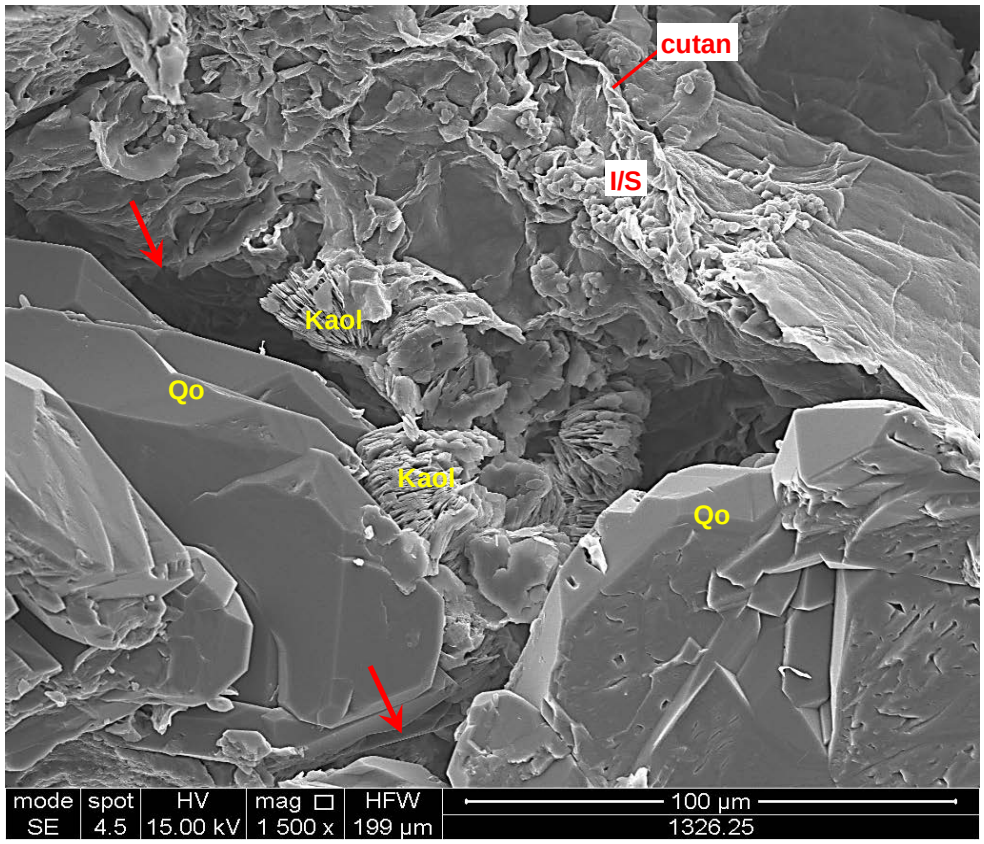
C

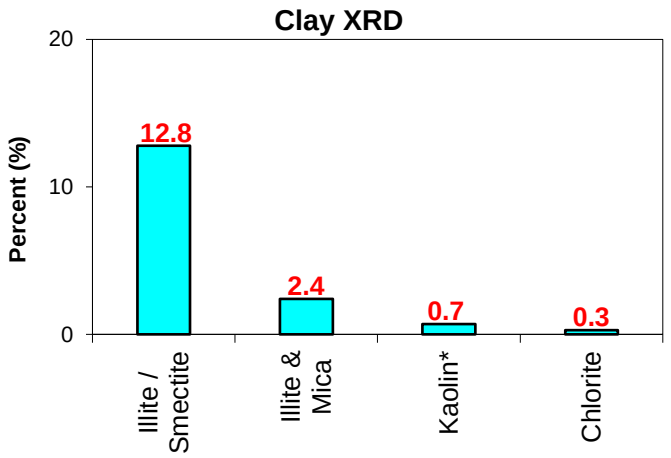


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 60-70
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM and EDS analysis shows that most grains are coated by smectite-rich mixed-layer illite/smectite (I/S) clay in the form of cutans (cutan). The cutans are mechanically-infiltrated clay and the clay platelets are oriented parallel to grain surfaces. Intergranular areas are indicated by the red arrows. Euhedral quartz overgrowths (Qo) reduce the intergranular areas. Traces of kaolinite (Kaol) occurs in intergranular areas.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	20.00
Permeability (md)*:	371.0
Grain Density (g/cc):	2.63

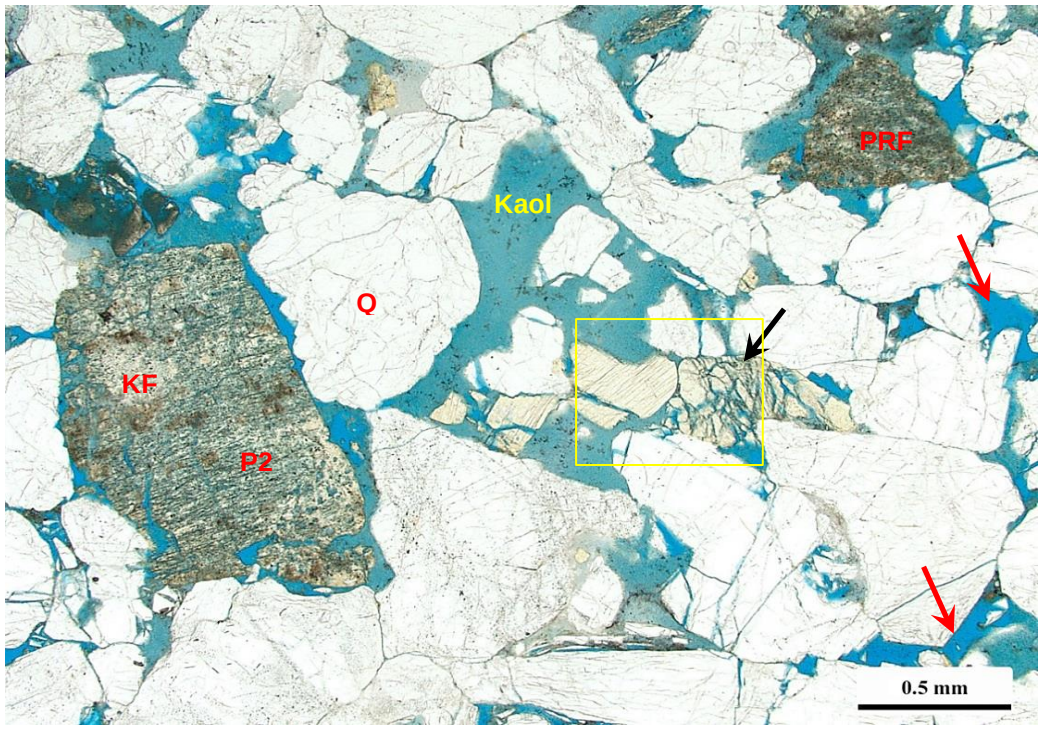
**Core analysis data taken at 1250 psi*

PLATE 34

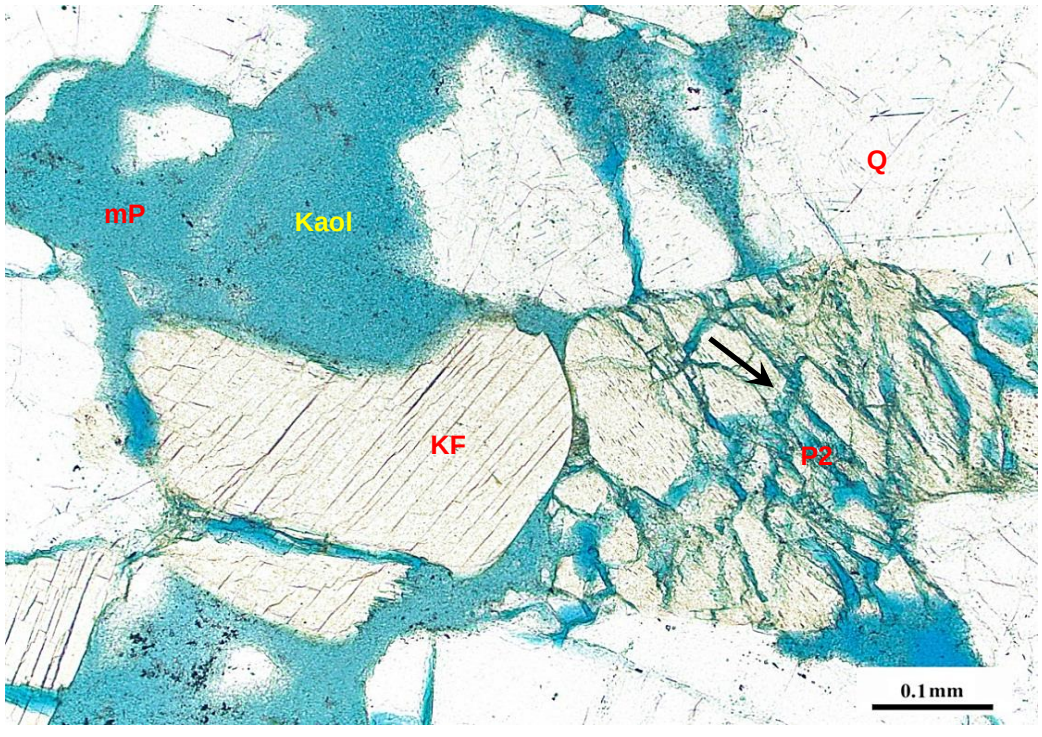
Thin Section Petrography

Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1793.00
Sample ID: 4

A



B



**The GSWA is currently reviewing the stratigraphy of the southern Perth Basin, including the usage of units originally defined in the northern Perth Basin. Formation names and tops quoted in the DMP's Harvey studies are therefore preliminary and may be subject to change following this review.*

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	21.10
Permeability (md)*:	2230.0
Grain Density (g/cc):	2.64

**Core analysis data taken at 1700 psi*

Sample Description

Lithology: sandstone

Est.Classif. (Folk, 1980): quartzarenite
Grain Size (mm): 1.195 (Coarse sand)
Grn.Sorting: well

Structures:
massive; moderate compaction (long grain contacts); feldspar grains exhibit intragranular fractures; long to concavo-convex grain contacts indicates moderate to strong compaction

Framework Grains:
abundant quartz; moderate K-feldspar and plutonic lithic fragments; minor altered biotite

Accessory Grains:
minor muscovite, biotite (mostly altered to kaolinite/dickite); trace garnet, zircon, amphibole

Matrix:
none observed

Cements:
abundant intergranular kaolinite; minor quartz overgrowths, pyrite, dickite replacement of biotite flakes

Pore Types:
moderate intergranular pores; minor intragranular pores (in feldspars); moderate intercrystal micropores associated with kaolinite

XRD-Whole Rock Mineralogy (Weight %)

Quartz	70.7	Goethite	0.0
K-Feldspar	11.8	Hematite	0.0
Plagioclase	0.4	Pyrite	0.0
Calcite	0.0	Total Clay	17.1

Clay Abundance (Weight %)

Illite / Smectite	1.9	Kaolin*	12.5
Illite & Mica	1.4	Chlorite	1.3

%smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Photomicrograph Caption

This coarse-grained sandstone is composed of abundant quartz (Q) and lesser K-feldspar (KF; stained yellow) and plutonic lithic fragments (PRF). Moderate compaction is indicated by point and long grain contacts (Photo A) and fractured K-feldspar grains (black arrows). Authigenic minerals include quartz overgrowths and kaolinite (Kaol). Pore types include intergranular pores (blue epoxy; red arrows), intragranular dissolution pores in K-feldspar (P2), and intercrystal micropores (mP) associated with authigenic kaolinite (blue haze coloration).

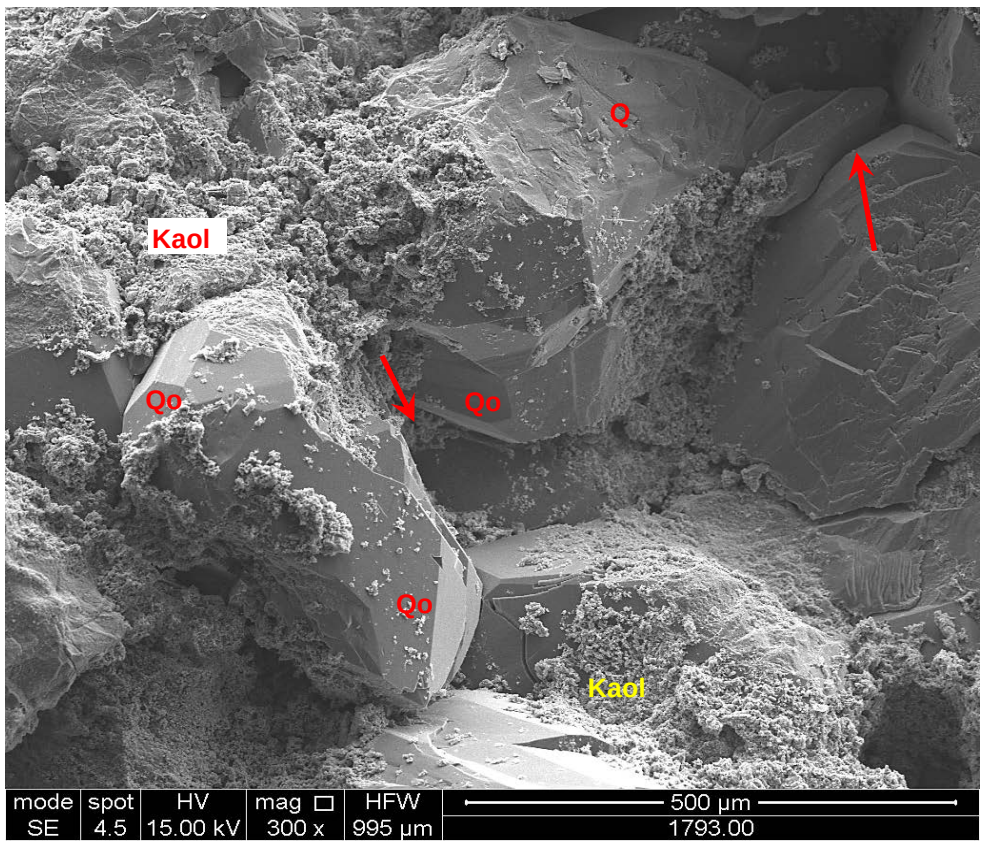
PLATE 34 (cont'd)

Scanning Electron Microscopy

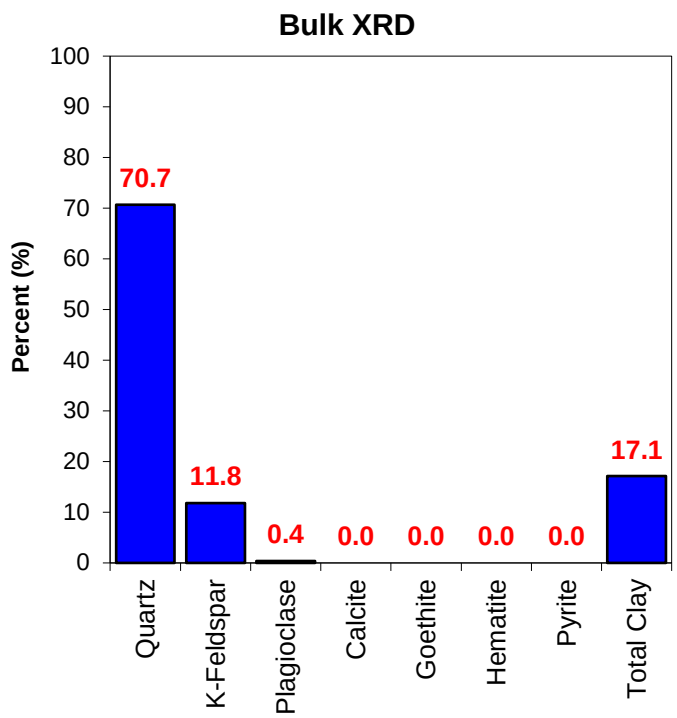
Company: Australia Department of Mines and Petroleum
Well: Harvey-4
Location: Perth Basin, Australia
Formation*: Yalgorup Mbr.
Depth (m): 1793.00
Sample ID: 4

Lithology: sandstone

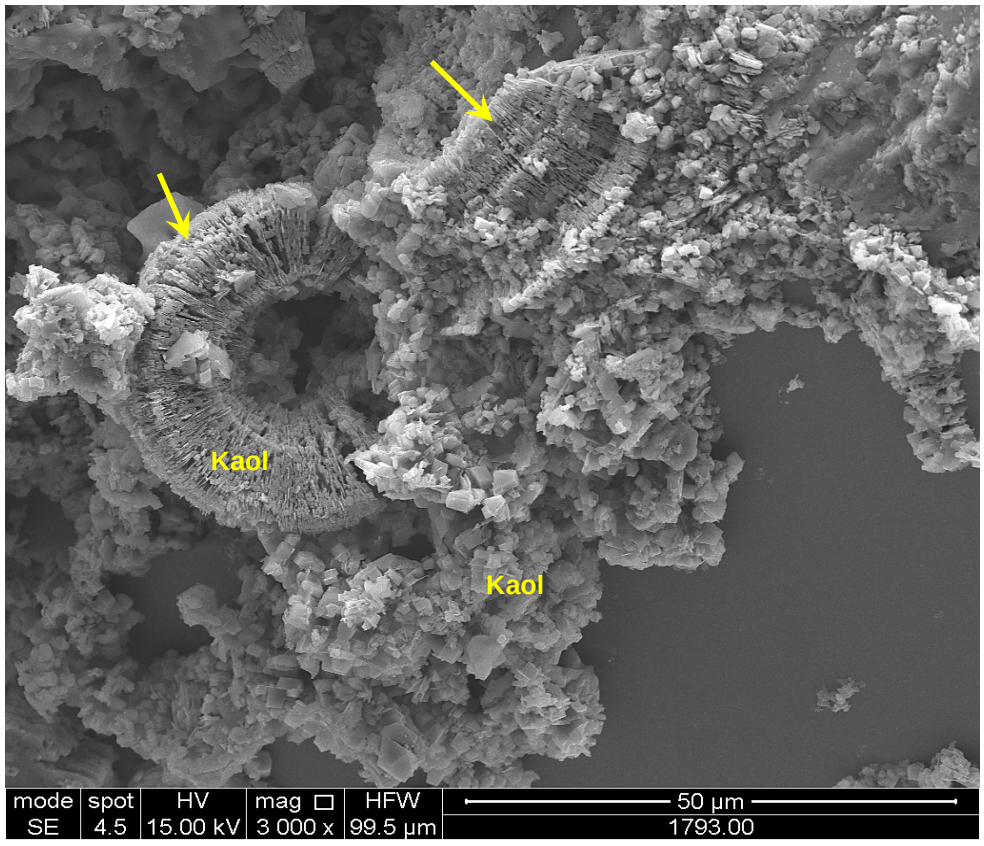
C

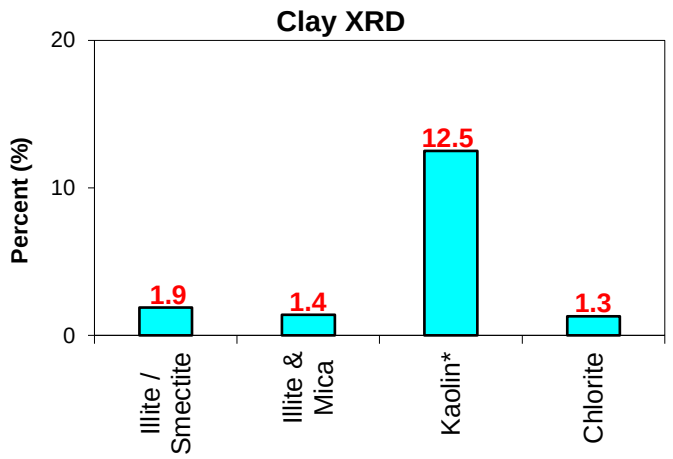


Mineralogy Determined by X-Ray Diffraction (Wt %)



D





%Smectite in mixed-layer illite/smectite is 25-35
**Kaolin includes both kaolinite and dickite*

Micrograph Caption

SEM images show that this coarse-grained sandstone is cemented with syntaxial quartz overgrowths (Qo) on detrital quartz grains (Q) and highly microporous kaolinite (Kaol). Vermiform kaolinite is indicated by the arrows in image D. Intergranular pores bounded by quartz overgrowths are indicated by the red arrows.

Core Lab
RESERVOIR OPTIMIZATION

Relative Abundances:

Trace	**<1%**
Minor	**1-5%**
Moderate	**5-10%**
Common	**10-20%**
Abundant	**>20%**

Core Analysis Data:

Porosity (%)*:	21.10
Permeability (md)*:	2230.0
Grain Density (g/cc):	2.64

**Core analysis data taken at 1700 psi*