Pontifex & Associates Pty Ltd

MINERALOGY — PETROLOGY

A.B.N. 25 007 521 084

1A Lancelot Avenue
Hazelwood Park
South Australia 5066
Tel: +61 08 8379 4583
Fax: +61 08 8338 4866
Mob: 0427 326 744

PO Box 91
Kent Town SA 5071
AUSTRALIA

Email:
ian@pontifexpetrographics.com.au
Website:
www.pontifexpetrographics.com.au

MINERALOGICAL REPORT No. 10601

Ian R. Pontifex MSc.

21st February 2017

TO:	Andy Bennett andy@phoenixcopper.com.au
YOUR REFERENCE:	Your personal delivery of samples 27/01/17
MATERIAL:	Eight drill core samples from PNX Metals Barossa Prospect Pine Creek Geosyncline, N.T.
WORK REQUESTED:	Thin and polished thin sections and petrographic report
SAMPLES & SECTIONS:	Temporarily retained, awaiting your collection
DIGITAL COPY:	Emailed (22/02/17) to: < andy@phoenixcopper.com.au >

PONTIFEX & ASSOCIATES PTY LTD

INTRODUCTION (including procedures)

This report petrographically describes eight core samples received from Andy Bennett, 25/1/17 PNX Metals, labelled "Barossa Prospect", Pine Creek Geosyncline, N.T. Sample numbers are BTS-1, 2, 3, 6, 7, 9, 10 and 12.

Five samples were examined in normal thin sections, and three samples BTS #3, #7 and #9 which contain sulphide mineralisation, were examined in polished thin sections. One sample BTS #3 was analysed by semiquantitative XRD to help identify the composition of an ultra fine matrix, which could not be resolved optically.

Each description includes field notes, a summary of gross mineralogy, selected photomicrographs, and interpretation. A separate Summary Comments (next page) includes references to the field notes.

SUMMARY COMMENTS

Six of the eight core samples petrographically examined for this report, i.e. BTS Nos #1, #2, #3, #6, #9 and #10 are interpreted as regionally metamorphosed very fine clastic sediments which were originally argillaceous, quartz/feldspar silt to very fine sandy sediments, now with (later) metamorphic biotite derived from original "clays". The other two samples no. BTS #7 and BTS #12 are calc-silicates dominated by metamorphic hornblende > chlorite > quartz, garnet, interpreted as metamorphosed chemical sediment, with up to 15% irregularly interlayered pyrrhotite.

The petrology indicates the following listed rock types of the meta-clastics (together with some individual characteristics), then the two calc-silicates.

BTS #1, massive weakly laminated 'schist' as a meta-pelitic siltstone to very fine sand-size, meta sediment, composed of quartz, feldspar (?), fine ± biotite sericite. [Could be interpreted as possible fine greywacke/turbidite, as questioned in the field notes.]

BTS #2, laminated metapelitic siltstone (shale or fine schist), with fine biotite schistosity at right angles to bedding. Trace very small pyrrhotite grains.

BTS #3, laminated pelitic siltstone composed of albite, quartz, chlorite with abundant disseminated fine biotite, not especially schistose. Scattered small (1.0mm) grains of pyrrhotite (7–10%), mostly with rims of garnet.

BTS #6, laminated meta silty-pelite, with a very fine biotite-schistosity at right angles to bedding.

BTS #9, ultrafine sericite > quartz, intercalated meta-pelitic (shale). Minor very small altered biotite (some along bedding). Several thin beds of ex-silt to fine sand, same as BTS #1 facies.

BTS #10, laminated/thin bedded, meta silt to fine quartz grains > sericite, abundant "bedded" biotite not particularly schistose. One central bed selectively with the same whole rock matrix, but hosting abundant small authigenic, porphyroblastic garnets.

The remaining two calc-silicate samples, BTS #7 and #12, are dominated by layered course crystalline green metamorphic hornblende, with sporadic interlayers and interstitial irregular lenses variably of quartz, extremely fine massive chlorite > garnet, pyrrhotite, and rare carbonate. The pyrrhotite forms ~15% of BTS #7, and ~10% of BTS #12. Sample BTS #7 is irregularly tightly crenulated-folded.

Both of these samples are interpreted as calc-silicates, which in the context of this whole suite of meta-sediments, may represent metamorphosed, Ca Mg Fe Si chemical sediments, (if this is regarded as "geologically feasible?").

[The XRD results for BTS #3 are next page.]

MINERAL IDENTIFICATION REPORT No. 22139

1. INTRODUCTION

One sample, BTS-3 was received from Ian Pontifex of Pontifex & Associates Pty Ltd with a request for determination of its mineralogy.

2. PROCEDURE

The sample was pulverized then analyzed by X-ray diffraction to identify the minerals present.

3. RESULTS

The semi-quantitative mineralogy of the sample follows.

Mineral name	Composition	Relative abundance
		BTS3
Quartz	SiO_2	A
Biotite	$K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$	D
Muscovite	$KAl_2Si_3AlO_{10}(OH)_2$	A
Chlorite	$(Mg,Al,Fe)_{12}(Si,Al)_8O_{20}(OH)_{16}$	A-SD
Albite	$NaAlSi_3O_8$	A
Pyrrhotite	Fe_x–S	Tr

Semiquantitative Abbreviations

D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.
CD = Co-dominant. Used for two (or more) predominating components, both or all of which are judged to be present, in roughly equal amounts.
SD = Sub-dominant. The next most abundant component(s) providing its percentage level is judged above about 20.
A = Accessory. Components judged to be present between the levels of roughly 5 and 20%.
Tr = Trace. Components judged to be below about 5%.

INDIVIDUAL PETROGRAPHIC DESCRIPTIONS (including photomicrographs)

Sample No. BTS #1, 20.86 to 20.89

Field Note: ***Greywacke/siltstone/turbidite.***

Macro (binocular microscope)

The hand specimen of this core piece is a homogenous greenish grey, massive, extremely fine grained and compact rock with vague, very poorly defined laminations. A broken surface indicates abundant extremely fine micas within an even finer silicate-mineral matrix. Macroscopically it seems to be a meta-pelite or metasiltstone.

Micro

Petrographically, the thin section shows the following estimated gross mineralogy. The whole-rock "matrix" seems to be a mix of quartz, feldspar, and sericite, but is too fine to optically resolve.

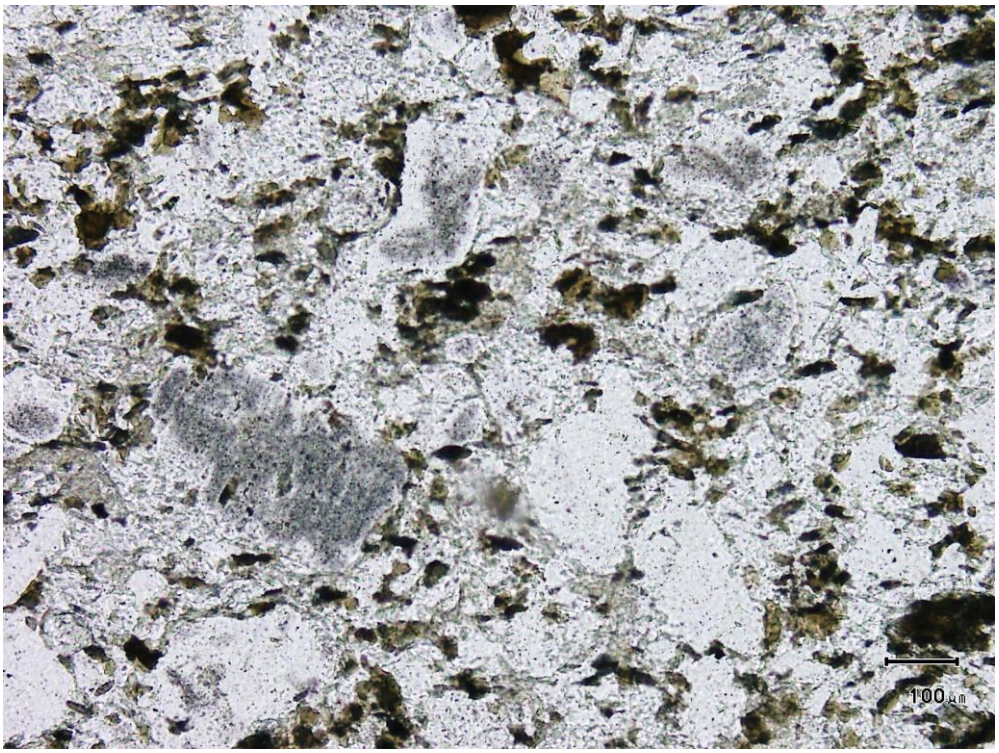
		Approx vol %
*	quartz, as detrital silt to medium sandsize grains	10%
*	probable feldspar(s), of same size range	10%
*	biotite scattered composites of random extremely fine flakes, in clusters up to 0.3mm	~30%
*	whole-rock matrix of meta ultra fine (< 0.1mm) quartz/feldspar undifferentiated, and subequal intricately mixed sericite	~50%

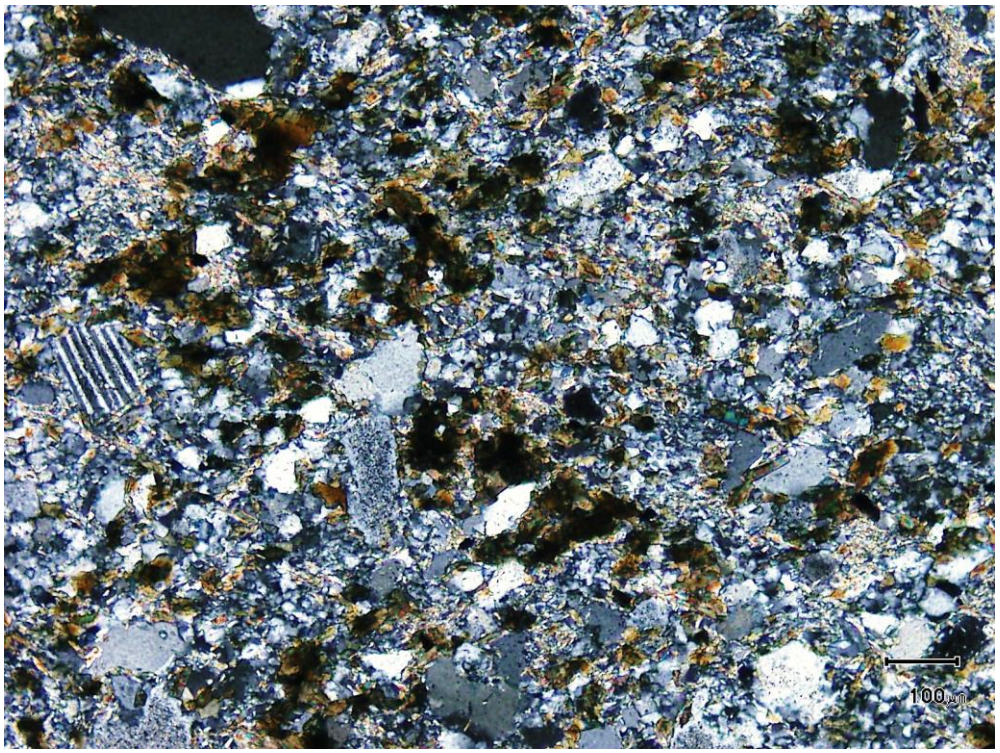
The relative mineral abundances vary slightly to give rise to vague (bedding) laminations.

Of the individually listed minerals above, the "coarser" residual ex-detrital grains of quartz and feldspar mostly have angular (to incipiently corroded-looking) morphology, perhaps indicative of relative immaturity, "short" travel distances, and rapid deposition (which may be consistent with fine greywacke/turbidite ?).

Interpretation

Classified as a low grade, (regionally) metamorphosed, quartz, feldspar, silty pelitic, fine sandstone may be interpreted as fine greywacke or turbidite as questioned in the field note.





Figs 1 and 2 **Sample No BTS #1**

Thin section (TS), Ordinary light (OL), and crossed nicols (X nic). Moderately high magnification (X100). Different fields of view both typical of this homogenous whole sample. Ordinary light **Fig 1**, shows distribution and abundance of dark biotite in small clusters, more or less schistose (to random), and interstitial between a quartz /feldspar low grade meta-sediment. The X nic **Fig 2** highlights the rock-forming aggregate of "dusty" and some twinned feldspar, relatively brighter (and smaller) quartz grains, also minor very small bright flakes of sericite together with the biotite.

<u>BTS #2</u>, 34.88 to 34.96

Field Note: ***Well bedded SLST turbidite.***

Macro

This core piece is a homogenous laminated rock, with a darkish greenish-grey color, predominantly extremely fine grained and compact, with local (schistose) laminations. The "homogeneity" is varied by minor thin beds (to 3mm), bounded by the schistosity, slightly paler than the whole rock, producing laminations.

Micro

This thin section confirms the almost complete macro homogeneity of composition, also of textures dominated by extremely fine schistosity along the length of this core piece. This schistosity consists of a close-packed and common orientation of micro-braided sericite (35%) incorporating ultra fine quartz (25%) and/or feldspar, also commonly oriented slightly coarser metamorphic biotite flakes (up to 35%).

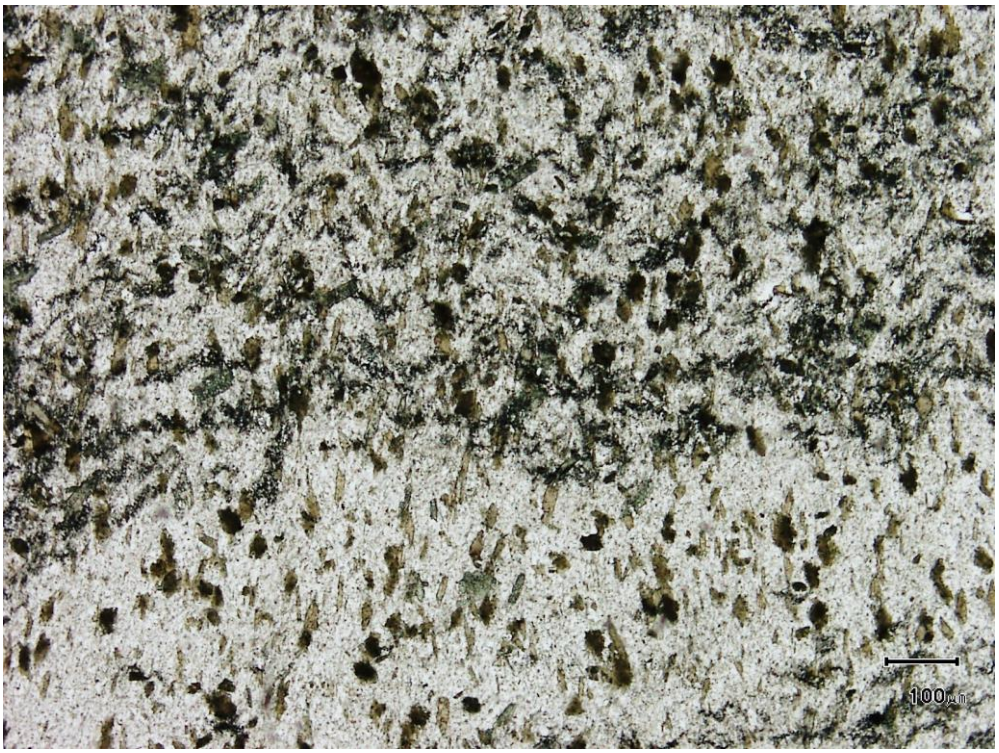
An original bedding is poorly defined by "residual" carbonaceous 'dust' forming slightly crenulated bedding trails, (see fig 4), oriented east-west across the core axis (parallel to the laminations). Therefore the fine schistosity is at right angles to bedding, (north-south).

Other components are rare, sporadic, very small lenses (1.0mm x 0.5mm) of very fine granular pyrrhotite, less than 2% of this whole section, also trace small lenses of pyrrhotite (2%). A single thread-like veinlet of carbonate occurs along the schistosity, along the core length.

Interpretation

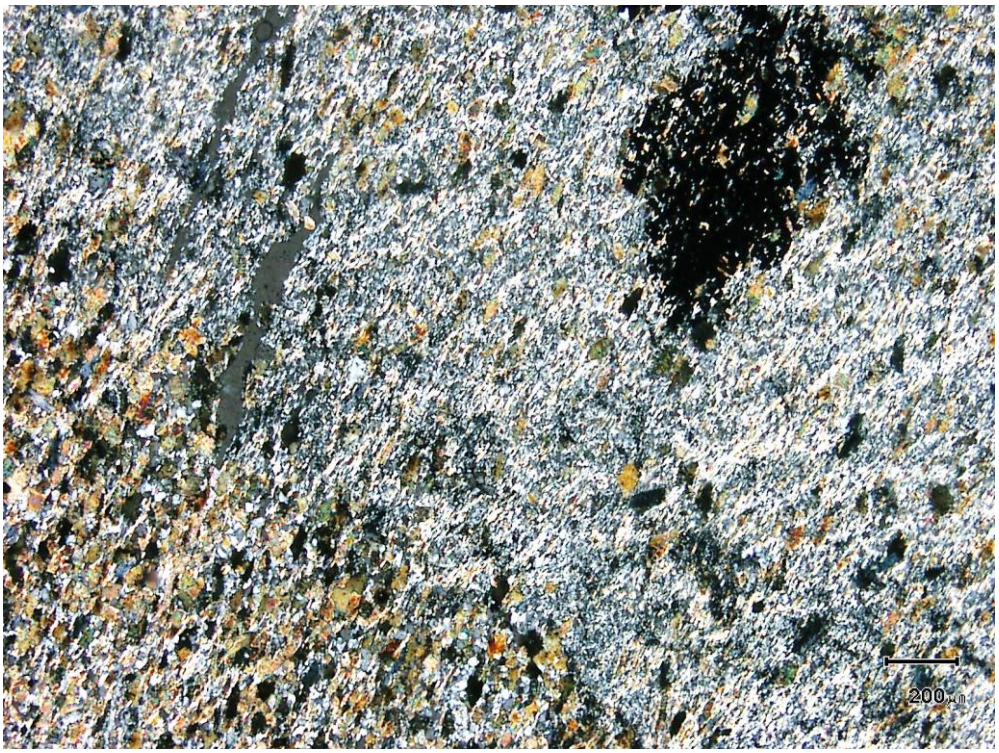
"Shale" with an extremely fine schistosity along the core length, cutting bedding laminations which are at a high angle to the core axis. The composition is sericitic ± incorporated ultra fine quartz, and = coarser biotite, forming a fine schistosity along the core length. Bedding laminations cut across the core axis. There are rare very small pyrrhotite grains and lenses, and dusty relict carbon/graphite along original bedding.

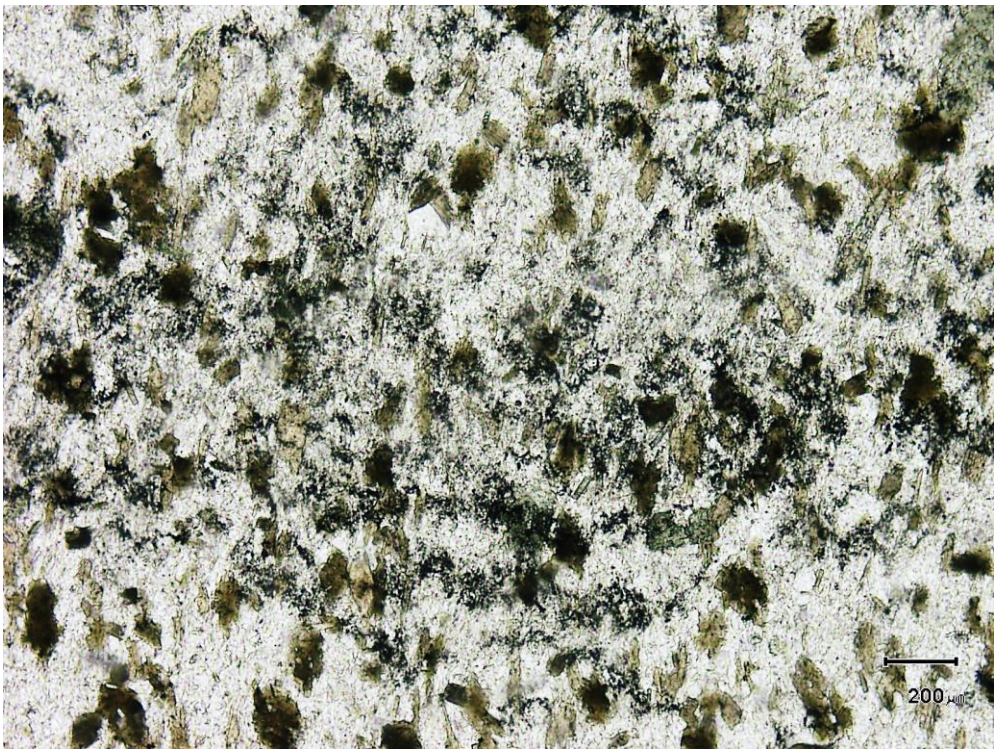
Genesis is a low grade, metamorphosed, pelitic siltstone.



Figs 3 and 4 **Sample No BTS #2**

Fig 3, TS, lowest magnification (X20), showing laminations in this metapelite, extremely fine quartz/sericite shale, with greater and lesser dark equally fine biotite. **Fig 4**, higher magnification (X100), contact between east-west paler and darker laminations, (bedding). Dark biotite flakes commonly oriented at right angles across bedding as a weak schistosity. Sericite dominates the whole rock matrix.





Figs 5 and 6 **Sample No BTS #2**

Fig 5, TS, X nic, (X50). Further example of weakly schistose, dark-biotite (SW corner), and pale sericite-rich laminations. Opaque ovoid in NE quadrant is black-opaque pyrrhotite. **Fig 6**, (X50), pale sericitic-shale or metasiltstone with black opaque-carbonaceous "dust", outlining relict E–W crenulated bedding. Coarser greenish-khaki biotite flakes oriented N–S as a very weak schistosity. [Essentially the same as BTS #6; see **fig nos. 10 & 11** below.]

BTS #3, 36.46 to 36.53

Field Note: ***SLST/MDST, py-altered.***

Macro

Macroscopically, this greenish to dark-grey very compact and fine grained "metapelite" or metasiltstone) is similar in hand specimen as the two samples above. There is however a "stronger" single bedding plane contact, between a relatively pale (greenish) laminated sequence (same as BTS #2), forming 1/3 of the thin section, and the other 2/3, which is slightly darker without laminations, but with numerous small scattered "spots" of pyrrhotite < 1.0mm to 3.0mm size.

Micro

Petrography and XRD, identify a matrix throughout, dominated by extremely fine metamorphic chlorite, albite, quartz, sericite, evenly dispersed throughout, but more in the dark area than in the pale area. Small (0.5mm) grains of pyrrhotite (7–10%) are also disseminated, most in the dark area.

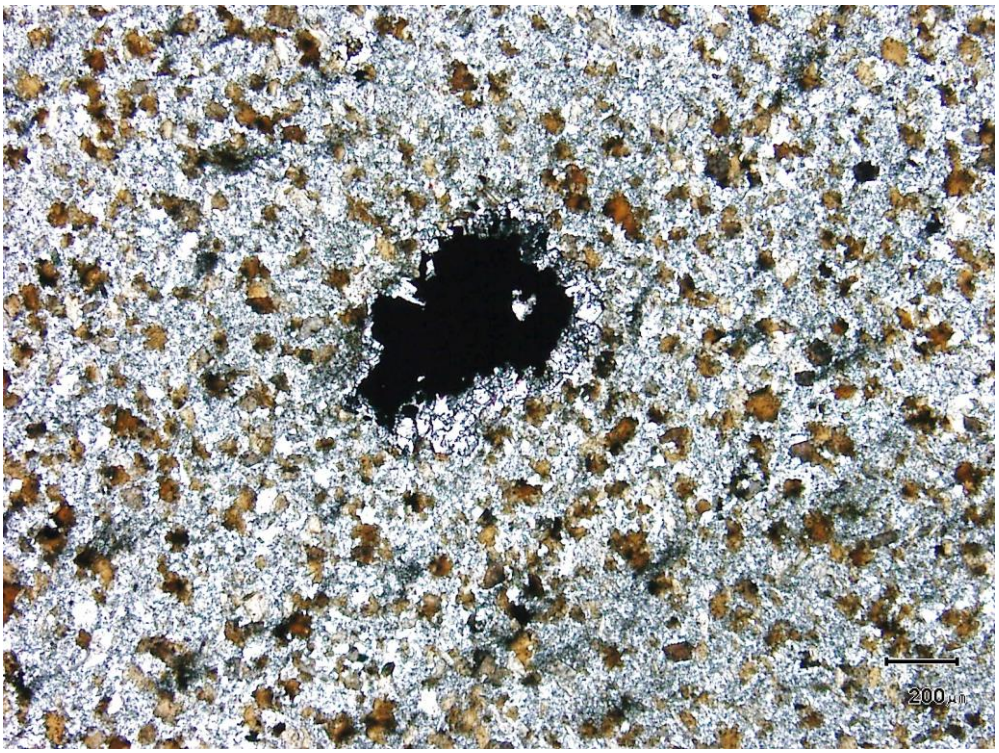
Minor small lenses of pyrrhotite are rimmed by garnet, and sparse chalcopyrite occurs within the pyrrhotite. Rare ovoids of this same size consists of garnet and of quartz, and rarely of chlorite. Ultra fine carbon/graphite? occurs in the darker area.

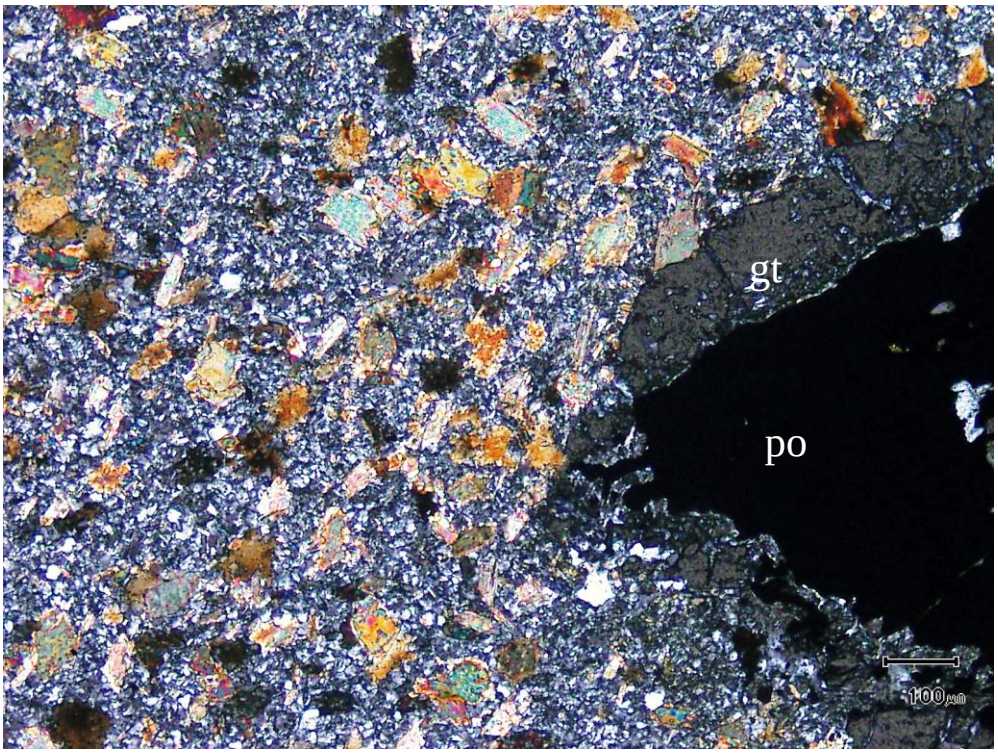
Estimated gross mineralogy (both areas) is:

		Approx vol %
*	biotite, evenly disseminated to weakly layered crystals	35%
*	less evenly disseminated, equally fine chlorite crystals (identified by XRD), largely forming a matrix together with extremely fine quartz.	45%
*	pyrrhotite very small scattered grains mostly in the dark area	10%
*	garnet, rims around pyrrhotite, also some individual crystals	5–7%

Interpretation

Meta silty sericitic pelite, with abundant disseminated biotite.





Figs 7 and 8 **Sample No BTS #3**

Fig 7, TS, OL, (X50). Relatively low magnification, massive quartz-feldspar-biotite metasiltstone, with biotite randomly disseminated. Central black-opaque grain of pyrrhotite with a surrounding rim of colorless high RI garnet. **Fig 8**, X nic, higher magnification (X100), showing microscopic chlorite quartz-feldspar matrix, also part of a "large" black-opaque pyrrhotite (po); with a surrounding rim of garnet (gt).

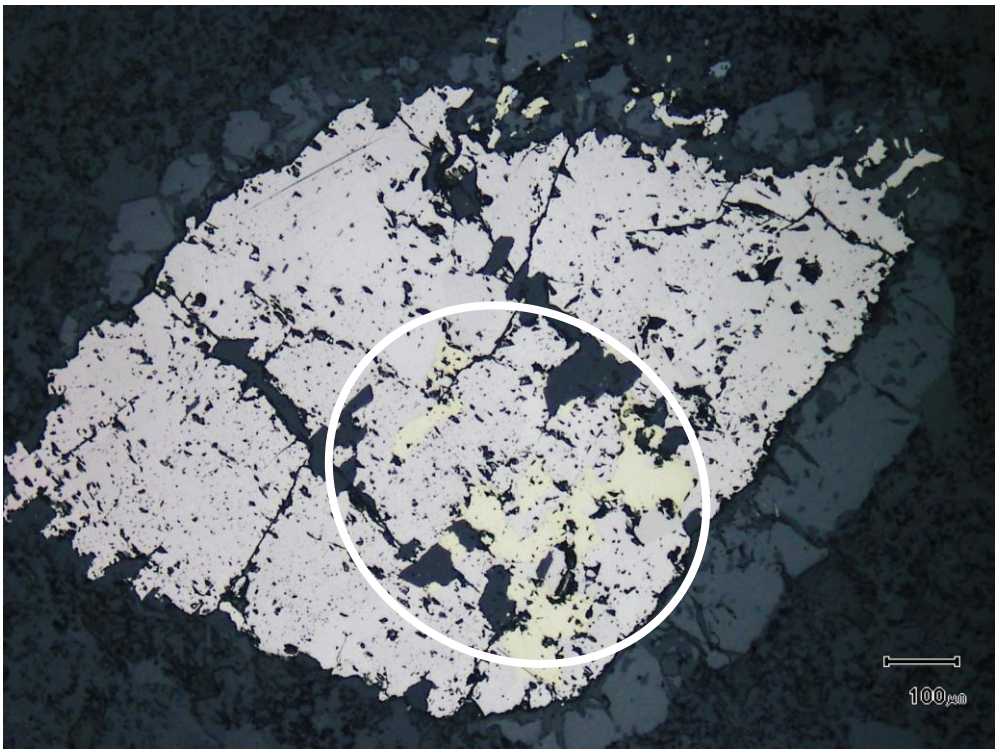


Fig 9 **Sample BTS #3**

Polished section (PS), (X100). Reflected light photo of pyrrhotite, surrounded by a rim of darkish-grey garnet. Sparse inclusions of pale-yellow chalcopyrite in SE quadrant (circled).

BTS #6, 55.66 to 55.73

Field Note: SLST/MDST

Macro

Macroscopically, about 95% of the length of this core piece is remarkably homogenous-laminated, with individual laminae identified by slight color variations of overall slightly greenish mid-grey. One corner of the section (10%) has a local very fine scale undulating fold structure including one micro layer of "different" mineralogy, seen optically as garnet-rich.

Micro

An ubiquitous micro(to crypto)-crystalline matrix throughout this rock consists of extremely fine quartz ± sericite ± feldspar (but too fine to quantify optically). This matrix is crowded with extremely fine strongly schistose biotite flakes, commonly oriented along the length of the core, (as in sample BTS #2). This schistosity cuts across at right angles the bedding laminations, which are defined by poorly defined discontinuous/crenulated trains of apparent ultra fine (dusty) black opaque carbonaceous material (see fig 10).

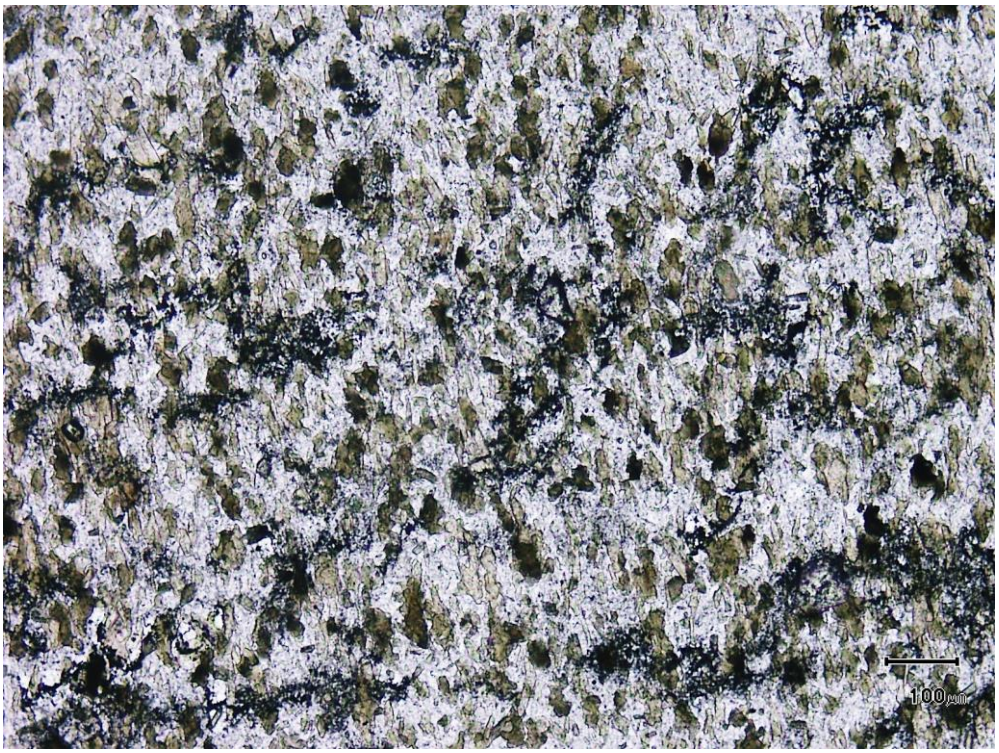
The local folded structure has a vague core of small garnets and associated vein quartz.

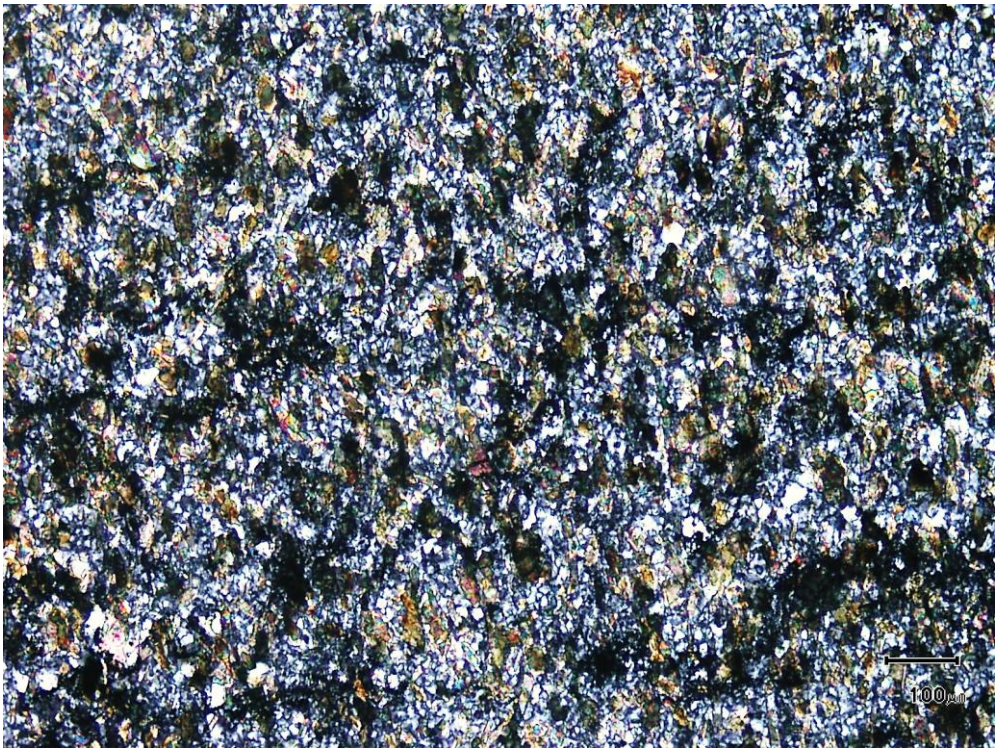
Estimated gross mineralogy is:

		Approx vol %
*	biotite, commonly oriented along the core axis	35%
*	clearer whole-rock matrix of ultra fine quartz, sericite	40%
*	ultra fine relict carbonaceous dust along bedding	7–10%
*	garnets, scattered and in a fold structure	7–10%
*	local vein quartz in the fold structure	5%

Interpretation

Meta silty-pelite, "fine schist", with biotite schistosity at right angles to bedding laminations.





Figs 10 and 11 **Sample No BTS #6**

TS, OL and X nic, equivalent, (X100). Laminated metasiltstone (essentially the same as BTS #2 described above.) OL shows poorly defined E–W bedding laminations defined by relict ultra fine apparent carbonaceous (crenulated) trails, within a matrix of very fine quartz feldspar and sericite. Superimposed weakly schistose biotite flakes commonly oriented N–S, cutting across laminations at right angles.

BTS #7, 64.18 to 64.24

Field Note: ***Pyrrhotite-carbonate altered metasediment.***

Macro

Most areas of this thin section offcut is seen to consist of irregular isoclinal to crenulated folding, of mostly a green mineralogy, (subsequently identified in the thin section as hornblende and chlorite). Thin (2mm) white interlayers within this folding, consist of fine quartz and carbonate, ± pyrrhotite.

Micro

As indicated above, the thin section confirms most of this section to consist of heterogeneous folded bands of green metamorphic hornblende, variably of composite prismatic crystals; also in patchy and more or less fibrous bundles. Subordinate thinner interlayers (also within the folds), consist variably of pale quartz, cloudy carbonate, pale chlorite, and irregularly fine to coarse pyrrhotite ± minor local margins of garnet.

Estimated gross mineralogy is:

		Approx vol %
*	hornblende	35%
*	pyrrhotite	20%
*	carbonate	10%
*	quartz	10–15%
*	garnet	7–10%
*	apatite	2–3%
*	chalcopyrite (trace inclusions within pyrrhotite)	trace

Interpretation

Objectively this sample is considered as a layered / folded calc-silicate assemblage, which in the context of the metasediments throughout this suite, may be interpreted as a metamorphosed chemical sediment.

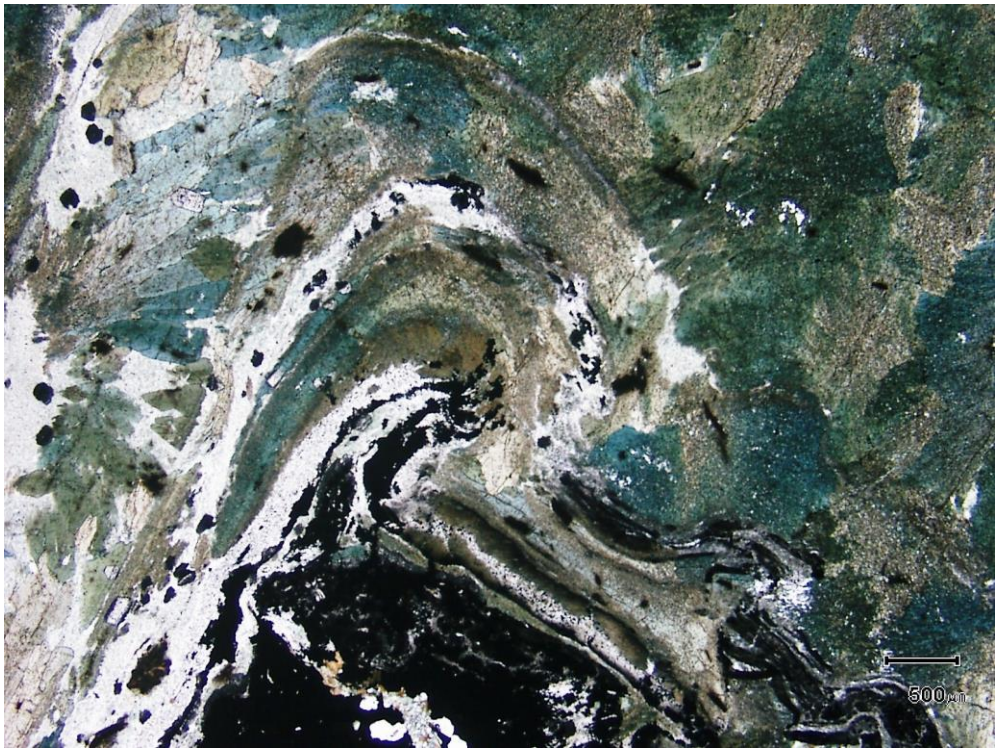


Fig 12 **Sample BTS #7**

TS, OL, (X20). Irregular folding within a sequence of coarse, massive, dark green hornblende ± ultra fine pale green chlorite. Colorless (white) interlayers of quartz > carbonate, and black-opaque pyrrhotite.

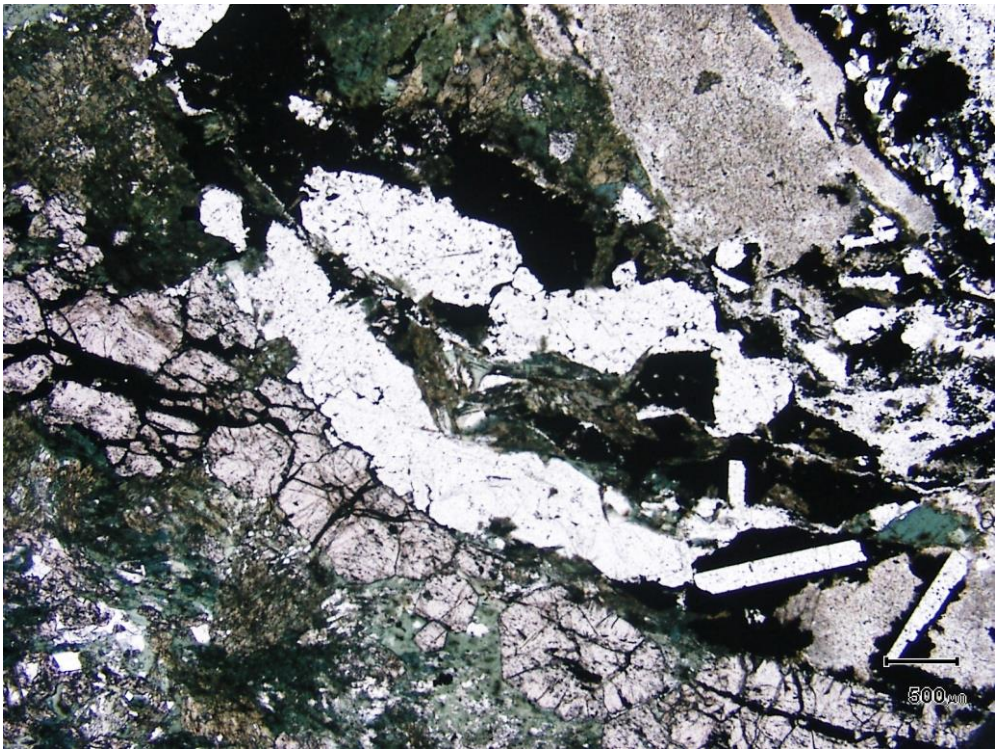
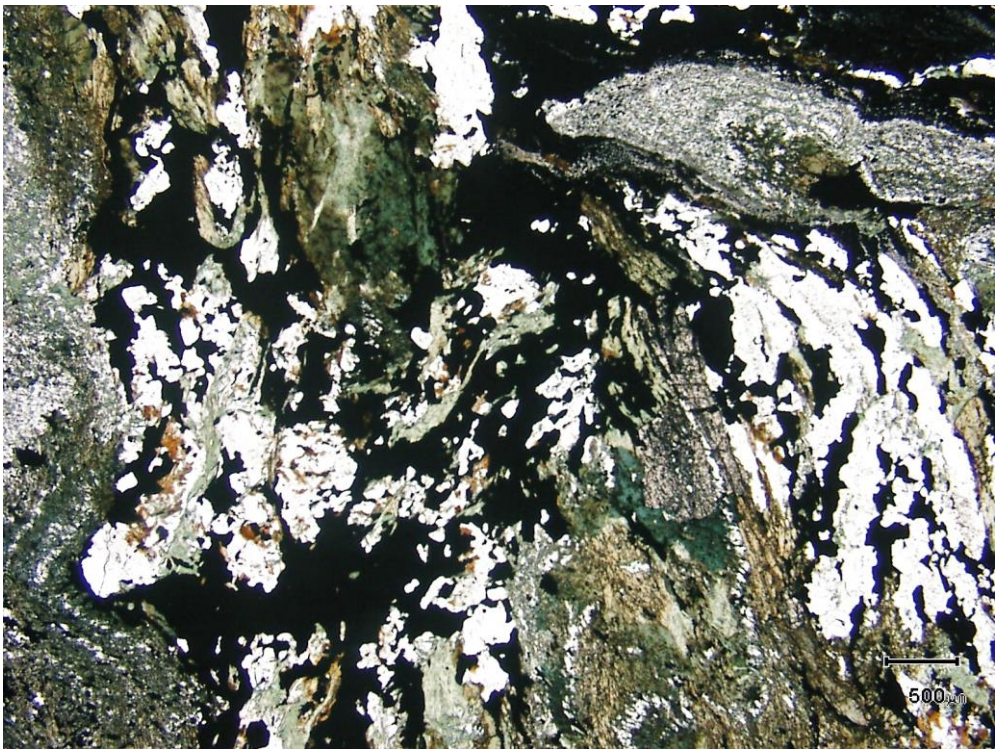
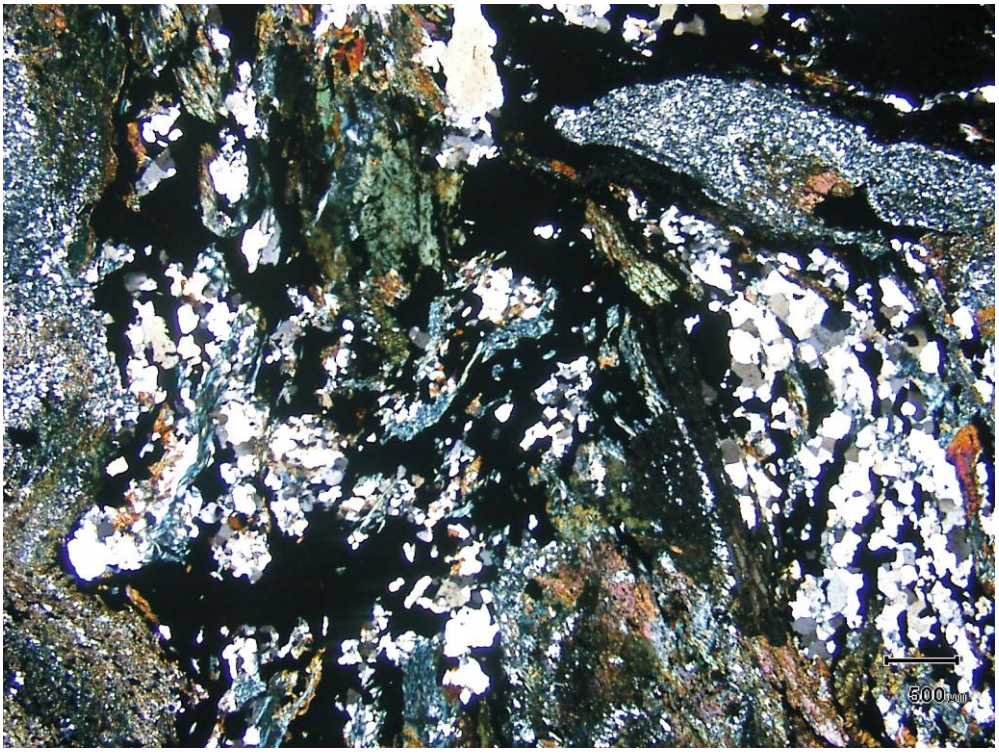


Fig 13 **Sample BTS #7**

TS, OL, (X20). Layered sequence adjacent to folding. In NE quadrant is a patch of dusty extremely fine pale chlorite, with adjacent black-opaque pyrrhotite > white quartz. Central area, interlayered white quartz and black-opaque pyrrhotite. Toward SW quadrant, a layer of high relief garnet crystals ± adjacent green fine chlorite. White lathes in SE corner apparent apatite.





Figs 14 and 15 **Sample No BTS #7**

TS, OL and X nic, (X20). Central area, tight folding of interlayered white quartz, green hornblende ± extremely fine chlorite, black-opaque pyrrhotite. Right hand 1/3, lenses/layers of quartz and opaque pyrrhotite, and in NE corner lens of ultra fine chlorite. Left hand margin of ultra fine chlorite and quartz.

BTS #9, 102.77 to 102.84

Field Note: ***SLST with carbonate veinlet*.**

Macro

This core piece is dominated by a slightly greenish mid-grey, homogenous and compact extremely fine grained rock, with one thin inter-sedimentary bed of slightly coarser quartz/feldspar, 5mm thick. Also numerous disseminated extremely small "spots", and two thread-like veinlets 1.0mm thick, all seen optically as carbonate.

Micro

The petrography and the XRD confirms about 85% of the thin section as a homogenous compact mass of intricately mixed sericite >> equally fine quartz, (similar to BTS #2), with the sericite having a weak schistosity throughout, oriented approaching 45° to the core axis. This incorporates ultra fine quartz which is only just resolvable optically.

The spots seen under binocular microscope, are all about 0.15mm size, fairly evenly disposed, and weakly elongated, more or less commonly oriented along schistosity. These are densely clouded altered biotite flakes (15%), equivalent to those seen as fresh biotite in other samples. This bulk composition and texture is classified as quartz-sericite-rich metapelitic shale.

The single thin bed seen macroscopically consists of sericite, and detrital quartz ± feldspar, and minor muscovite, a meta-pelitic, fine grained sandstone, very similar to the whole rock BTS #1 above.

Interpretation

Laminated sericitic shale (meta-pelite) with minor intercalated thin beds of fine-grained sandstone, similar to the whole rock BTS #1.

Fig 16 **Sample BTS #9**

TS, X nic, (X20). Typical of whole sample, massive, albeit weakly layered, intricately mixed ultrafine quartz and sericitic shale. Crosscutting carbonate veinlet, + minor chlorite. Disseminated minute dark spots appear to be altered biotite.

Fig 17 **Sample BTS #9**

TS, X nic, (X20). Host rock sericite-rich shale, (same as **Fig 16**), in NE and SW corner. Two central layers possibly representing graded bedding, with a bottom layer relatively silty shale, top band is a bed of very fine detrital quartz sandstone within meta-silty-shale matrix same as whole of BTS #1. Rare detrital colored muscovite.

<u>BTS #10</u>, 109.49 to 109.55

Field Note: ***SLST/SDST with nodular band.***

Macro

This section offcut is macroscopically seen in hand specimen to have three areas. Two of these are the same homogenous slightly greenish-grey, and very fine grained (as in most other samples), but only vague laminations, and they form about 15mm length at each end of the section. The third area is a central band (bed) about 15mm thick characterised by about 30% scattered pale garnets, 1.0mm to 1.5mm in size, within a matrix the same as each rock forming area. (The garnets would be the nodules referred to in the field note.)

Micro

The petrography of the two 1/3 ends of this thin section are very similar to the whole of samples #1 and #6 described above, i.e. a low grade metamorphosed quartz/feldspar/biotite siltstone.

This rock type continues into the central 1/3, where it forms a matrix (up to 50%) incorporating evenly scattered small porphyroblasts of garnets, noted macroscopically up to 1.5mm diameter. In detail these porphyroblasts are seen to be somewhat skeletal with micro-serrated margins "growing into the host rock, also crowded with inclusions of quartz silt grains, i.e. classically authigenic.

Figs 18 and 19 **Sample No BTS #10**

TS, OL and X nic, (X50). Homogenous metasediment of very fine quartz-feldspar-biotite, metasiltstone, which forms the 1/3 of both ends in this thin section, similar to the whole of BTS #1.

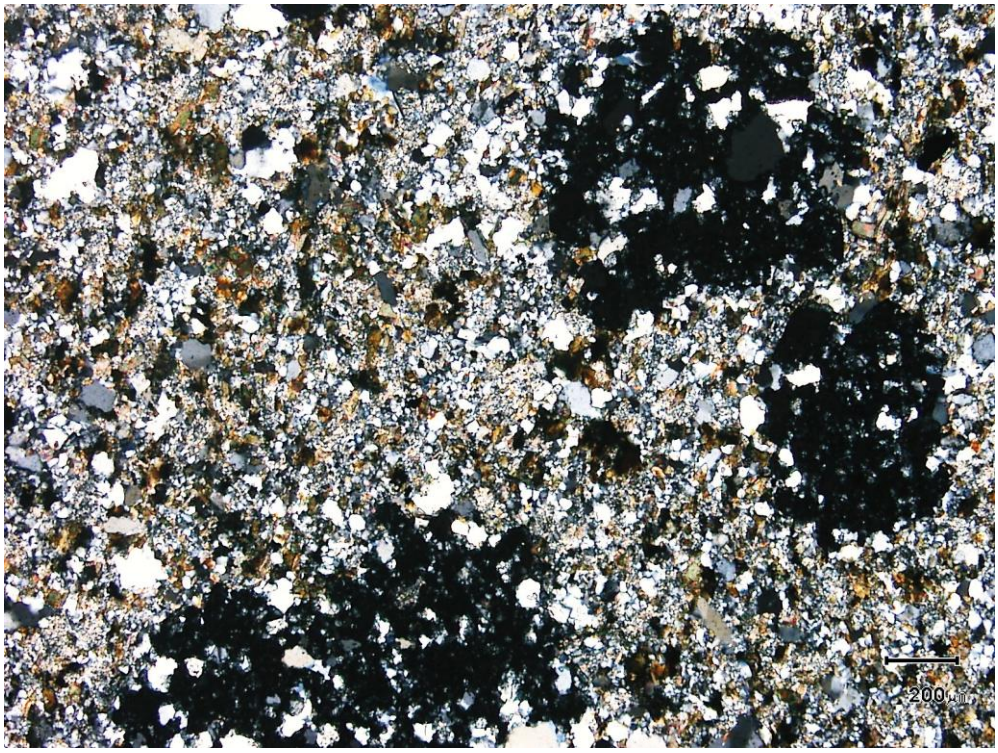


Fig 20 Sample BTS #10

TS, X nic, (X50). Middle 1/3 of this thin section, largely the same as **figs 18 and 19**, but as a matrix to numerous scattered porphyroblasts of garnet (black-isotropic in X nic).

BTS #12, 135.38 to 135.44

Field Note: ***Pyrrhotite-carbonate altered metasediment.***

Macro

Layers forming this distinctively banded rock range in thickness from 5 to 10mm, defined by various shades of green-grey, including hornblende ± chlorite. Dominant greenish layers are coarser crystalline than the lesser finer grained paler layers. Minor fine sulphides, (total 7–10%), are scattered indiscriminately. Macroscopically it is seen to be the same as BTS #7.

Micro

About 2/3 of this thin section consist of relatively thick green layers of randomly interlocking coarse, metamorphic hornblende, with interstitial patches and interlayers of compact extremely fine chlorite. Minor thinner layer consist variably of fine quartz and of fairly continuous trains of small (0.5mm) garnet crystals.

Minor other small garnets, some charged with ultra fine (darkish) chlorite (or possible carbonaceous dust), occur within interstitial pale green chlorite. Other almost clear very fine pale green chlorite occurs in short discontinuous layers.

Minor pyrrhotite occurs as irregular patches, and discontinuous granular trains, together with thinner layers of quartz and/or garnets, all as an integral component within this whole metamorphic crudely layered rock aggregate.

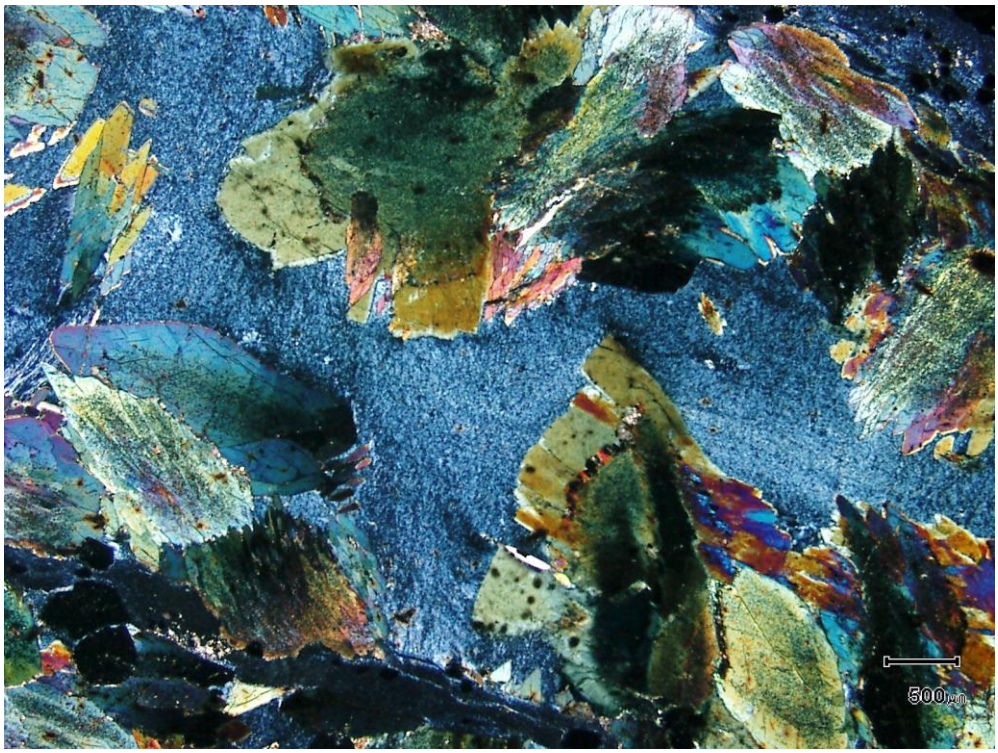
Minor apparent very small crystals of possible apatite occurs within some of the thin intercalated quartz layers.

Estimated gross mineralogy is:

		Approx vol %
*	hornblende	40-50%
*	chlorite	15–20%
*	quartz	10%
*	garnet	10%
*	apatite ?	3%
*	pyrrhotite	10%
*	chalcopyrite trace within some pyrrhotite	1%

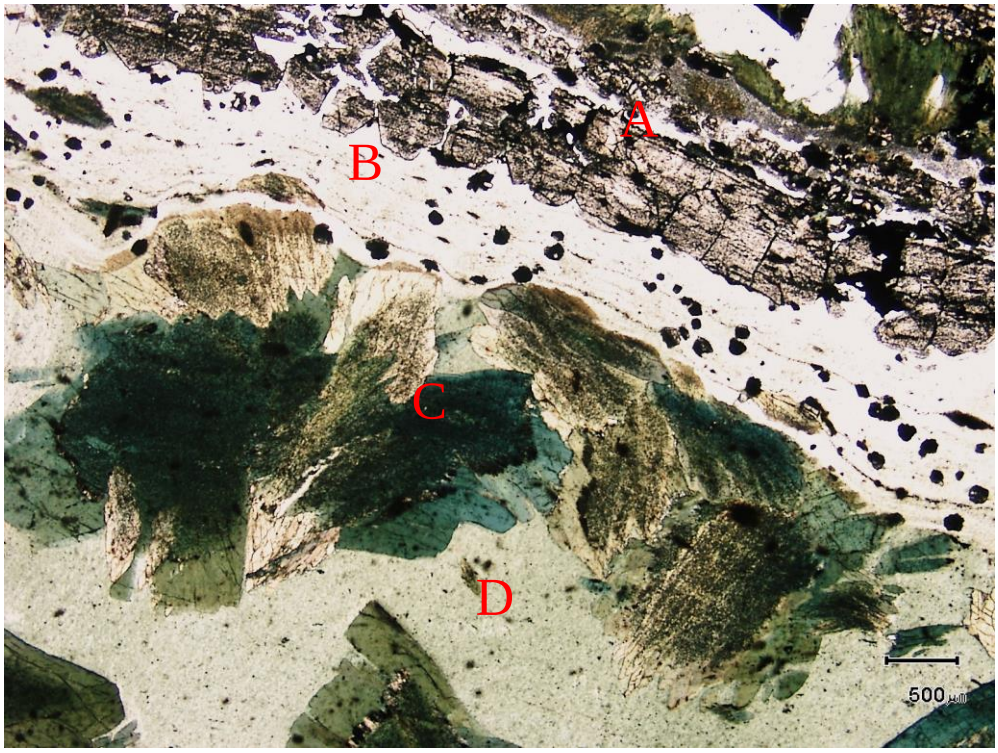
Interpretation

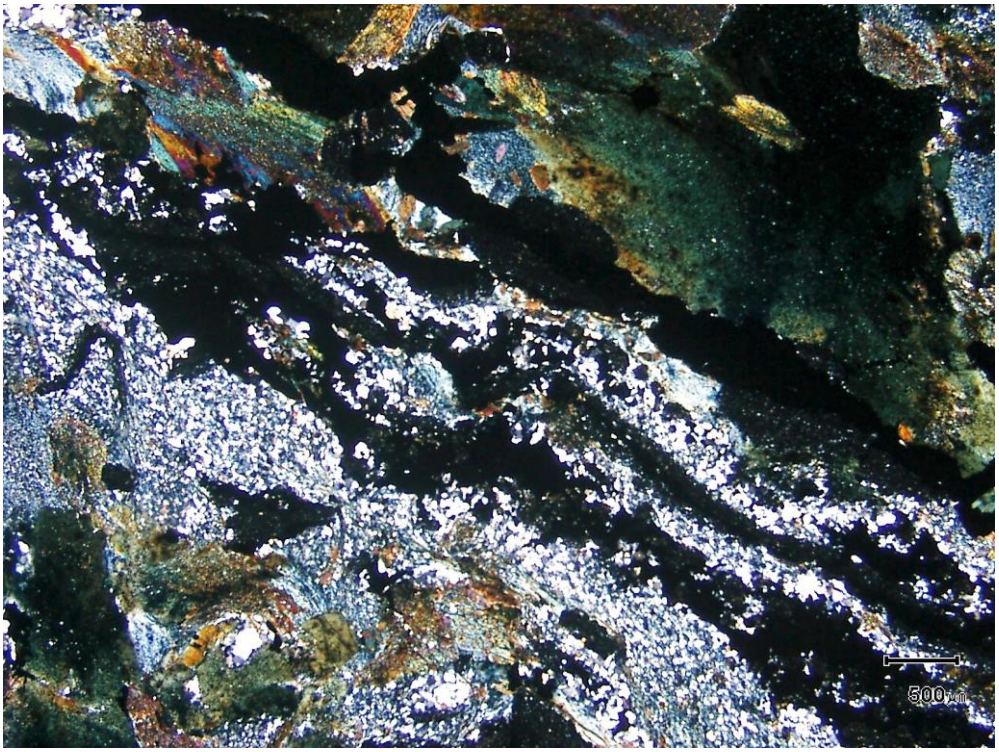
The composition of this sample, (and the comparable BTS #7 in this suite), being within this suite of metasediments, suggest a metamorphosed chemical sediment, (which contained Ca, Mg, Fe and Si). It is questioned if this is geologically feasible (i.e. on drill hole or even broader scale).



Figs 21 and 22 **Sample No BTS #12**

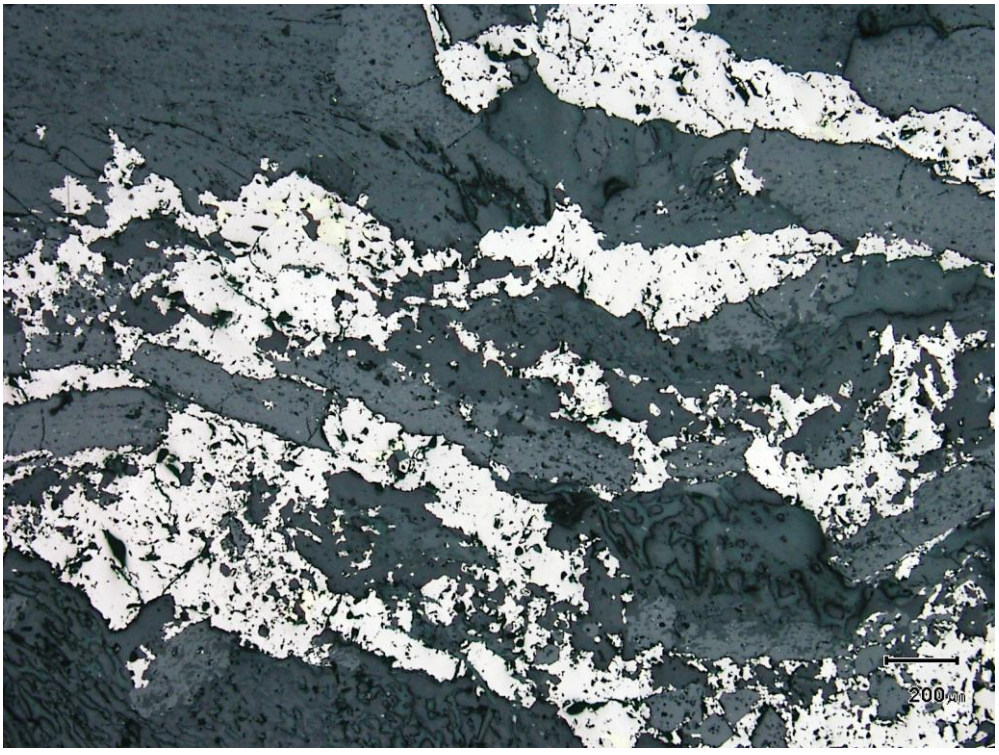
Fig 21, TS, OL, (X20). Crude (disrupted) layering of more or less individual crystals of dark green to yellowish-grey hornblende, fractured black-opaque bands of pyrrhotite, and local dusty small garnets (central, circled). Irregular pale areas between consist of very pale ultra fine chlorite. **Fig 22**, X nic crudely layered coarse crystals of hornblende, with interstitial ultra fine chlorite.





Figs 23 and 24 **Sample No BTS #12**

Fig 23, OL, (X20). Crude layered sequence, (A) garnet, (B) fine quartz with unknown micro spherulites, (C) hornblende, (D) very pale ultra fine chlorite. **Fig 24,** X nic (X50). Layered sequence of black opaque pyrrhotite (with trace chalcopyrite), white-grey quartz, green to tan-colored hornblende.



Figs 25 and 26 **Sample No BTS #12**

Fig 25, OL, (X50). Three central garnets, densely clouded, (with chlorite or carbonaceous dust), within green completely chlorite-altered hornblende with minor white interstitial quartz. **Fig 26**, PS, (X50), pyrrhotite interlayered between layers of garnet and hornblende.