Mason Geoscience Pty Ltd

Petrological Services for the
Minerals Exploration and Mining Industry

ABN 64 140 231 481 ACN 063 539 686

Postal & Delivery: 141 Yarrabee Rd Greenhill SA 5140 Australia
Phone: +61-8-8390-1507
Email: masongeo@ozemail.com.au

Petrographic Descriptions for Twelve Rock Samples,
The Cottage IOCG Project
(East Tennant Project, Northern Territory)

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CONTACT	**Neil Chalmers**
REPORT BY	**Dr Douglas R Mason**
SIGNED	
	for Mason Geoscience Pty Ltd
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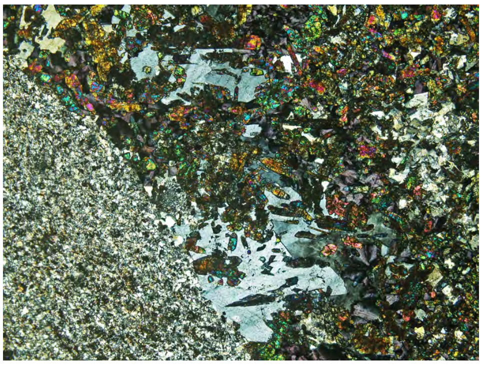

Petrographic Descriptions for Twelve Rock Samples, The Cottage IOCG Project (East Tennant Project, Northern Territory)

SUMMARY

1. Rock Samples

- Twelve drill core rock samples from drill hole BKDD001 at The Cottage Prospect (East Tennant IOCG Project, Northern Territory) have been studied using routine optical petrography.

2. Brief Results

- A summary of rock names and mineralogy is provided in TABLE 1.

- *Protoliths*

  – **Mudstones** were originally deposited as abundant fine-grained detrital clays and trace clastic grains (quartz, K-feldspar, tourmaline, zircon). A primary ferruginous component is inferred in ferruginous mudstones, either adsorbed in the clays or as a separate primary component. Some of the mudstones contained small ovoid clay balls <2 mm in size (542.4m, 562.9m), and lenticular primary depositional lamination is observed at 583.2m.

  – **Arenites** were deposited as varied abundances of clast-supported poorly-sorted crystal fragments (quartz, K-feldspar, plagioclase, Fe-Ti oxide, tourmaline, zircon) and lithic fragments (siliciclastic sediment, acid igneous rock, basalt) in fine-grained matrix (detrital clays). Like the mudstones, a primary Fe component is inferred in the matrix of the arenites.

- *Metamorphism and alteration*

  – **Low-grade regional metamorphism** at P-T conditions of the subgreenschist to lower greenschist facies modified all of the sedimentary rocks. Particular effects included the following:

    Meta-mudstones are now composed of a fine-grained mat of sericite ± stilpnomelane ± chlorite + minor opaques (magnetite) + trace tourmaline. Identification of the stilpnomelane is supported by its well-shaped flakes even though very small, strong pleochroism from colourless to brown (mostly Fe^{2+}-bearing ferrostilpnomelane, uncommon local green Fe^{3+}-rich ferristilpnomelane), and lack of twinkling at extinction (contrast with twinkling of optically similar biotite). The presence of stilpnomelane rather than biotite as the hydrated K-Fe-Mg-Al silicate phase confirms the low grade of metamorphism. The phyllosilicates may be more-or-less massive, or display weak preferred orientation (foliation) subparallel to layering. The presence of uniformly distributed Fe-minerals (stilpnomelane, chlorite, magnetite) supports interpretation that the protolith contained a significant proportion of primary Fe (~10% total FeO), either in the clays or as a separate component. Early large millimetre-sized porphyroblastic prisms formed locally (BKD001-498.9m, -540.9m) but have been replaced by the same metamorphic assemblage (sericite, stilpnomelane, magnetite); these may have been ?carbonate or ?andalusite porphyroblasts but none are preserved for confirmation.

    Meta-arenites were modified by a similar metamorphic assemblage (sericite + stilpnomelane + chlorite + opaques (magnetite)), mainly by recrystallisation of the matrix but also by selective replacement of some lithics.

    Fracturing and veining has affected the rocks at different times:

    i) Syn-peak metamorphic fractures in meta-mudstones may be sealed by fine-grained stilpnomelane alone, or quartz + stilpnomelane + chlorite + opaque (magnetite). In meta-arenite, quartz-chlorite-opaques (magnetite) vein is identified (610.3m) and the vein quartz recrystallised in response to ongoing mild metamorphic deformation.

ii) Post-peak metamorphic fractures display varied orientations of thin brittle fractures and local brecciation. The fractures and breccia pores are filled by varied assemblages of carbonate-chlorite-hematite (CO_2-Ca-Mg-Fe-rich fluid), quartz-clinozoisite-chlorite (CO_2-poor and silica-Ca-Fe-Al-rich fluid), and quartz-K-feldspar-chlorite-hematite (silica-K-Fe-Al-rich fluid). Sericite-chlorite alteration formed in selvages of some veins. Hematite commonly formed as a pink-red stain in selvages and more diffusely through the rock at this time, and partly replaced magnetite (not properly evaluated without reflected light observations).

- *Some Principal Results*

  – All protoliths were sedimentary in origin. There are no igneous rocks (eg mafic igneous rocks such as basalts or dolerites, although basaltic lithic fragments are noted in arenite at 610.3m).

  – The dark grey to greenish grey colour of the rocks is attributable to the significant amount of fine-grained stilpnomelane and lesser magnetite.

  – The consistent presence of metamorphic magnetite will provide a strong positive magnetic anomaly in the relevant meta-sedimentary layers.

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

SAMPLE	ROCK NAME	MINERALOGY*			
		Primary**	**Metamorphic/ Alteration*****	**Space fillings*****	**Weath-ering**
BKDD001, 457.3-457.35m	Brecciated meta-silty mudstone:				
	Weakly foliated chlorite-sericite-?magnetite altered meta-silty mudstone	Qtz, pla, zir	Ser, chl, opq(?mt), tou; Chl, hem	-	-
	Carbonate-chlorite-hematite breccia cement	-	-	Car(dol), chl, hem, Kf	-
BKDD001, 459.9-459.95m	Fractured altered meta-lithic-crystal arenite:				
	Hematite overprinted, sericite-chlorite-?magnetite altered meta-lithic-crystal arenite	Lith1, qtz, Kf, zir	Qtz, fld, ser, chl, opq(?mt); Hem	-	
	Space fillings: early quartz fracture seals	-	-	Qtz	
	Space fillings: late carbonate breccia pore fillings	-	-	Car(dol)	
BKDD001, 471.15-471.2m	Fractured and altered stilpnomelane-?magnetite meta-lithic-crystal arenite	Lith1, qtz, opq, zir	Flm(qtz,fld), stlp, opq(?mt), alb; Ser	Qtz, clz; Qtz, Kf, car, chl, opq; Qtz, chl, hem	
BKDD001, 498.9-498.95m	Weakly hematite overprinted, sericite-stilpnomelane-?magnetite meta-silty mudstone	Qtz, Kf	Ser, stlp, chl, opq(?mt), tou; Hem	-	
BKDD001, 519.2-519.25m	Thinly fractured and sericite-chlorite-hematite altered meta-siliceous sediment	-	Qtz, Kf; Ser, hem, chl	Qtz, chl, Kf	
BKDD001, 532.05-532.1m	Carbonate-hematite veined, quartz-chlorite fractured meta-layered siltstone/mudstone	Qtz, Kf, zir	Ser, chl, opq(?mt); Hem	Qtz, chl; Car(cal), qtz, hem	-
BKDD001, 540.9-540.05m	Chlorite-sericite-hematite retrogressed, porphyroblastic meta-mudstone	Qtz, zir	Ser, Kf; Ser, chl, hem	Kf	
BKDD001, 542.4-542.45m	Weakly foliated sericite-stilpnomelane-magnetite meta-laminated ferruginous mudstone	-	Ser, stlp, ser, opq(mt)	Qtz, stlp, chl, opq(mt)	-
BKDD001, 562.9-562.95m	Weakly foliated sericite-stilpnomelane-magnetite meta-ferruginous mudstone	-	Ser, stlp, opq(mt), tou	-	-
BKDD001, 577.7-577.75m	Brecciated meta-layered sediments:				
	Clinozoisite-chlorite-hematite altered meta-sandstone	Qtz, zir	Flm(qtz,fld), alb; Clz, hem	-	-
	Clinozoisite altered meta-silty mudstone	Qtz, zir	Ser; Clz	-	-
	Quartz-clinozoisite-chlorite breccia cement	-	-	Qtz, clz, chl	-
BKDD001, 583.2-583.25m	Thinly fractured and hematite altered, sericite-stilpnomelane meta-lenticular mudstone	-	Ser, flm, stlp; Hem	Kf, chl, car(cal), hem	-

cont…

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY (cont.)

SAMPLE	ROCK NAME	MINERALOGY*			
		Primary**	**Metamorphic/ Alteration*****	**Space fillings*****	**Weath-ering**
BKDD001, 610.3-610.35m	Veined meta-layered sediments:				
	Sericite-stilpnomelane-magnetite meta-mudstone	Zir	Ser, stlp, opq(mt), tou	-	-
	Sericite-stilpnomelane-magnetite meta-lithic-crystal arenite	Lith1, lith2, lith3, qtz, pla, opq, tou, zir	Ser, stlp, opq(?mt), tou	-	-
	Recrystallised quartz-chlorite-magnetite vein	-	-	Qtz, chl, opq(?mt)	-

NOTES

*: Minerals are listed in each paragenesis according to approximate decreasing abundance.

**: Only primary minerals currently present in the rock are listed. Others may have been present, but are altered.

***: Earlier parageneses are separated from later parageneses by a semicolon.

Mineral abbreviations

Alb = albite; cal = calcite; car = carbonate minerals; chl = chlorite; clz = clinozoisite (low-Fe monoclinic epidote-group mineral); dol = dolomite; fld = feldspar minerals; flm = fine-grained felsic mosaic (quartz, albite); hem = hematite; Kf = K-feldspar; lith1 = fine-grained siliciclastic rock; lith2 = basaltic lava; lith3 = acid igneous rock; mt = magnetite; opq = opaque minerals; pla = plagioclase; qtz = quartz; ser = sericite (fine-grained muscovitic mica); stlp = stilpnomelane; tou = tourmaline; zir = zircon; ?min = uncertain mineral identification.

1 INTRODUCTION

A collection of 12 drill core rock samples was received from Neil Chalmers (Strategic Energy Resources Ltd, South Melbourne, Victoria) on 12 October 2021.

Sample details were provided by the client, indicating the samples originate from drill hole BKDD001 at the Cottage Prospect in the East Tennant Project, Northern Territory:

> 'I have 12 samples from a diamond drillhole approximately 150km east of Tennant Creek that I'd like to get petrological descriptions on. The area is broadly interpreted to be metasediments equivalent to Tennant Creek, but the area is poorly explored and we've drilled a remote hole better understand the prospectivity of the area. So basically a new area that I'm trying to understand the fundamentals of.
>
> I've planned the samples to capture the different alteration phases and some lithological units. The samples will be cut portions of half core. I have photos of the planned sections and initial descriptions. We are waiting on full geochemical results of the hole.'
>
> Additional notes are provided by SER ASX Announcement, 20 September 2021:
>
> '…drilling has completed at the Cottage Iron Oxide Copper-Gold (IOCG) Prospect at our East Tennant Project…'
>
> 'Drill hole BKDD001 was drilled towards 180° with an inclination of 75°. Basement rocks were intersected from 204.3m with end of hole at 690.4m…'
>
> 'Initial on-site logging of core suggests drilling has not intersected a major mineralising system and the geological source of the gravity and magnetic anomalies have not been identified.'

Excerpts from this report were provided by email to Mr Chalmers on 10 November 2021. This report contains the full results of this work.

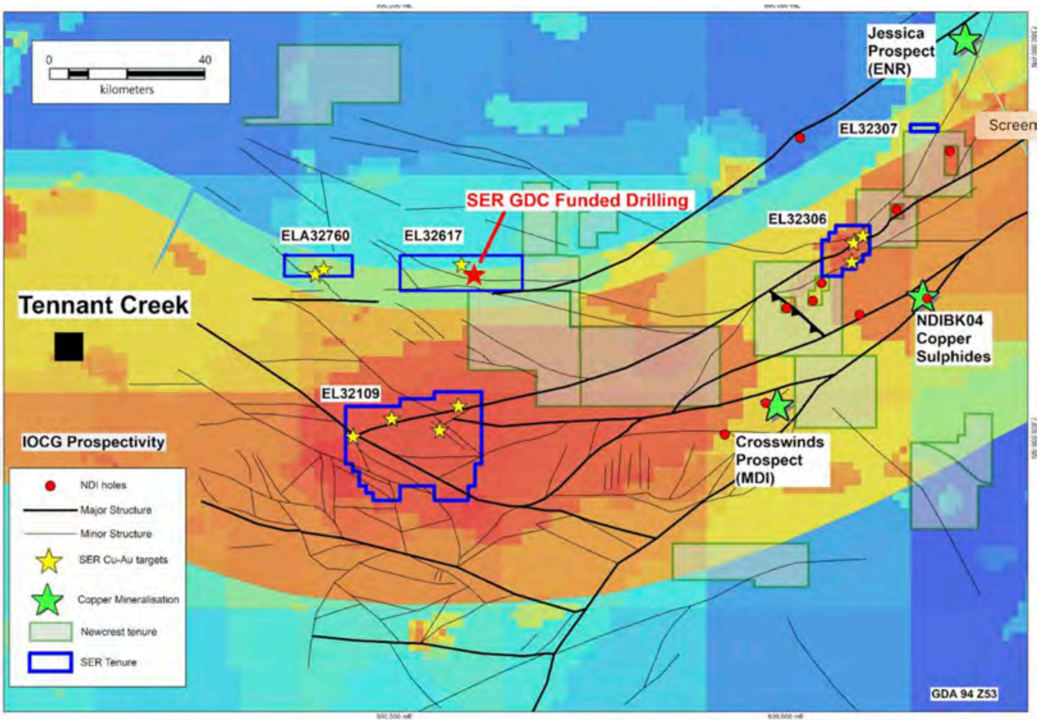

FIG. 1: Map showing location of SER's licence areas of the East Tennant Project. Drill hole BKDD001 of this petrology report is located in EL32617 as red star ('SER GDC Funded Drilling') (from SER pdf file 2111028-Mining-the-Territory-Presentation-2021.pdf).

2 METHODS

At Mason Geoscience Pty Ltd the drill core samples were examined and marked for thin section preparation. After discussion with the client, it was decided that standard thin sections would be appropriate for these rocks, and the sections were obtained from an external commercial laboratory. Conventional transmitted polarised light microscopy was used to prepare the routine petrographic descriptions. Modal mineral abundances are optical estimates, and are considered to have approximate absolute errors as follows: ±~5 vol.% at an abundance of 20 vol.%, ±~3 vol.% at 10 vol.%, and ±~2 vol.% at 5 vol.%. Paragenetic stages of development of each rock are indicated in the mineral modal list, where each mineral is assigned to a numerical paragenesis (paragenesis 1 is earliest; paragenesis 2 overprints 1; paragenesis 3 overprints both 2 and 1; etc). **The paragenetic stages display relative timing insofar as they can be determined within each sample**, and are not meant to be directly equated between samples although this may be correct for some samples.

3 PETROGRAPHIC DESCRIPTIONS

The petrographic descriptions are provided in the following pages.

SAMPLE : **BKDD001, 457.3-457.35m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : chl breccia with carbonate - qrtz +- amph +- hm

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SECTION NO. : BKDD001, 457.3

HAND SPECIMEN : The drill core sample represents a fine-grained dull greenish grey rock in which localised fracturing and incipient brecciation has produced pores sealed by white mineral stained by pink mineral.

The section offcut bubbles weakly in reaction with dilute HCl, suggesting dolomitic carbonate occurs in the white breccia pores.

The sample failed to respond to the hand magnet, suggesting magnetite is absent (but see ?magnetite below).

FIG. 2: Macrophotograph of sample BKDD001, 457.3-457.35m (courtesy of N. Chalmers, SER)

ROCK NAME : Brecciated meta-silty mudstone:

Weakly foliated chlorite-sericite-?magnetite altered meta-silty mudstone

Carbonate-chlorite-hematite breccia cement

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Weakly chlorite-hematite overprinted, foliated chlorite-sericite-?magnetite altered meta-silty mudstone		
Quartz	3 (1-5)	Clastic grains 1
Feldspar (plagioclase)	Tr	Clastic grains 1
Zircon	Tr	clastic grains 1
Sericite	87	Metamorphic 2 (after precursor 1)
Chlorite	2	Metamorphic 2
Opaques (?magnetite)	2	Metamorphic alteration 2
Tourmaline	Tr	Metamorphic alteration 2
Chlorite	5 (0-10)	Overprinting alteration 3
Hematite	Tr	Overprinting alteration 3
Carbonate-chlorite-hematite breccia cement		
Carbonate (dolomite)	88 (10-99)	Breccia cement 3
Chlorite	10 (0-99)	Breccia cement 3
Hematite	1 (0-5)	Breccia cement 3
K-feldspar	Tr	Breccia cement 3

In thin section, this sample displays different minerals and textures in host rock and breccia cement.

Weakly chlorite-hematite overprinted, foliated chlorite-sericite-?magnetite altered meta-silty mudstone represents the fine-grained green wallrock observed in the hand sample. It retains its fine-grained primary clastic sedimentary texture defined by small silt-sized clastic grains of quartz (clear, non-twinned, unaltered) and minor feldspar (twinned). In places, the feldspar grains display partial replacement by very fine-grained hematite (reddish specks). Uncommon small zircon grains are observed in thin heavy-mineral laminae.

Much of the rock is composed of small colourless sericite flakes with preferred orientation defining a weak metamorphic foliation. Minor small pale green chlorite flakes are interleaved with the sericite. Small cubic opaque crystals (likely ?magnetite) are sprinkled sparsely through the rock, with no physical relationship to breccia pores. Tourmaline occurs in trace amount as small subhedral pleochroic green prisms.

In areas modified by brecciation, fine-grained drab green chlorite forms small scattered alteration patches in varied abundance, with no preferred orientation of the chlorite flakes (ie post-foliation chlorite).

Carbonate-chlorite-hematite breccia cement represents the pink-strained white pore fillings observed in the hand sample. Carbonate (dolomite) is abundant, forming anhedral sparry grains and granular aggregates filling the pores. Chlorite is less abundant, mostly occurring as fine-grained massive aggregates concentrated at margins of some breccia pores, but it has completely filled the open space where the pores are thinner and smaller in size. Hematite occurs as cryptocrystalline small aggregates scattered through the carbonate. K-feldspar occurs locally as small bladed grains and aggregates; mostly it is absent.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained silty mudstone was deposited as part of the stratigraphic sequence. It was composed of a minor proportion of clastic grains (quartz, feldspar including plagioclase and ?K-feldspar, trace zircon) in abundant fine-grained detrital clays.

2. Regional metamorphism

Prograde modification in a weak directed stress regime, produced a weakly foliated metamorphic assemblage of sericite + minor chlorite + opaques (?magnetite) + tourmaline. This assemblage formed pervasively throughout the rock, mainly after the clay matrix, leaving most of the clastic grains unaffected.

3. Fracturing, incipient brecciation and alteration

The meta-sediment was further modified by localised brittle fracturing and infiltration by CO_2-Ca-Fe-Mg-Al-K-bearing aqueous fluid in a static regime (no directed stress). Particular effects included the following:

i) Precipitation of minerals from the fluid produced fillings of carbonate (dolomite) + minor chlorite + hematite + K-feldspar in the breccia pores.

ii) Reaction of the fluid with the wallrock produced new chlorite + hematite. Most of the chlorite formed as tiny massive (non-foliated) aggregates generally in the vicinity of the breccia pores, and are essentially absent elsewhere. Minor hematite formed as pervasive weak staining of the rock, and it is likely that hematite has completely replaced the earlier small ?magnetite crystals of the prograde assemblage.

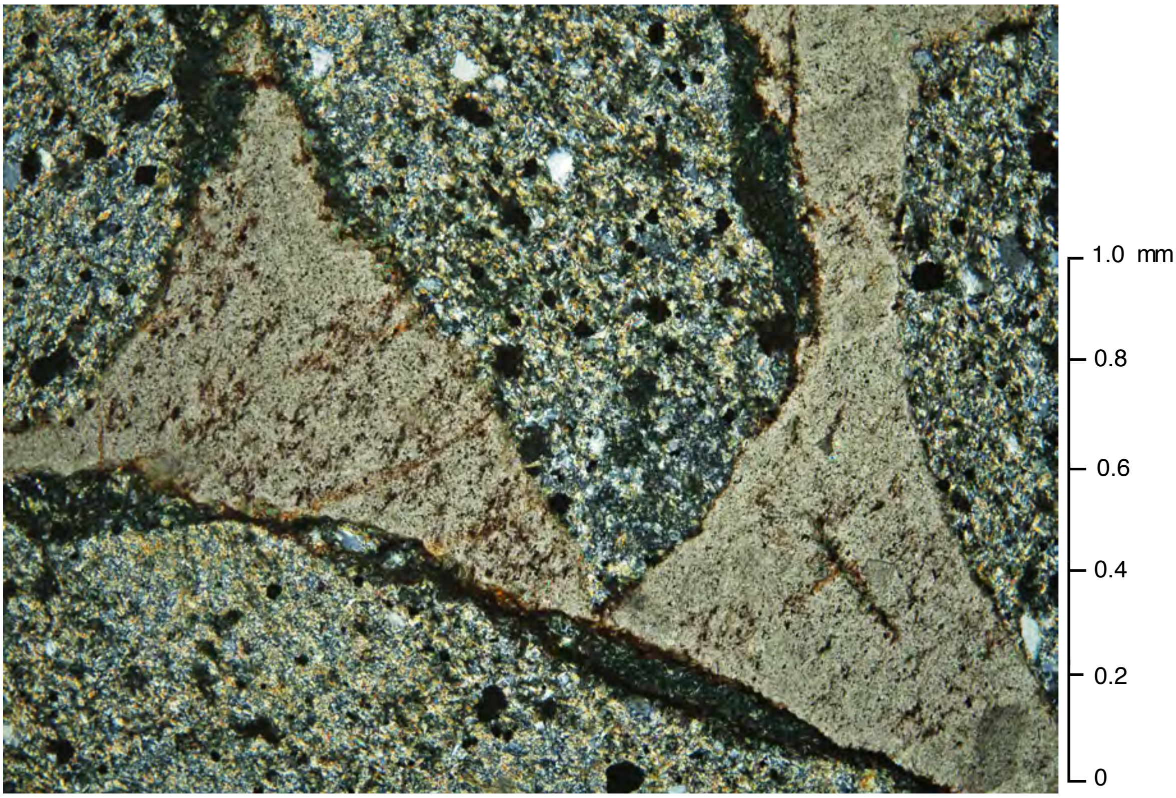

FIG. 3: SAMPLE BKDD001, 457.3-457.35m (Transmitted light with crossed polarisers, Obj. x10, Image PB104891). This view illustrates fragments of meta-silty mudstone wallrock enclosed by breccia cement (large sparry carbonate grains, small dull red hematite spots in the carbonate, fine-grained dark green chlorite concentrations at the margins of the pore fillings).

SAMPLE : **BKDD001, 459.9-459.95m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : hm breccia veining hm + qrtz + yellow mineral

SECTION NO. : BKDD001, 459.9

HAND SPECIMEN : The drill core sample represents a drab dark pink-red rock, with local dull green ragged patches (non-hematised kernels, see top left of macrophotograph but not captured in the thin section). Localised fracturing and brecciation has produced white breccia pores.

The sample fails to respond to the hand magnet, suggesting magnetite is absent (but see opaques below).

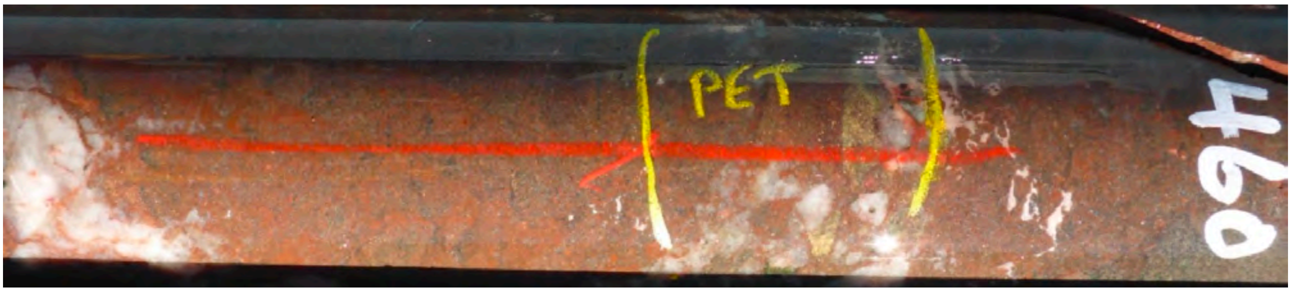

FIG. 4: Macrophotograph of sample BKDD001, 459.9-459.95m (courtesy of N. Chalmers, SER)

ROCK NAME : **Fractured altered meta-lithic-crystal arenite:**

Hematite overprinted, sericite-chlorite-?magnetite altered meta-lithic-crystal arenite

Space fillings: early quartz fracture seals

Space fillings: late carbonate breccia pore fillings

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (siliceous mosaic)	15	Lithic fragments 1
Quartz	20	Clastic grains 1
K-feldspar / hematite staining	15	Clastic grains 1 / alteration 3
Zircon	Tr	Clastic grains 1
Quartz, feldspar / hematite staining	19	Metamorphic 2 (after fine-grained matrix 1)
Sericite	19	Metamorphic 2
Chlorite	5	?Metamorphic 2
Albite	1	Metamorphic 2 (after clastic plagioclase 1)
Opaques	<1	Altered clastic grains 2
Opaques (cubic, ?magnetite)	1	Metamorphic alteration 2
Quartz	1	Early fracture seals 2
Carbonate (dolomite)	3	Late breccia pore fillings 3

In thin section, this sample displays a moderately sorted, clast-supported sedimentary texture, with different minerals and textures in different parts of the rock.

Clastic grains are abundant, and different types are identified:

i) Siliceous lithic fragments occur in moderate amount. They are subangular to subrounded in shape, and range ~0.5-0.8 mm in size. Their massive microcrystalline texture suggests they represent meta-siliceous sedimentary rocks. They are distributed throughout the rock without layering.

ii) Crystal fragments are abundant. Quartz forms angular to subrounded grains ~0.2-0.8 mm in size. K-feldspar forms angular grains similar in size to quartz; all display its typical optical uniformity and birefringence lower than quartz. Plagioclase is uncommon, forming angular grains replaced by optically continuous twinned albite. Possible ?Fe-Ti oxide clastic grains ~0.2-0.4 mm in size are sparsely scattered through the rock; all appear to have been replaced by microgranular opaques. Zircon occurs in trace amount as small to larger clastic grains; some larger ones are rounded in shape and ~100 μm in size.

Fine-grained matrix is composed of very fine-grained felsic mosaic (mainly quartz, feldspar), fine-grained colourless sericite flakes, and fine-grained chlorite flakes intergrown with the sericite. Trace small opaque crystals are much smaller than the altered ?clastic opaque grains, they are cubic in form, and may be ?magnetite (likely hematite altered magnetite, but no reflected light observations are available from the standard thin section).

Hematite lightly pervades the rock as submicron red specks loosely concentrated in diffuse clouds in the K-feldspar grains and in the matrix areas. Trace hematite also clouds the late carbonate breccia pore seals, and therefore may be later than those features.

Two types of fracture seals are identified:

i) Minor thin brittle fractures formed a local discontinuous subparallel set. They are thin (<0.4 mm wide) and are sealed entirely by fine-grained anhedral quartz grains.

ii) Late local breccia pores are filled mostly by carbonate (dolomite), which forms large anhedral sparry cleaved grains. In places, minor hematite lightly cloud the carbonate.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Sandy sediment (lithic-crystal arenite) was deposited as part of the stratigraphic sequence, forming a non-layered clast-supported assemblage of lithic fragments (meta-siliceous sediment) and crystal fragments (quartz = K-feldspar >> plagioclase > ?Fe-Ti oxide > zircon) in a moderate amount of fine-grained matrix (tiny clastic grains, clays).

2. Regional metamorphism

The rock was modified by low-grade regional metamorphism in the lower greenschist facies. Particular effects included the following:

i) Recrystallisation of the fine-grained matrix produced new felsic grains + sericite + chlorite + trace opaques (?magnetite). The ?magnetite formed as trace tiny cubic crystals.

ii) Early thin discontinuous fractures were sealed by fine-grained quartz.

iii) Late local fracturing produced breccia pores which were sealed by sparry carbonate (dolomite).

iv) Latest oxidation produced very fine-grained hematite staining throughout the rock, particularly after the K-feldspar clastic grains and in the fine-grained matrix. This may have occurred at the same time as the localised breccia pore fillings, or slightly later. Hematite may have replaced early ?magnetite – the hand sample fails to respond to the hand magnet which suggests that magnetite is no longer in the assemblage.

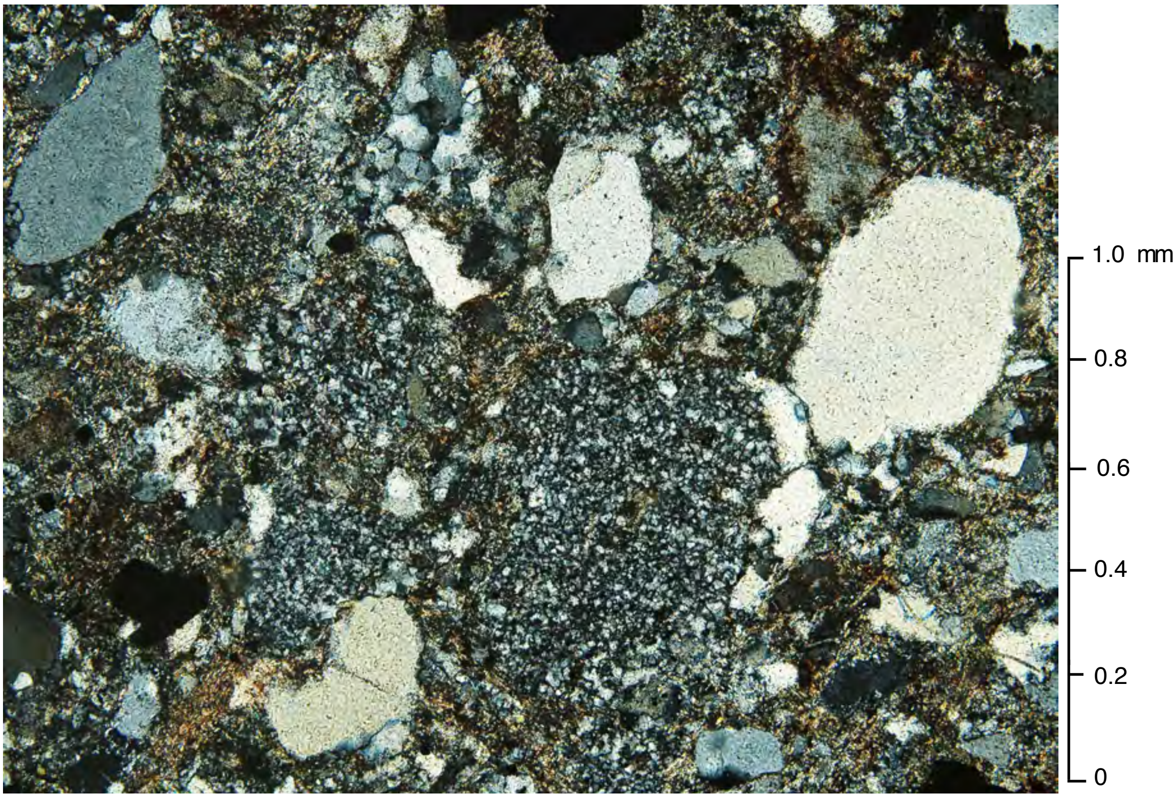

FIG. 5: SAMPLE BKDD001, 459.9-459.95m (Transmitted light with crossed polarisers, Obj. x10, Image PB104892). This view of meta-arenite illustrates its quartz crystal fragments (clear, white to grey) and fine-grained siliceous lithic fragments (centre) in fine-grained matrix (sericite, chlorite).

SAMPLE : BKDD001, 471.15-471.2m (The Cottage Prospect, East Tennant Project, Northern Territory)

CLIENT NOTE : qrtz + chl +- amph +- sulp +- epidote veining into f.g pervasive hm metased

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SECTION NO. : BKDD001, 471.15

HAND SPECIMEN : The drill core sample represents a fine-grained massive dark grey rock which is cut by thin grey (quartz-rich) veinlets with pink-red selvages. Uncommon early fracture seals re pale greenish yellow (epidote-group mineral, see zoisite below) and appear to be cut by the later hematite-associated fractures.

FIG. 6: Macrophotograph of sample BKDD001, 471.15-471.2m (courtesy of N. Chalmers, SER)

ROCK NAME : Fractured and altered stilpnomelane-?magnetite meta-lithic-crystal arenite

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (microcrystalline, massive)	10	Lithic fragments 1
Quartz	29	Clastic grains 1
Opaques	Tr	Altered clastic grains 1
Zircon	Tr	Clastic grains 1
Felsic mosaic (quartz, feldspar)	38	Metamorphic 2a (after matrix 1)
Stilpnomelane	15	Metamorphic 2a
Opaques (?magnetite)	1	Metamorphic 2a / alteration 2b
Albite	2	Metamorphic 2a (after plagioclase clasts 1)
Quartz, clinozoisite / sericite	3	Veinlet fillings 2b / retrogressive 2b
Quartz, K-feldspar, carbonate, chlorite, opaques possible ?sulfide	<1	Veinlet fillings 2b
Quartz, chlorite, hematite	1	Late fracture seals 2c

In thin section, this sample displays a non-layered partly-sorted clastic sedimentary texture, modified by recrystallisation and thin veining effects in different stages.

Clastic grains are moderately abundant, and different types are identified:

i) Lithic fragments occur in moderate amount. They form subangular to subrounded clasts mostly ~0.4-0.6 mm in size, rarely up to ~1 mm in size. All are composed of a microgranular mosaic of tiny quartz grains; these lithics are interpreted as meta-siliceous sediments.

ii) Crystal fragments are abundant. Quartz is most abundant, forming angular grains ~0.2-0.4 mm in size. Minor plagioclase grains similar in size and shape have been replaced by optically continuous weakly twinned albite. Possible minor opaque clasts ~0.4 mm in size occur in minor amount, but appear to be altered. Zircon occurs as trace subrounded grains (colourless, high relief, high birefringence) ~100 μm in size.

Matrix is composed of very fine-grained sutured felsic grains (feldspar, quartz) through which are distributed tiny but well-shaped randomly oriented stilpnomelane flakes ~10 μm in size. They superficially resemble biotite, but display strong pleochroism (pale straw yellow to medium greenish brown) and lack the 'twinkling' at extinction characteristic of biotite. Tiny euhedral opaque crystals with cubic morphology likely are ?magnetite (or hematite-altered magnetite) but no reflected light observations are available from the standard thin section.

Two types of fracture fillings are distinguished:

i) Some veinlets are filled by massive microgranular quartz and clinozoisite prisms (moderate relief, pale yellow colour, anomalous interference colours, inclined extinction to prism faces). Some of the clinozoisite prisms have been partly to completely replaced by fine-grained massive retrogressive sericite. Identical fine-grained sericite occurs as pervasive replacement of matrix in selvages in the wallrock, where all stilpnomelane has been destroyed. Fine-grained pale chlorite is locally intergrown with the sericite, and cryptocrystalline red hematite lightly stains the rock.

ii) Some veinlets are filled by massive microgranular quartz, similar granular K-feldspar, aggregates of carbonate, local subradiating chlorite aggregates, and local opaque grains (?sulfide). Cryptocrystalline red hematite forms irregular stained patches in the K-feldspar. Selvages are replaced by fine-grained sericite, chlorite and hematite staining.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Sandy clastic sediment was deposited as part of the stratigraphic sequence. It was composed of clastic mineral grains (quartz >> plagioclase >> Fe-Ti oxide > zircon) and lithic fragments (siliceous sediment) in fine-grained matrix (quartz, feldspar, clays). The matrix likely contained a significant proportion of Fe, either in the clays or as a discrete Fe-phase.

2. Regional metamorphism

The protolith was modified during low-grade regional metamorphism in the lower greenschist facies, with the following effects:

i) Recrystallisation of the matrix produced firmly sutured small felsic grains and uniformly fine-grained stilpnomelane + opaques (?magnetite). The presence of stilpnomelane rather than biotite confirms that P-T conditions were in the subgreenschist to lower greenschist facies, below the stability field of biotite.

ii) Brittle fracturing encouraged infiltration by hydrothermal fluids, producing new veinlet assemblages of quartz + clinozoisite, or quartz + K-feldspar + carbonate + chlorite + opaques (?sulfide). Selvage alteration marginal to the veinlets produced new fine-grained sericite + chlorite + hematite, destroying the precursor stilpnomelane and ?magnetite; hence the selvages are pale pink in hand sample. In the veinlets, some of the clinozoisite was partly replaced by retrogressive sericite, and K-feldspar was stained by hematite.

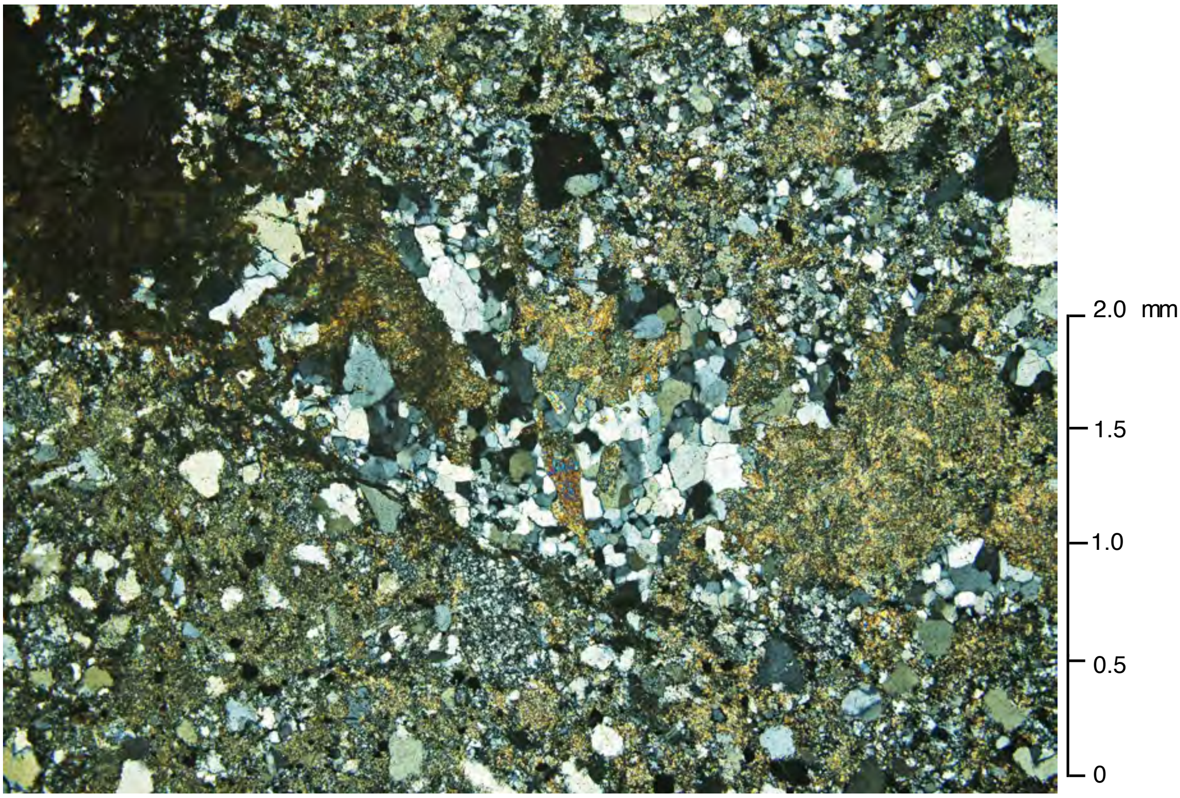

FIG. 7: SAMPLE BKDD001, 471.15-471.2m (Transmitted light with crossed polarisers, Obj. x4, Image PB104896) This view illustrates a post-peak metamorphic veinlet (oriented NW-SE) filled by quartz (white to grey) and clinozoisite crystals (upper left) partly to severely replaced by fine-grained retrogressive sericite (lower right). Also note sericitic alteration of wallrock marginal to the veinlet (top right, bottom left).

SAMPLE : **BKDD001, 498.9-498.95m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : contact btw bands of spotted amph? Unit with f.g less spotted band

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SECTION NO. : BKDD001, 498.9

HAND SPECIMEN : The drill core sample represents a fine-grained massive medium grey rock which contains a moderate proportion of small (millimetre-sized) stumpy dark grey prismatic crystals. The crystals are more abundant in some thick horizons.

The sample fails to respond to the hand magnet, suggesting magnetite is absent (but see ?hematite altered ?magnetite below).

FIG. 8: Macrophotograph of sample BKDD001, 498.9-498.95m (courtesy of N. Chalmers, SER)

ROCK NAME : **Weakly hematite overprinted, sericite-stilpnomelane-?magnetite meta-silty mudstone**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	20	Clastic grains 1a
K-feldspar / hematite clouding	10	Clastic grains 1a / alteration 2b
Sericite	44	Metamorphic 2a (after matrix 1)
Stilpnomelane	8	Metamorphic 2a
Sericite, chlorite	15	Metamorphic 2a (after porphyroblasts 1b)
Opaques (?magnetite / ?hematite)	2	Metamorphic 2a / alteration 2b
Tourmaline	Tr	Metamorphic 2a

In thin section, this sample displays a massive fine-grained metamorphic texture.

Clastic grains are distinguishable in minor amounts:

i) Quartz occurs as small angular clear grains ~30 μm in size distributed uniformly through the rock.

ii) K-feldspar formed small angular grains similar in size to the quartz, but all display selective staining by reddish submicron specks of hematite.

Fine-grained matrix is dominated by tiny well-shaped sericite flakes ~30 µm long. Most are randomly oriented with no clear preferred orientation (ie no foliation). Small stilpnomelane flakes are intergrown with the sericite; they are similar in size to the sericite and display the typical very pale yellow to greenish brown pleochroism of this mineral, without 'twinkling' at extinction (contrast with biotite). Opaques (?magnetite) occur as tiny cubic crystals ~30-60 µm in size; they display the size, shape and abundance expected in a fine-grained ferruginous meta-sediment, but no reflected light observations are available. The lack of magnetic response of the hand sample suggests that the ?magnetite has been replaced by hematite. Some thinnest margins of these tiny cubic crystals display the deep red colour appropriate for hematite. Tourmaline occurs as uncommon small stumpy prisms with typical hexagonal basal sections; they are pleochroic in green colours (likely Fe-rich schorl composition).

Scattered through the rock are large blocky prismatic crystal shapes ~1.5 mm long. All have been completely replaced by a fine-grained massive mat of sericite flakes and minor patches of pale green chlorite flakes, accompanied by small cubic opaques (magnetite) similar in abundance to the ?magnetite in the host rock.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained silty mud was deposited as part of the stratigraphic sequence. It was composed of minor small clastic grains (quartz > K-feldspar) in fine-grained ferruginous clay matrix. The Fe is considered to have been a primary sedimentary component. During diagenesis, large porphyroblastic crystals several millimetres in size formed; their identity is uncertain, but they may have been ?carbonate or possibly ?andalusite.

2. Regional metamorphism

The protolith was modified during low-grade regional metamorphism in the subgreenschist to lower greenschist P-T conditions. Particular effects included the following:

i) Recrystallisation of the aluminous ferruginous clay matrix produced new fine-grained massive sericite + stilpnomelane + minor magnetite + trace tourmaline.

ii) The porphyroblastic crystals were completely replaced by fine-grained sericite + chlorite + minor magnetite.

iii) Weak retrogressive alteration produced minor fine-grained hematite as selective replacements of the primary clastic K-feldspar grains and the small metamorphic magnetite crystals.

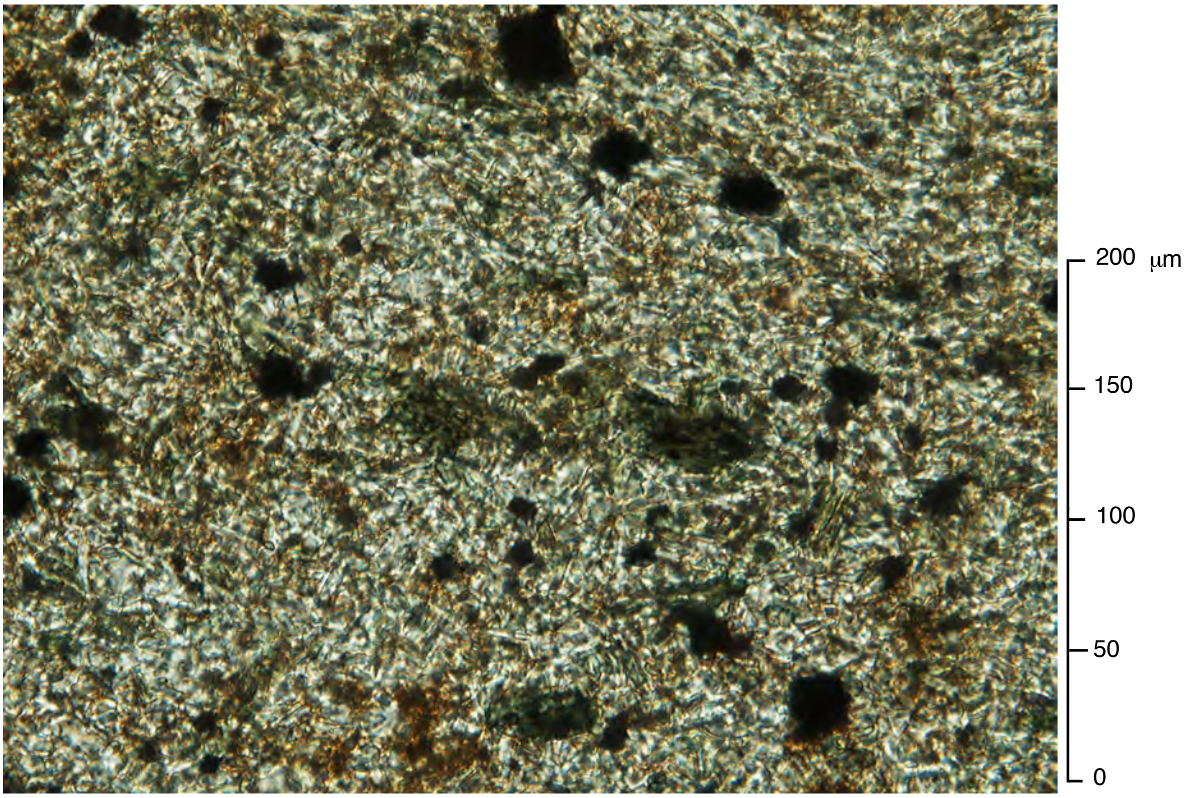

FIG. 9: SAMPLE BKDD001, 498.9-498.95m (Transmitted plane polarised light, Obj. x50, Image PB104900). This is a close view of meta-mudstone, with low-grade metamorphic assemblage of sericite (colourless flakes), stilpnomelane (small green-brown flakes) and magnetite (small cubic black crystals). The presence of Fe-bearing stilpnomelane and magnetite as prograde metamorphic minerals suggests that the clay-rich protolith contained a significant primary Fe content.

SAMPLE : **BKDD001, 519.2-519.25m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : intense hm veinlets into pv hm altered fg metased, wit qrtz + chlorite veining

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SECTION NO. : BKDD001, 519.2

HAND SPECIMEN : The drill core sample represents a fine-grained brick red rock cut by thin dark green (chloritic) fracture seals and diffuse paler green alteration patches.

FIG. 10: Macrophotograph of sample BKDD001, 519.2-519.25m (courtesy of N. Chalmers, SER)

ROCK NAME : **Thinly fractured and sericite-chlorite-hematite altered meta-siliceous sediment**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz, hematite clouding	50	Metamorphic 2a (after precursor 1)
K-feldspar	25	Metamorphic 2a
Sericite, hematite	20	Alteration 2b (after K-feldspar 2)
Chlorite	3	Alteration 2b
Quartz, chlorite, K-feldspar	2	Fracture seals 2b

In thin section, this sample displays a very fine-grained patchy metamorphic microgranular texture, modified by thin fracturing and pervasive alteration effects.

Quartz is abundant, forming tiny anhedral grains uniformly ~30-50 μm in size. The sutured quartz grains define an even-grained microgranular mosaic throughout the rock. Tiny red hematite specks are sprinkled through the quartz mosaic.

K-feldspar occurs in significant amount as ragged patches ~1-2 mm in size scattered through the quartz mosaic. The grain size and texture of the K-feldspar in the patches is similar to the grain size and texture of the enclosing quartz mosaic. In large areas, the K-feldspar grains display partial to severe replacement by fine-grained sericite, fine-grained drab green chlorite, and tiny red hematite specks.

Cutting the rock are minor thin variably oriented sharp fractures. They are sealed by locally varied abundances of small quartz grains, small K-feldspar grains, and tiny chlorite flakes and aggregates. Fine-grained hematite clouds the selvages of some of these fractures, confirming the relationship between hematite and fracturing.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Siliceous sediment of cherty type was deposited as part of the stratigraphic sequence. It is inferred to have been mainly chemical sedimentary components, not clastic components, including siliceous chemical sediment and feldspathic components.

2. Regional metamorphism

2a. The rock recrystallised in response to low-grade regional metamorphism, producing a fine-grained microgranular mosaic of quartz + K-feldspar. The K-feldspar formed as small ragged patches in siliceous matrix.

2b. Fracturing encouraged circulation of silica-K-Fe-Al-bearing hydrothermal fluid:

i) Precipitation of minerals from the fluid produced fracture seals composed of varied assemblages of quartz, K-feldspar and chlorite. Fine-grained hematite clouding formed in thin selvages marginal to the fractures.

ii) In the wallrock, reaction with the fluid produced new fine-grained sericite + chlorite + hematite. Fine-grained sericite and hematite formed by selective partial replacement of the K-feldspar aggregates, and hematite formed diffusely through the rock.

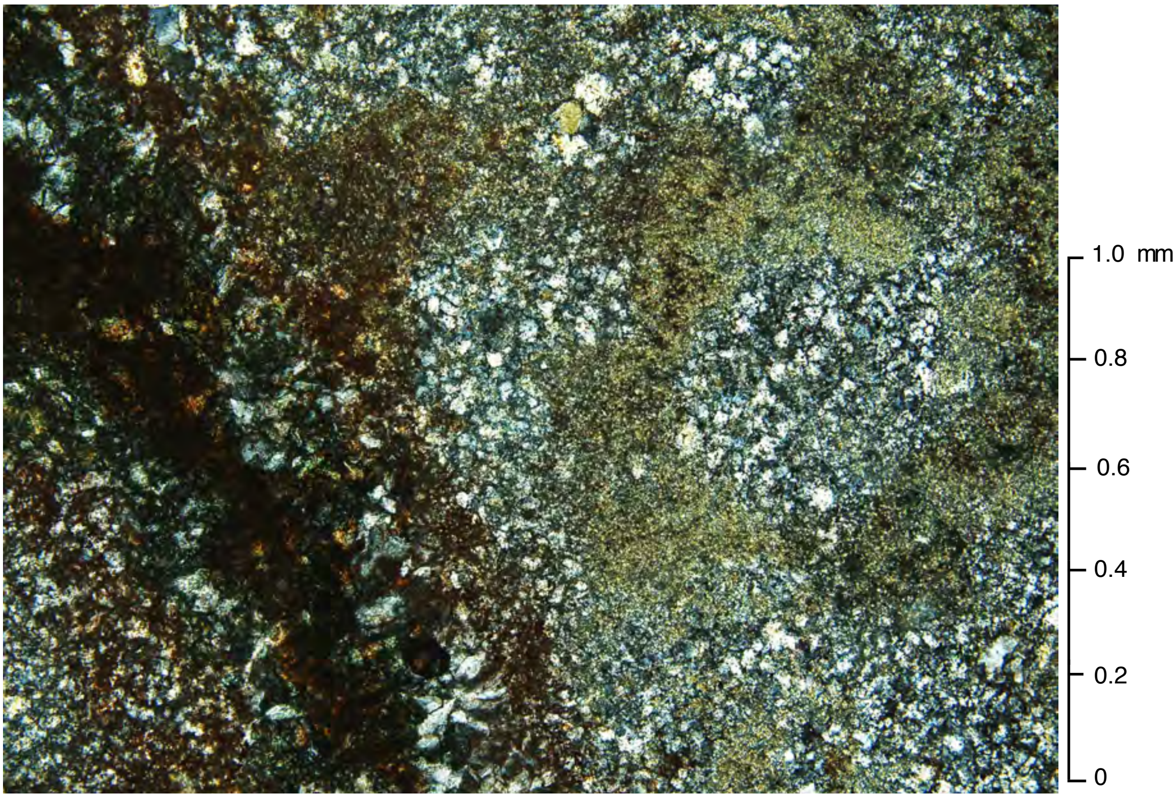

FIG. 11: SAMPLE BKDD001, 519.2-519.25m (Transmitted light with crossed polarisers, Obj. x10, Image PB104902). This view captures a thin fracture seal (left, oriented NW-SE) filled by K-feldspar (dull grey bladed grains), hematite (dull dark red) and chlorite (not distinguishable). Fine-grained hematite clouds the immediate selvage, and fine-grained sericite (yellowish, right, upper right) has replaced patches in the meta-sedimentary host rock.

SAMPLE : **BKDD001, 532.05-532.1m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : hm + carb + sulphide veins core parallel vn into dark fg unit

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SECTION NO. : BKDD001, 532.05

HAND SPECIMEN : The drill core sample represents a fine-grained dull green rock. It is cut by a network of thin fractures and related small breccia pore fillings, and is further cut by a centimetre-wide vein filled by calcite and fine-grained pink-red hematite.

FIG. 12: Macrophotograph of sample BKDD001, 532.05-532.1m (courtesy of N. Chalmers, SER)

ROCK NAME : **Carbonate-hematite veined, quartz-chlorite fractured meta-layered siltstone/ mudstone**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	5 (0-20)	Clastic grains 1
K-feldspar	<1 (0-10)	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	57	Metamorphic 2a (after matrix 1)
Chlorite	5	Metamorphic 2a
Opaques (?magnetite/?hematite)	2	Metamorphic 2a / alteration 2c
Quartz, chlorite	20	Early breccia pore fillings 2b
Carbonate (calcite), quartz, hematite	10	Late vein filling 2c

In thin section, this sample displays a fine-grained sedimentary texture modified by metamorphic recrystallisation effects and subsequent fracturing and veining in 2 stages.

Two types of meta-sedimentary rocks are identified:

i) Meta-mudstone is abundant. It is composed almost entirely of fine-grained phyllosilicate flakes, mostly sericite mat which contains minor small pale green chlorite flakes. Tiny euhedral opaque crystals ~10-30 μm in size are sprinkled through the phyllosilicate mat.

ii) Meta-siltstone comprises a single layer several millimetres thick. It is composed of a moderate proportion of small angular quartz crystal fragments ~50-80 µm in size, and similarly sized angular K-feldspar grains clouded by reddish hematite, in finer-grained felsic mosaic (quartz, ?feldspar, minor fine-grained sericite). Small opaque crystals (?magnetite) are sparsely sprinkled through the rock.

Cutting the rock are 2 types of space-filling fractures:

i) Early fracturing produced randomly oriented sharp discontinuous fractures with only minor dislocation of wallrock (incipient brecciation). The breccia pores were sealed by small to large anhedral clear quartz grains, and fine-grained chlorite formed as concentrations along margins of some of the pores.

ii) Later fracturing produced a single centimetre-wide vein filled by anhedral carbonate grains (calcite) in a massive granular mosaic, minor local quartz grains and aggregates, and a significant amount of fine-grained deep red hematite concentrated in discontinuous ragged bands near the adjacent wallrock.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained sediments were deposited as part of the stratigraphic sequence. Most of the sediment was mudstone composed of fine-grained clays; minor layers of siltstone were composed of crystal fragments (quartz, K-feldspar, trace zircon) in fine-grained felsic clastic matrix and clays.

2. Regional metamorphism

The protolith was modified in response to low-grade regional metamorphism, with the following effects:

i) Recrystallisation in the dominant mudstone produced a fine-grained massive assemblage of sericite + chlorite + opaques (?magnetite). The presence of the ?magnetite as uniformly disseminated small crystals suggests that the Fe was a primary component in the sediment, not introduced in the fluids related to later fracturing.

ii) In the siltstone, clastic grains (quartz, K-feldspar, zircon) were preserved, but the finer-grained matrix recrystallised to felsic mosaic + sericite + opaques (?magnetite).

iii) Brittle fracturing generated local thin discontinuous fractures and micro-breccia pores, which were filled by quartz + chlorite from silica-Fe-Al-bearing fluid. No hematite is associated with this fracturing and space-filling stage.

iv) Ongoing brittle fracturing and infiltration by silica-CO_2-Ca-Fe-bearing fluid produced a centimetre-wide vein filled by calcite + quartz + hematite. The hematite is confined to this late veining stage.

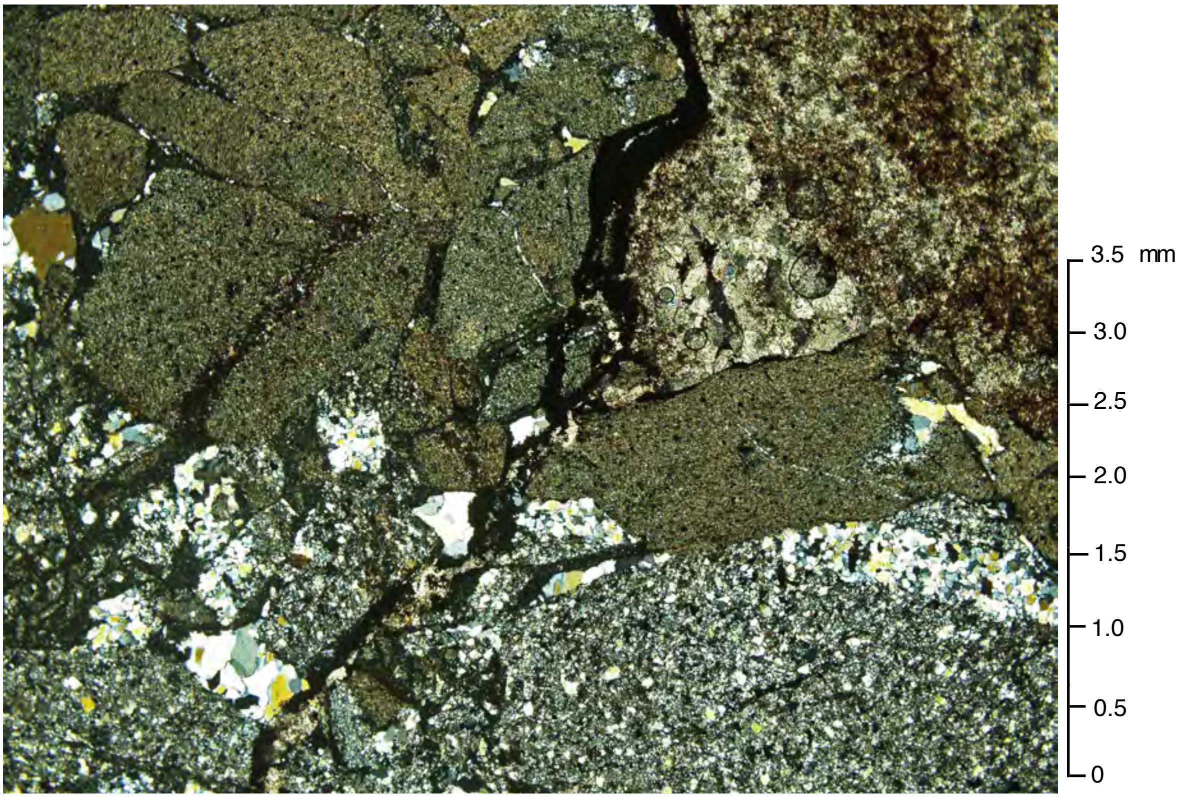

FIG. 13: SAMPLE BKDD001, 532.05-532.1m (Transmitted light with crossed polarisers, Obj. x2.5, Image PB104905). This view illustrates meta-layered sediments (mudstone at top, siltstone at bottom) modified by brittle fracturing and fluid infiltration, which produced initial breccia pore fillings (white quartz, dull green chlorite) and late carbonate vein (top right; high-pastel carbonate, fine-grained dull dark red hematite).

SAMPLE : **BKDD001, 540.9-540.05m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : cg 3-5mm amph (alumino silicate) spotted zone with garnet(?)

SECTION NO. : BKDD001, 540.9

HAND SPECIMEN : The drill core sample represents a fine-grained massive pinkish grey rock which contains a moderate proportion of blocky dark green prismatic crystals uniformly several millimetres in size.

FIG. 14: Macrophotograph of sample BKDD001, 540.9-540.05m (courtesy of N. Chalmers, SER)

ROCK NAME : **Chlorite-sericite-hematite retrogressed, porphyroblastic meta-mudstone**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz	Tr	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	67	Metamorphic 2a (after precursor 1)
K-feldspar / hematite	10	Metamorphic 2a / alteration 2b
K-feldspar	2	Fracture seals 2a
Sericite, chlorite	20	Alteration 2b (after porphyroblasts 2a)

In thin section, this sample displays a porphyroblastic metamorphic texture, modified by selective retrogressive alteration effects.

Clastic grains are observed in trace amounts. Quartz occurs as uncommon small angular grains ~50-200 μm in size. Zircon (high relief, colourless, high birefringence) occurs as uncommon angular crystal fragments of similar size.

Sericite (fine-grained muscovite) occurs abundantly as tiny colourless flakes which form a uniformly fine-grained massive mat throughout the rock. Scattered through the mat are small uniformly distributed patches of microgranular K-feldspar, clouded by tiny red hematite specks.

Large porphyroblastic crystals ~4-6 mm in size are scattered through the rock. They display blocky subhedral prismatic crystal shape, but all have been completely replaced by fine-grained dense sericite and intergrown drab green chlorite. None of the precursor mineral is preserved, but it may have been a silicate mineral (eg ?andalusite).

Cutting the rock are minor thin discontinuous fractures. They are sealed by microgranular K-feldspar where widest, but thin fractures are sealed mainly by fine-grained deep red hematite.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained muddy sediment was deposited as part of the stratigraphic sequence. It was composed mostly of detrital clays, accompanied by trace clastic grains (quartz, zircon).

2. Regional metamorphism

The protolith recrystallised in response to low-grade regional metamorphism, and 2 stages are identified:

2a. Initial recrystallisation producing a fine-grained massive mat of sericite, small patches of fine-grained K-feldspar, and scattered large porphyroblastic crystals (?andalusite).

2b. Thin fracturing produced thin fracture seals (K-feldspar, hematite), caused hematite staining of the small K-feldspar aggregates, and caused complete replacement of the porphyroblasts by fine-grained massive sericite + chlorite.

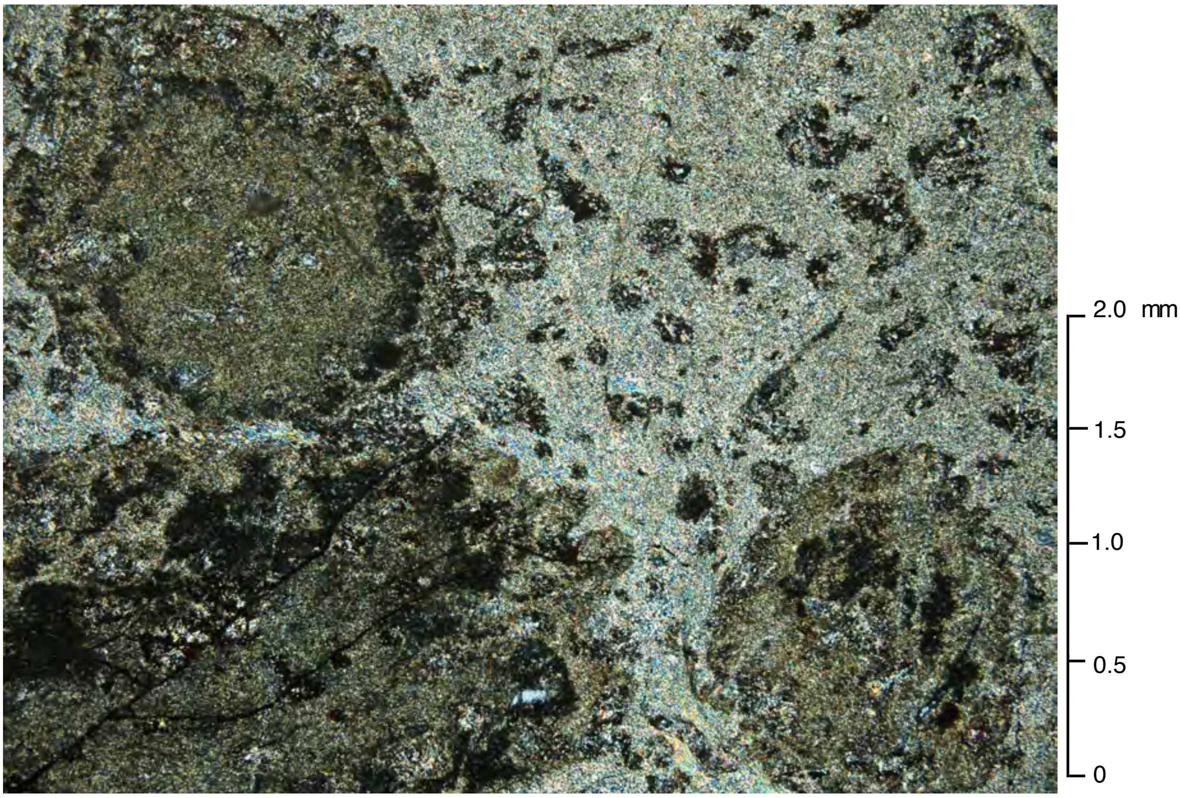

FIG. 15: SAMPLE BKDD001, 540.9-540.05m (Transmitted light with crossed polarisers, Obj. x4, Image PB104907). This view of porphyroblastic meta-mudstone captures large porphyroblastic crystals of unknown type, completely replaced by fine-grained sericite and chlorite. They lie in fine-grained massive sericite-rich matrix.

SAMPLE : **BKDD001, 542.4-542.45m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : homogenous dark fg ubit (metased, amphobilite?)

SECTION NO. : BKDD001, 542.4

HAND SPECIMEN : The drill core sample represents a fine-grained massive greenish grey rock without layering or foliation.

The sample responds positively to the hand magnet, confirming fine-grained magnetite pervades the rock.

FIG. 16: Macrophotograph of sample BKDD001, 542.4-542.45m (courtesy of N. Chalmers, SER)

ROCK NAME : **Weakly foliated sericite-stilpnomelane-magnetite meta-laminated ferruginous mudstone**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Sericite	71	Metamorphic 2 (after precursor 1)
Stilpnomelane	20	Metamorphic 2
Sericite, stilpnomelane, opaques (magnetite)	5	Metamorphic 2 (after ?clay balls 1)
Opaques (magnetite)	3 (1-10)	Metamorphic 2
Quartz, stilpnomelane, chlorite, magnetite	<1	Fracture seals 2

In thin section, this sample displays a fine-grained metamorphic texture, with no primary clastic textures.

Sericite (fine-grained white mica) is abundant, forming small but well-shaped flakes ~30 μm long. They form a fine-grained mat throughout the rock, and a weak metamorphic foliation is defined by weak preferred orientation of a significant proportion of the flakes.

Stilpnomelane occurs in moderate amount as small flakes similar in size to the sericite. It is distributed throughout the rock without layering, and displays the characteristic strong pleochroism (colourless to dark green or brownish green) and lack of twinkling at extinction.

Opaques occur in minor amount as small cubic crystals ~10-20 μm in size. They are sprinkled more or less uniformly through the rock, but are more abundant in some subparallel laminae several millimetres thick, and are most abundant in uncommon thin laminae <0.2 mm thick. These opaques are magnetite, as supported by their euhedral cubic form and the positive magnetic response of the hand sample.

Small ovoid bodies ~0.4-0.8 mm in size are sparsely scattered through the rock. Some are almost spherical and others are ovoid with varied orientations. They are composed of the same minerals as the host rock in similar proportions (sericite > stilpnomelane >> magnetite). In places, the ovoid bodies are weakly enwrapped by foliated sericite of the matrix, confirming that the ovoids are pre-metamorphic in origin.

Minor thin planar fractures cut the rock. They are sealed mostly by small anhedral quartz grains. Small stilpnomelane flakes project from the wallrock contacts into the fracture seals. Chlorite occurs as small pleochroic green flakes, similar in size and shape to the stilpnomelane. Magnetite forms minor small cubic crystals.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained ferruginous muddy sediment was deposited as part of the stratigraphic sequence. It was composed of abundant detrital clays accompanied by a moderate proportion of Fe, either adsorbed in the clays or as a fine-grained chemical sedimentary component. Primary layering was defined by slightly higher abundance of the ferruginous component in subparallel laminae (ie Fe-richer laminae). During deposition, small ovoid bodies (clay balls) formed from the same components as the principal sediment.

2. Regional metamorphism

The protolith recrystallised in response to low-grade regional metamorphism, producing a new weakly foliated metamorphic assemblage of sericite + stilpnomelane + minor magnetite. Higher abundance of magnetite in some thin laminae reflects the primary Fe-richer character of those laminae. Clay balls recrystallised to the same metamorphic assemblage (sericite + stilpnomelane + minor magnetite), and were enwrapped by foliation of sericite in the enclosing sediment. Minor thin planar fractures encouraged circulation of a small volume of synmetamorphic fluid, producing thin fracture seals (quartz + stilpnomelane + magnetite + chlorite).

This sample is significant for 2 reasons:

i) It illustrates weak primary lamination in ferruginous claystone sediments.

ii) It illustrates that ferruginous minerals (stilpnomelane, magnetite) formed as part of the low-grade regional metamorphic assemblage, not as an overprinting alteration event.

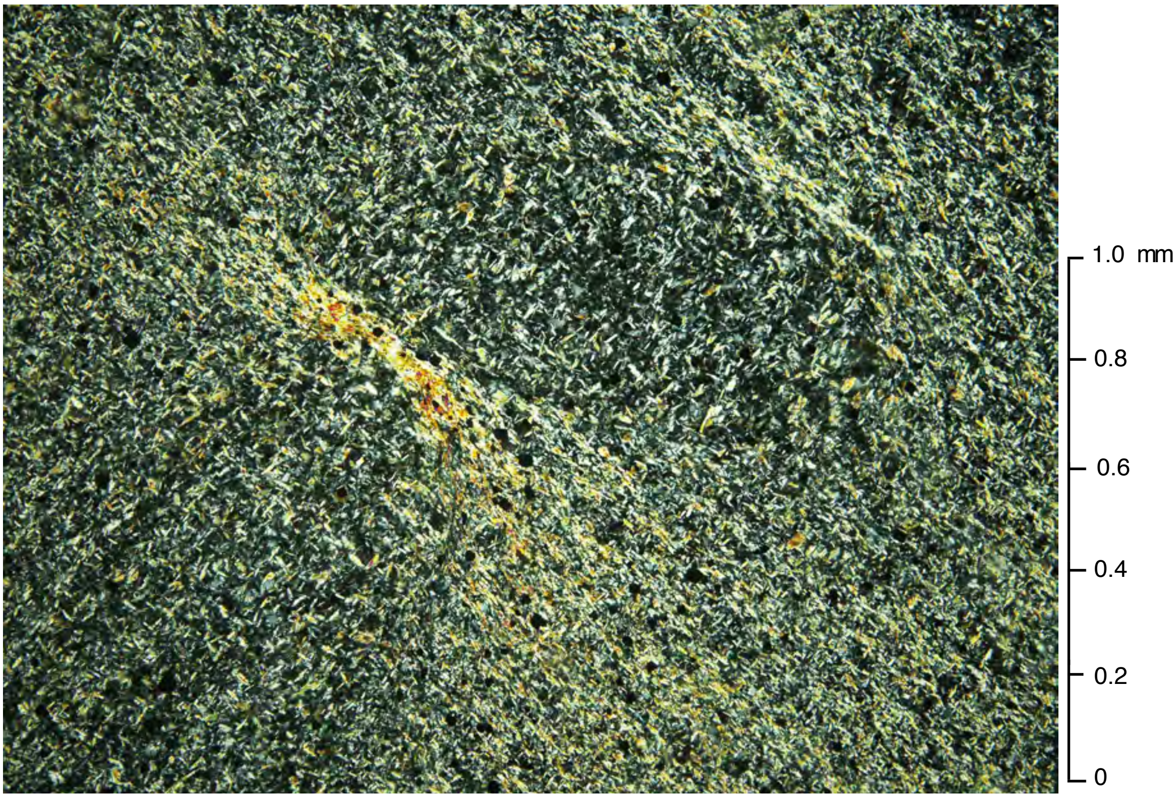

FIG. 17: SAMPLE BKDD001, 542.4-542.45m (Transmitted light with crossed polarisers, Obj. x10, Image PB104908). This view of meta-mudstone illustrates its primary ovoid clay balls (lower left, upper right) enwrapped by weakly foliated sericite (yellow, oriented NW-SE) of the matrix. Both the clay balls and the matrix are composed of the same metamorphic assemblage (sericite + stilpnomelane + magnetite). Magnetite forms the tiny equant black grains sprinkled uniformly through the rock.

SAMPLE : **BKDD001, 562.9-562.95m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : homogeneous dark gry massive metased? Fg mafic

SECTION NO. : BKDD001, 562.9

HAND SPECIMEN : The drill core sample represents a fine-grained massive dark grey rock.

The sample responds weakly but positively to the hand magnet, confirming minor magnetite is present throughout.

FIG. 18: Macrophotograph of sample BKDD001, 562.9-562.95m (courtesy of N. Chalmers, SER)

ROCK NAME : **Weakly foliated sericite-stilpnomelane-magnetite meta-ferruginous mudstone**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Sericite	76	Metamorphic 2 (after precursor 1)
Stilpnomelane	20	Metamorphic 2
Opaques (magnetite)	3	Metamorphic 2
Tourmaline	Tr	Metamorphic 2

In thin section, this sample displays a weakly foliated metamorphic texture.

Sericite is abundant, forming small but well-shaped flakes mostly ~30 µm long. A significant proportion of the flakes display a preferred orientation which defines a weak metamorphic structure (foliation).

Stilpnomelane occurs in lower abundance as small plates similar in size and shape to the white mica, and is distributed uniformly through the white mica. Like the white mica, the stilpnomelane flakes display a weak metamorphic foliation. Its pleochroism from colourless to drab brown suggests that the stilpnomelane has a moderately reduced composition (compare Fe^{2+}-Fe^{3+} in associated magnetite).

Opaques occur in minor amount as small euhedral crystals ~10-20 µm in size. They are distributed uniformly through the sericite-stilpnomelane mat. They are readily identified as magnetite from their cubic morphology and the magnetic response of the hand sample.

Minor small ovoid bodies ~0.4 mm in size are sparsely scattered through the rock. They are composed of the same minerals as the enclosing meta-sediment, but with stilpnomelane > sericite. The ovoid bodies lack foliation but are enwrapped by the weakly foliated matrix; they therefore formed with pre-metamorphic timing (eg primary clay balls in the sediment).

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained ferruginous muds were deposited as part of the stratigraphic sequence. Primary components were mostly clays, but a significant primary Fe content is inferred either as adsorbed into the clays or as a discrete fine-grained ferruginous chemical sedimentary component. Minor small ovoid clay balls were deposited in the mostly featureless fine-grained sediment. An approximate calculated bulk rock composition using the mineral mode above and published mineral analyses gives 44% SiO_2, 28% Al_2O_3, 10% total FeO, 2% MgO, <1% CaO, <1% Na_2O, 8% K_2O, 5% H_2O.

2. Regional metamorphism

The protolith was modified by a low-grade regional metamorphic event in the subgreenschist to lower greenschist facies. Recrystallisation produced a weakly foliated metamorphic assemblage of sericite + stilpnomelane + minor magnetite. The weakly foliated sericite-stilpnomelane flakes enwrapped the primary clay balls which recrystallised to the same assemblage but with higher stilpnomelane content.

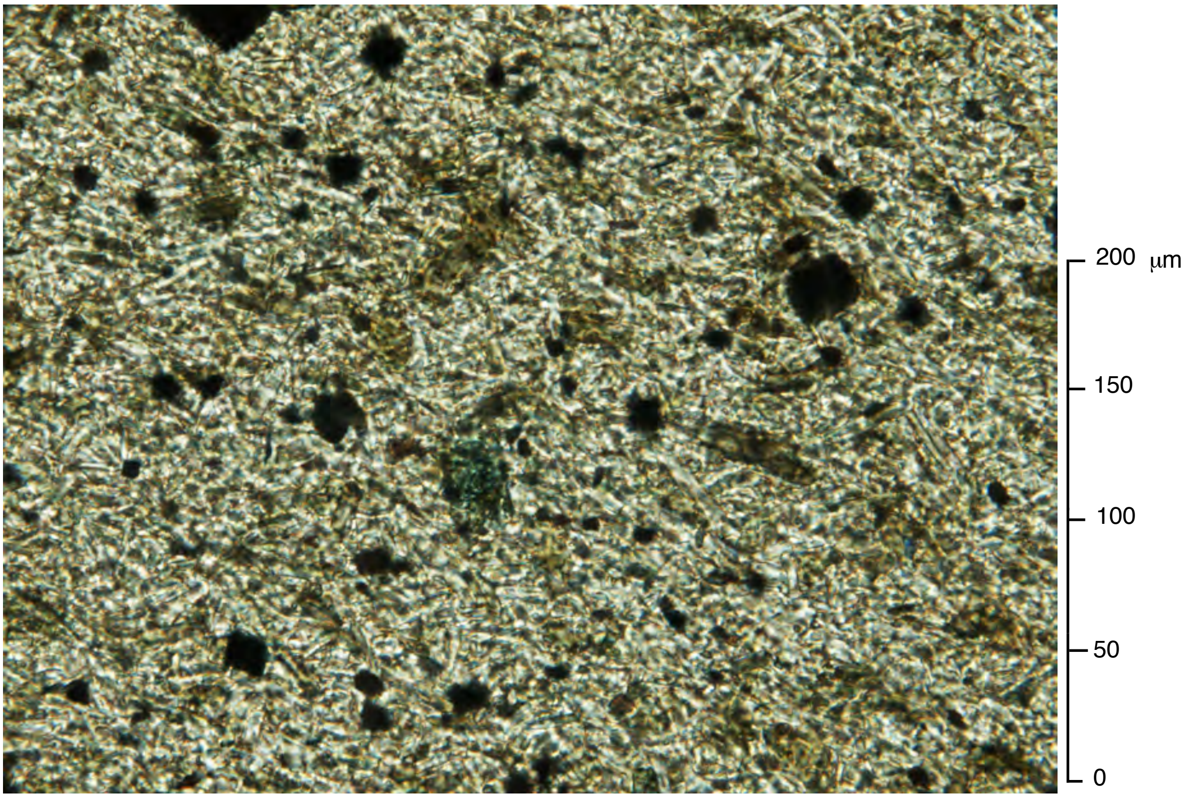

FIG. 19: SAMPLE BKDD001, 562.9-562.95m (Transmitted plane polarised light, Obj x50, Image PB104912)
This view of meta-mudstone illustrates its fine-grained metamorphic assemblage of sericite (colourless flakes), stilpnomelane (small brown flakes) and magnetite (small black crystals). Note a small tourmaline crystal (green, centre). The uniform fine grain size and uniform distribution of the Fe-bearing minerals (stilpnomelane, magnetite) indicates that the primary clay-rich sediment contained a significant Fe content (~10%).

SAMPLE : **BKDD001, 577.7-577.75m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : hm + ch + sulphide internal zone with qrtz + chl salvage vein

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SECTION NO. : BKDD001, 577.7

HAND SPECIMEN : The drill core sample represents a fine-grained massive red rock which is brittly fractured, brecciated and cemented by green-yellow minerals

FIG. 20: Macrophotograph of sample BKDD001, 577.7-577.75m (courtesy of N. Chalmers, SER)

ROCK NAME : **Brecciated meta-layered sediments:**

Clinozoisite-chlorite-hematite altered meta-sandstone

Clinozoisite altered meta-silty mudstone

Quartz-clinozoisite-chlorite breccia cement

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Clinozoisite-chlorite-hematite altered meta-sandstone		
Quartz	35	Clastic grains 1
Zircon	Tr	Clastic grains 1
Felsic mosaic (quartz, feldspar)	52	Recrystallised 2 (after clastic matrix 1)
Albite	2	Metamorphic 2 (after plagioclase grains 1)
Clinozoisite	10	Alteration 2b
Hematite clouding	1	Alteration 2b
Clinozoisite altered meta-silty mudstone		
Quartz	20	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	80	Metamorphic 2a(after matrix 1)
Clinozoisite	1	Alteration 2b

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Mineral	Vol %	Origin
Quartz-clinozoisite-chlorite breccia cement		
Quartz	35	Breccia cement 2b
Clinozoisite	35	Breccia cement 2b
Chlorite	30	Breccia cement 2b

In thin section, this sample displays different minerals and textures in different parts of the rock.

Clinozoisite-chlorite-hematite altered meta-sandstone retains its clastic sedimentary texture, modified by alteration effects.

Clastic grains were abundant. Angular grains of quartz ~0.2-0.4 mm in size (fine to medium sand size) are moderately abundant and are accompanied by minor angular grains of twinned albite (after primary clastic plagioclase), and trace small zircon grains ~100 μm in size.

The larger clastic grains lie in a finer-grained microgranular mosaic of firmly sutured small grains of quartz and feldspar which are difficult to resolve. Scattered through the felsic mosaic are subhedral crystals and small aggregates of pale yellow clinozoisite. Hematite occurs as cryptocrystalline red clouding pervasively through the rock, but more abundant in haloes around the clinozoisite crystals.

Clinozoisite altered meta-silty mudstone occupies a single horizon through the rock. It is composed of a minor proportion of small angular clastic quartz grains and rare small zircon grains in abundant fine-grained sericite matrix with weak metamorphic foliation. Clinozoisite occurs as small subhedral grains and small aggregates.

Quartz-clinozoisite-chlorite breccia cement occupies pores between the wallrock fragments. Quartz forms anhedral clear grains ~2 mm in size. Clinozoisite occurs as stumpy prismatic crystals (pale yellow, anomalous interference colours, inclined extinction to prism faces) ~0.4 mm long, mostly enclosed within the larger quartz grains. Chlorite occurs as randomly oriented flakes in local dense aggregates; its strong pleochroism from almost colourless to green suggests it has an Fe-rich chlorite composition.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Clastic sediments were deposited as part of the stratigraphic sequence. Sandy deposits were composed of moderately abundant sand-sized clastic grains (quartz >> plagioclase >> zircon) in finer-grained felsic clastic matrix. Silty mudstone was deposited with minor clastic grains (quartz, zircon) in abundant detrital clay matrix.

2. Regional metamorphism

2a. The sediments were modified by low-grade regional metamorphism, with the following effects:

i) In the sandstone, recrystallisation of matrix produced a fine-grained sutured mosaic of quartz + feldspar.

ii) In the silty mudstone, recrystallisation of the clay matrix produced a weakly foliated mat of sericite.

2b. Subsequent fracturing and infiltration by silica-Ca-Fe-Al-bearing hydrothermal fluid produced a space-filling cement (quartz + clinozoisite + chlorite) and caused weak pervasive alteration of the sediments (clinozoisite + minor hematite).

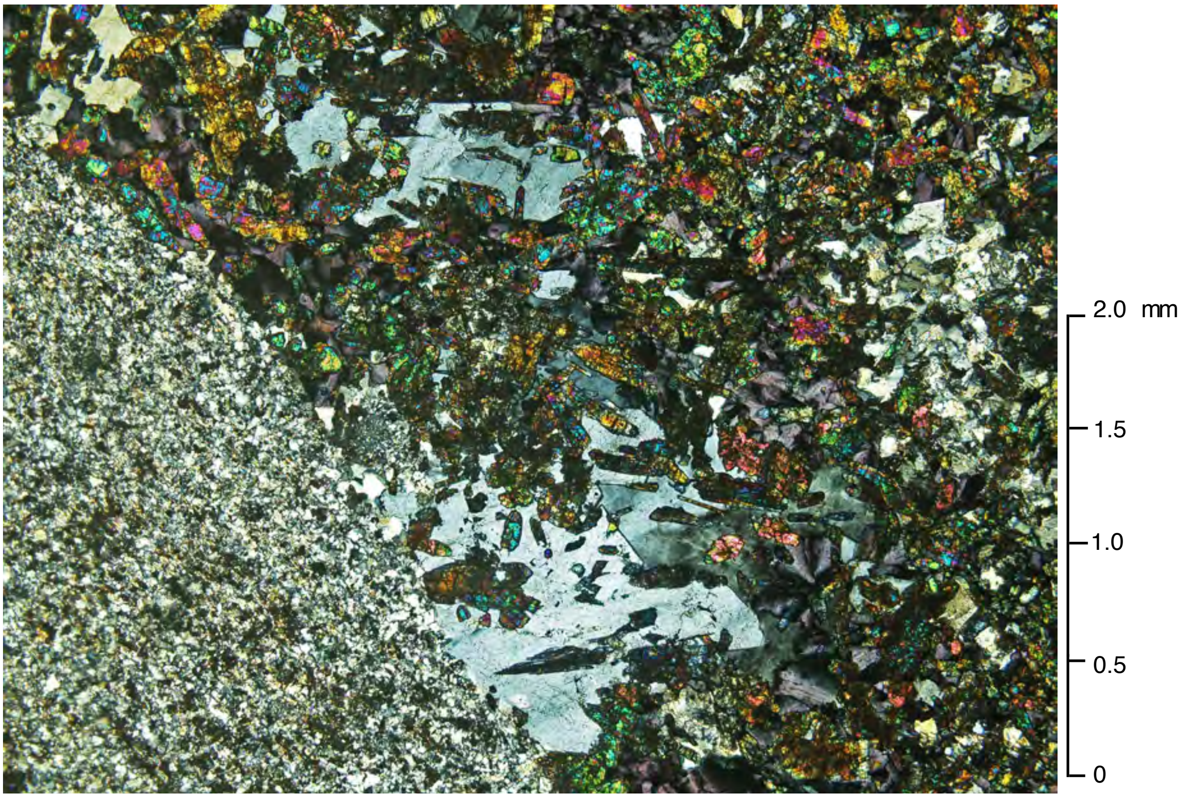

FIG. 21: SAMPLE BKDD001, 577.7-577.75m (Transmitted light with crossed polarisers, Obj. x4, Image PB104916). This view illustrates breccia pore filling (right) and altered wallrock (lower left). The breccia pore filling is composed of clinozoisite crystals (bright anomalous interference colours), quartz (white to grey), and chlorite (local interstitial anomalous mauve flakes). Altered meta-sandstone is composed of small quartz grains, fine-grained sericite, fine-grained alteration clinozoisite, and light hematite clouding (see red colour of altered rock fragments in FIG. 20.

SAMPLE : **BKDD001, 583.2-583.25m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : intense hm veinlets into chl altered spotted metased, siliceous alteration as well

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SECTION NO. : BKDD001, 583.2

HAND SPECIMEN : The drill core sample contains kernels of dark greenish grey rock which is cut by thin variably oriented fractures emphasised by pink-red hematite, accompanied by pervasive pink-red alteration of the host rock.

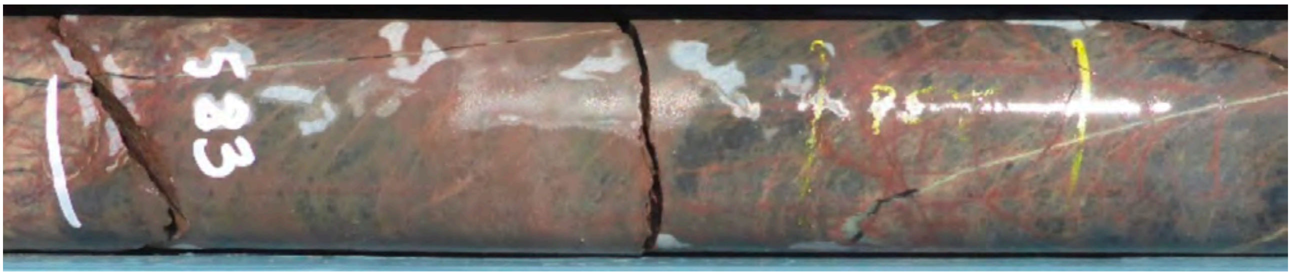

FIG. 22: Macrophotograph of sample BKDD001, 583.2-583.25m(courtesy of N. Chalmers, SER)

ROCK NAME : **Thinly fractured and hematite altered, sericite-stilpnomelane meta-lenticular mudstone**

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Sericite	46	Metamorphic 2a (after precursor 1)
Felsic mosaic	41	Metamorphic 2a
Stilpnomelane (brown, green)	10	Metamorphic 2a
Hematite	2	Alteration 2b
K-feldspar, chlorite, calcite, hematite	<1	Fracture seals 2b

In thin section, this sample displays a uniformly very fine-grained metamorphic texture, with lenticular structure of primary sedimentary origin.

Approximately half of the rock is composed of fine-grained dense mats of small poorly-shaped sericite flakes which are densely concentrated in elongate lenses. In places, these sericite-rich lenses occupy most of the rock. A minor amount of stilpnomelane is sprinkled sparsely through the lenses as tiny poorly-formed randomly-oriented flakes.

The other half of the rock is composed mostly of minute felsic grains in a fine-grained felsic mosaic. This felsic mosaic encloses the sericite-rich lenses. Stilpnomelane is concentrated in the felsic mosaic as tiny randomly oriented flakes that are pleochroic colourless to brown (ferrostilpnomelane, Fe^{2+}-rich stilpnomelane), but local patches are composed of pleochroic colourless to green stilpnomelane (ferristilpnomelane, Fe^{3+}-rich stilpnomelane). In places brown stilpnomelane is concentrated along thin rails in felsic mosaic between sericite-rich lenses.

Cutting the rock are thin sharp fractures sealed by fine-grained anhedral K-feldspar grains, small pleochroic green chlorite flakes, and fine-grained dense hematite aggregates. Submicron hematite clouds the selvages.

Other thinner fractures are densely sealed by hematite, and similarly are flanked by pink-red hematite clouding in selvages.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Fine-grained mudstone was deposited as part of the stratigraphic sequence. It was composed of lenticular bodies of detrital clay in very fine-grained felsic matrix. The lenticular structure is interpreted as a primary sedimentary structure.

2. Regional metamorphism

The protolith was modified during a low-grade regional metamorphic event. Particular effects are interpreted in the following stages:

i) Initial recrystallisation produced a new fine-grained assemblage of sericite + felsic mosaic + stilpnomelane. Sericite formed as dense replacement of the primary clay-rich lenses. Fine-grained stilpnomelane formed mainly in fine-grained felsic matrix and in thin subparallel trails.

ii) Late thin fracturing encouraged infiltration by silica-CO_2-Ca-Fe-K-Al-bearing hydrothermal fluid. The thin fractures were sealed by assemblages of K-feldspar, chlorite, hematite and calcite. Cryptocrystalline hematite clouding (red in hand sample) formed as selvages in the fracture margins and weakly pervasively through the rock.

FIG. 23: SAMPLE BKDD001, 583.2-583.25m (Transmitted light with crossed polarisers, Obj. x4, Image PB104917). This view of meta-mudstone illustrates its partly preserved lenticular sedimentary layering defined by sericite-rich lenses and felsic lenses. Thin trails of very fine-grained stilpnomelane (dark) lie broadly in the trace of layering.

SAMPLE : **BKDD001, 610.3-610.35m (The Cottage Prospect, East Tennant Project, Northern Territory)**

CLIENT NOTE : contact btw fg dark homogenous magnetic unit and qrtz vned altered metased - Note fg dark magnetic unit truncates veins (later unit?)

SECTION NO. : BKDD001, 610.3

HAND SPECIMEN : The drill core sample represents two different rock types: fine-grained dull greenish grey rock and coarser-grained particulate rock. A single quartz-rich vein cuts the coarser-grained rock.

The rock sample responds positively to the hand magnet, confirming magnetite

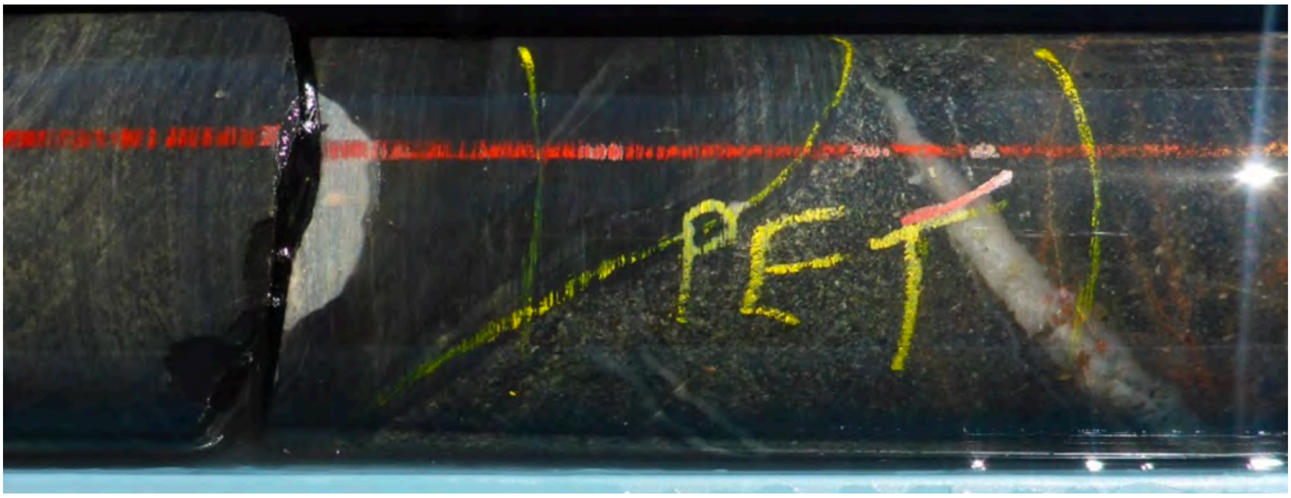

FIG. 24: Macrophotograph of sample BKDD001, 610.3-610.35m (courtesy of N. Chalmers, SER)

ROCK NAME : **Veined meta-layered sediments:**

Sericite-stilpnomelane-magnetite meta-mudstone

Sericite-stilpnomelane-magnetite meta-lithic-crystal arenite

Recrystallised quartz-chlorite-magnetite vein

PETROGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Sericite-stilpnomelane-magnetite meta-mudstone		
Zircon	Tr	Clastic grains 1
Sericite	85	Metamorphic 2 (after precursor 1)
Stilpnomelane	12	Metamorphic 2 / thin fracture seals 2
Opaques (magnetite)	2	Metamorphic 2
Tourmaline	Tr	Metamorphic 2

cont…

Mineral	Vol %	Origin
Sericite-stilpnomelane-magnetite meta-lithic-crystal arenite		
Lithics (albite, quartz)	10	Altered acid igneous rock 1 / 2
Lithics (albite, stilpnomelane, opaques)	10	Altered basaltic rock 1 / 2
Lithics (quartz)	5	Altered ?siliciclastic 1 / 2
Quartz	10	Clastic grains 1
Albite	10	Clastic grains 1 / metamorphic 2
Opaques	1	Altered clastic grains 1 / metamorphic 2
Opaques (?magnetite)	1	Metamorphic 2 (after matrix 1)
Stilpnomelane	21	Metamorphic 2 (after matrix 1)
Sericite	31	Metamorphic 2 (after matrix 1)
Zircon	Tr	Clastic grains 1
Tourmaline (brown/green overgrowths)	Tr	Clastic grains 1 / metamorphic 2
Recrystallised quartz-chlorite-magnetite vein		
Wallrock fragments	5	Wallrock fragments 2a
Quartz	91	Vein filling 2a / recrystallised 2b
Chlorite	3	Vein filling 2a
Opaques (?magnetite)	Tr	Vein filling 2a

In thin section, this sample displays different minerals and textures in different parts of the rock.

Sericite-stilpnomelane-magnetite meta-mudstone represents the finer-grained greenish grey rock observed in the hand sample. It displays a massive fine-grained metamorphic texture dominated by uniformly small but well-shaped sericite flakes ~50 μm long. Stilpnomelane is less abundant, forming small flakes of similar size distributed between the sericite flakes; pleochroism of the stilpnomelane from colourless to drab greenish brown suggests it has a moderately reduced composition. Small cubic opaque crystals (magnetite) are sprinkled sparsely throughout. Tourmaline is observed as small euhedral prisms pleochroic in green colours (likely schorl composition).

Sericite-stilpnomelane-magnetite meta-lithic-crystal arenite represents the coarser-grained particulate rock observed in the hand sample. It displays a poorly-sorted clast-supported primary fragmental texture.

Lithic fragments ~0.4-2.0 mm in size and angular in shape are moderately abundant, and different types are identified:

i) Some fragments represent felsic crystalline rock (?granitoid) composed of albite-altered plagioclase grains, angular and quartz grains.

ii) Some fragments represent altered basaltic lava. Small plagioclase laths are replaced by optically continuous albite, and lie in a matrix of fine-grained alteration brown stilpnomelane and tiny opaque grains.

iii) Some fragments represent fine-grained silicic rock composed entirely of a fine-grained microgranular mosaic of tiny quartz grains. It may be a siliciclastic sediment.

Crystal fragments are moderately abundant. Quartz forms angular grains ~0.2-0.8 mm in size. Albite (alteration of plagioclase clasts) forms similarly sized grains. Fe-Ti oxide grains ~0.4 mm in size appear to be altered. Zircon is observed as uncommon subhedral to subrounded grains up to ~100 μm in size. Tourmaline occurs as small subrounded grains with drab yellow-green colour, overgrown by subhedral green metamorphic rims.

Matrix areas are composed of tiny sericite flaks and similarly small stilpnomelane flakes. The stilpnomelane tends to form poorly-defined patches and trails, and displays the strong colourless to dark brown pleochroism of ferrostilpnomelane (Fe^{2+}-rich stilpnomelane). Tiny opaque crystals (magnetite) are sprinkled through the matrix.

Recrystallised quartz-chlorite-magnetite vein represents the single white vein observed in the hand sample. It is composed mostly of quartz, which forms small anhedral grains in a sutured (recrystallised) mosaic. Chlorite occurs as small green flakes and small aggregates. Opaques (magnetite) form tiny cubic crystals near chlorite. Minor ragged patches of wallrock are irregularly distributed through the vein, and are composed of fine-grained stilpnomelane, opaques (magnetite) and chlorite.

Minor thin fractures sealed by microgranular quartz cut the host meta-arenite. These are interpreted as belonging to the same generation as the thick vein.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following stages, from earliest to latest:

1. Sedimentation

Layered sediments were deposited as part of the stratigraphic sequence. Ferruginous mudstone was composed of abundant fine-grained detrital clays and trace clastic zircon. A significant primary Fe content is inferred, either adsorbed into the clays or as a chemical sedimentary component. Ferruginous arenite was deposited as a coarser-grained clastic sediment composed of abundant lithic fragments of diverse types (felsic igneous, basaltic, siliciclastic) and crystal fragments (quartz, plagioclase, trace Fe-Ti oxide, zircon, tourmaline) in fine-grained ferruginous clay matrix similar to the muddy facies.

2. Regional metamorphism

The layered sediments were modified by a low-grade regional metamorphic event in the subgreenschist to lower greenschist facies. Particular effects included the following:

i) The mudstone recrystallised to form a fine-grained massive assemblage of sericite + stilpnomelane + minor opaques (magnetite) + trace tourmaline. Trace clastic zircon survived.

ii) In the arenite, matrix recrystallised to form new fine-grained sericite + stilpnomelane + minor opaques (magnetite). Basaltic lithic fragments were replaced by stilpnomelane, albite and opaques. Plagioclase clasts were replaced by albite.

iii) In the meta-arenite, open fractures were filled by veins of quartz + minor others (chlorite, magnetite), and thinner fractures were sealed by quartz. In the meta-mudstone, thin fractures were sealed by stilpnomelane.

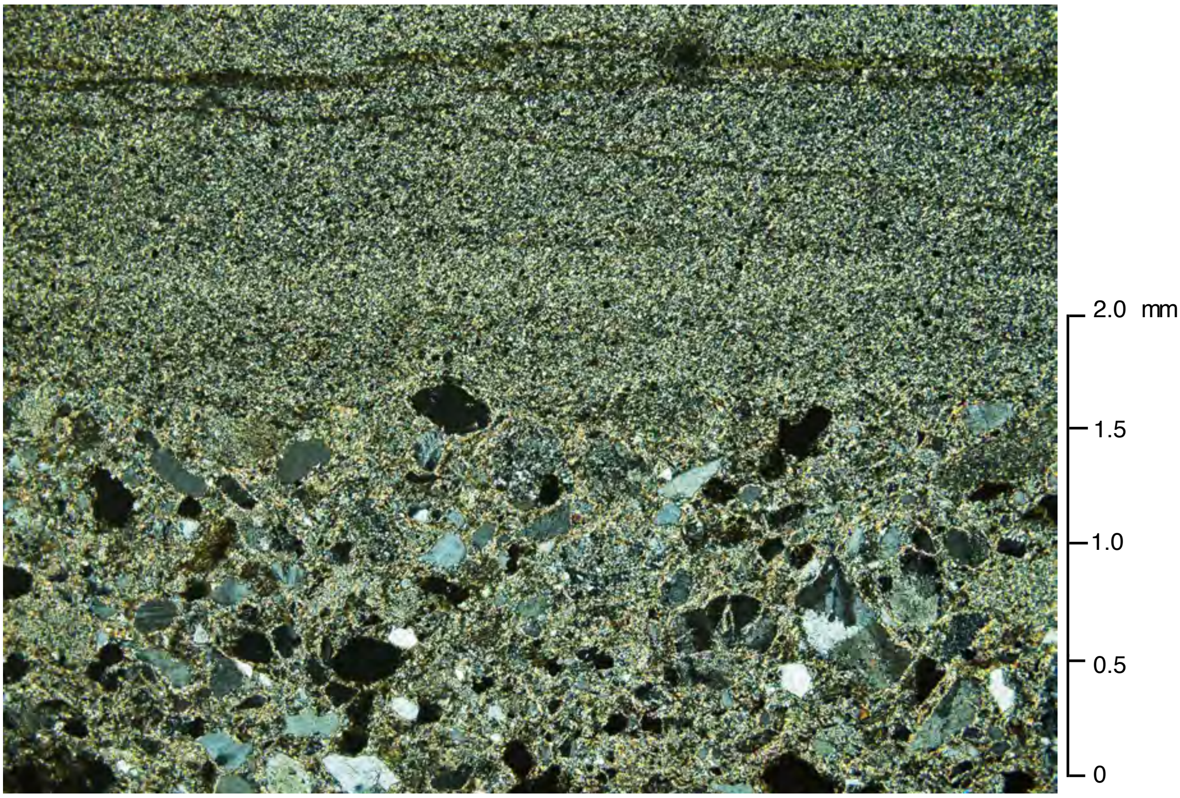

FIG. 25: SAMPLE BKDD001, 610.3-610.35m (Transmitted light with crossed polarisers, Obj. x4, Image PB104920). This view captures the sedimentary contact (E-W) between meta-mudstone (top) and meta-arenite (bottom). Both contain the same fine-grained metamorphic assemblage (sericite + stilpnomelane + magnetite), which occurs pervasively in the meta-mudstone and in the matrix of the meta-arenite.