PETROGRAPHIC REPORT ON FOURTEEN ROCK SAMPLES: SURAT-BOWEN BASIN STUDY, QUEENSLAND

For

International Base Metals Limited

Reference: letters from Garry Baglin dated 10-10-07 and 5-11-07

P.M. Ashley (MAusIMM, FSEG)
Paul Ashley Petrographic and Geological Services
37 Bishop Crescent
Armidale
NSW 2350
Phone: 02 6772 8293, email: pashley@une.edu.au

ABN 59 334 039 958

December, 2007

Report #463

P. M. Astley

SUMMARY

Two separate batches of rock samples derived from a study of the Surat and Bowen Basins in Queensland were submitted for petrographic preparation, description and interpretation. The first batch of nine samples, labelled 01412 (surface rock sample) and 01441-01448 (drill core samples) was submitted in October, 2007. The second batch of five samples, labelled 01449-01453, comprising drill core, was submitted in November, 2007. Polished thin sections were prepared from each sample following impregnation of the sample offcuts in blue resin. Subsequently, the sections were examined microscopically in transmitted and reflected light. Photomicrographs were taken of selected textural and mineralogical features. Magnetic susceptibility was measured on all samples; readings were all very low except for two carbonate-rich samples (01445, 01446) that displayed low-moderate susceptibility. Carbonate-rich samples were tested with dilute HCl and the lack of reaction suggested that the carbonate was not calcite.

Summary descriptions of all the samples in the two batches are listed following:

01412 PTS

Summary: Siltstone, grading to fine grained sandstone, with well preserved relict detrital grain texture and later strong impregnation of matrix material by supergene Fe oxide phases. The sedimentary rock has angular to sub-rounded detrital grains, dominated by quartz, but with lesser amounts of fine grained quartz-rich and clay-rich lithic grains, K-feldspar and a little detrital muscovite, Fe oxide (hematite), leucoxene/rutile, tourmaline and zircon. The subordinate matrix component is probably composed of diagenetically developed, finely crystallised clay (e.g. kaolinite). Strong impregnation of the rock by hematite, or by goethite, is interpreted as a weathering-related phenomenon. The boundary between hematite-pigmented and goethite-pigmented domains is transgressive to diagenetic "flattening" in the rock.

01441 PTS

Summary: Massive, medium grained quartz-rich sandstone (orthoquartzite), with a minor clay-rich matrix component and considerable interstitial void space, causing the rock to be rather friable. Detrital quartz grains may have been slightly polygonised due to diagenetic alteration. There is a small population of detrital fine grained lithic grains and traces of muscovite, tourmaline, hornblende and rutile. The minor matrix clay component might be kaolinitic and also contains a tiny trace of diagenetic fine grained pyrite.

01442 PTS

Summary: Fine to medium grained quartz-rich sandstone with local clay-rich partings containing slight carbonaceous pigmentation. The rock also displays minor detrital muscovite and fine grained lithics and shows patchy replacement of clay-rich matrix by fine to medium grained pyrite. The rock appears to have undergone diagenetic alteration under reducing conditions.

01443 PTS

Summary: Fine to medium grained quartz (-lithic-feldspar) sandstone with thin shale/siltstone partings and displaying clay-rich matrix material and considerable replacement by fine grained carbonate cement. The sandstone has well preserved detrital grain texture and interstitial clay-rich matrix and the associated shale/siltstone laminations have slight pigmentation by carbonaceous material. The carbonate cement might be Fe-bearing (e.g. siderite/ankerite) and has an associated trace of fine grained pyrite.

01444 PTS
Summary: Fine to medium grained quartz (-lithic-feldspar) sandstone with irregular shale/siltstone laminations. Detrital grains are enclosed in a clay-rich matrix, with the shale/siltstone intercalations being matrix-dominated. Diagenetic alteration has caused patchy replacement of the matrix and detrital grains in the sandstone by fine grained Fe-bearing carbonate. There might also have been recrystallisation of the clayey matrix and claystone detrital lithic grains, as well as diffuse carbonaceous pigmentation.

01445 PTS
Summary: Fine grained chemically precipitated micritic carbonate-rich rock, locally grading into carbonate-bearing siltstone. The carbonate is probably Fe-bearing (e.g. siderite, ankerite) and textures suggest that it has partly replaced a pre-existing clastic sedimentary rock (e.g. siltstone). Surficial oxidation of the drill core has led to local replacement of carbonate by goethite (possibly Mn-bearing).

01446 PTS
Summary: Fine to medium grained siltstone, with scattered detrital grains and abundant clay-rich matrix, displaying extensive porphyroblastic development of fine to medium grained carbonate. The siltstone has detrital grains of quartz, K-feldspar and variably altered biotite, along with a trace of carbonised plant material. The replacement carbonate masses are interpreted to have grown during diagenetic alteration. They are likely to be Fe-bearing (e.g. siderite, ankerite).

01447 PTS
Summary: Medium to coarse grained quartz-rich sandstone, with a significant interstitial matrix component. Detrital grains are commonly sub-rounded and are mostly quartz, although there are a few fine grained clay-rich lithics present. The matrix ranges from kaolinitic to being dominated by strongly brownish pigmented clay/mica material, e.g. nontronite/celadonite. It is possible that there might have been a fine grained volcaniclastic component in the matrix prior to diagenetic alteration to the clay assemblage. A little fine grained disseminated goethite also occurs in the matrix.

01448 PTS
Summary: Weakly laminated fine to medium grained sandstone, grading into siltstone, with abundant quartz detrital grains, along with a significant amount of pelletal clay grains. The sandstone matrix, as well as the siltstone, are dominated by fine grained quartz, clay and a little muscovite/sericite. The rock exhibits extensive diagenetic goethite cement, but within goethite, there are traces of relict fine grained pyrite, suggesting that pyrite was originally more abundant, but was oxidised to goethite. The rock also contains a few clay-rich aggregates that might have developed diagenetically.

01449 PTS
Summary: Massive, medium grained, quartz-rich sandstone, with minor amounts of fine grained clay matrix and a little disseminated fine grained pyrite. In places, pyrite becomes more abundant, forming aggregates interstitial to detrital grains. The rock displays a moderate amount of porosity and locally, thin quartz overgrowths on detrital grains.

01450 PTS
Summary: Weakly laminated, fine grained siltstone, with dominant detrital quartz and minor amounts of detrital clay-rich lithics, muscovite, K-feldspar and plagioclase. There is a minor clay-rich matrix component and the rock has been affected by diagenetic growth of scattered small porphyroblastic carbonate aggregates and a couple of pyrite-rich aggregates.

<u>01451</u> **<u>PTS</u>**

<u>Summary</u>: Fine grained sandstone, grading to siltstone, with diffuse bedding laminations. The rock has abundant detrital quartz, but also minor fine grained lithic grains and K-feldspar, with a subordinate amount of fine grained sericite/clay matrix. There has been patchy replacement of matrix and detrital grains by porphyroblastic aggregates of pyrite, considered to have formed by diagenetic alteration.

<u>01452</u> **<u>PTS</u>**

<u>Summary</u>: Fine to medium grained quartz-rich sandstone, with a minor component of clay-rich matrix as well as minor porosity. Detrital grain texture is well preserved and quartz is accompanied by minor lithic detrital grains (clay-rich, chert) and a little muscovite and K-feldspar. Diagenetic alteration has led to development of a little disseminated pyrite in the matrix, locally grading into small aggregates that act as cement to detrital grains. There has also been slight development of quartz overgrowths on detrital grains.

<u>01453</u> **<u>PTS</u>**

<u>Summary</u>: Medium to coarse grained quartz-rich sandstone, with interstitial clay-rich matrix as well as minor porosity. Detrital grains are sub-rounded to sub-angular and are dominated by quartz. In places there are thin quartz overgrowths on detrital grains. Matrix clay is finely crystalline and probably kaolinite. It contains traces of fine grained disseminated pyrite, but in one part of the sample, matrix clay has been replaced by semi-continuous pyrite aggregates, acting as a cement to detrital grains.

Samples in the suite exhibit a range of sedimentary rock types, mostly clastic in origin, that have undergone diagenetic alteration. The samples are dominated by fine grained through to medium to coarse grained sandstone, but with intercalation with, and gradation to, fine grained siltstone (and locally to shale). Samples 01445 and 01446 are carbonate-rich, but much of the carbonate might be diagenetic in origin (see later) and may not necessarily mean abundant carbonate deposition at the time of formation of the sedimentary rock.

Detrital grain textures are generally well preserved in the samples. There are also sedimentary bedding laminations, defined by differences in compositions and grainsizes. Where observed, the bedding laminations are at high angles to the core axis. Detrital grains tend to range from sub-rounded to angular, with higher degrees of rounding in the more quartz-rich sandstones. Grainsize of detrital grains ranges from typically 0.3-3 mm in sandstones (although mostly <1 mm) to <0.3 mm in siltstones and <0.05 mm in a few shaly intercalations. The carbonate-rich samples also display fine grainsize, although no detrital grain textures are evident in the carbonate (although they are present in associated siltstone).

Sandstones and siltstones are commonly dominated by quartz, with some of the sandstones being orthoquartzites and having >90% of detrital grains being composed of quartz. The sandstones also typically have a minor lithic detrital grain component and this component, along with small amounts of detrital K-feldspar, muscovite, altered biotite (variably chloritised) and trace amounts of other accessory phases (e.g. zircon, tourmaline, rutile/leucoxene, plagioclase, carbonaceous fragments (phytoliths: former plant material) and rare chlorite, celadonite, ilmenite and hornblende, tends to increase with decreasing grainsize. In other words, some of the finer grained sandstones, and the siltstones, tend to have a higher proportion of lithics, K-feldspar, micas and the accessory phases, as well as a considerably higher matrix component.

Detrital lithic grains are fine grained and include claystone (fine grained kaolinitic clay), chert and sericite ± quartz material (e.g. low grade metasediments). In sample 01448, there are scattered small pelletal grains of fine grained clay, different to the other clay-rich detrital lithic grains. Textures in the clastic sedimentary rocks range from grain-supported to matrix-supported, with the proportion of the latter only becoming significant (e.g. >20-30%) in the finer grained sandstones and siltstones. The matrix component is generally clay-rich (e.g. kaolinite), but can include sericitic material (e.g. in 01451) and a little quartz. In sample 01447, it is possible that matrix material included fine grained volcaniclastic detritus, judging by relict textures. The detrital grain assemblage in the sample suite indicates an ultimate provenance from a continental felsic igneous and/or metamorphic source, but probably recycled through prior sedimentary rock sequences. There could have been a minor volcaniclastic input as implied by the matrix of sample 01447.

Diagenetic alteration is interpreted to have affected all samples in the suite. It is manifest by the following:

1) Minor occurrence of thin quartz overgrowths on detrital grains (i.e. mostly on quartz).
2) Locally extensive replacement of matrix clay by scattered to locally massive amounts of generally fine grained carbonate, acting as a cement. This occurs particularly in samples 01445 and 01446, but is also present in 01443, 01444 and 01450. Carbonate is commonly porphyroblastic and textures can be implied as indicating replacement of matrix and detrital grains (e.g. in 01445 and 01446). Carbonate is turbid and generally pale brown in colour; it does not react with dilute HCl and hence is considered to be Fe-bearing , e.g. siderite, ankerite.
3) Development of disseminations and scattered zones of semi-massive pyrite, replacing matrix (clay) and locally replacing detrital grains. The semi-massive aggregates are porphyroblastic in character (e.g. in 01451), but can affect considerable rock volumes (e.g. in 01442, 01451). Pyrite is fine to medium grained and crystalline (anhedral to subhedral grains) and there is no textural evidence for the formation of framboids. The amount of pyrite is very variable, even within a single sample (e.g. none to 30 %), with 01451 and 01442 containing the highest proportions. No other sulphides have been observed in association with pyrite. However in sample 01447, there is a trace of fine grained chalcopyrite, but this is enclosed in detrital quartz and is probably "accidental detrital" and has not grown diagenetically.

4) Local replacement of matrix components by goethite (e.g. in 01448) and by nontronite/celadonite and minor goethite (e.g. in 01447). In 01448, it is possible that diagenetic pyrite was formerly more abundant, but was replaced by goethite.
5) Possible recrystallisation of matrix clay (and clay-rich lithic detrital grains) to fine grained aggregates. Most matrix clay is considered to be kaolinite. In sample 01448, there may have been growth of clay aggregates up to a few millimetres across (distinct from the pelletal clay grains in this sample). The clay aggregates are associated with minor amounts of chalcedonic quartz and botryoidal goethite.
6) Minor impregnation of matrix material (and clay-rich detrital) by a brown carbonaceous substance and the maturation of phytoliths to coaly material (e.g. a range from vitrinite to inertinite).
7) It could be speculated that porosity (void space) that commonly occurs in some of the coarser grained sandstones (e.g. up to 15%) might be due to diagenetic dissolution, e.g. of matrix or cement components. On the other hand, it might also represent primary porosity or the loss of matrix clay during manufacture of the sections.

Sample 01412 has been affected by weathering and the strong Fe oxide pigmentation of this sample is interpreted to be due to supergene mobility and precipitation of goethite and hematite. In this sample, a distinct boundary between goethite-pigmented and hematite-pigmented domains is oblique to bedding laminations. The Fe oxides impregnate the clay-rich matrix material and do not show any diagnostic texture indicative of the former presence of sulphides.

In summary, diagenetic alteration has been imposed on the clastic sedimentary rock materials, most commonly occurring under probable reducing conditions. This is inferred by the presence of carbonaceous material in a few samples, the occurrence of pyrite disseminations and cementing material and the occurrence of Fe-bearing carbonate cement and massive replacements. However, some samples display evidence of oxidising conditions, e.g. 01447 and 01448, with the presence of goethite and possible replacement of pyrite by goethite. The obviously oxidising conditions manifest in sample 01412 are interpreted to be the result of weathering effects imposed on the rock. It could be speculated that there might be diagenetically produced redox boundaries in the clastic sedimentary sequence due to differences in basin fluid oxidation states. This has implications for the potential for certain types of sediment-hosted, low-temperature epigenetic mineralisation, e.g. of "red bed" Cu or redox-controlled U types. It is recommended that drill core intervals be analysed for suites of elements specific to these styles of mineralisation.

Individual sample descriptions

01412 PTS

Summary: Siltstone, grading to fine grained sandstone, with well preserved relict detrital grain texture and later strong impregnation of matrix material by supergene Fe oxide phases. The sedimentary rock has angular to sub-rounded detrital grains, dominated by quartz, but with lesser amounts of fine grained quartz-rich and clay-rich lithic grains, K-feldspar and a little detrital muscovite, Fe oxide (hematite), leucoxene/rutile, tourmaline and zircon. The subordinate matrix component is probably composed of diagenetically developed, finely crystallised clay (e.g. kaolinite). Strong impregnation of the rock by hematite, or by goethite, is interpreted as a weathering-related phenomenon. The boundary between hematite-pigmented and goethite-pigmented domains is transgressive to diagenetic "flattening" in the rock.

Handspecimen: The handspecimen is composed of a weakly laminated, fine to medium grained siltstone/sandstone, with a prominent transgressive colour change from yellow-brown (goethite-pigmented) to brick red (hematite-pigmented) at about 20° to the lamination. The rock is probably rather quartz-rich, but also appears to contain detrital feldspar and muscovite. The typical grainsize is <0.5 mm, although there are a few detrital quartz grains up to 1.5 mm across. The matrix to the detrital grains may be Fe-oxide-impregnated clay. The sample is essentially non-magnetic, with susceptibility of <10 x 10^{-5} SI units.

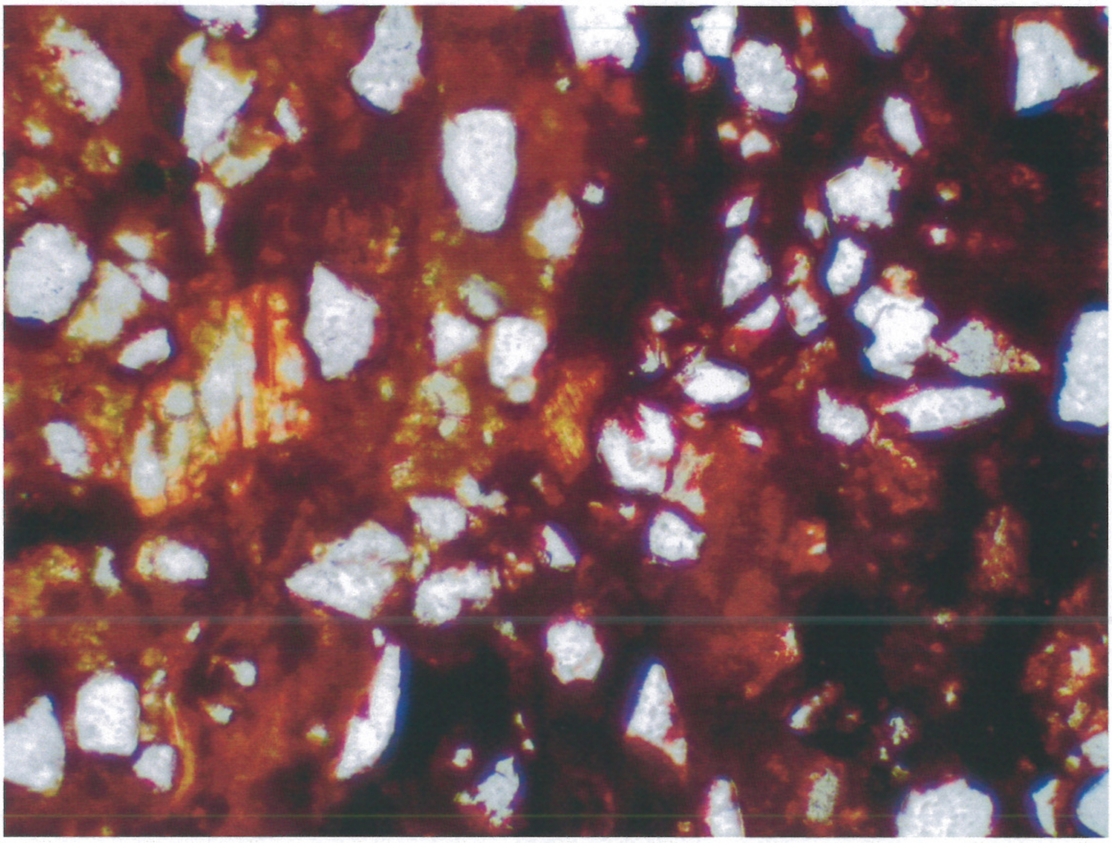

Figure 1: Relict detrital grain texture in siltstone component, with relict quartz grains and variably degraded (clay-altered) muscovite, hosted in an Fe oxide impregnated matrix. In the latter, there is a boundary between orange-brown goethite-pigmented material (left) and red-brown hematite-pigmented material (right). This boundary is oblique to bedding laminations (elsewhere in the rock). Plane polarised transmitted light, field of view 1 mm across.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is well preserved (Fig. 1). In general, the texture of the sedimentary rock is fine to medium grained and grain-supported, although there is a considerable matrix component (e.g. 25-30%). Relict detrital grains are angular to sub-rounded and mostly up to 0.5 mm across, although there are rare larger grains of quartz up to 1.5 mm across. Quartz is the main detrital phase and accompanied by subordinate amounts of fine grained lithic grains (e.g. polycrystalline quartz aggregates and clay-rich aggregates), K-feldspar, a little detrital muscovite and traces of Fe oxide (maybe hematite, perhaps pseudomorphous after a prior phase such as magnetite, ilmenite), rutile/leucoxene, tourmaline and zircon. The matrix is composed dominantly of fine grained, low-birefringent crystalline clay (e.g. kaolinite), but with strong pigmentation by Fe oxide phases (Fig. 1). The primary characteristics of the sample indicate that it is a quartz (-feldspar-lithic) siltstone, grading into fine sandstone. Its provenance is probably mostly felsic plutonic/metamorphic in character.

b) Alteration and structure: The rock has undergone diagenetic alteration and later weathering effects. Diagenesis led to development of finely crystalline, low-birefringent clay (e.g. kaolinite) as a dominant matrix component and in some of the lithic grains. There has also been some retrograde replacement of detrital feldspar and muscovite grains by clay phases (e.g. kaolinite, illite). A weak to moderate "flattening" effect is apparent in the sample, due to diagenesis, with incipient stylolite development, now outlined by Fe oxide pigmentation. There is no textural evidence for any chemically precipitated overgrowths on to detrital grains. The rock displays prominent pigmentation by dusty Fe oxide material, mainly in the matrix component (Fig. 1). There is a near-planar boundary between a goethite-impregnated domain and a hematite-impregnated domain (Fig. 1), at a low-moderate angle to the diagenetic "flattening" and later than the growth of crystalline clays. The Fe oxides are interpreted as being formed as a result of weathering and oxidising groundwater deposition. There is no textural evidence of either the replacement of earlier disseminated sulphides or that one Fe oxide phase replaces the other.

c) Mineragraphy and paragenesis: No sulphides, or pseudomorphs thereof, have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 50%, clays 38%, K-feldspar and goethite + hematite each 5%, muscovite 1% and traces of detrital hematite, leucoxene/rutile, tourmaline and zircon.

Interpretation and Comments: It is interpreted that the sample represents a quartz (-feldspar-lithic) siltstone, grading to fine grained sandstone, with well preserved relict detrital grain texture and later strong impregnation of matrix material by supergene Fe oxide phases. The sedimentary rock has angular to sub-rounded detrital grains, dominated by quartz, but with lesser amounts of fine grained quartz-rich and clay-rich lithic grains, K-feldspar and a little detrital muscovite, Fe oxide (hematite), leucoxene/rutile, tourmaline and zircon. The subordinate matrix component is probably composed of diagenetically developed, finely crystallised kaolinite. Strong impregnation of the rock by hematite, or by goethite, is interpreted as a weathering-related phenomenon. The boundary between hematite-pigmented and goethite-pigmented domains is transgressive to diagenetic "flattening" in the rock.

01441 PTS

Summary: Massive, medium grained quartz-rich sandstone (orthoquartzite), with a minor clay-rich matrix component and considerable interstitial void space, causing the rock to be rather friable. Detrital quartz grains may have been slightly polygonised due to diagenetic alteration. There is a small population of detrital fine grained lithic grains and traces of muscovite, tourmaline, hornblende and rutile. The minor matrix clay component might be kaolinitic and also contains a tiny trace of diagenetic fine grained pyrite.

Handspecimen: The drill core is composed of a massive, pale grey, rather friable quartz-rich sandstone. It appears to have considerable porosity and permeability, with only a little fine grained clay matrix evident. The sample is essentially non-magnetic, with susceptibility of <10 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is well preserved (Fig. 2), although there may have been diagenetic modification. The rock is a medium grained quartz-rich sandstone (orthoquartzite), with a grain-supported texture (Fig. 2). Detrital grains are angular to sub-rounded and commonly rather tightly packed. There is only a minor (<5%) matrix component, but there is also considerable void space interstitial to detrital grains (Fig. 2) that could reflect zones where matrix might have been removed (e.g. diagenetically, or during section preparation). Detrital grains are up to 1.5 mm across and are dominated by quartz, most of which are single grains, but a few are polycrystalline aggregates (i.e. quartzite). There is also a minor population of fine grained lithic grains (e.g. fine grained argillite composed of quartz and sericite, and chert), plus traces of detrital muscovite, hornblende, tourmaline and rutile. Where preserved, the matrix is composed of fine grained, pale brown, low-birefringent clay (e.g. kaolinite), with a little quartz and trace of fine grained pyrite.

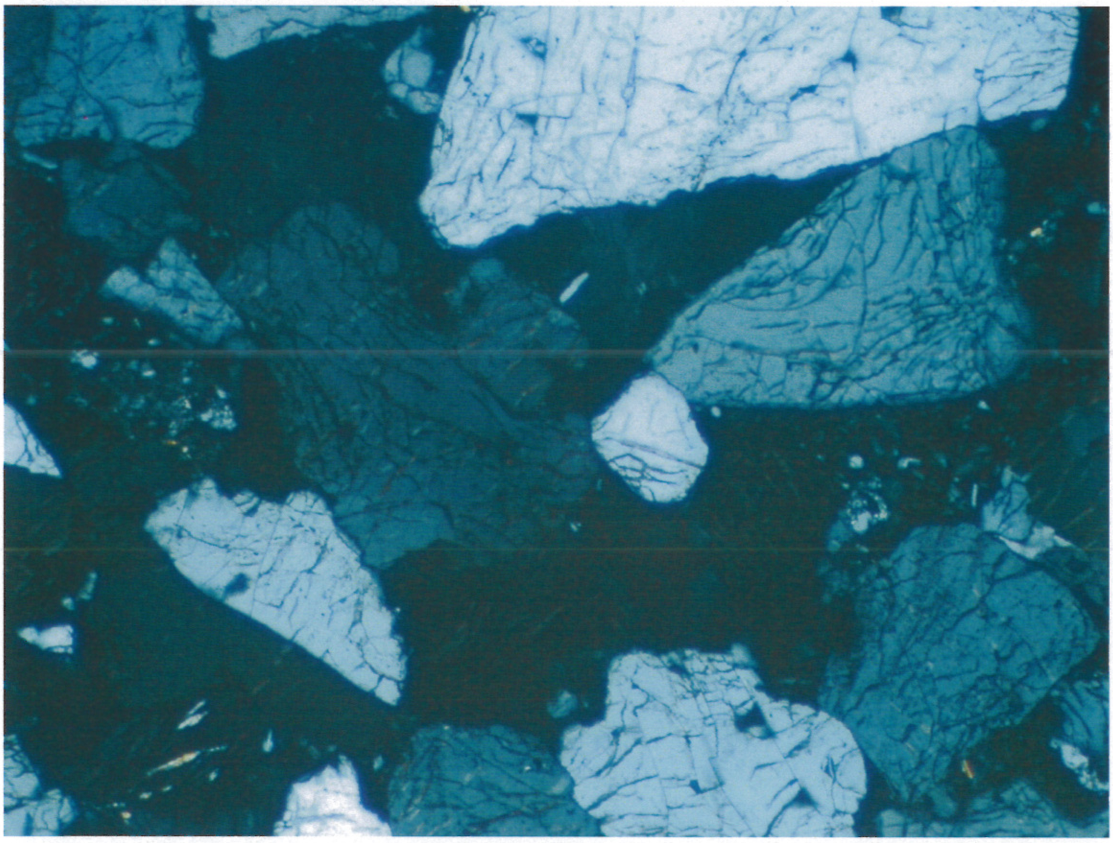

Figure 2: Sub-rounded detrital quartz grains, with a little interstitial fine grained clay-quartz matrix and void space (black). Detrital grains locally show very thin quartz overgrowths. Transmitted light, crossed polars, field of view 2 mm across.

b) Alteration and structure: It is interpreted that the sandstone may have undergone diagenetic alteration. This could have led to slight polygonisation of detrital quartz grains, and there are rare thin quartz overgrowths on detrital grains (Fig. 2). Although matrix emplacement could have occurred during diagenesis, the matrix could have also been partly leached out, leaving void space. Traces of fine grained disseminated in the matrix might have grown diagenetically.

c) Mineragraphy and paragenesis: There is a tiny trace of fine grained pyrite, forming grains up to 0.05 mm across, in the clay-rich matrix, as well as in one of the detrital lithic grains.

Mineral Mode: Approximate modal proportions are: quartz 95%, clay 4% and traces of muscovite/sericite, hornblende, tourmaline, pyrite and rutile.

Interpretation and Comments: It is interpreted that the sample is a massive, medium grained quartz-rich sandstone (orthoquartzite), with a minor clay-rich matrix component and considerable interstitial void space, causing the rock to be rather friable. Detrital quartz grains may have been slightly polygonised due to diagenetic alteration. There is a small population of detrital fine grained lithic grains and traces of muscovite, tourmaline, hornblende and rutile. The minor matrix clay component might be kaolinitic and also contains a tiny trace of diagenetic fine grained pyrite. It is possible that some of the matrix clay might have been removed (leached out) during diagenesis.

01442 PTS

Summary: Fine to medium grained quartz-rich sandstone with local clay-rich partings containing slight carbonaceous pigmentation. The rock also displays minor detrital muscovite and fine grained lithics and shows patchy replacement of clay-rich matrix by fine to medium grained pyrite. The rock appears to have undergone diagenetic alteration under reducing conditions.

Handspecimen: The drill core is composed of a pale grey-brown, rather fine grained sandstone, with thin wispy dark grey partings up to 1 mm wide that define sedimentary bedding which is approximately normal to the core axis. The partings may contain carbonaceous clayey material as well as exhibiting scattered detrital muscovite grains. The sandstone is probably relatively rich in quartz and has been locally strongly impregnated by a dark mass of fine grained pyrite, with boundaries slightly transgressive to the clayey partings. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock has well preserved detrital grain texture (Fig. 3). It is fine to medium grained, with most detrital grains being <0.4 mm across, but a few detrital muscovite flakes are up to 1 mm across. The texture is generally grain-supported, although there is a considerable matrix/cement component (e.g. up to 30 %). Detrital grains are angular to sub-rounded and dominated by quartz. There is a minor population of detrital lithic grains (e.g. fine grained quartz-sericite argillite, chert, chloritic material), muscovite and traces of carbonaceous material, rutile/leucoxene, tourmaline, zircon and K-feldspar (Fig. 3). The subordinate matrix component is dominated by very fine grained, low-birefringent clay (e.g. kaolinite), commonly pigmented varying shades of brown by diffuse carbonaceous material (Fig. 3). In about 60% of the section, the matrix component appears to have been replaced by fine to medium grained pyrite cement (Fig.4). The characteristics of the sample indicate that it is a fine to medium grained quartz-rich sandstone, in places impregnated by pyrite.

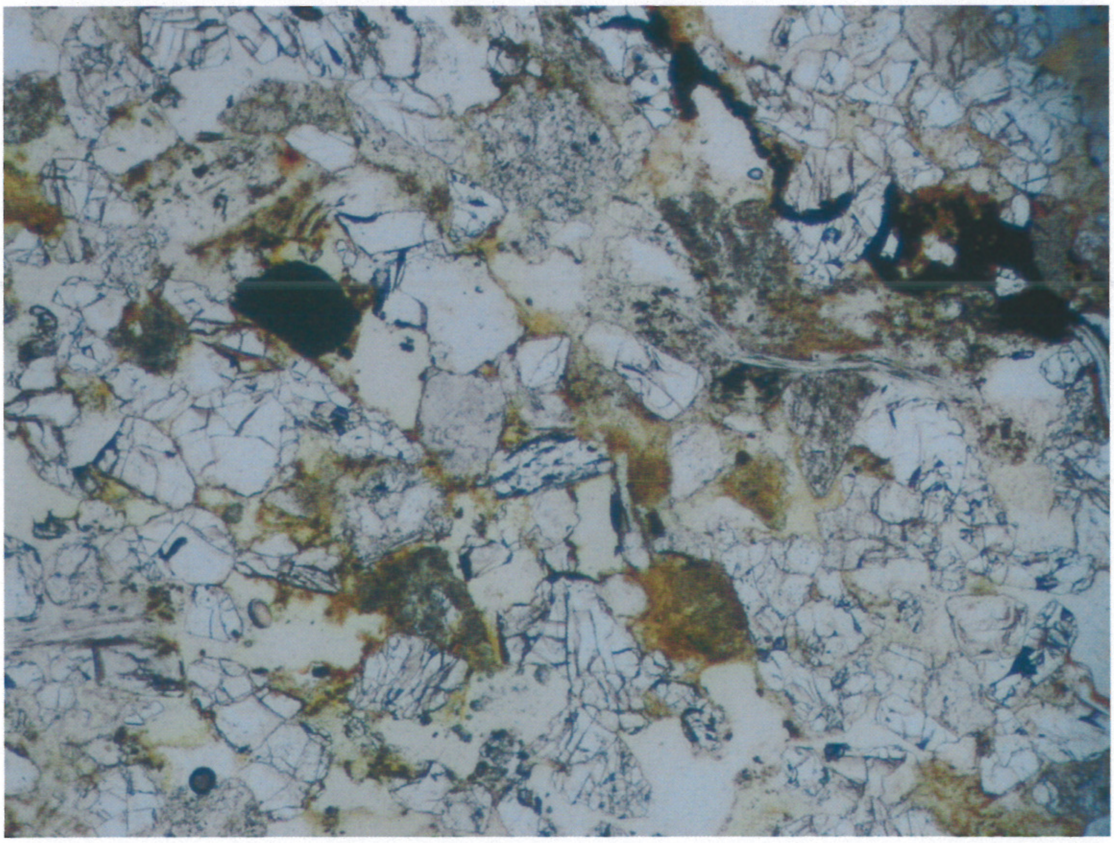

Figure 3: Relict detrital grain texture, with detrital grains (quartz > lithics) hosted in pale brown, slightly carbonaceous-pigmented clay matrix. Opaque grain to left is detrital leucoxene and irregular black aggregates upper right are carbonaceous material. Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: It is interpreted that the sandstone has undergone diagenetic alteration. This is manifest in the carbonaceous impregnation of clay matrix and especially by the replacement of the matrix by disseminated to semi-massive fine to medium grained aggregates of pyrite (Fig. 4). The pyritic domain shows slightly transgressive boundaries with respect to local clay-rich partings.

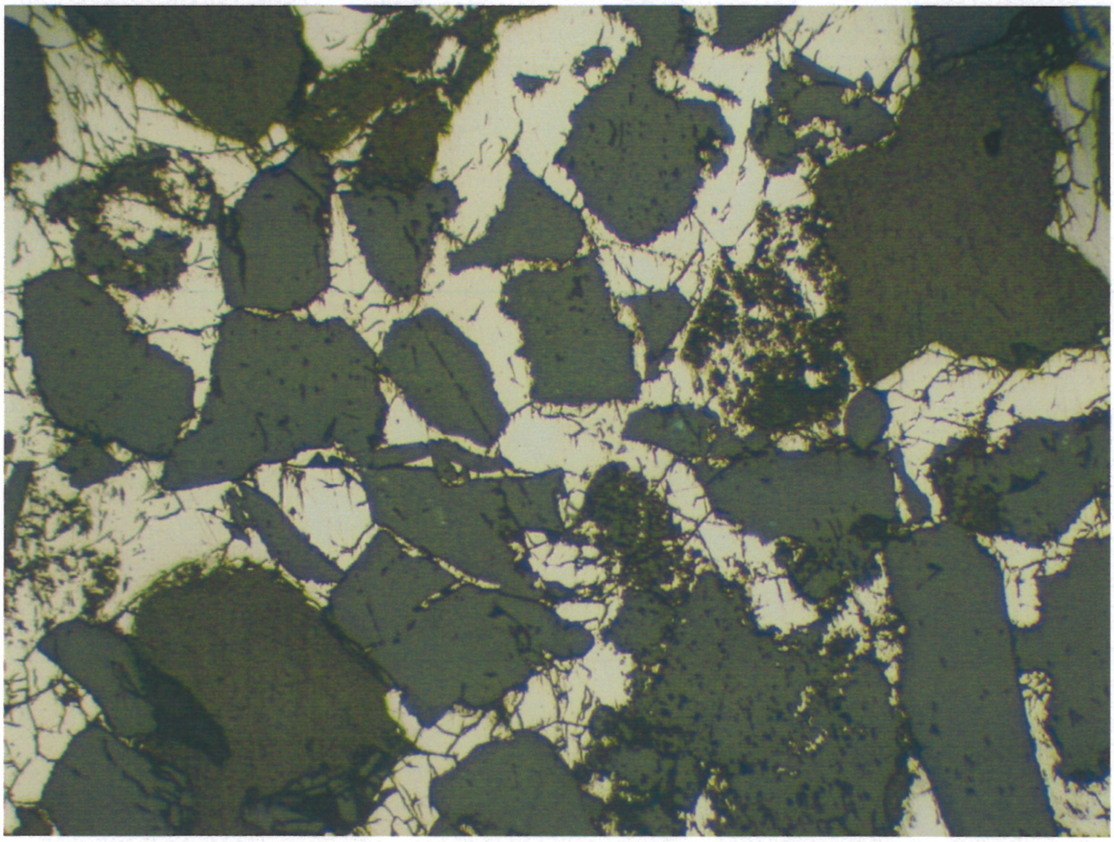

Figure 4: Diagenetic pyrite cement (pale creamy) that has replaced matrix. It surrounds detrital quartz grains, but has partly replaced fine grained lithic grains. Plane polarised reflected light, field of view 1 mm across.

c) Mineragraphy and paragenesis: The sandstone displays a domain with strongly disseminated to semi-continuous aggregates of pyrite that have replaced the clay matrix and in places appears to have invaded detrital grains (Fig. 4). In the pyritic aggregates, individual pyrite grains are anhedral to subhedral and up to 0.4 mm across.

<u>Mineral Mode</u>: Approximate modal proportions are: quartz 80%, clay 10% pyrite 7%, muscovite/sericite 2% and traces of rutile/leucoxene, K-feldspar, zircon, tourmaline, chlorite and carbonaceous material.

<u>Interpretation and Comments</u>: It is interpreted that the sample is a fine to medium grained quartz-rich sandstone with minor detrital fine grained lithics and muscovite. There are local clay-rich partings containing slight carbonaceous pigmentation. There has been patchy replacement of clay-rich matrix by fine to medium grained pyrite. The rock appears to have undergone diagenetic alteration under reducing conditions.

01443 PTS

Summary: Fine to medium grained quartz (-lithic-feldspar) sandstone with thin shale/siltstone partings and displaying clay-rich matrix material and considerable replacement by fine grained carbonate cement. The sandstone has well preserved detrital grain texture and interstitial clay-rich matrix and the associated shale/siltstone laminations have slight pigmentation by carbonaceous material. The carbonate cement might be Fe-bearing (e.g. siderite/ankerite) and has an associated trace of fine grained pyrite.

Handspecimen: The drill core is dominated by fine to medium grained speckled brown to pale grey, weakly laminated sandstone, with several irregular to sub-planar bedding laminations of dark grey shaly material up to 1 cm thick that are approximately normal to the core axis. In the shaly laminations, the dark colour might be due to carbonaceous material and these laminations also contain a little flaky muscovite on the bedding planes. The sandstone is probably quartz-rich and it is interpreted that the brown colour is due to the occurrence of Fe-bearing carbonate interstitial to quartz. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock has well preserved detrital grain texture. The texture ranges from being grain-supported to be matrix-supported, with detrital grains being angular to sub-rounded. A significant matrix component is present and becomes more abundant in a few diffuse laminations up to 2 mm wide of finer grained siltstone/shale that are intercalated with the otherwise fine to medium grained sandstone (Fig. 5). In these intercalations, there are traces of wispy relict plant material, matured into a carbonaceous substance (Fig. 5). Detrital grains are up to 1 mm across, although most are <0.5 mm across. Quartz is the dominant detrital phase, but there is a considerable fine grained lithic detrital grain component (e.g. claystone, chert), minor K-feldspar and muscovite/sericite, plus traces of plagioclase, tourmaline, zircon, rutile and garnet. The matrix component is dominated by fine grained, low-birefringent clay (e.g. kaolinite), with minor quartz and sericite, and generally pigmented brown by carbonaceous material. Throughout the sandstone, patchy fine grained carbonate cement occurs interstitial to the detrital grains (Fig. 6).

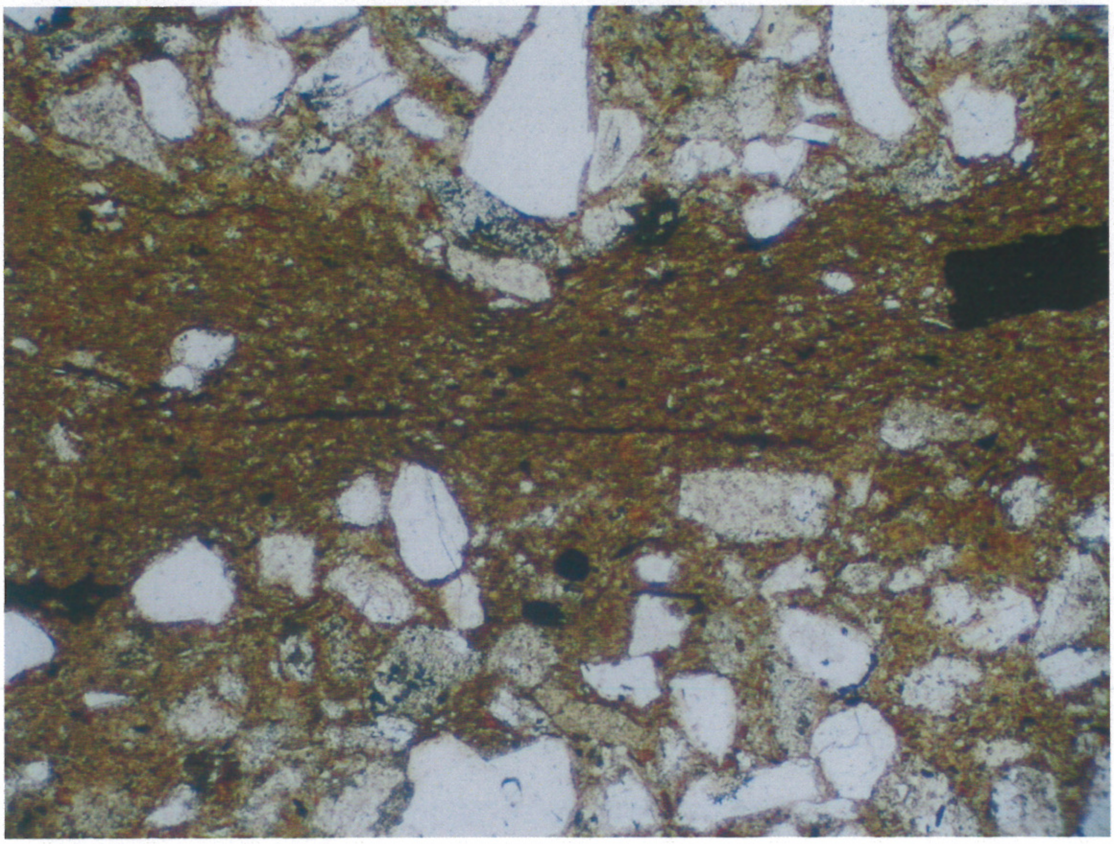

Figure 5: Carbonaceous pigmented shale-siltstone lamination with black wispy carbonised plant fragments, enclosed in fine grained sandstone with detrital grains (quartz > lithics > K-feldspar) displaying a considerable matrix component. Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: The rock has undergone diagenetic alteration. This is mostly indicated by the patchy replacement of matrix material (and portions of detrital grains) by fine grained, pale brown, turbid carbonate cement (Fig. 6). The carbonate is probably Fe-bearing (e.g. siderite, ankerite) and displays local slight oxidation to orange-brown goethite. A trace of fine grained pyrite is locally associated with carbonate. Elsewhere in the sample, there could have been diagenetic recrystallisation of kaolinitic clay in the matrix and lithic grains, along with the carbonaceous impregnations. Overall, diagenetic alteration appears to have occurred under somewhat reducing conditions.

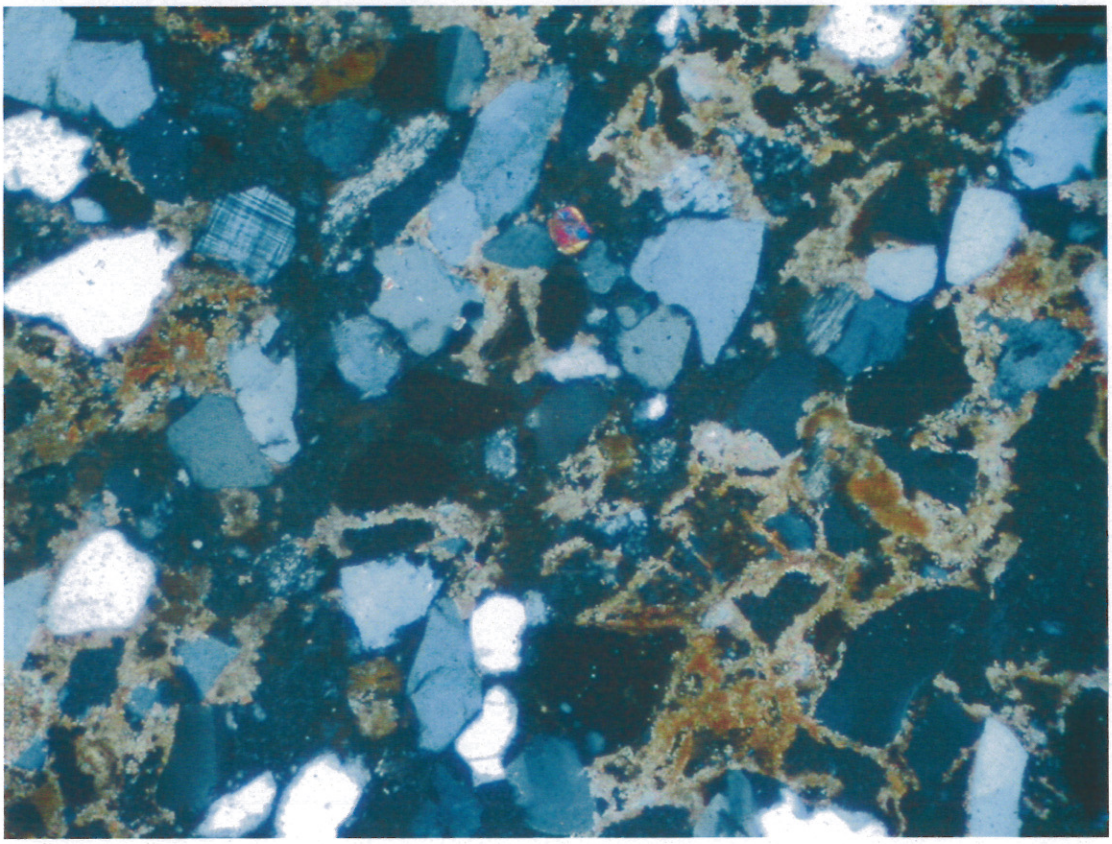

Figure 6: Relict detrital grain texture with detrital grains (quartz > lithics > K-feldspar, trace zircon), enclosed in a low-birefringent clay matrix, with extensive replacement by brownish fine grained carbonate cement. Transmitted light, crossed polars, field of view 1 mm across.

c) Mineragraphy and paragenesis: There is a trace of pyrite associated with diagenetic carbonate cement. Irregular pyrite grains are up to 0.05 mm across.

<u>Mineral Mode</u>: Approximate modal proportions are: quartz 50%, clay 35% carbonate 10%, K-feldspar 3%, muscovite/sericite 1% and traces of carbonaceous material, plagioclase, zircon, tourmaline, rutile, garnet, pyrite and goethite.

<u>Interpretation and Comments</u>: It is interpreted that the sample is a fine to medium grained quartz (-lithic-feldspar) sandstone with thin shale/siltstone partings and displaying clay-rich matrix material and considerable replacement by fine grained carbonate cement. The sandstone has well preserved detrital grain texture and interstitial clay-rich matrix and the associated shale/siltstone laminations have slight pigmentation by carbonaceous material. The carbonate cement might be Fe-bearing (e.g. siderite/ankerite) and has an associated trace of fine grained pyrite. Diagenetic alteration has probably occurred under reducing conditions.

01444 PTS

Summary: Fine to medium grained quartz (-lithic-feldspar) sandstone with irregular shale/siltstone laminations. Detrital grains are enclosed in a clay-rich matrix, with the shale/siltstone intercalations being matrix-dominated. Diagenetic alteration has caused patchy replacement of the matrix and detrital grains in the sandstone by fine grained Fe-bearing carbonate. There might also have been recrystallisation of the clayey matrix and claystone detrital lithic grains, as well as diffuse carbonaceous pigmentation.

Handspecimen: The drill core is dominated by fine to medium grained pale grey to orange-brown coloured sandstone, within which are irregular, wispy and laminated masses of dark grey shaly material. The latter are up to 8 mm thick, commonly oriented approximately normal to the core axis, and probably have the dark colour due to carbonaceous material. The orange-brown colour of the sandstone is likely to be caused by interstitial carbonate cement. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, detrital grain texture is well preserved and there are a few diffuse laminae, grading to irregular masses of finer grained shale/siltstone intercalated with dominant fine to medium grained sandstone (Fig. 7). The texture of the sandstone ranges from grain-supported to matrix-supported, but there is an overall rather large matrix component (Fig. 7), with the latter becoming more abundant in the finer grained shale/siltstone domains (that are up to 8 mm thick). Detrital grains are angular to sub-rounded and up to 1 mm across. Quartz is the dominant detrital mineral, but there is a subordinate population of fine grained lithic grains (e.g. kaolinitic claystone, sericite-quartz argillite, chert, fine quartzite), a little K-feldspar and muscovite/sericite (the latter more abundant in the finer grained shale/siltstone domains.

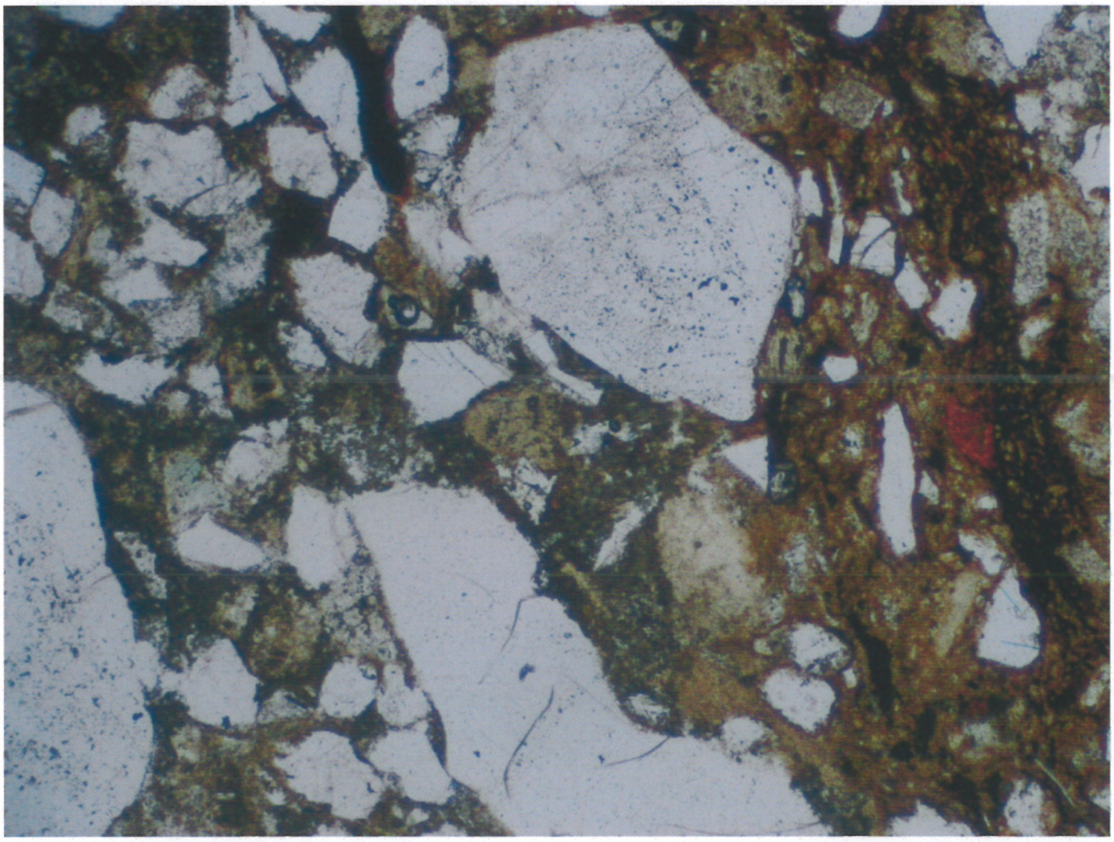

Figure 7: Relict detrital grain texture in sandstone, with a thin slightly carbonaceous siltstone layer at right. The sandstone displays a considerable matrix component of fine grained clay as well as patchy diagnetic carbonate cement (turbid grey interstitial zones). The black grain

near top is carbonaceous material. Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: The rock has undergone diagenetic alteration. This is mostly indicated by the patchy replacement of matrix material (and portions of detrital grains) by fine grained, pale brown, turbid carbonate cement (Fig. 7). The carbonate is probably Fe-bearing (e.g. siderite, ankerite) and displays local slight oxidation to orange-brown goethite. There could have been diagenetic recrystallisation of kaolinitic clay in the matrix and lithic grains, along with the development of carbonaceous impregnations. Diagenetic alteration appears to have occurred under somewhat reducing conditions.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 40%, clay 35% carbonate 19%, K-feldspar and muscovite/sericite each 2%, carbonaceous material 1% and traces of plagioclase, zircon, tourmaline, rutile, garnet and goethite.

Interpretation and Comments: It is interpreted that the sample is a fine to medium grained quartz (-lithic-feldspar) sandstone with irregular shale/siltstone laminations. Detrital grains are enclosed in a clay-rich matrix, with the shale/siltstone intercalations being matrix-dominated. Diagenetic alteration has caused patchy replacement of the matrix and detrital grains in the sandstone by fine grained Fe-bearing carbonate. There might also have been recrystallisation of the clayey matrix and claystone detrital lithic grains, as well as diffuse carbonaceous pigmentation. Diagenetic alteration has probably occurred under reducing conditions. The samples is similar to sample 01443.

01445 PTS

Summary: Fine grained chemically precipitated micritic carbonate-rich rock, locally grading into carbonate-bearing siltstone. The carbonate is probably Fe-bearing (e.g. siderite, ankerite) and textures suggest that it has partly replaced a pre-existing clastic sedimentary rock (e.g. siltstone). Surficial oxidation of the drill core has led to local replacement of carbonate by goethite (possibly Mn-bearing).

Handspecimen: The drill core is mostly composed of a massive, fine grained, rather dense, pale grey-brown sedimentary rock. It is dominated by micritic carbonate, forming an apparent zone (?bed) about 10 cm thick and bordered by grey, carbonate-bearing fine grained clastic sedimentary rock, e.g. siltstone. The exterior of the core, where carbonate-rich, has developed a strong dark brown to black coating, possibly an oxidation product (e.g. Mn oxide, goethite). Testing of the section offcut with dilute HCl did not produce a significant reaction, indicating that the carbonate is not calcite. The sample is moderately magnetic, with susceptibility up to 190 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, which was cut from the carbonate-rich portion of the sample, the rock is relatively massive and dominated by fine grained, turbid, pale brown micritic carbonate. There are no bedding laminations or fossil remains. At one end of the section, the content of carbonate decreases and there is a zone a few millimetres thick of siltstone, with porphyroblastic carbonate masses somewhat subordinate to detrital grains and fine grained clayey matrix material (Fig. 8). In the carbonate-rich portion of the sample, there is a minor population of relict detrital grains enclosed within finely crystalline carbonate rims and there are relict textures in carbonate implying that it has replaced detrital grains up to 0.5 mm across (Fig. 8). The relict detrital grains are up to 0.3 mm across dominated by quartz, with a small amount of fine grained, clay-rich lithic grains and traces of K-feldspar, muscovite and variably chloritised biotite. The composition of the rock and relict textures suggest that the original rock might have been a siltstone, perhaps carbonate-bearing, but that it has been extensively replaced by carbonate.

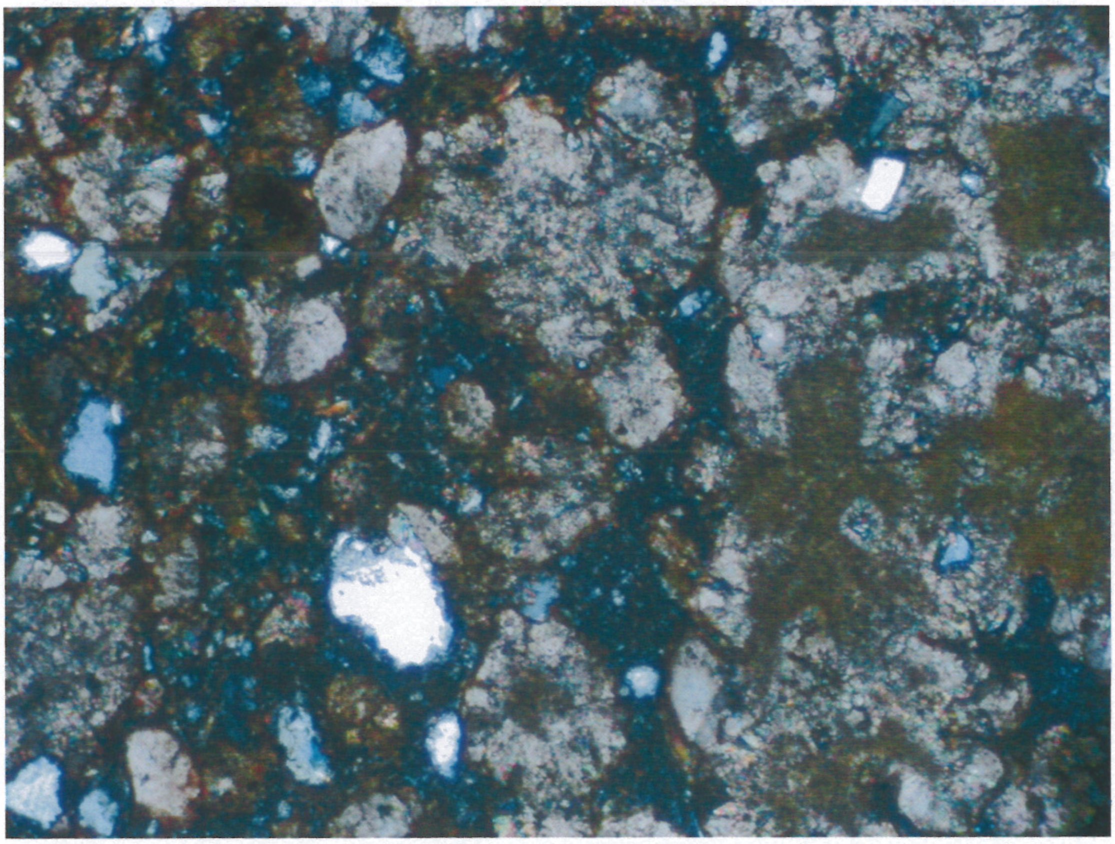

Figure 8: Matrix-rich siltstone (left) with scattered detrital grains (mostly quartz), with porphyroblastic carbonate development, and grading into zone at right of semi-massive micritic carbonate (turbid pale brown) that might represent total replacement of siltstone protolith. Transmitted light, crossed polars, field of view 2 mm across.

b) Alteration and structure: It is interpreted that the rock has undergone diagenetic alteration, with extensive replacement of original detrital grains and matrix material by fine grained, commonly micritic, turbid, pale brown carbonate (Fig. 8). The density of the sample and its lack of reactivity towards HCl imply that the carbonate is Fe-bearing, e.g. siderite, ankerite. The carbonate forms finely crystalline rims around relict detrital grains and also enclosing irregular masses of fine grained, low-birefringent clay (e.g. kaolinite) up to 1 mm across. Textures in the carbonate imply that it is of chemical precipitation origin and that it may have developed largely by replacement of protolith material. Along one side of the section, there is a local zone of globular to irregular replacement of carbonate by a dark brown, somewhat translucent, anisotropic phase that is taken to be goethite. The blackish surface staining on the exterior of the handspecimen implies that significant Mn might be present in the goethite. This phase is likely to be of supergene origin, e.g. exposure of the Fe-bearing carbonate in the drill core to the atmosphere over a period of time.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

<u>Mineral Mode</u>: Approximate modal proportions are: carbonate (Fe-bearing) 93%, clay 3%, quartz 2%, goethite 1% and traces of muscovite, K-feldspar and chlorite/biotite.

<u>Interpretation and Comments</u>: It is interpreted that the sample is a fine grained chemically precipitated micritic carbonate-rich rock, locally grading into carbonate-bearing siltstone. The carbonate is probably Fe-bearing (e.g. siderite, ankerite) and textures suggest that it has partly replaced a pre-existing clastic sedimentary rock (e.g. siltstone). The replacement process is likely to have occurred during diagenesis. Surficial oxidation of the drill core has led to local replacement of carbonate by goethite (possibly Mn-bearing).

01446 PTS

Summary: Fine to medium grained siltstone, with scattered detrital grains and abundant clay-rich matrix, displaying extensive porphyroblastic development of fine to medium grained carbonate. The siltstone has detrital grains of quartz, K-feldspar and variably altered biotite, along with a trace of carbonised plant material. The replacement carbonate masses are interpreted to have grown during diagenetic alteration. They are likely to be Fe-bearing (e.g. siderite, ankerite).

Handspecimen: The drill core is composed of a relatively massive, fine grained, brown-grey carbonate-rich rock, within which are scattered irregular grey aggregates of fine grained green-grey siltstone up to 1 cm across. On the surface of the core, there is black staining of the carbonate-rich portion of the sample (?Mn oxide). Testing of the section offcut with dilute HCl did not produce a significant reaction, indicating that the carbonate is not calcite. The sample is weakly-moderately magnetic, with susceptibility up to 140 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is well preserved in places, but elsewhere, porphyroblastic carbonate growth has tended to obscure detrital grain texture (Fig. 9). Where carbonate is not abundant, there are irregular domains up to several millimetres across of fine to medium grained siltstone, with scattered angular detrital grains up to 0.4 mm across enclosed in a large matrix component. The latter is fine grained and dominated by low-birefringent clay (e.g. kaolinite), with lesser amounts of quartz and porphyroblastic carbonate. Detrital grains include quartz, fine grained lithics (e.g. clay-rich, quartz-rich), K-feldspar, variably altered biotite (replacement by chlorite and clay), rare small carbonised plant fragments and traces of rutile/leucoxene and epidote. A weak fissility is defined in the siltstone by preferred orientation of detrital biotite flakes (Fig. 9).

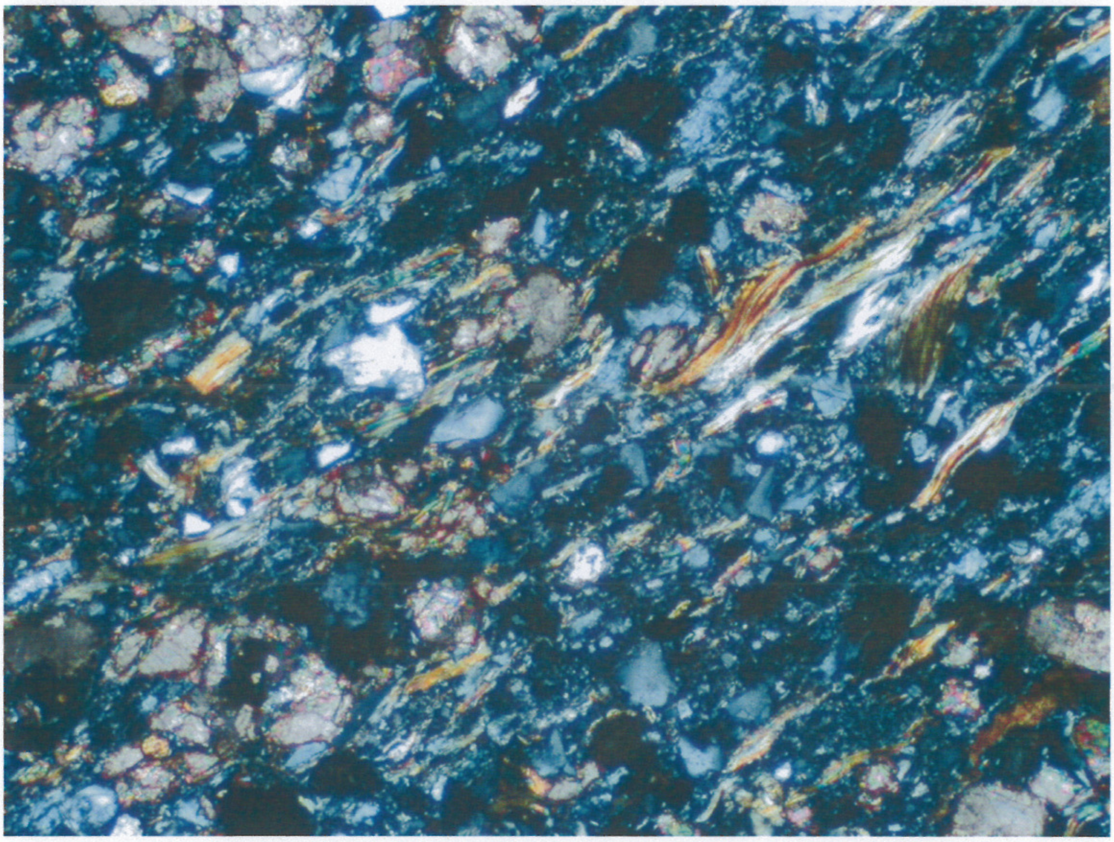

Figure 9: Matrix-rich siltstone, with detrital grains of quartz, altered biotite and K-feldspar, with preferred orientation of mica defining a fissility. The rock also shows local development

of carbonate porphyroblasts (pale pink-brown) by replacement of clay-rich matrix. Transmitted light, crossed polars, field of view 2 mm across.

b) Alteration and structure: It is interpreted that there has been extensive growth of diagenetic porphyroblastic carbonate as fine to medium grained masses (Fig. 9). The amount of carbonate ranges from <5 % to almost massive in places. Carbonate is slightly turbid and probably Fe- (and maybe Mn-) bearing, based on lack of reactivity towards dilute HCl and the black surface staining on the drill core. It could be of siderite or ankerite type and it has replaced siltstone matrix material as well as some of the detrital grains. Diagenetic alteration has also probably led to recrystallisation of the fine grained matrix of the siltstone and the variable degradation of biotite to chlorite and clay.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: carbonate (Fe-bearing) 55%, clay 30%, quartz 10%, biotite/chlorite/clay 3%, K-feldspar 2% and traces of carbonaceous material, rutile and epidote.

Interpretation and Comments: It is interpreted that the sample is a fine to medium grained siltstone, displaying extensive porphyroblastic development of fine to medium grained carbonate. The siltstone has detrital grains of quartz, K-feldspar and variably altered biotite, along with a trace of carbonised plant material. The detrital grains occur in a clay-rich matrix. The replacement carbonate masses are likely to be Fe-bearing (e.g. siderite, ankerite) and are interpreted to have grown as a result of diagenetic alteration.

01447 PTS

Summary: Medium to coarse grained quartz-rich sandstone, with a significant interstitial matrix component. Detrital grains are commonly sub-rounded and are mostly quartz, although there are a few fine grained clay-rich lithics present. The matrix ranges from kaolinitic to being dominated by strongly brownish pigmented clay/mica material, e.g. nontronite/celadonite. It is possible that there might have been a fine grained volcaniclastic component in the matrix prior to diagenetic alteration to the clay assemblage. A little fine grained disseminated goethite also occurs in the matrix.

Handspecimen: The drill core is composed of a massive, medium to coarse grained grey sandstone. It is evidently dominated by detrital quartz grains, but there is pale grey to dark grey-brown interstitial clayey matrix material as well as a few voids. The sample is essentially non-magnetic, with susceptibility of <10 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, detrital grain texture is well preserved (Fig. 10). The rock is a medium to coarse grained sandstone, with texture ranging from grain-supported to matrix-supported (Fig. 10). The matrix component averages ~40%. Detrital grains are commonly sub-rounded, but range to angular and are up to 3.5 mm across. They are mostly single quartz grains, but there are a few polycrystalline quartz aggregates. Rarely, the quartz grains enclose grains of muscovite and one quartz grain encloses a small chalcopyrite grain. The rock also contains a few discrete lithic grains up to 1 mm across, composed of fine grained, low-birefringent clay (e.g. kaolinite) and rare detrital grains of rutile up to 0.2 mm across. Detrital grains are commonly variably enclosed by the matrix component that is dominated by fine grained, generally turbid clay phases (Fig. 10).

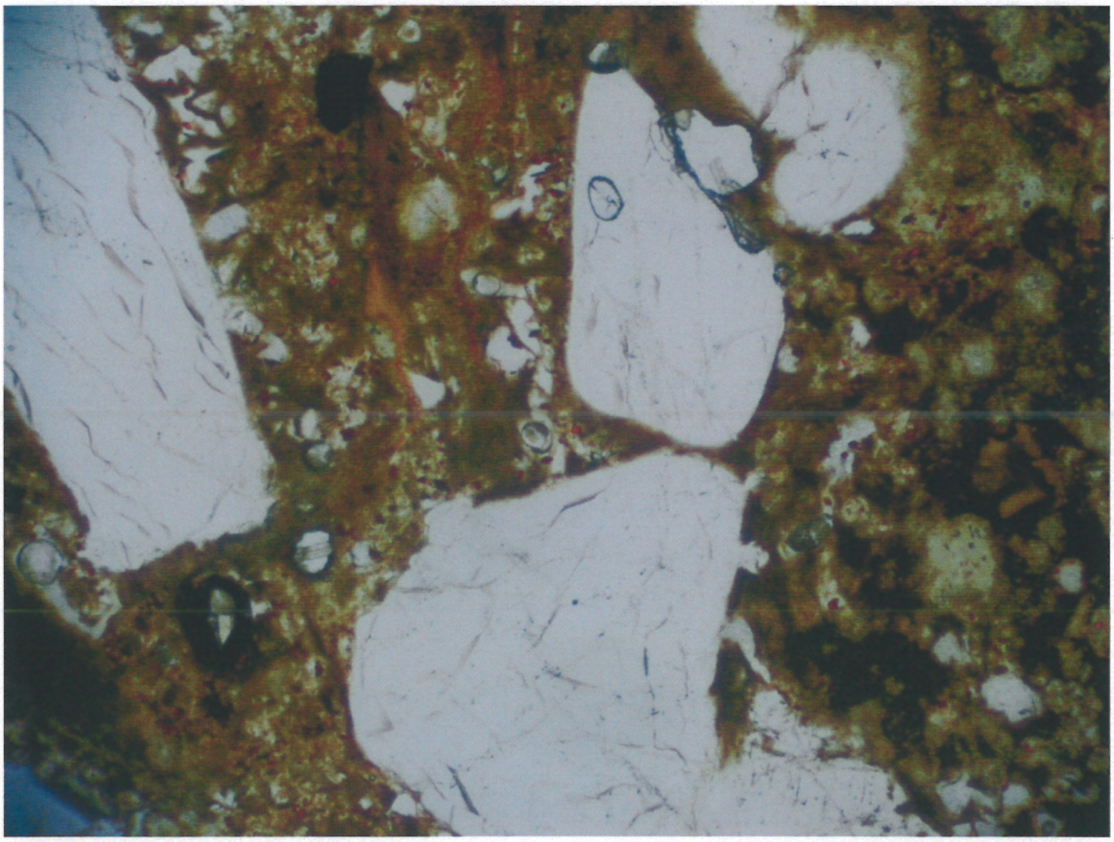

Figure 10: Medium grained, relatively matrix-rich sandstone, with detrital quartz grains hosted in brown altered matrix that could have included former volcanic detritus, replaced by nontronitic clay and tiny goethite grains. Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: It is interpreted that diagenetic alteration has affected the matrix of the sandstone, although the detrital grains are unaffected and there is no evidence of overgrowth development. The matrix locally displays possible fine grained relict textures suggestive of the presence of former fine grained volcaniclastic detritus (Fig. 10). Matrix material is dominated by fine grained clays and clay/mica phases, along with a little quartz and fine granules of goethite. The clay phases include pale khaki, low-birefringent kaolinite and dark brown, orange-brown and khaki coloured, turbid material, considered to be nontronite or nontronite/celadonite mixtures (Fig. 10). In places, the clay material is stained orange-brown by goethite.

c) Mineragraphy and paragenesis: Mostly, there are no sulphides in the sample. However, one detrital quartz grain encloses a single grain of chalcopyrite about 0.05 mm across. The chalcopyrite is probably an accidental inclusion.

Mineral Mode: Approximate modal proportions are: quartz 60%, clay phases, including nontronite/celadonite 39%, goethite 1% and traces of chalcopyrite, rutile and muscovite.

Interpretation and Comments: It is interpreted that the sample is a medium to coarse grained quartz-rich sandstone, with a significant matrix component. Detrital grains are commonly sub-rounded and are mostly quartz, although there are a few fine grained clay-rich lithics present. The matrix includes kaolinitic material and strongly brownish pigmented clay/mica material, e.g. nontronite/celadonite. It is possible that there might have been a fine grained volcaniclastic component in the matrix prior to diagenetic alteration to the clay assemblage. A little fine grained disseminated goethite also occurs in the matrix.

01448 PTS

Summary: Weakly laminated fine to medium grained sandstone, grading into siltstone, with abundant quartz detrital grains, along with a significant amount of pelletal clay grains. The sandstone matrix, as well as the siltstone, are dominated by fine grained quartz, clay and a little muscovite/sericite. The rock exhibits extensive diagenetic goethite cement, but within goethite, there are traces of relict fine grained pyrite, suggesting that pyrite was originally more abundant, but was oxidised to goethite. The rock also contains a few clay-rich aggregates that might have developed diagenetically.

Handspecimen: The drill core is composed of a weakly laminated, dark brown, fine to medium grained sandstone, grading into finer grained siltstone, with irregular to sub-planar bedding laminations approximately normal to the core axis. Although the coarser laminae are rather quartz-rich, the finer laminae are dominated by goethite. There are also a few pale grey clay aggregates ("spots") up to 3 mm across. The sample is essentially non-magnetic, with susceptibility of <10 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, detrital grain texture is well preserved and there are weak bedding laminations, defined by variations in detrital grainsize and by mineral proportions. Fine to medium grained sandstone dominates, with maximum detrital grainsize up to 0.7 mm across; there are irregularly intercalated with fine grained siltstone interbeds in which maximum detrital grainsize is <0.2 mm. Quartz is commonly the dominant detrital phase, occurring as angular to sub-rounded grains. There are also rather abundant sub-rounded detrital pelletal clay grains up to 0.6 mm across, composed of very fine grained aggregates of low-birefringent clay (e.g. kaolinite), variably pigmented by goethite (Fig. 11). There is also a little detrital muscovite (variably degraded to clay) and traces of detrital rutile, tourmaline, zircon and ilmenite. Matrix material in the sandstone is the same composition as the siltstone; they are composed of quartz, clay and minor muscovite/sericite. The detrital components in the rock are cemented by fine grained goethite (Figs 11, 12).

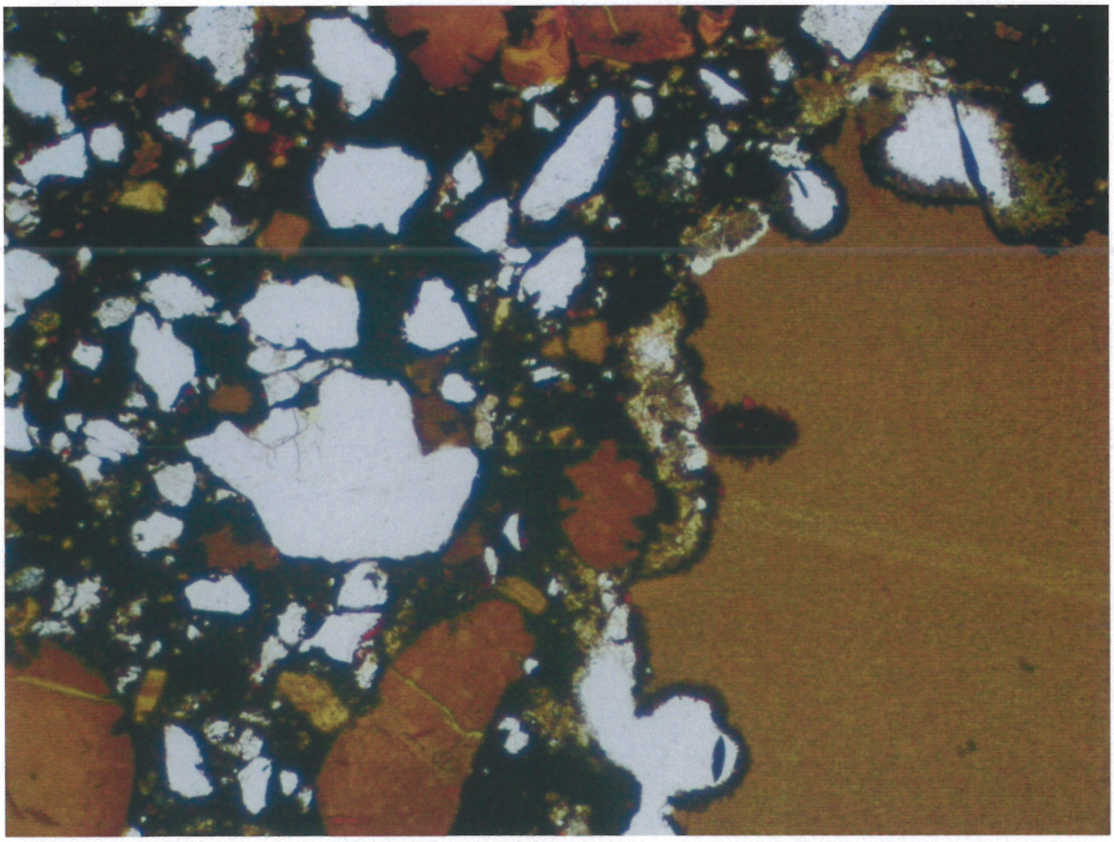

Figure 11: Detrital quartz grains accompanied by pelletal clay aggregates (ovoid, brown) in fine to medium grained sandstone, with abundant goethite cement (almost black) interstitially. On the right hand side is a portion of a large diagenetic clay aggregate, with minor fringing botryoidal goethite and quartz. Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: Diagenetic alteration has occurred, with the growth of scattered irregular to globular clay-rich aggregates up to 2.5 mm across. These are filled by fine grained, kaolinitic clay, in places with a little quartz and botryoidal goethite (Fig. 11). Alteration is also manifest by abundant goethite cement and impregnations of pelletal clay grains and detrital muscovite/sericite. Within goethite masses, there are traces of fine grained pyrite and it could therefore be implied that pyrite was formerly more abundant (as a cementing agent), but has been largely oxidised and replaced by goethite (Fig. 12). The latter phase has probably also been deposited "exotically" from groundwater and has not necessarily always replaced former pyrite.

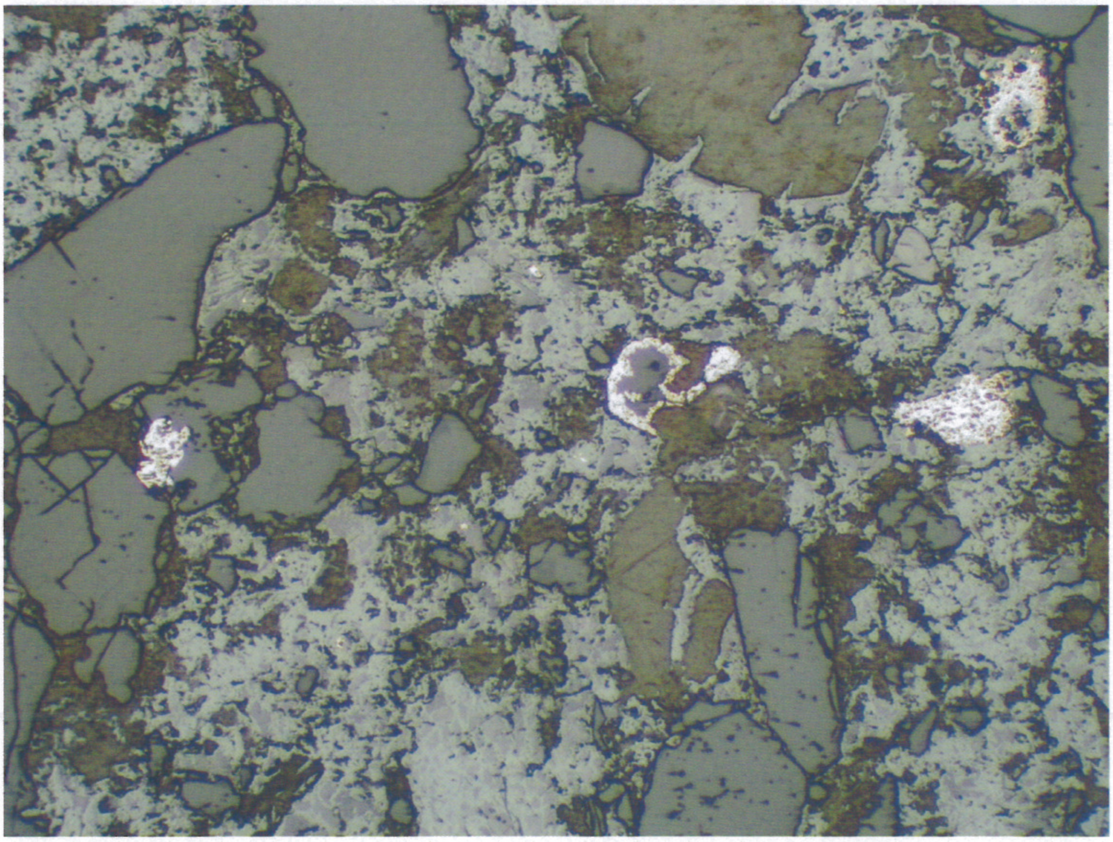

Figure 12: Matrix-supported texture with scattered detrital quartz grains hosted in clay + sericite matrix, impregnated by abundant goethite (pale grey), with a little relict pyrite (off white). Textures might imply that goethite has replaced pyrite (but not necessarily so). Plane polarised reflected light, field of view 1 mm across.

c) Mineragraphy and paragenesis: The sample has a trace of fine grained disseminated pyrite in grains up to 0.1 mm across, hosted in the goethite cement (Fig. 12). Pyrite might have originally been more abundant as cement to detrital components, but has since been largely oxidised and replaced by goethite.

<u>Mineral Mode</u>: Approximate modal proportions are: quartz and clay (e.g. kaolinite) each 40%, goethite 17%, muscovite/sericite 2% and traces of pyrite, tourmaline, zircon, rutile and ilmenite.

Interpretation and Comments: It is interpreted that the sample represents a weakly laminated fine to medium grained sandstone, grading into siltstone, with abundant quartz detrital grains, along with a significant amount of pelletal clay grains. The sandstone matrix and siltstone are dominated by fine grained quartz, clay and a little muscovite/sericite. The rock exhibits extensive diagenetic goethite cement, but within goethite, there are traces of relict fine grained pyrite, suggesting that pyrite was originally more abundant, but was oxidised to goethite. There are also a few clay-rich aggregates that might have developed diagenetically.

<u>01449</u> **<u>PTS</u>**

Summary: Massive, medium grained, quartz-rich sandstone, with minor amounts of fine grained clay matrix and a little disseminated fine grained pyrite. In places, pyrite becomes more abundant, forming aggregates interstitial to detrital grains. The rock displays a moderate amount of porosity and locally, thin quartz overgrowths on detrital grains.

Handspecimen: The drill core is composed of a massive, pale grey, slightly friable and porous, medium grained quartz-rich sandstone. There are faint bedding laminations at ~80° to the core axis. Locally, the core has a mid-grey colour, due to the presence of a little fine grained interstitial pyrite. The sample is essentially non-magnetic, with susceptibility of <10 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, there is well preserved detrital grain texture (Fig. 13). There are abundant, rather tightly packed angular to sub-rounded detrital grains, with a maximum grainsize of ~1 mm. There is only minor interstitial matrix and cement, but in places, considerable porosity (up to 15%) is present (Fig. 13). Quartz is the dominant detrital phase, mostly as single grains, but there are a few polycrystalline aggregates. There are also a few lithic grains, composed of fine grained clay-rich material and chert, along with a trace of detrital K-feldspar, muscovite, tourmaline and leucoxene. The matrix is fine grained and composed of turbid, pale brown, low-birefringent clay (e.g. kaolinite). Within the matrix, there is a trace of finely disseminated pyrite (Fig. 13), although towards one end of the section, there is relatively abundant fine grained pyrite, acting as a cement in-between detrital grains.

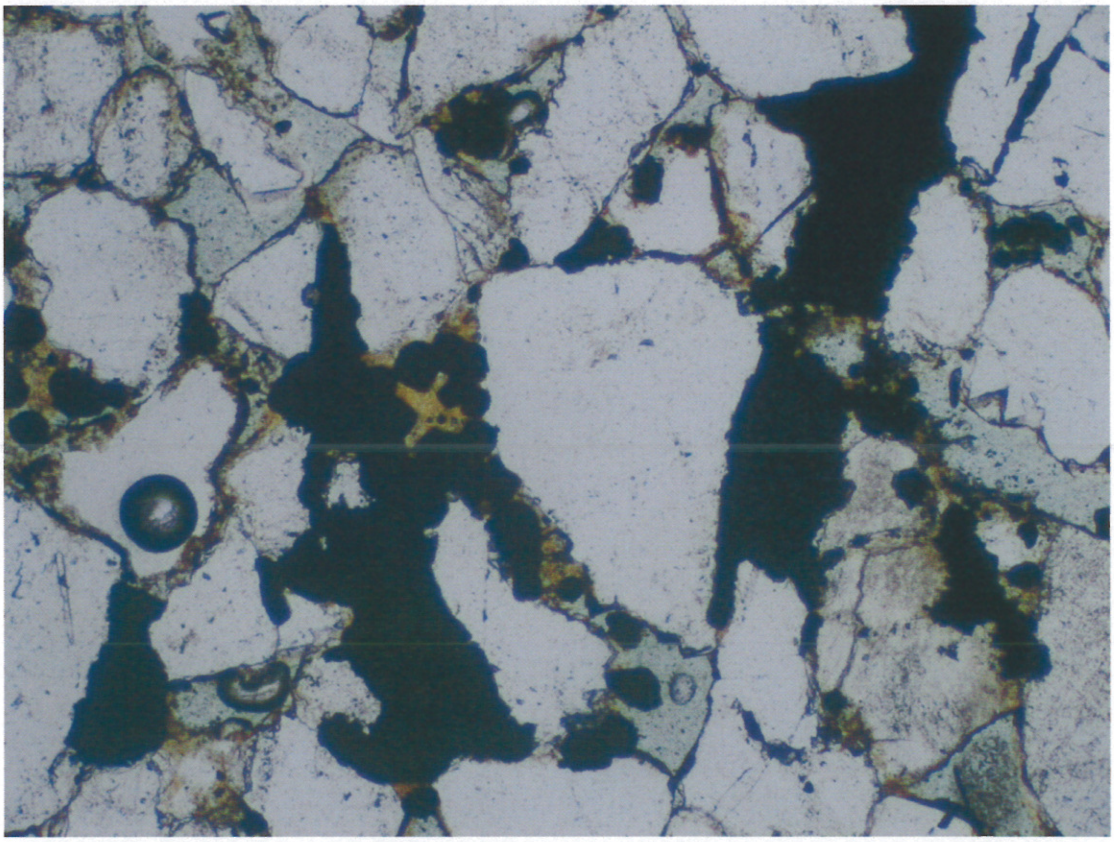

Figure 13: Relict detrital grain texture, with rather tightly packed grains of quartz, plus a little pale brown clay matrix, scattered aggregates of fine grained pyrite (black) and minor void space (very pale blue). There is a slight tendency for thin quartz overgrowths to have formed on detrital grains. Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: The rock has probably undergone diagenetic alteration, manifest in the local development of thin quartz overgrowths on detrital grains and the development of a little pyrite, either disseminated as traces in the clay matrix (Fig. 13), or towards one end of the section, as more strongly disseminated material, forming fine grained aggregates up to 1 mm across, interstitial to detrital grains.

c) Mineragraphy and paragenesis: The sample has a trace of fine grained disseminated pyrite within most of the clay matrix (Fig. 13). However, towards one end of the section, there is more abundant pyrite, forming fine grained aggregates up to 1 mm across, interstitial to detrital grains. Within the pyrite aggregates, individual grains are up to 0.05 mm across.

<u>Mineral Mode</u>: Approximate modal proportions are: quartz 94%, clay (e.g. kaolinite) 3%, pyrite 2% and traces of K-feldspar, muscovite, tourmaline and leucoxene.

<u>Interpretation and Comments</u>: It is interpreted that the sample is a massive, medium grained, quartz-rich sandstone, with minor amounts of fine grained clay matrix, a little disseminated fine grained pyrite, and in places, considerable porosity. It is interpreted that pyrite is a diagenetic product and it becomes more abundant locally, forming aggregates interstitial to detrital grains. There is also minor development of thin quartz overgrowths on detrital grains.

01450 PTS

Summary: Weakly laminated, fine grained siltstone, with dominant detrital quartz and minor amounts of detrital clay-rich lithics, muscovite, K-feldspar and plagioclase. There is a minor clay-rich matrix component and the rock has been affected by diagenetic growth of scattered small porphyroblastic carbonate aggregates and a couple of pyrite-rich aggregates.

Handspecimen: The drill core is composed of a finely, but diffusely laminated, fine grained, pale grey siltstone. Laminations are approximately normal to the core axis. The rock is probably quartz-rich but also displays minor muscovite on the bedding planes. There are a couple of dark, fine grained aggregates of pyrite up to a few millimetres across, elongate parallel to the bedding planes. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the sample has generally well preserved detrital grain texture (Fig. 14) and there are weakly evident bedding laminations, defined by slight differences in detrital grain size and mineral proportions. Detrital grains are mostly angular and up to 0.3 mm across, although most are <0.1 mm across. The texture is mostly grain-supported, with a subordinate component of matrix and cement (Fig. 14). Quartz is the dominant detrital phase, but there are also minor amounts of fine grained, clay-rich lithic grains, muscovite flakes, a little K-feldspar and plagioclase and traces of chlorite, celadonite, tourmaline, zircon and rutile/leucoxene (Fig. 14). The matrix is composed of fine grained clay (e.g. kaolinite) and there is a subordinate amount of carbonate cement, (Fig. 14) along with a couple of zones with considerable pyrite cement.

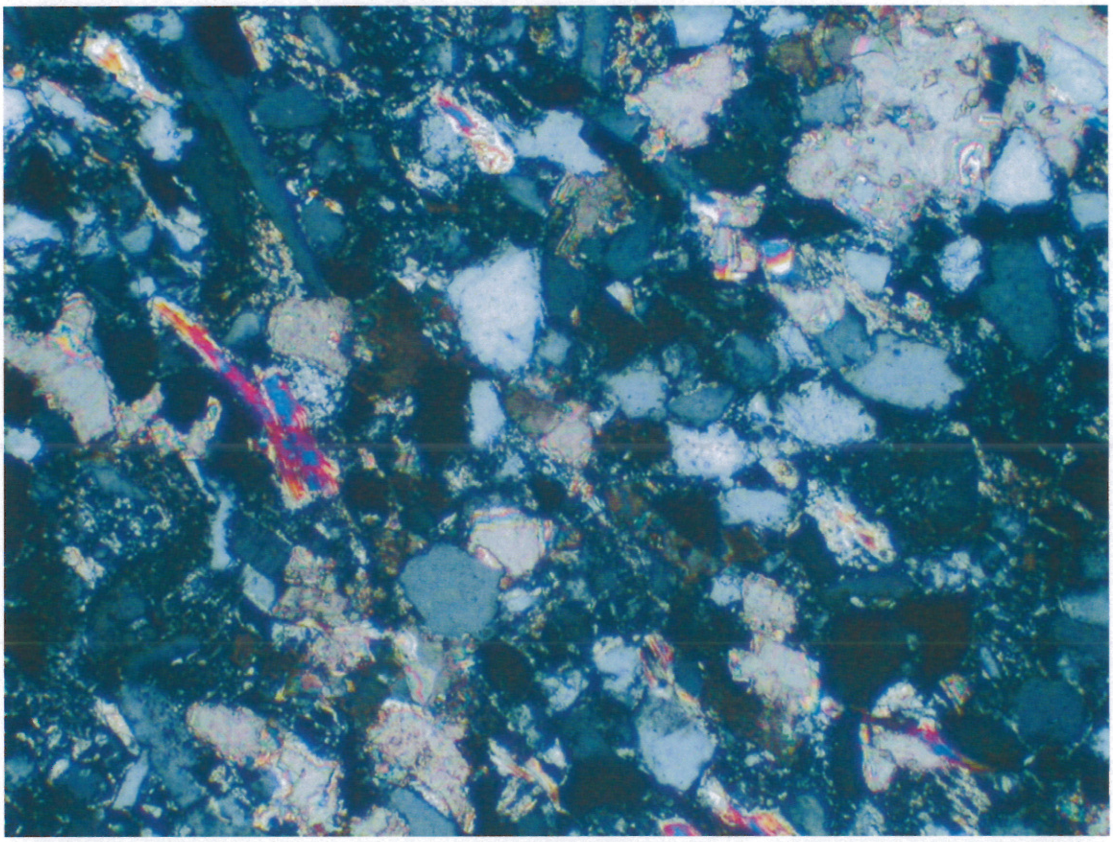

Figure 14: Siltstone with relict detrital grain texture (with quartz > lithics > muscovite) and minor clay matrix, plus minor porphyroblastic carbonate (pale pink-brown) development. Transmitted light, crossed polars, field of view 1 mm across.

b) Alteration and structure: It is interpreted that the rock has undergone diagenetic alteration, indicated by growth of fine grained irregular porphyroblastic carbonate aggregates up to 0.5 mm across (Fig. 14). There are also a couple of domains up to several millimetres across in which matrix material has been strongly replaced by fine grained pyrite. Some "flattening" of the rock has occurred, causing preferred orientation of detrital muscovite flakes. Adjacent to the pyrite-rich zones, carbonate displays slight alteration to goethite.

c) Mineragraphy and paragenesis: The rock displays a couple of zones up to a few millimetres across where matrix material has been replaced by fine grained pyrite, forming semi-continuous aggregates. The pyrite acts as a cementing agent, interstitial to relict detrital grains.

Mineral Mode: Approximate modal proportions are: quartz 60%, clay (e.g. kaolinite) and carbonate each 15%, muscovite 4%, K-feldspar and pyrite each 2%, plagioclase 1% and traces of chlorite, celadonite, tourmaline, zircon, rutile/leucoxene and goethite.

Interpretation and Comments: It is interpreted that the sample is a weakly laminated, fine grained siltstone, with dominant detrital quartz and minor amounts of detrital clay-rich lithics, muscovite, K-feldspar and plagioclase. There is a minor clay-rich matrix component and the rock has been affected by diagenetic growth of scattered small porphyroblastic carbonate aggregates and a couple of pyrite-rich aggregates.

<u>01451</u> **<u>PTS</u>**

Summary: Fine grained sandstone, grading to siltstone, with diffuse bedding laminations. The rock has abundant detrital quartz, but also minor fine grained lithic grains and K-feldspar, with a subordinate amount of fine grained sericite/clay matrix. There has been patchy replacement of matrix and detrital grains by porphyroblastic aggregates of pyrite, considered to have formed by diagenetic alteration.

Handspecimen: The drill core is composed of a fine grained, moderately laminated, rather quartz-rich sandstone, grading to siltstone, with considerable development of irregular masses of pyrite replacement. The latter appear as dark grey, fine grained, irregular masses up to 1-2 cm across, within an otherwise pale grey host rock that has been variably stained pale yellow by oxidation of pyrite and the formation of trace jarosite. Bedding laminations are on the millimetric scale and are approximately normal to the core axis. The sample is essentially non-magnetic, with susceptibility of <10 x 10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, detrital grain texture is well preserved (Fig. 15) and there are weak bedding laminations on a scale of a few millimetres in thickness. The laminations are defined by slight variations in detrital mineral grain size. Detrital grains are mostly angular and rarely up to 1 mm across; mostly they are <0.2 mm across. They comprise dominant quartz, but there are minor amounts of fine grained lithics (e.g. clay-rich, sericite-rich, chert and polycrystalline quartz) and K-feldspar, a little plagioclase and traces of chlorite, muscovite, tourmaline, zircon and rutile (Fig. 15). The texture is generally grain-supported, although there is a moderate matrix component of fine grained brownish pigmented sericite and clay (Fig. 15). In places, pyrite aggregates form irregular zones of matrix replacement, leading to pyrite being a cementing agent to detrital grains (Figs 15, 16). The characteristics of the rock indicate that it is a fine grained, laminated, rather quartz-rich sandstone, grading to siltstone and with patchy pyrite replacement of matrix.

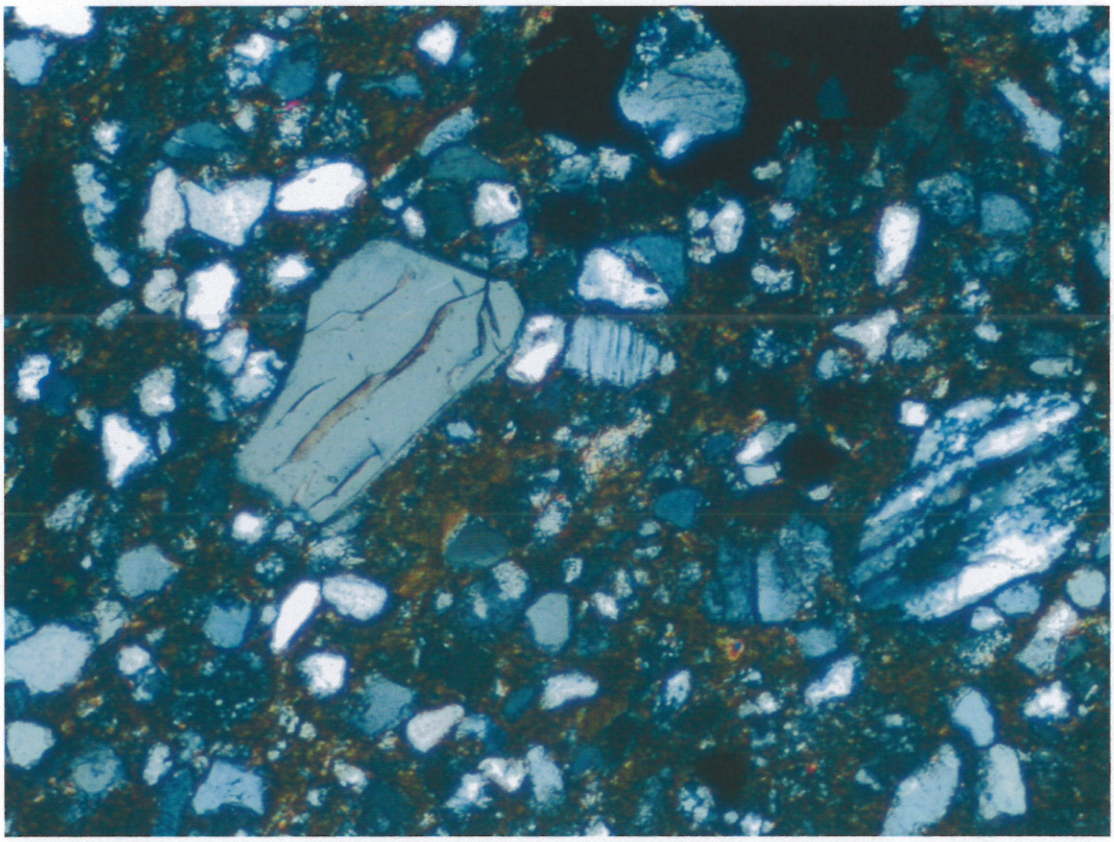

Figure 15: Typical matrix-supported texture in sandstone/siltstone, with quartz > K-feldspar > lithics, in turbid clay/sericite matrix and porphyroblastic pyrite aggregates (black). Transmitted light, crossed polars, field of view 2 mm across.

b) Alteration and structure: It is interpreted that the rock has undergone diagenetic alteration, indicated by growth of fine grained irregular porphyroblastic pyrite aggregates up to 1-2 cm across (Fig. 16). These have replaced matrix material and act as a cement to partly replaced relict detrital grains. It is possible that diagenetic alteration of the matrix has occurred with recrystallisation of sericite and clay.

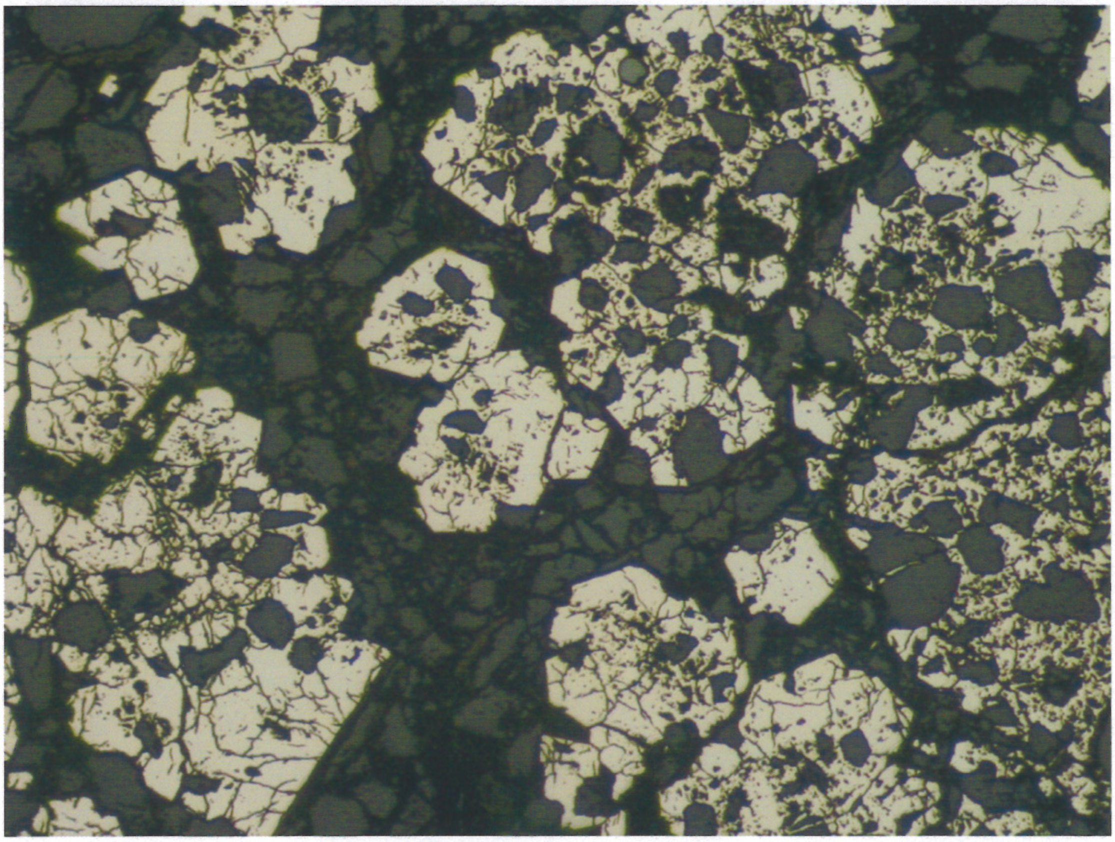

Figure 16: Porphyroblastic development of pyrite cement as anhedral to subhedral masses, enclosing relict detrital quartz grains and replacing the matrix. Plane polarised reflected light, field of view 2 mm across.

c) Mineragraphy and paragenesis: There are irregular distributed, semi-massive pyrite aggregates up to 1-2 cm across (Fig. 16), throughout the rock, along with a little finely disseminated pyrite. There has been replacement of matrix material, and to a lesser extent, detrital grains, by pyrite (Fig. 16). Within pyrite aggregates, the mineral is fine to medium grained and inequigranular.

<u>Mineral Mode</u>: Approximate modal proportions are: quartz 55%, sericite/muscovite and pyrite each 15%, clay (e.g. kaolinite) 10%, K-feldspar 3%, plagioclase 1% and traces of chlorite, tourmaline, zircon and rutile.

<u>Interpretation and Comments</u>: It is interpreted that the sample is a diagnetically altered fine grained sandstone, grading to siltstone, with diffuse bedding laminations. The rock has abundant detrital quartz, but also minor fine grained lithic grains and K-feldspar, with a subordinate amount of fine grained sericite/clay matrix. There has been patchy replacement of matrix and detrital grains by porphyroblastic aggregates of pyrite, with pyrite acting as a cement to detrital grains.

<u>01452</u> **<u>PTS</u>**

<u>Summary</u>: Fine to medium grained quartz-rich sandstone, with a minor component of clay-rich matrix as well as minor porosity. Detrital grain texture is well preserved and quartz is accompanied by minor lithic detrital grains (clay-rich, chert) and a little muscovite and K-feldspar. Diagenetic alteration has led to development of a little disseminated pyrite in the matrix, locally grading into small aggregates that act as cement to detrital grains. There has also been slight development of quartz overgrowths on detrital grains.

<u>Handspecimen</u>: The drill core is composed of a massive to weakly laminated, fine to medium grained, pale creamy to pale grey quartz-rich sandstone. It is slightly friable and may have minor porosity. Laminations are on a scale of a few millimetres and are at ~75° to the core axis; they are defined by the presence of absence of small amounts of fine grained disseminated pyrite. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

<u>Petrographic Section</u>:

a) Primary mineralogy and textures: In the section, detrital grain texture is well preserved (Fig. 17). Detrital grains are angular to sub-rounded and up to 0.9 mm across. They are relatively tightly packed and there is only a minor component of matrix and cement, although there is a minor amount of porosity (void space), estimated at ~5%. Detrital grains are dominated by quartz, but there is a minor amount of detrital fine grained lithics (e.g. clay-rich, chert and rare sericite-rich), plus a little detrital muscovite and K-feldspar, and a trace of tourmaline, zircon and leucoxene/rutile. The matrix is composed of fine grained, low-birefringent clay (e.g. kaolinite) (Fig. 17), in places with a trace of finely disseminated pyrite. Locally, pyrite is more abundant, apparently replacing the matrix and occurring as a cement surrounding detrital grains. The characteristics of the rock indicate that it is a fine to medium grained, quartz-rich sandstone.

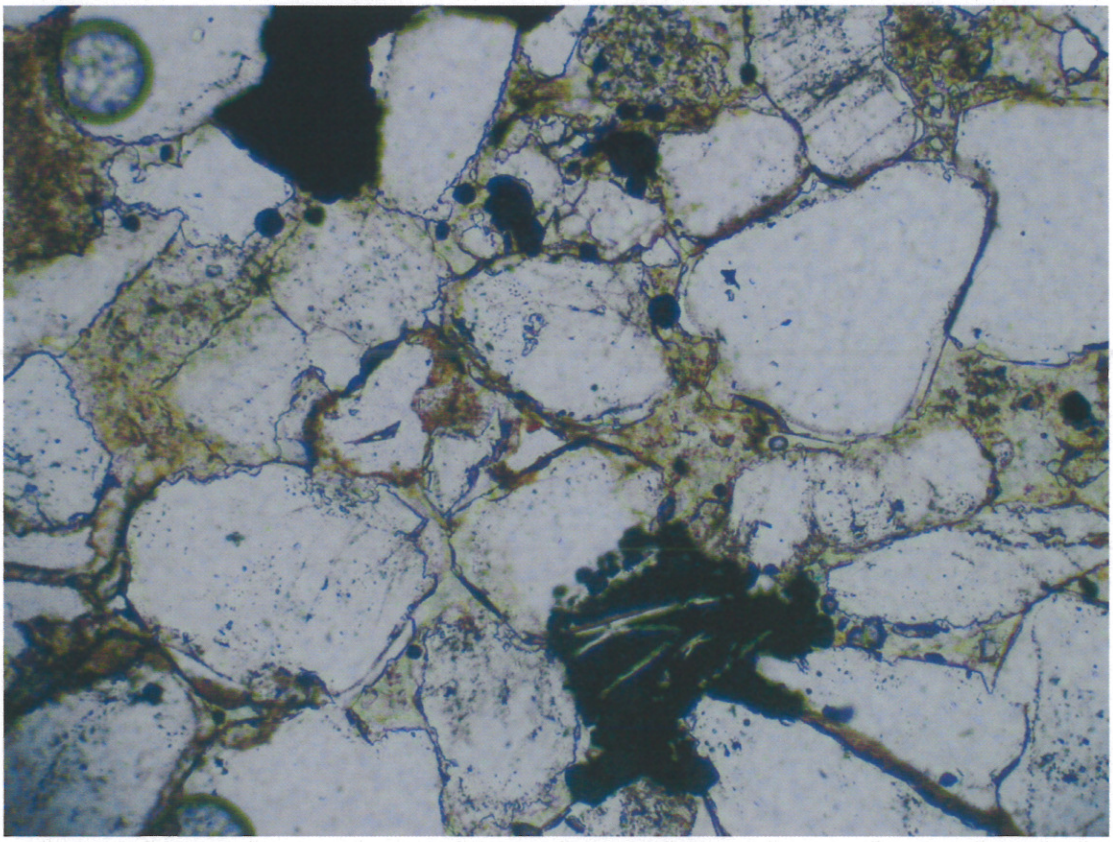

Figure 17: Detrital grain texture in quartz-rich sandstone, with detrital grains showing thin quartz overgrowths. There is a minor amount of pale brown clay matrix and scattered pyrite aggregates (black). Plane polarised transmitted light, field of view 1 mm across.

b) Alteration and structure: It is interpreted that the rock has undergone diagenetic alteration. This is indicated by the local growth of thin quartz overgrowths on detrital grains (Fig. 17), the possible recrystallisation of fine grained kaolinitic clay in the matrix and in clay-rich lithic grains, and the formation of fine disseminations and small aggregates of fine grained pyrite (Fig. 17). The latter appears to have replaced matrix, and locally, detrital grains.

c) Mineragraphy and paragenesis: The rock contains a little pyrite, in places as sparse fine grained disseminations in the matrix, and locally as more abundant aggregates up to 1 mm across that act as a cement to detrital grains (Fig. 17). Textures indicate that pyrite has replaced matrix, and locally, detrital grains (e.g. muscovite). Within aggregates, pyrite is fine grained (<0.1 mm) and anhedral to subhedral in shape.

Mineral Mode: Approximate modal proportions are: quartz 85%, clay (e.g. kaolinite) 12%, sericite/muscovite, K-feldspar and pyrite each 1% and traces of tourmaline, zircon and leucoxene/rutile.

Interpretation and Comments: It is interpreted that the sample represents a fine to medium grained quartz-rich sandstone, with minor clay-rich matrix as well as a small amount of porosity. Detrital grain texture is well preserved and quartz is accompanied by minor lithic detrital grains (clay-rich, chert) and a little muscovite and K-feldspar. Diagenetic alteration has led to development of a little disseminated pyrite in the matrix, locally grading into small aggregates that act as cement to detrital grains. There has also been slight development of quartz overgrowths on detrital grains.

<u>01453</u> <u>PTS</u>

Summary: Medium to coarse grained quartz-rich sandstone, with interstitial clay-rich matrix as well as minor porosity. Detrital grains are sub-rounded to sub-angular and are dominated by quartz. In places there are thin quartz overgrowths on detrital grains. Matrix clay is finely crystalline and probably kaolinite. It contains traces of fine grained disseminated pyrite, but in one part of the sample, matrix clay has been replaced by semi-continuous pyrite aggregates, acting as a cement to detrital grains.

Handspecimen: The drill core is composed of a massive, pale grey, medium to coarse grained quartz-rich sandstone with detrital grains up to 4 mm across. The rock has minor porosity as well as a small amount of white clay interstitial to detrital grains. Locally, there is minor disseminated pyrite. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, detrital grain texture is well preserved and it is evident that the rock is a medium to coarse grained quartz-rich sandstone (Fig. 18). The rock has a grain-supported texture, although there is a minor matrix component and porosity is estimated at 5-10% (Fig. 18). Detrital grains are sub-rounded to sub-angular and up to 4 mm across. They are dominated by quartz, mostly as single grains, but there are a few polycrystalline aggregates. There only other detrital phases are traces of lithics (e.g. fine grained quartz-sericite), muscovite, zircon and rutile. The matrix is composed of finely crystalline, low-birefringent clay (e.g. kaolinite), in places with a trace of finely disseminated pyrite (Fig. 18). In one part of the section, the clay matrix has been replaced by pyrite, forming cement interstititial to detrital grains (Fig. 19). In this situation, pyrite is locally associated with traces of fine grained quartz.

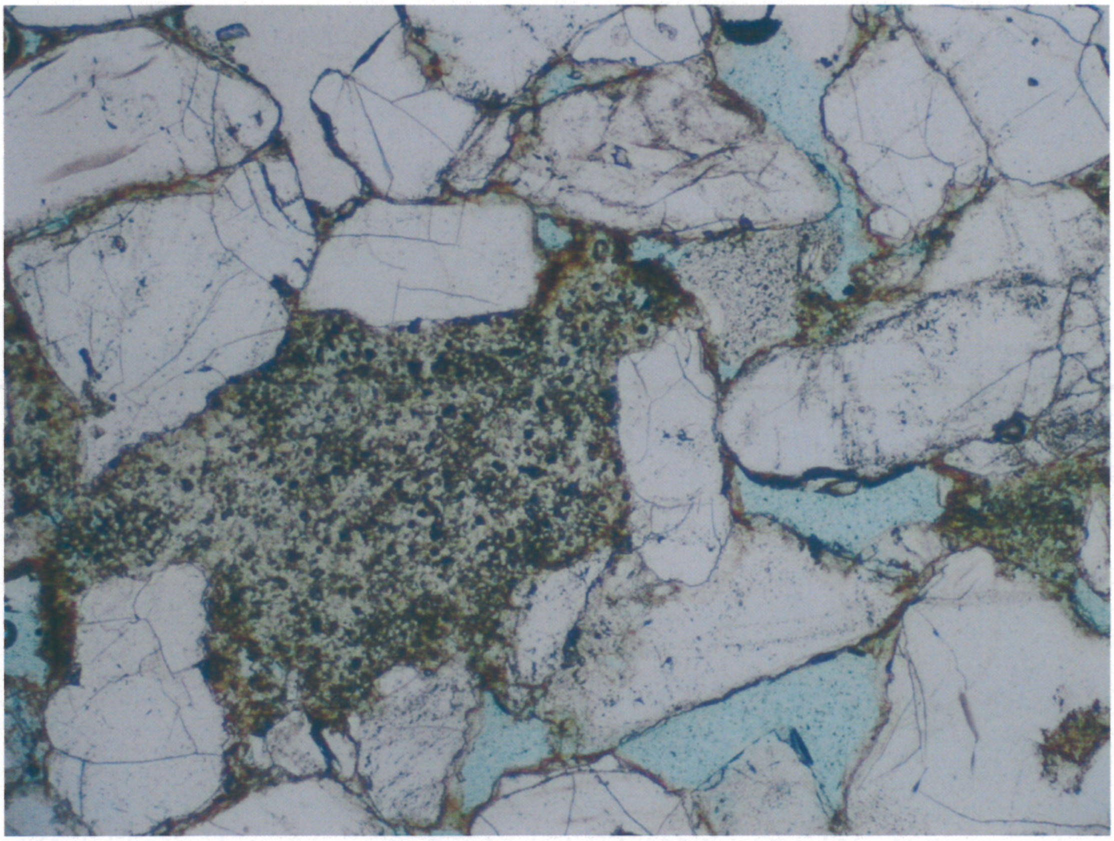

Figure 18: Typical texture in medium grained sandstone with detrital quartz grains, interstitial slightly turbid clay matrix and minor void space (pale blue). Plane polarised transmitted light, field of view 2 mm across.

b) Alteration and structure: It is interpreted that the rock has undergone diagenetic alteration. This is indicated by the local growth of thin quartz overgrowths on detrital grains (Fig. 18), the possible recrystallisation of fine grained kaolinitic clay in the matrix and development of traces of disseminated pyrite. In one part of the section, there has been strong replacement of matrix clay by semi-continuous aggregates of pyrite (Fig. 19) and traces of fine grained quartz. It is possible that there has been later slight oxidation, causing formation of a little goethite staining (perhaps from dissolution of pyrite).

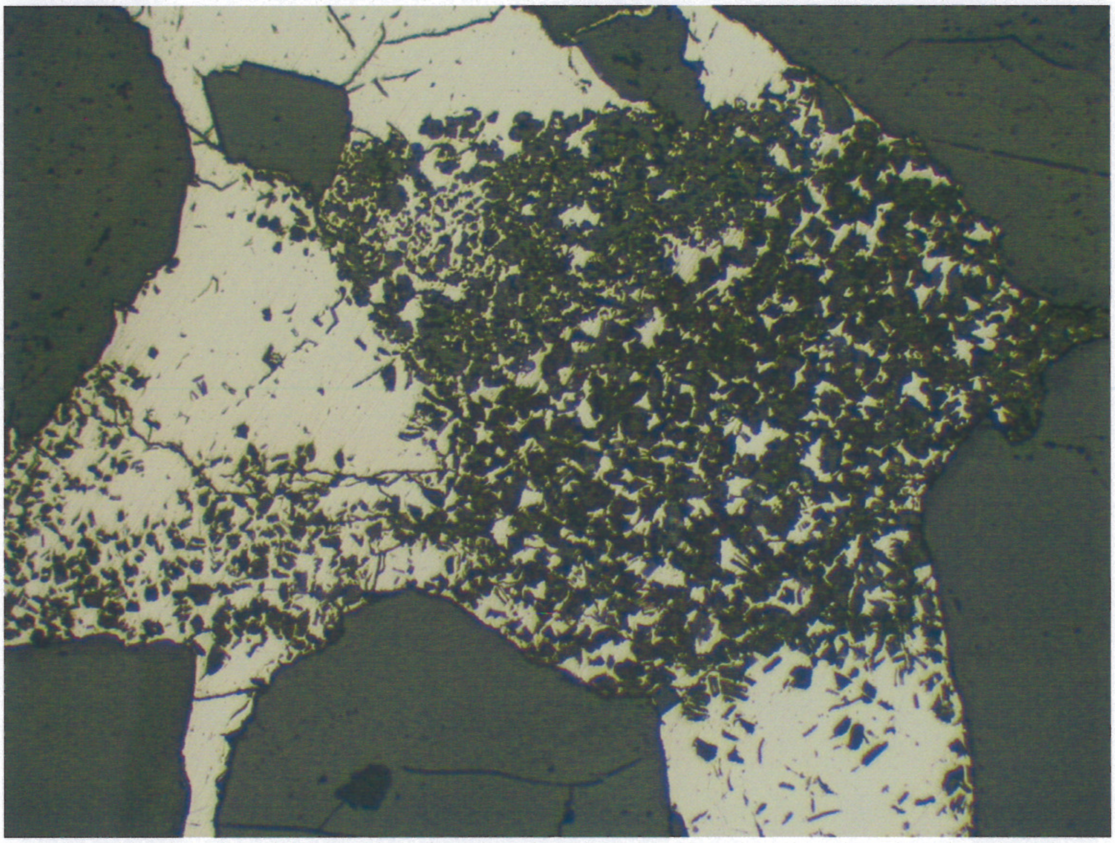

Figure 19: Intergrowth of diagenetic pyrite and fine grained matrix clay (dark grey granular) interstitial to detrital quartz grains. The pyrite may have replaced the clay. Plane polarised reflected light, field of view 1 mm across.

c) Mineragraphy and paragenesis: The rock contains a domain in which there has been extensive replacement of matrix clay by semi-continuous aggregates of pyrite up to several millimetres across (Fig. 19). Elsewhere in the sample, there are traces of fine grained pyrite in the matrix. In the pyrite aggregates, the mineral is fine to medium grained.

Mineral Mode: Approximate modal proportions are: quartz 90%, clay (e.g. kaolinite) 7%, pyrite 3% and traces of muscovite/sericite, zircon, rutile and goethite.

Interpretation and Comments: It is interpreted that the sample is a medium to coarse grained quartz-rich sandstone, with interstitial clay-rich matrix as well as minor porosity. Detrital grains are dominated by quartz. Diagenetic alteration has led to formation of thin quartz overgrowths on detrital grains. Matrix clay is finely crystalline and probably kaolinite. It contains traces of fine grained disseminated pyrite, but in one part of the sample, matrix clay has been replaced by semi-continuous diagenetic pyrite aggregates, acting as a cement to detrital grains.