Petrological observations regarding 14 samples from the Mt Molloy prospect (Axiom Mining) – North Queensland

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April 2008

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INTRODUCTION.

The project was commissioned via Glen Little, Exploration Manager – Axiom Mining Limited with a general brief to investigate host rocks, paragenesis, mineralisation and genetic aspects concerning 13-14 samples from the Mt Molloy prospect, North Queensland.

Host Rocks.

A. Meta-sediments.

The samples reveal a sequence of well layered mildly metamorphosed sediments now represented as meta-pelites, meta-arenites, and meta-greywacke (an original sequence of argillaceous, arenaceous, and muddy sand/greywacke. Some narrow ex-fragmental units are present containing fragments similar to the above and also minor basaltic components. The fragmental rocks (now deformed/compacted) could represent ex-conglomerates, rip up beds, mass flow units, etc.

Many of the meta-pelitic (phyllitic) units are dark with minor carbonaceous components (shale like) and exhibit moderately developed cleavage, suggesting the sequence has undergone active tectonism and folding.

Several areas within the core contain layers with fine carbonate, which reacts with dilute HCL. Sample 168.06-168.30 contains an early generation of fine carbonate, some of which seems to have re-crystallised to a layer parallel fabric. It is thus suspected that early fine grained muddy/sandy/carbonate units are present. (See also sulphide alteration).

Pictorial and petrological details are given in the main sector of the report (Figures 1-30).

Meta-pelites (Figures 5, 6, 10, 12, 16, 17, 18).
Meta-arenites (Figures 5, 6, 10, 11, 12, 16, 17, 18)
Calcareous –?calcilutites (Figures 21, 21A, 22)
Fragmental (Figures 18, 24, 25)

B. Igneous units.

Six of the selected samples are of igneous origin, and all are extremely altered (sericite-illite-clays) appearing as rather vaguely textured fine grained buff coloured rocks within the core. Some ex-feldspar phenocrysts are usually visible via close inspection. The rocks appear to be narrow sills or even thin layers paralleling the sedimentary compositional layering. (Figures 1, 2, 3, 4, 19, 28, 29, 30, 31, 32, 33, 34).

The majority of the rocks sectioned proved to be essentially porphyritic basalt/dolerite, with massive alteration obliterating much visual texture. Grain size and phenocrysts/matrix ratios differ, and some exhibit signs of deformation (shortening) whilst others appear undeformed.

Given that all exhibit similar alteration overprinting (and/or alteration via metamorphic/deformation-readjustment) it is probable that they are all pre-tectonic/pre-cleavage development, with their competency contrast making them a focus for subsequent fracturing/fluid flow.

It is certainly noticeable in the core that the 170-180m zone of major dolerite occurrence is also a zone of major sulphide/quartz vein development.

At 180.45m, a slightly more quartz rich intrusive rock occurs classified here as monzonite. It is similarly altered to the dolerites, although exhibits no evidence of deformation, (Figures 38-39).

Stages – paragenesis.

The paragenetic sequence is difficult to totally resolve, and the current indications are given below (see also Table 1).

Early	Quartz veins	(very early-minor)
	Sulphide stage ± quartz	(Veins and along permeable sandy horizons). (Pre-cleavage).
	Sericite/illite ± TiO_2 compounds clay, chlorite	(Difficult to time could be with tectonism, and/or earlier??
Cleavage - development	Clay	(Late veins – brittle fracture post cleavage).
	Carbonate ± quartz	
Late	Clay	(Clay alteration is widespread within the igneous units – suspect more than one generation).

Timing relationships concerning the serecite/illite and related stages are difficult to establish. Some sericite clearly forms during the layer shortening/cleavage stage, but there could be more than one event with late (or even early) sericite/clay/chlorite/TiO_2 effects.

Stages – alteration/infill.

Specimen No.	**Host rocks**	**Sericite/illite ± chlorite TiO_2, carbonate**	**Quartz vein (early)**	**Quartz vein + sulphide or sulphide in quartz layer**	**Late white carbonate veins ± quartz**	**Clay alteration and/or veins**
68.57-68.66m	Dolerite/'basalt'	✓	✓	Tr in basalt	✓	✓ Cuts CO_3
71.30-71.42m	Dolerite	✓	✓?	-	✓	-
77.30-71.50m	Meta-pelite Meta-arenite	✓	-	✓	✓	-
80.35-80.65m	Meta-pelite Meta-arenite	✓ (foliation)	-	✓	✓	-
106.75-107.00	Meta-pelite Meta-arenite Fragmental	✓ (foliation)	-	-	✓	
138.70-138.80	Dolerite/basalt	✓?	-	-	✓	✓
168.06-168.30	Meta-pelite Meta-arenite Carbonate	?	-	✓	✓	✓✓
168.70-168.95	Meta-'conglomerate?' (fragmental)	✓ (foliation)	-	✓	-	✓
171.18-171.43	Dolerite/basalt	✓	-	✓	✓	✓
175.0-175.25	Dolerite/basalt	✓	-	✓	✓cuts clay	✓
173.25-173.60	Dolerite/basalt	✓ (TiO_2)	-	✓?	✓?	✓✓
176.73-177.03	Dolerite/basalt	✓	-	✓	-	✓
180.45-180.70	Monzonite	✓	-	-	-	✓?

Table 1 – Summary data.

Mineralisation.

The mineralisation (sulphide stage) occurs in several formats consisting of pyrite accompanied/associated with variable minor amount of chalcopyrite, sphalerite and more rarely galena and pyrrhotite.

1. Vein styles are visible at several points with minor stockworks and/or individual veinlets occurring. They seem to concentrate in regions of igneous (dolerite/basalt) units.

The veins are at the 0.5-1.0cm scale composed of grey quartz ± sulphides. The quartz within vein structures exhibits a wide range of textures, ranging from irregular mosaic style grains (100-200 microns) interpreted as original vein quartz, through to small grains which seem to represent recrystallisation of the above in response to deformation? Fibre/elongate quartz styles are prolific, and interpreted as new growths in response to the major tectonism/cleavage development. The fibre styles are present in pressure shadow style to isolated pyrite grains suggesting sulphide formation pre-cleavage development, (Figures 15, 36). The quartz veins-layers often have zipper-textured "layer shorted" cleavage bordered effects (Figures 10, 11, 12).

The sulphides dominated by pyrite do not exhibit obvious deformation effects.

Pyrite is present in variable grain size, with the majority of grains exhibiting some crystal faces, clear cut infill textures are not present (i.e. pyrite infilling around quartz or visa versa). The range in pyrite styles is evident from the figures contained within the report.

Chalcopyrite occurs sporadically in association with the pyrite, and is generally much finer grained (20-100 microns) and not easily visible by eye. It occurs as inclusions within pyrite, interstitially to pyrite, attached to pyrite rims and in slightly larger scale irregularly bordered patches with quartz hosts.

Sphalerite is present in trace amounts, mostly occurring with quartz hosts, and occasionally within pyrite. The largest occurrence is of semi-transparent – low iron yellow-brown colour. Galena is even more poorly represented, and textural variations of the above are presented within the various plates. (Figures 8, 9, 13, 23, 36, 37).

2. Bed/lithology related styles (Figures 10-15).

    a. Quartz rich.

Some of the more sandy style beds contain pyrite grains similar in all respects to those described above, and with similar associated sulphides. The format of the pyrite is usually granular, although some discontinuous vein styles are present 'cross cutting' the beds and angles similar to the cleavage.

    b. Carbonate rich (Figures 20-23).

The suspected meta-carbonate units, contain dense pyrite grain spotting zones, again similar in all regards to the vein pyrite associated with the other sulphides (including rare pyrrhotite). Sulphide alteration of carbonate is suspected (pre-cleavage).

Genetic implications/discussion.

The sulphide assemblages are uniform throughout, with pyrite being dominant, accompanied by minor and variable amounts of chalcopyrite, sphalerite, galena and pyrrhotite (in descending abundance). This suggests just one major stage of sulphide introduction. The various sulphide formats despite modification via deformation are interpreted to represent:

1. Vein styles. Veinlet style – small stockwork zones. Quartz sulphide veins. Formed via brittle fracture of consolidated rock.
2. Replacement/permeability styles.
   (a) Within arenaceous units. Occurring as sulphide (pyrite spots) within narrow originally sandy, arkosic?, layers. Some small cracks with sulphide content are noted, but layer parallel spotting is the dominant format.
   (b) Within suspected fine grained carbonate units, as densely packed pyrite grains. Carbonate replacement?

The evidence suggests that sulphides and quartz were in place prior to the major deformation/cleavage event.

It remains unclear whether or not the original format represents the distal portion of an epigenetic deposit – vein style ± layer replacement, or stringer, layer replacement leading towards a volcanogenic style.

The author is aware of a PhD study (Peter Gregory) on the deposit, which concluded that Mt Molloy was a deformed massive sulphide. The author recalls massive sulphide rocks (chalcopyrite, pyrrhotite ± pyrite, and pyritic granular rocks) collected from the dumps, which support the concept of massive sulphide (exhalative) lenses. These rocks are not however represented in the drill core, and the above comments are from memory of a visit some 30 years ago, together with observation of P. Gregory's samples at that time. This aspect merits some follow up collection/inspection of these rocks/photographs. At this stage the exhalative model seems attractive, and the core would thus represent peripheral materials to lensoid sea-floor massive sulphides

SAMPLE DESCRIPTIONS – HAND SPECIMENS AND PETROLOGY.

Specimens taken from Diamond Drill Hole MM07, DD05 between 68.53 and 180.7m. (13 specimens – 14 thin sections).

Specimen MM07 DD05 - 68.53-68.66m.

Altered porphyritic dolerite. *Hand specimen (Figure 1).*

Pale grey, fine/medium grained altered igneous rock. General grain size is around 1.0mm with a uniform massive texture.

Dark crystal shapes (50% of rock) are generally rectangular to ovoid with very ill defined crystal margins. Suspect sericitised feldspars and ex-ferromagnesium minerals (some chlorite?) – set in paler grey matrix with some areas of large pale ex-feldspar crystals (almost phenocrysts in places). Most dark crystals have minute buff dots (TiO_2) – suggesting a mafic composition prior to alteration (hornblende/biotite).

Rare, 1mm white ovoid grains (carbonate?, clay?). The whole rock is soft, and little or no quartz is present. Possibly dolerite.

Veins.

1. Grey quartz (infill) – crystalline nature just visible, 2-3mm.
2. Grey quartz (infill) + white crystalline – (Co_3) ± rare pyrite – 2-3mm.
3. White – 0.5mm, carbonate – several. Cut the above.

Petrology (Figure 2).

The rock is porphyritic (50-60%) igneous with phenocrysts at the 1-2mm scale.

Phenocryst include:
Ex-feldspar – the feldspars (1-2mm, 50%) are oblong to equant, and altered to fine sericite. Remnant feldspars exhibit some simple twins, are rarely multiple twins. No extinction angles proved suitable for compositional measurement. Most feldspars are untwinned.

Ex-ferromagnesium – the ex-ferromagnesium phenocrysts (50%) are now completely altered to chlorite/carbonate combinations and some retain shapes suggesting amphibole. There are also traces of TiO_2.

The matrix contains feldspars converting to clay/sericite (40-50 micron) and some 10% TiO_2 compounds (some elongate). A large TiO_2 grain (300 micron) was probably magnetite. Traces of pyrite (20 micron) and chalcopyrite (30 microns) are present.

The textures suggest an original porphyritic dolerite/basalt rock type. A quartz vein is present with traces of pyrite (60 micron wide).

Figure 1. **Specimen MM07 DD05 - 68.53-68.66, altered porphyritic dolerite. White carbonate vein, cutting grey quartz. Width of frame (WOF) c10.1cm.**

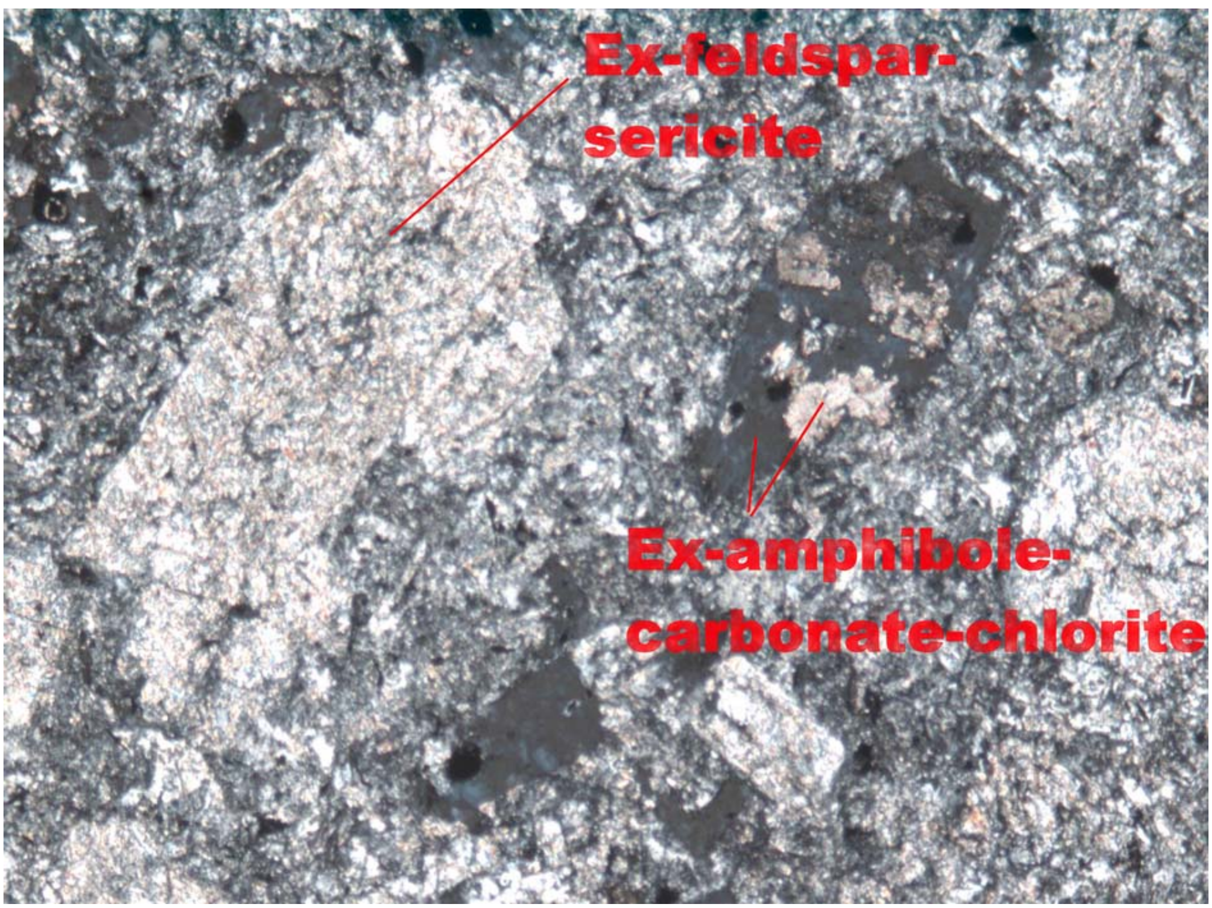

Figure 2. **Specimen MM07 DD05 - 68.53-68.66. Altered porphyritic dolerite. WOF c5.6mm.**

Specimen MM07 DD05 - 71.30-71.42m.

Altered porphyritic dolerite. *Hand specimen (Figure 3).*

Deformed, disrupted, layered, fine grained meta-sedimentary units (dark to pale) siltstone and possible carbonate rich siltstone.

The deformed host rocks (cleavage development) are a high strain zone which has been further disrupted, by very irregular carbonate (± quartz?) veining both parallel and at right angles (tension style infill gashes). Carbonate alteration and/or re-crystallisation is strongly suspected in the paler layers – blurring the bedding traces. Rare (0.5mm) pyrite grains occur in the carbonate vein-gashes.

The rock is cut by a 2-3cm wide dyke running parallel to the general bedding, cleavage (high strain fabric). This is fine grained, cream coloured, soft-altered with small partially aligned phenocrysts (20-30% at1.0mm scale) in a fine grained matrix. Quartz content is low (none as phenocrysts).

The phenocrysts are very irregularly shaped 'ovoid to elongate' and very altered (clay-sericite) and presumably ex-feldspar (± ferromagnesium). A narrow slightly darker zone at the margin of the dyke (1-2m) looks like an altered sheared contact zone. The dyke is undeformed.

Petrology (Figure 4-5).

Igneous component (Figure 4).

The dyke rock is porphyritic igneous with some 50% phenocrysts at the 200 micron to 1.0mm scale.

Feldspar – the ex-feldspar phenocrysts are very sharply bordered, but totally altered to combinations of fine sericite (90%), clay (10%) and carbonate (1%) at 5 micron scales. Textural variation reveals zoned marginal zones.

Ferromagnesium – ex-ferromagnesium phenocrysts (200-800 micron) are now composed of combinations of chlorite and carbonate, ± pyrite, and chalcopyrite spots (15 micron). They constitute some 15-20% of the phenocrysts and some amphibole shapes are present.

Matrix – the matrix is extremely fine grained (2-5 microns), and very cloudy (clay, sericite wisps, and 20% fine TiO_2 compound spots).

The textural data and lack of quartz suggest porphyritic basalt/dolerite.

The dark layer "beneath" the dyke with white fragments (see rock) is mostly fine clay with minor quartz. The latter is probably vein related. The paler irregular blebs are fine carbonate.

The carbonate cuts the quartz and is cut by clay veining. A shear fabric clay (cuts along the edge of the dyke).

The finely layered banded zone is composed of carbonaceous clays/± sandy/silty layers, overprinted by sericite and later carbonate (Figure 5).

Figure 3. **Specimen MM07 DD05 - 71.30-71.42. Altered porphyritic dolerite. WOF c10cm.**

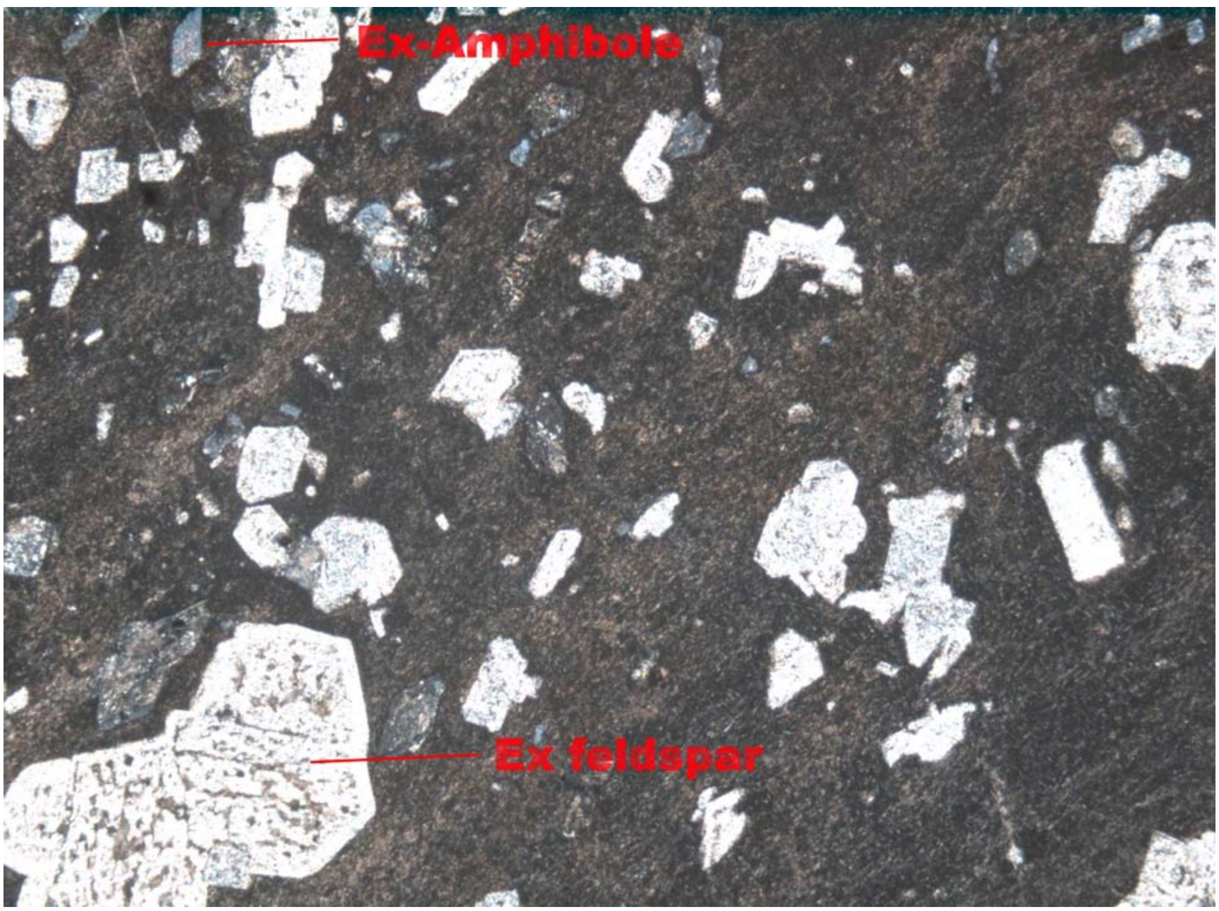

Figure 4. **Specimen MM07 DD05 - 71.30-71.42. Altered porphyritic dolerite. WOF c5.6mm.**

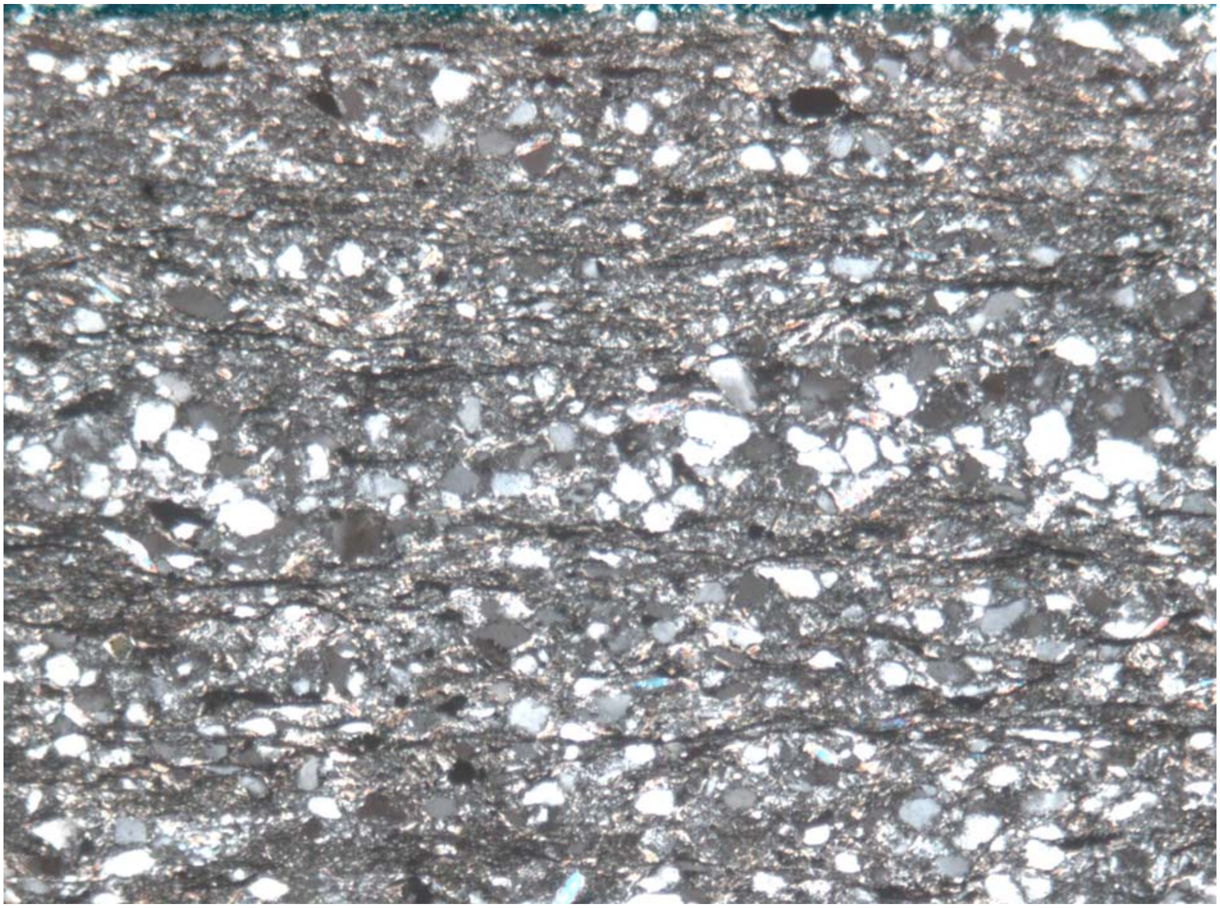

Figure 5. **Specimen MM07 DD05 - 71.30-71.42. Meta-arenaceous to meta-pelite unit with ?carbonaceous layers. WOF c2.8mm.**

Specimen MM07 DD05 77.30-77.50.

Foliated argillaceous/arenaceous metasediments (meta-pelite---meta-arenite) + deformed quartz-sulphide vein. *Hand specimen (Figure 6).*

The core sample contains some 8-10 parallel bands of altered deformed fine grained metasediments. These can be divided into units dominated by dark grey carbonaceous 'siltstone' (1-3cm) and paler coloured granular wavy textured units (1-3cm). The latter exhibit pinch/swell textures and although soft are slightly harder than the dark siltstones. They have a fine (50 micron) grainy texture , do not react with acid, and are suspected as siliceous mudstone/sandstone units. The units define a strong fabric at 30-40^{o} to the core axis.

Sulphides occur as:

1. Isolated grains (pyrite 1-2mm scale) within the paler units.
2. Discontinuous 1.0mm long cracks in some of the dark units..
3. As linked grains forming irregularly bordered wormy veins parallel to layering. These are discontinuous features (pyrite) up to 3-4cm long, with one continuous 'vein'. The latter looks deformed with a bend along it paralleling the host rock fabric.
4. Larger vein like features with pyrite grains up to 3mm in size linking in an irregular manner, within quartz (grey). These give an impression of fine grained semi-massive pyrite running parallel to the general fabric.

The main vein like feature is some 1.0cm wide – pyrite, quartz ± white-later carbonate. At one edge the vein seems to cross cut the main fabric. Small yellower grains could be chalcopyrite, and vague bronze patches could be pyrrhotite or sphalerite. (Petrology indicates sphalerite)

Late narrow carbonate veins (1.0mm) cut the fabric.

Petrology (Figure 7).

The host rocks are composed of fine (5 micron) sericite/illite dominated, shaley (Figure 7) units and (paler) fine grained sandy-quartz dominated layers (10-100 micron grain size), which are all well foliated. (See also 80.35-80.65 and 166.75-107.0). The units are flecked with sulphide grains or discontinuous trails of sulphide grains. The rock contains some 5% sulphide.

A quartz-sulphide zone occurs in a layer parallel setting, composed of some 45-50% quartz, 45-50% pyrite, and 5-10% chalcopyrite. The pyrite exhibits semi-crystalline texture with prominent crystal faces and ranges from 5 microns to 1.5mm. It occurs singly or in grain clusters.

Chalcopyrite tends to occur separately from pyrite, contained within 'broken'?? quartz (i.e. it is not interstitial to quartz crystals), (Figure 8).

One sulphide dominant zone also contains galena and sphalerite (5-15 microns) (pyrite 70-80%, chalcopyrite 20%, galena 5-10%, sphalerite 5-10%).

These are interstitial to chalcopyrite, but also occur rarely as 2-3 micron inclusions within pyrite. Minor chalcopyrite occurs similarly within pyrite. The quartz is extremely deformed with intense fibre development. The quartz-sulphide unit is interpreted as a deformed vein.

Figure 6. **Specimen MM07 DD05 - 77.30-77.50. Foliated meta-pelite - meta-arenite + deformed quartz sulphide vein. WOF c18cm.**

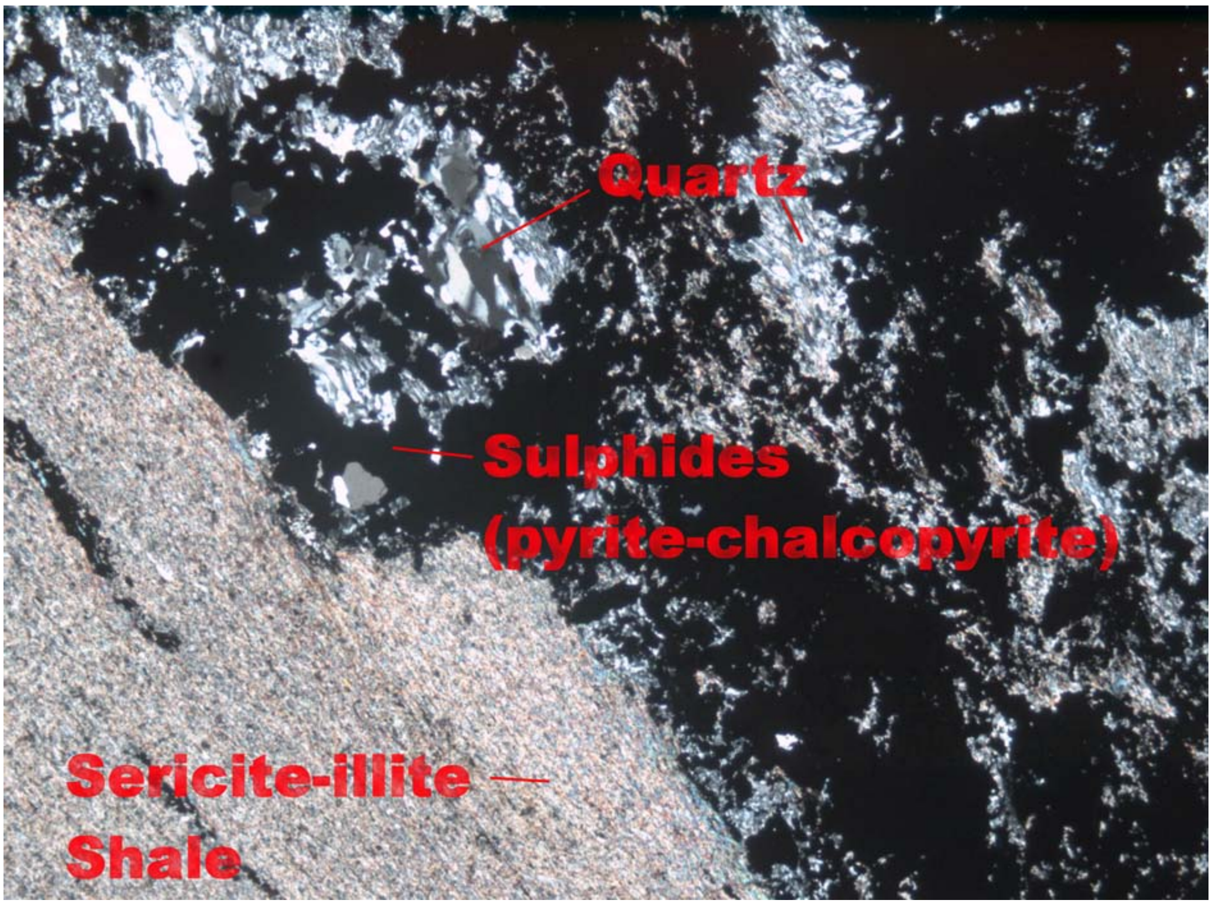

Figure 7. **Specimen MM07 DD05 - 77.30-77.50. Deformed quartz/recrystallised? with pyrite. WOF c5.6mm.**

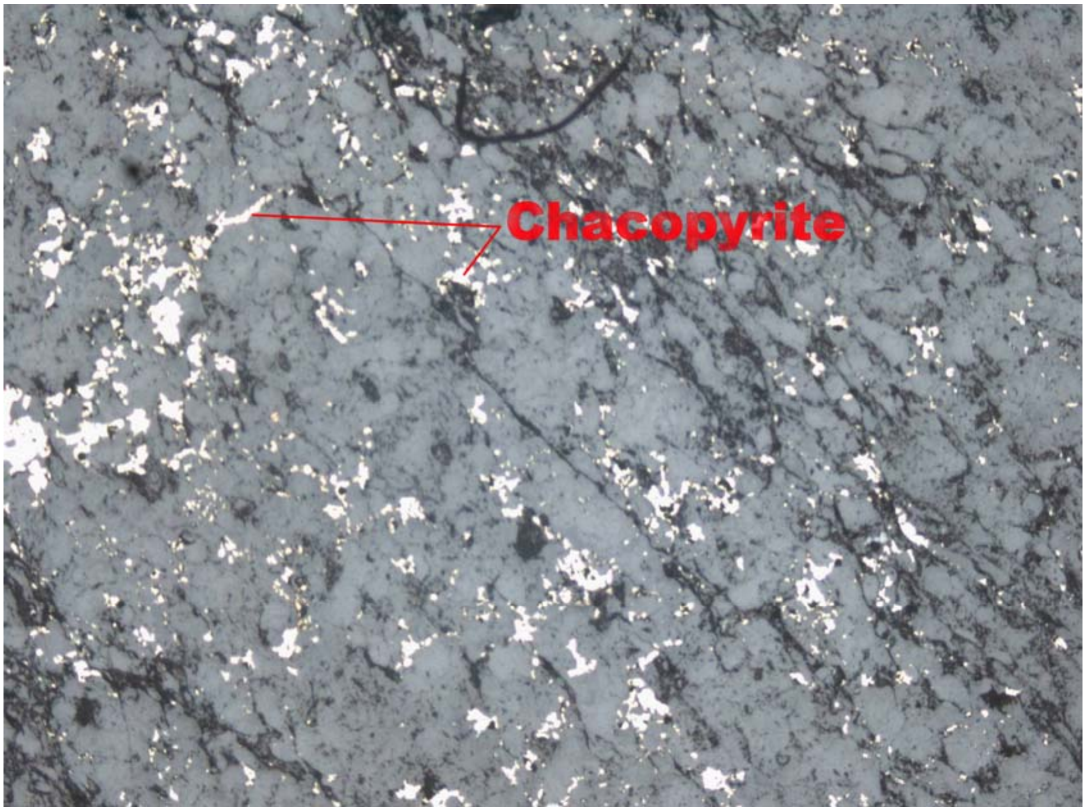

Figure 8. **Specimen MM07 DD05 - 77.30-77.50. Chalcopyrite in quartz. WOF c5.6mm.**

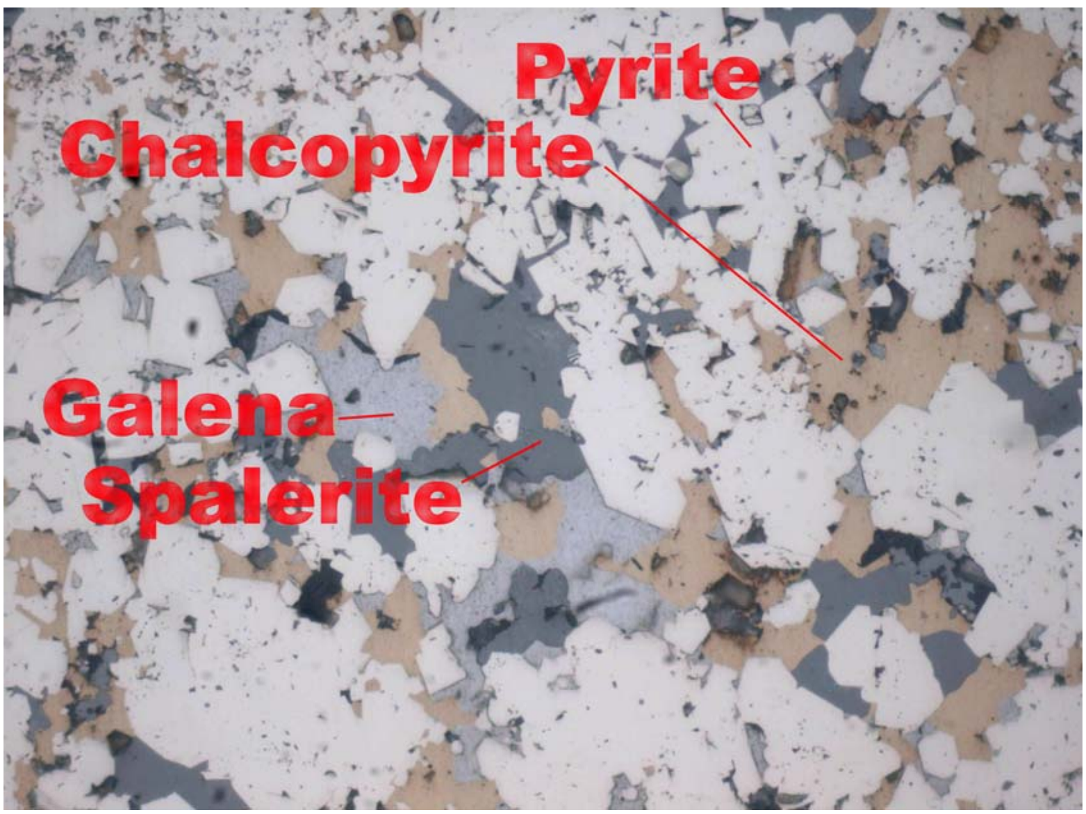

Figure 9. **Specimen MM07 DD05 - 77.30-77.50. Sulphide assemblage. WOF 0.25mm.**

Specimen MM07 DD05 80.35-80.65.

Argillaceous to mildly arenaceous foliated meta-sediment (meta-pelite—mete-arenite) + deformed sulphide/quartz layers*.* *Hand specimen (Figure 10).*

The 30cm long core sample consists of layered (banded) altered meta-sediment horizons. Some 20 bands are present. The majority are extremely fine grained dark soft claystone/shale (2-6cm wide) with no obvious foliation at hand specimen level. The remainder are generally narrower (0.5-1.0cm) sulphide dominant units with disseminated pyrite grains in pale quartz rich materials. One of these units is 4-5cm thick with 4 layers of pale siliceous (gritty) material ± sulphide separated by three narrow (0.5cm) darker claystone/shale units. The unit fizzes in acid suggesting significant fine carbonate content.

The 4-5cm unit appears to be composed of some 20% fine sulphide (pyrite), 40% dark quartz, and 40% pale carbonate all at submillimetre grain size. The other sulphide units seem to be more sulphide dominant with less carbonate.

Pyrite also occurs in spot and discontinuous thread vein format within the dark claystone/shale.

At hand lens scale,the pale-sulphide rich layers exhibit very irregular zipper-like boundaries, suggesting an overprinting cleavage/deformation effect.

Some late 1mm white carbonate infill veinlets angle across the core at 45^o, probably following a cleavage-foliation. They cut the sulphide layers.

Two thin sections were cut (A and B). (Figure 10).

Petrology, Section A (Figures 11-13).

The section covers several domains with layered textures.

(a) Main host rock – this is essentially shale/siltstone consisting of 5 micron components. Sericite/illite predominate (97%) with minor (3%) TiO_2 (rutile) compounds, and traces of pyrite. Several micron scale discontinuous lenses of slightly sandier meta-sediment are present (20 microns). A lower layer contains predominately sericite/illite with some 3-5% silica grains (5-7 microns), and a weak sericite/illite foliation. Some opaque discontinuous stringers (10 micron) contain TiO_2 ± brown ?carbonaceous material, ± pyrite
(b) Sulphide layer – this layer consists of pyrite and quartz grains arranged in a contorted zipper like layer with curving U shaped boundaries (layer shortened-Figure 11). The pyrite grains (60%) occur separately and in clusters at the 50-200 micron scale, with many crystal faces present. The quartz is of variable grain size in both granular and fibrous formats. Some of the fibrous formats form 'whiskers' on the pyrite. Suggesting that quartz recrystallisation was occurring whilst pyrite was present, (i.e., sulphide pre-cleavage). The shortened layer is cut by sericite along the foliation direction. Late 100 micron thick carbonate infill veins also traverse the layer.
(c) Quartz ± sulphide layer (Figures 10-12) – this zone is essentially similar to b above, but much wider (1-2cm), and exhibits the same contorted wavy texture. It is composed of quartz (80%), carbonate, sericite and pyrite and seems to have originally been a zone of sandy layering. The quartz is present as angular grains 50-150 microns with some evidence of finer grained recrystallisation and minor fibre development.

The sulphides are dominated by pyrite which occurs as crystals or crystal clumps (20/50-150 microns) mostly in linear chains which are discontinuous along the elongation (cleavage) direction. Sphalerite is also present (Figure 13) (3-5% of sulphide) occurring in short discontinuous grain clusters (interstitial to rock matrix) at 50-100 micron scales. It also occurs rarely as inclusions within pyrite. Chalcopyrite is a minor component (say 1% of sulphide) mostly at the 5-10 micron scale intestial to and on the edge of pyrite grains. One sphalerite contained chalcopyrite spots (chalcopyrite disease textures).

Petrology, Section B (Figures 14, 15).

The host rock is essentially shale/siltstone composed of sericite (90-95%), TiO_2 compounds (5%) ± minor clay, quartz, chlorite and pyrite. A weak cleavage is apparent in places and this direction is 'followed' by late carbonate-quartz veins, and some pyrite grain alignments. The sulphide rich layers are composed of quartz and pyrite in variable proportions, ranging from 70% sulphide to minor amounts. The layers are layer-shortened (cleavage) and the quartz is now in two formats, equant (100 microns) and strain style fibres approximately paralleling the cleavage (Figure 14).

The sulphides (94% pyrite) show little sign of deformation, although many contain strain shadow style quartz fibre development (Figure 15). The pyrite is in spongy-granular format (micron 10 0.5mm scale), with occasional crystal face development. Minor amounts of chalcopyrite occur in:

(a) interstices between pyrite grains (5-150 micron scales)
(b) attached to pyrite grains (5-30 micron scales)
(c) within pyrite grains (50 micron scales)

The interstitial style predominates.

Comments.

The sulphide and quartz are considered to be present prior to deformation. It is not clear whether the layers are ex-vein or ex-quartz rich sediment in origin. Veins are the favoured option (see also section B).

Figure 10. Specimen MM07 DD05 - 80.35-80.65. Meta-pelite – meta-arenite, foliated + deformed sulphide-quartz layers (cleavage overprint). WOF c30cm.

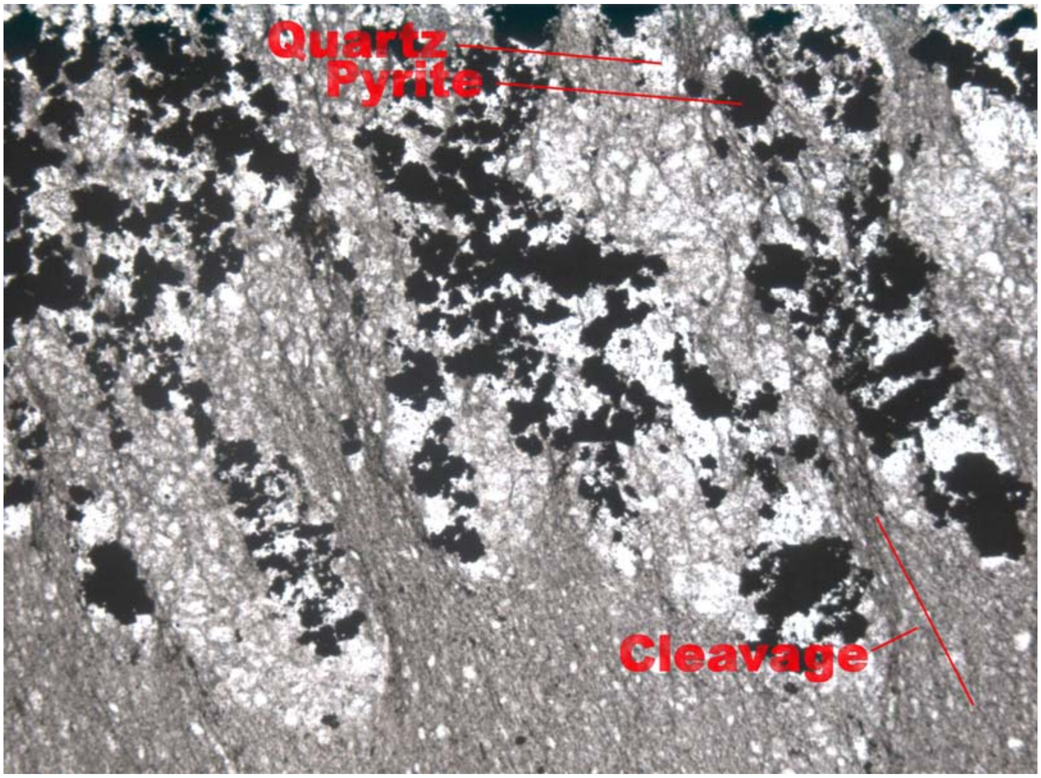

Figure 11. **Specimen MM07 DD05 - 80.35-80.65A. Deformed sulphide-quartz layer, with cleavage development in meta-pelite. WOF c5.6mm.**

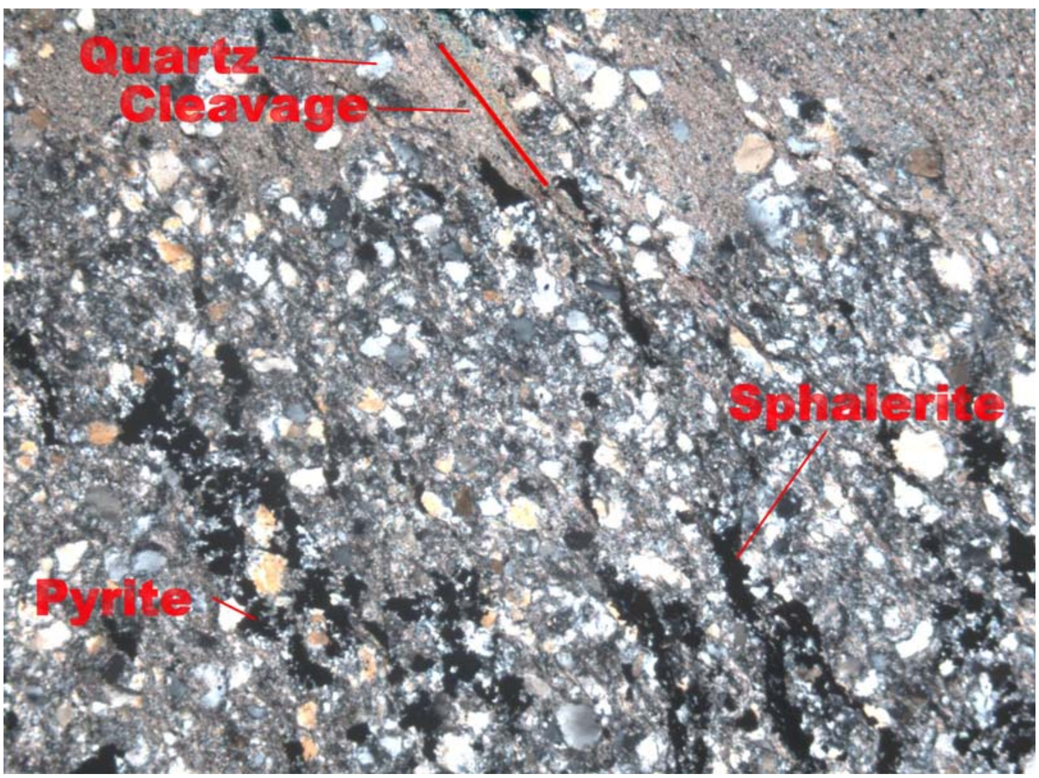

Figure 12. **Specimen MM07 DD05 - 80.35-80.65A. Close up of area similar to Figure 11, deformed meta-arenite/meta-pelite junction, with sulphides aligned along cleavage direction. WOF c5.6mm.**

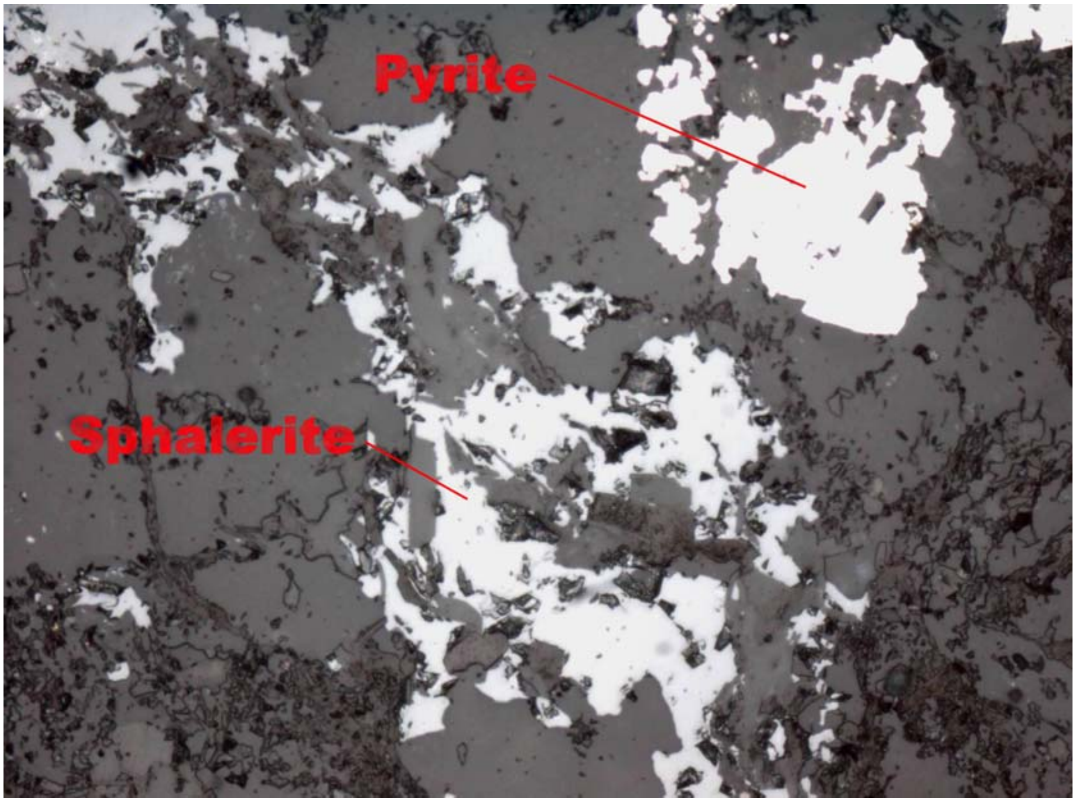

Figure 13. Specimen MM07 DD05 - 80.35-80.65A. Close up of sulphide from Figure 12. WOF c0.7mm.

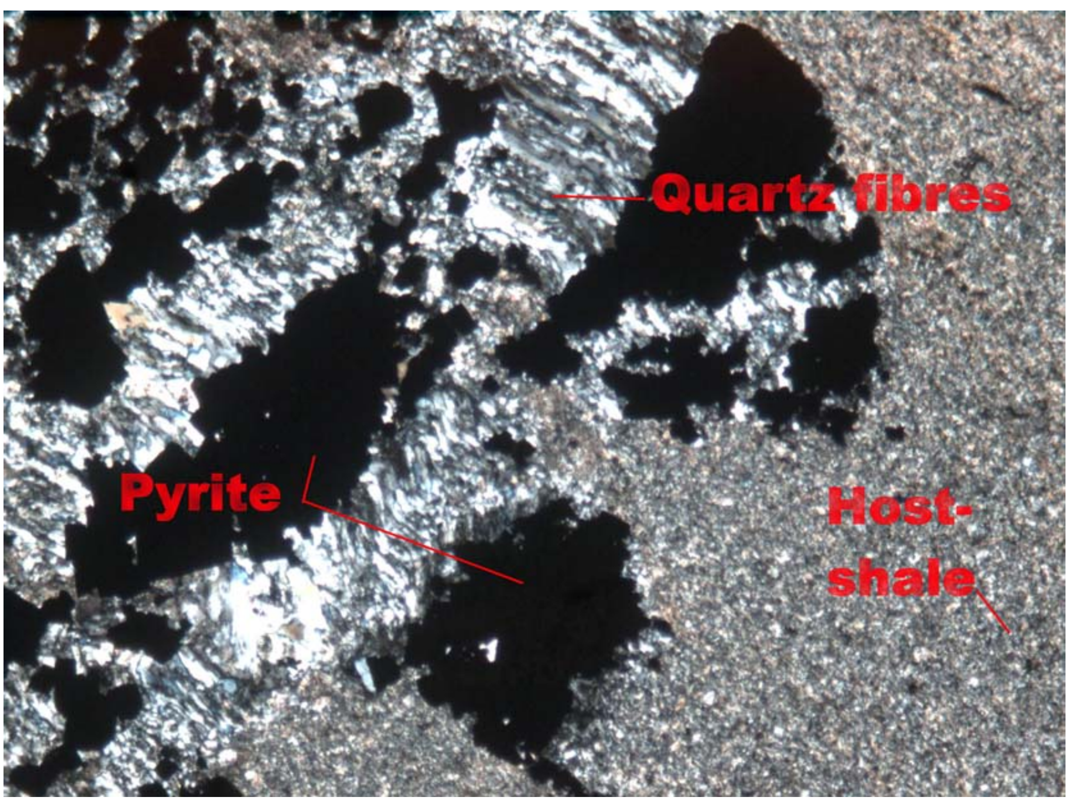

Figure 14. Specimen MM07 DD05 - 80.35-80.65B. Quartz deformation fibres. WOF c2.8mm.

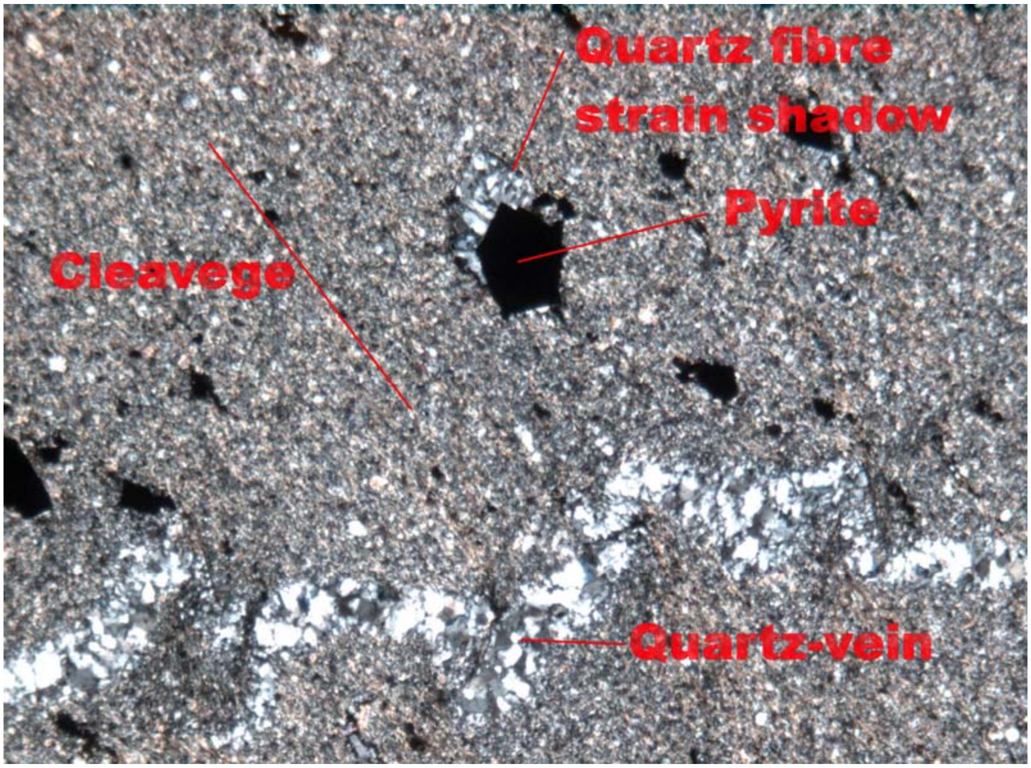

Figure 15. **Specimen MM07 DD05 - 80.35-80.65B. Quartz fibre growth on pyrite, and 'folded' quartz vein. WOF c2.8mm.**

MM07 DD05 (106.75-107.0).

***Argillaceous to arenaceous meta-sediments (meta-pelite---meta-arenite) including fragmental layer foliated** (Figures 16-18). Hand specimen.*

The 25cm core strip is composed of some 15-20 layers (20^{o} to core) of deformed fine grained meta-sediment ranging from sub-centimetre to 5cm widths and dark grey to pale grey in colours. Some of the smaller paler units are bulbous with possible boudinage effects (and/or soft sediment textures). All of the units are soft, with the darker units being extremely fine dark claystones.

The paler units (50% of rock) are slightly coarser, and although resembling peletal carbonate in some instances are non reactive to acid, and are presumed to be fine grained silica ± clay. The largest is some 5cm in width. Small discontinuous (1mm wide) carbonate rich veinlets occur both sub-parallel to the layering (bedding) and also at large angles to the core (Figure 16).

Petrology.

The fine grained layers are all meta-sediments and include (Figures 17-18).

(a) 'Sandstone' – layers composed of 85-90% quartz grains, which are mostly rounded, closely packed, ranging from 50-100 microns. There is some 5-10% extremely fine material (1-5 micron ? quartz) and 5-10% clouded material suspected as fine clay (1-2 micron) after original feldspars. Traces of TiO_2 compounds are present.

(b) 'Siltstone/shale – layer composed of some 70% fine (5 micron) flakes of muscovite/sericite/illite, 3% quartz, 15-20% very fine ?clay, and 5-10% TiO_2 compounds. The unit is foliated, via aligned micaceous grains.

(c) Fragmental sandstone – essentially a sandy layer (type a) with deformed (soft sediment?) clasts of type b, and also slightly coarser silty fragments (more quartz). Possible 'rip up' beds.

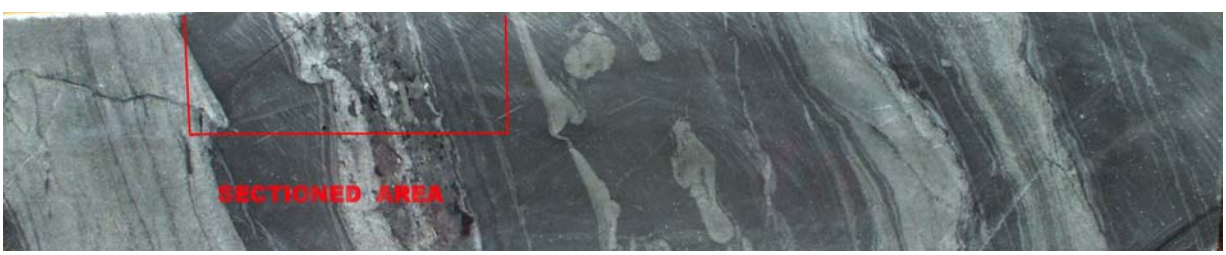

Figure 16. Specimen MM07 DD05 101.75-107.0. Metapelite – meta-arenite (+ fragmental layer) – foliated. WOF c25cm.

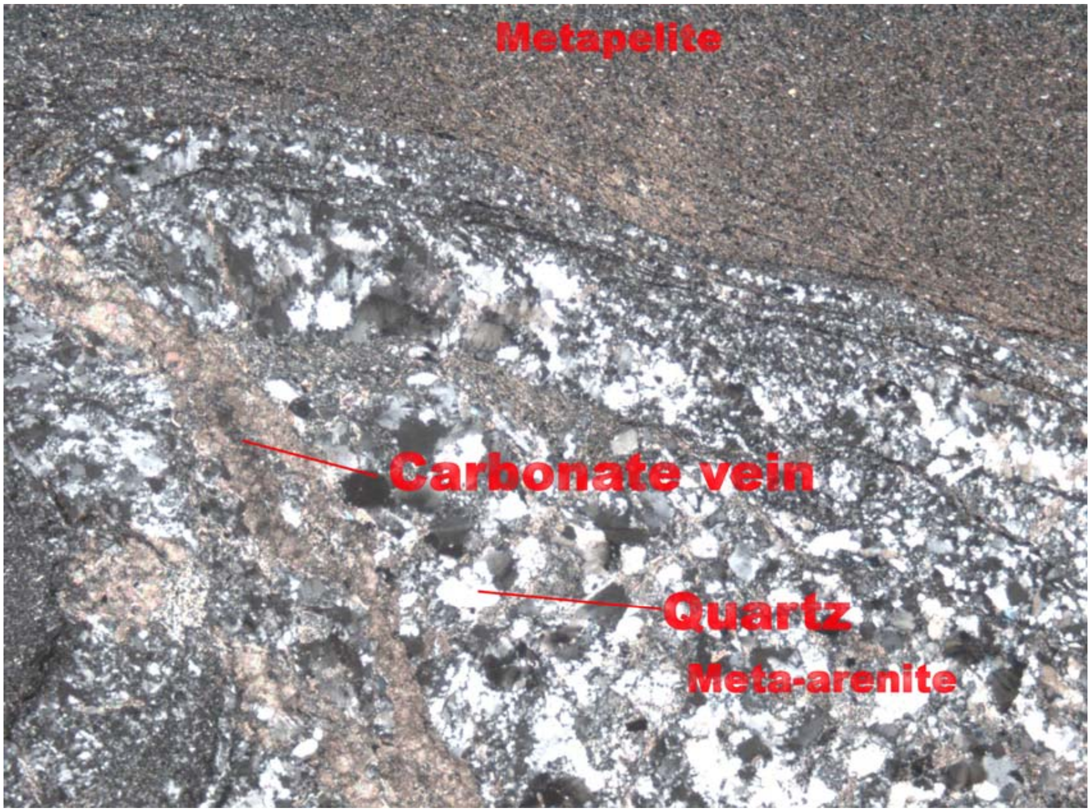

Figure 17. Specimen MM07 DD05 106.75-107.0. Meta-pelite – meta-arenite. WOF c5.6mm.

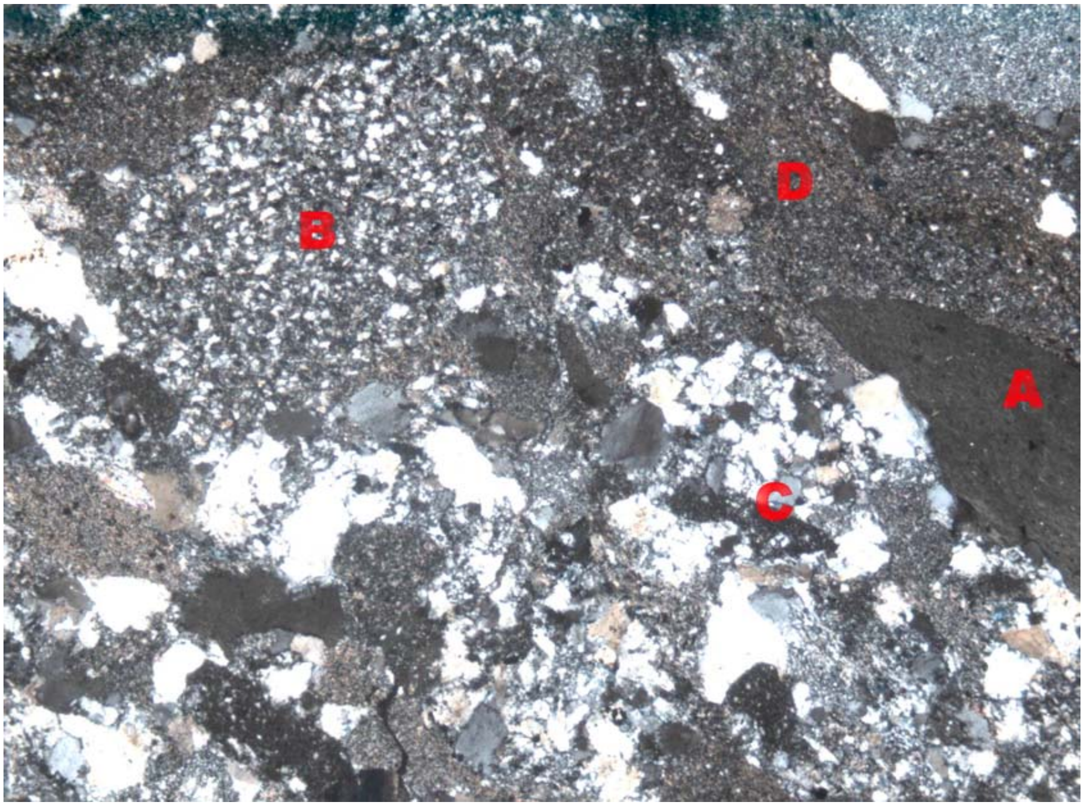

Figure 18. **Specimen MM07 DD05 106.75-107.0. Fragmental layer.**
A Meta-pelite
B Meta-arenite – fine (ex-siltstone)
C Meta-arenite-coarse (ex-sandstone)
D Matrix
WOF 5.6mm.

MM07 DD05 (138.70-138.80m).

Dolerite with quartz-carbonate vein *(Figures 19-20). Hand specimen (Figure 19).*

The 13cm core strip contains some 3.0cm of fine grained dark soft clay separated from some 8.0cm of coarser pale flecked dark material (0.5mm grain size) by a white carbonate vein The pale flecks seem like fine sericite, and minor carbonate is present (effervescence in acid). The pale flecks link in places with a greenish tinge (alteration effect). Minute spots of brown? TiO2 occur within the dark material.

The white carbonate-quartz infill has no alteration at the sharp margins.

Petrology.

The host rocks consist of narrow (dark on rock) layered units composed of extremely fine clay (1-3 microns). The coarser units (pale on rock) are extremely clay altered, with vaguely defined coarse grained phenocrysts (100-300 micron) which are probably ex-ferromagnesium components (amphiboles or more probably pyroxenes?). They are now clay altered, set in an extremely clay (brown) altered matrix. Some 2-3% TiO_2 compounds are scattered widely (rutile-leucoxene).

Figure 19. Specimen MM07 DD05 138.70-138.80. Altered dolerite + quartz carbonate vein. WOF c12.0cm.

Specimen MM07 DD05 (168.06-168.30m).

Meta-pelite--meta-arenite+carbonate rich layers (calci-lutite?) with sulphides *(Figure 21).*

A 24.0cm strip of core, with closely spaced dark and paler layers texture containing prominent high strain style textures sub-parallel to original layered texture. (Boundinage and shear style textures throughout). One 3.0cm pale layer contains flattened dark discontinuous strips – curving, Y shaped, ± rare ovoid white quartz grains (1.0mm).

Most of the paler layers/strips/boundinage lenses contain 20-50% granular carbonate (100-300 micron) and there are also discrete discontinuous 1.00mm wide carbonate veins (infill only) which run both sub-parallel to the general layering (30-40% to core axis) and also at low angles across layering.

The original sediments were fine shale/mudstone style materials with possible granular carbonate components, and occasional sand contributions? Sulphides occur in one 2-3cm zone as fine grained pyrite (10-50 micron) mimicking the ovate/bulbous pale boudinage/high strain textures of the paler style (carbonate rich) layers on either side. Carbonate replacement is suspected. The pyrite reaches up to 30-40% of the rock as 100-300 micron grains scattered in both paler and darker grained material. Some of the paler grains are carbonate.

Petrology (Figure 21A-23).

The dark layers on the rock are composed almost entirely of fine grained clay. Much of this is clearly late stage clay veining with associated alteration, but it is suspected that clay altered deformed meta-pelites are also involved.

The paler layers which are lensoid (boudinaged?) are composed of;

1. 50 micron scale quartz grains (ex-sandstone, now meta-arenite/quartzite, and
2. 50 micron scale quartz-clay combinations (formerly – siltstone).
3. Combinations of sulphide carbonate, and quartz, mostly at 1:1:1 proportions. (Figures 21A, 22). The sulphide is pyrite scattered throughout the bands as individual grains giving an overall spotted 'trout-like' appearance. The pyrite grains are 200-400 micron scale, ranging from ovoid to sub crystalline (Figure 23). The quartz at 100-200 microns is strained/recrystallised). The carbonate varies considerably in shape and size, but there are many domains where it forms elongate layer parallel grain aggregates with individual grains some 300-400 microns long and 100 microns wide, associated with some finer (5 micron) quartz grains. This texture is interpreted to represent recrystallised ex-carbonate dominant layers, reorienting to parallel cleavage/fabric and being replaced by sulphides (i.e. sulphide alteration of carbonate domains, with both being affected by fabric development. There are also areas of coarse granular style carbonate, which are generally clearer in ordinary light and their discontinuous vein like textures place them as part of the later carbonate/quartz vein set (white on rock).

There is considerable late fine clay veining which cuts the carbonate/sulphide rocks.

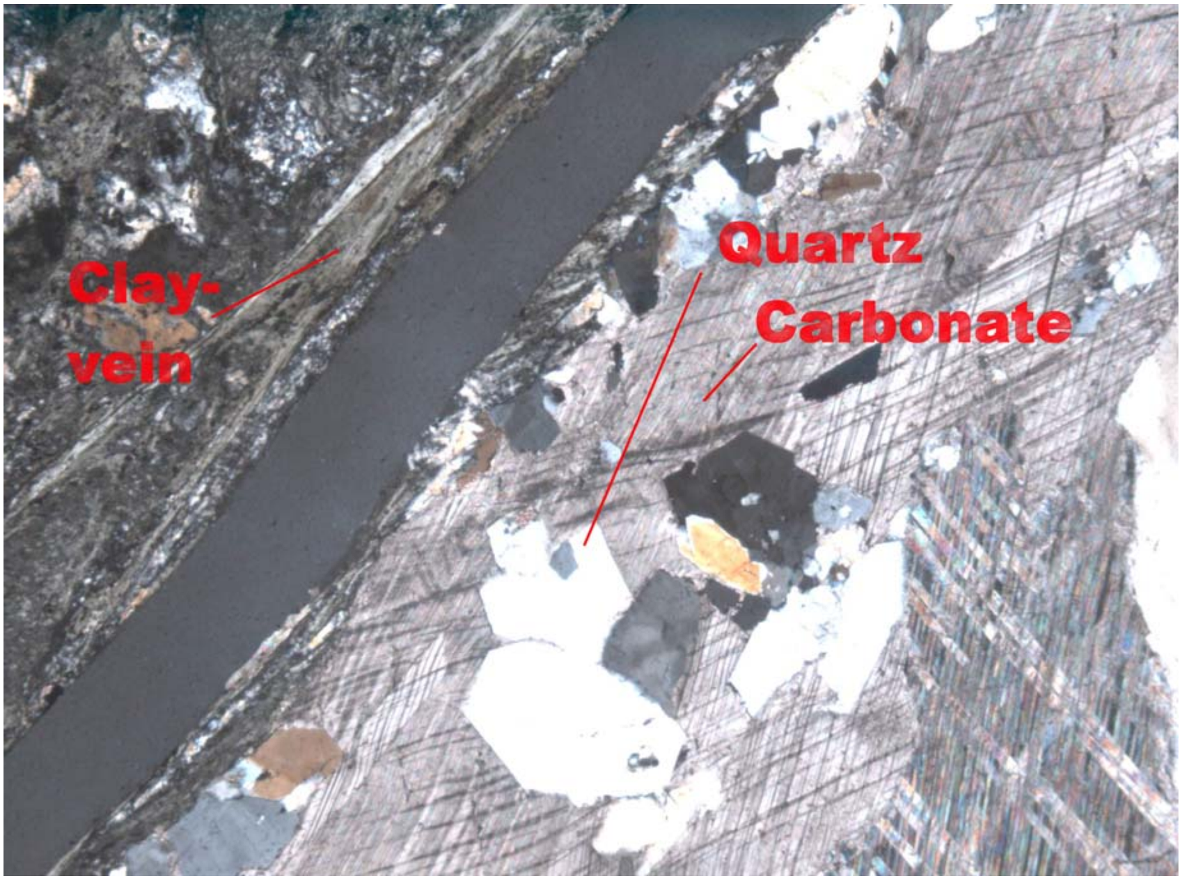

Figure 20. **Specimen MM07 DD05 - 138.70-138.80. Quartz-carbonate vein + clay vein. WOF c5.6mm.**

Figure 21. **Specimen MM07 DD05 - 168.06-168.30. Meta-pelite – meta-arenite with paler carbonate rich layers. Late carbonate (white) and sulphide (yellow). WOF c24cm.**

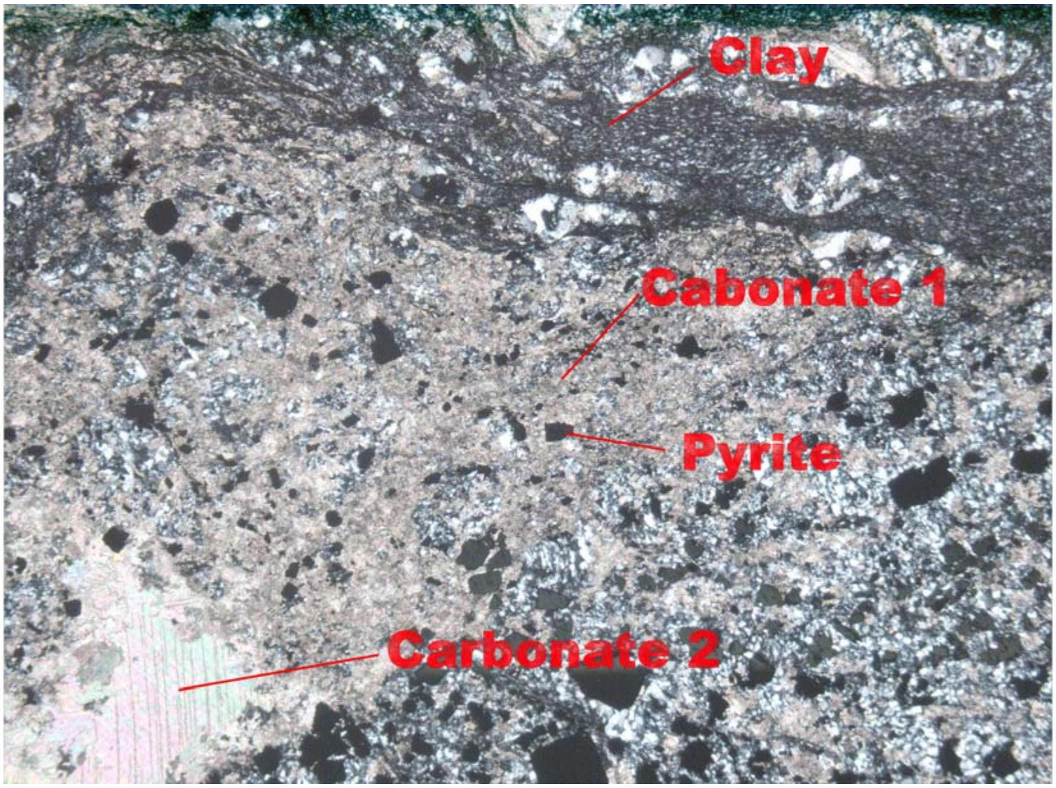

Figure 21A. **Specimen MM07 DD05 - 168.06-168.30. Two carbonate stages, with clay overprint vein. WOF c5.6mm.**

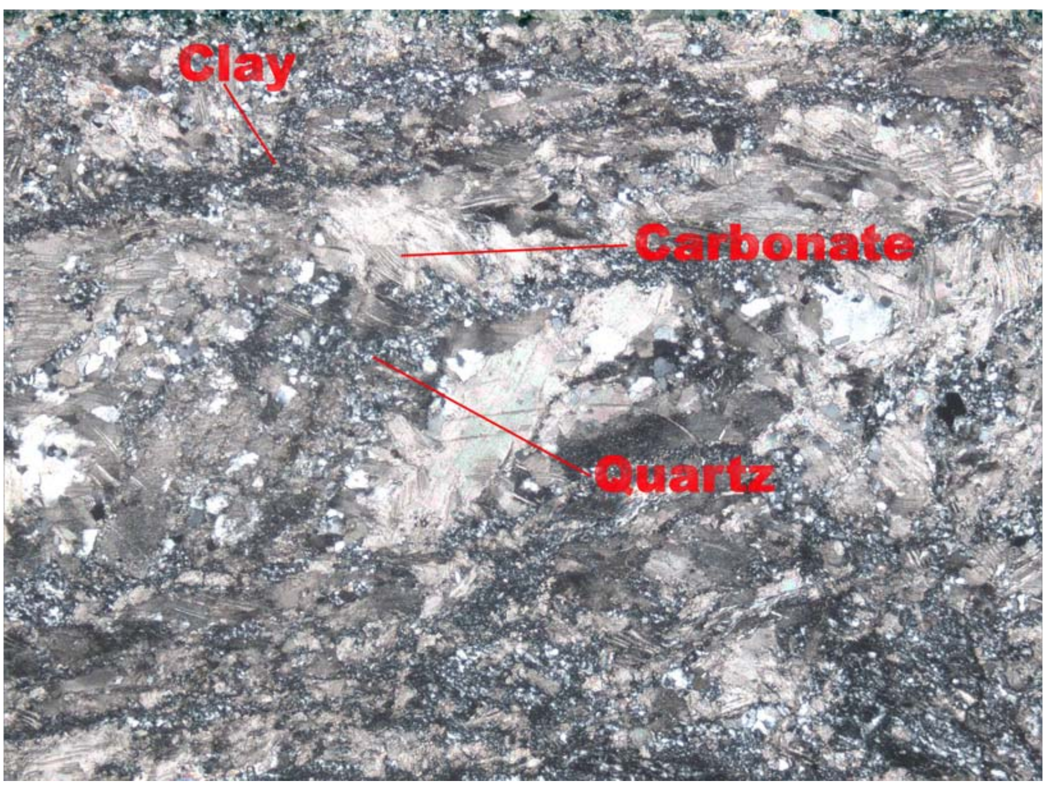

Figure 22. **Specimen MM07 DD05 - 168.06-168.30. Carbonate recrystallised?, cut by clay vein. WOF c5.6mm.**

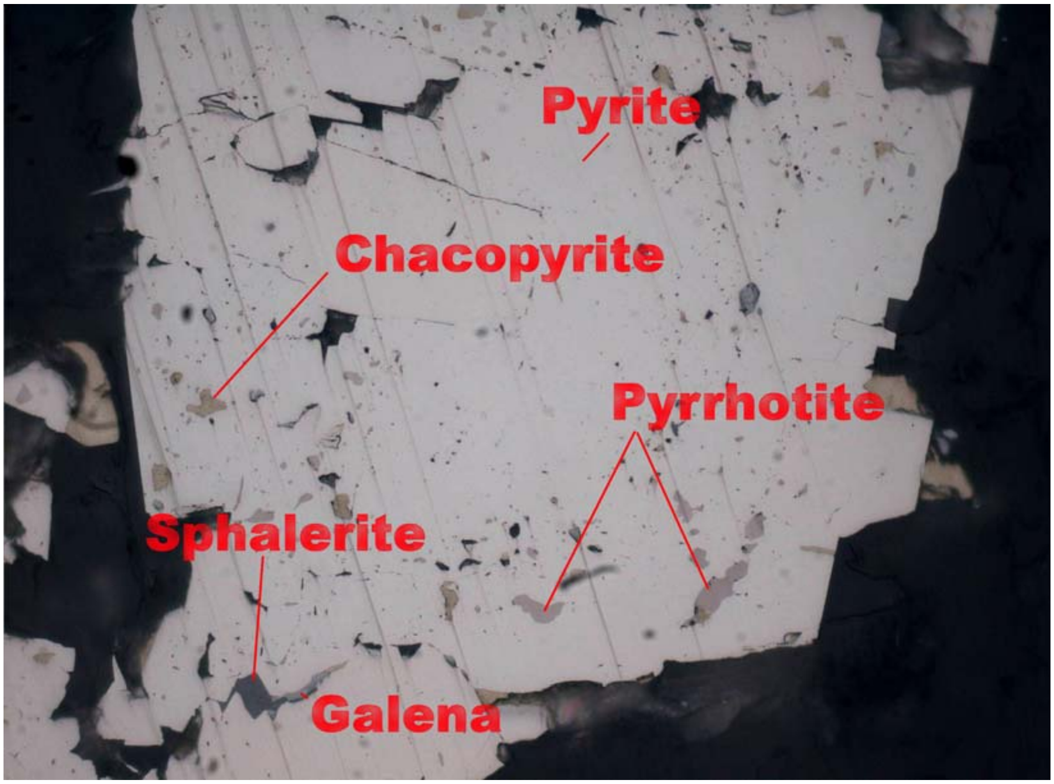

Figure 23. Specimen MM07 DD05 - 168.06-168.30. Pyrite with pyrrhotite, chalcopyrite, sphalerite and galena. WOF c0.28mm.

MM07 DD05 (168.70-168.95).

Deformed fragmental meta-sediment (including basaltic fragment) + deformed quartz-sulphide vein *(Figure 24).*

The 24cm long core strip contains some 30-40% flattened 2-3cm elongate pale fragments set within a dark fine grained carbonaceous matrix. At closer inspection smaller sub-centimetre scale fragments occur between the larger fragments which are extremely elongate composed of both darker (worm like) and paler materials. Original fragment content would have been some 80%.

The fragments are now clay altered, but seem to have been a mix of pale sandstones (50 micron grains), sandy-mudstones, mudstones, and darker siltstones/claystones. Little or no carbonate is present, other than in a curving cross cutting carbonate/quartz vein. Pyrite grains occur within one fragment. These are isolated 50-100 micron grains (say 20% pyrite). A second 2mm square fragment is massive granular pyrite at 50 micron grain size. The tectonic foliation is at 40^{o} to the core axis, and the original rock is interpreted as a poorly sorted fragmental sediment (conglomerate?, flysch?).

Petrology (Figures 25-27).

The rock is fragmental with various rock types (flattened) at about $40\text{-}50^{o}$ to the core axis giving a foliated effect. Fragment size is around to 1.0cm scale, with some 50% matrix at the 3.0mm scale. The paler fragments (60% of fragment) are mostly sandy/gritty style with minor clay, but include some white spotted pieces (Figure 25). The latter are ex-igneous, now composed of 50% elongate feldspars (clay altered) with no remnant twin texture (0.5-2.0mm long) and 50% ovoid cloudy spots of TiO_2 compounds (ex-ferromagnesium minerals) which are interstitial to the plagioclase (500 microns). There is no quartz, and a vague although inconsistent orientation could be interpreted. The rock may have originally been mafic (dolerite?). Minor pyrite spots aligned along fractures are present (50 microns) ± clay. The mid grey fragments are mudstone/ siltstone scale, and the darker ones (10%) carbonaceous shale (distorted).

The fine matrix (5-15 micron) is composed of combinations of fine clay, quartz, TiO_2 compounds and traces of pyrite.

A network of fine scale (100 micron) quartz veining cuts the matrix (Figure 26) and is in turn cut by vaguely bordered carbonate veins, which are all overprinted by fine clay (very dark on rock). One of the fragments is of a broken/re-crystallised quartz vein.

The cross cutting white feature in the right hand corner is a vein ± clay altered rock fragments. The vein contains coarse clay (Figure 27) with grains up to 50 x 150 microns long, and 20-30 microns wide. Some radiating clay textures are also present. The clay altered rocks are TiO_2 rich (10-75 microns) and there are also finer clay thread veins present.

Sulphides.

Sulphides occur associated with deformed fibrous quartz. This ?vein material cuts the matrix component, but was not seen clearly cutting fragments.

The sulphides are pyrite (500 micron scale) mostly as individual grains with partial crystalline face development. Traces of chalcopyrite occur within quartz and on the edges of pyrite (15-20 micron).

The quartz is both coarse granular (200-300 microns) suggesting an original vein, with finer ?re-crystallised materials, and quartz fibre development. Some pyrite has strain shadow quartz fibres, suggesting both quartz and sulphide are pre-deformation. Clay veins cut the quartz. The host rock is a fragmentary (deformed) sediment.

Figure 24. Specimen MM07 DD05 - 168.70-168.95. Deformed fragmental meta-sediment + quartz-sulphide vein. WOF c24cm.

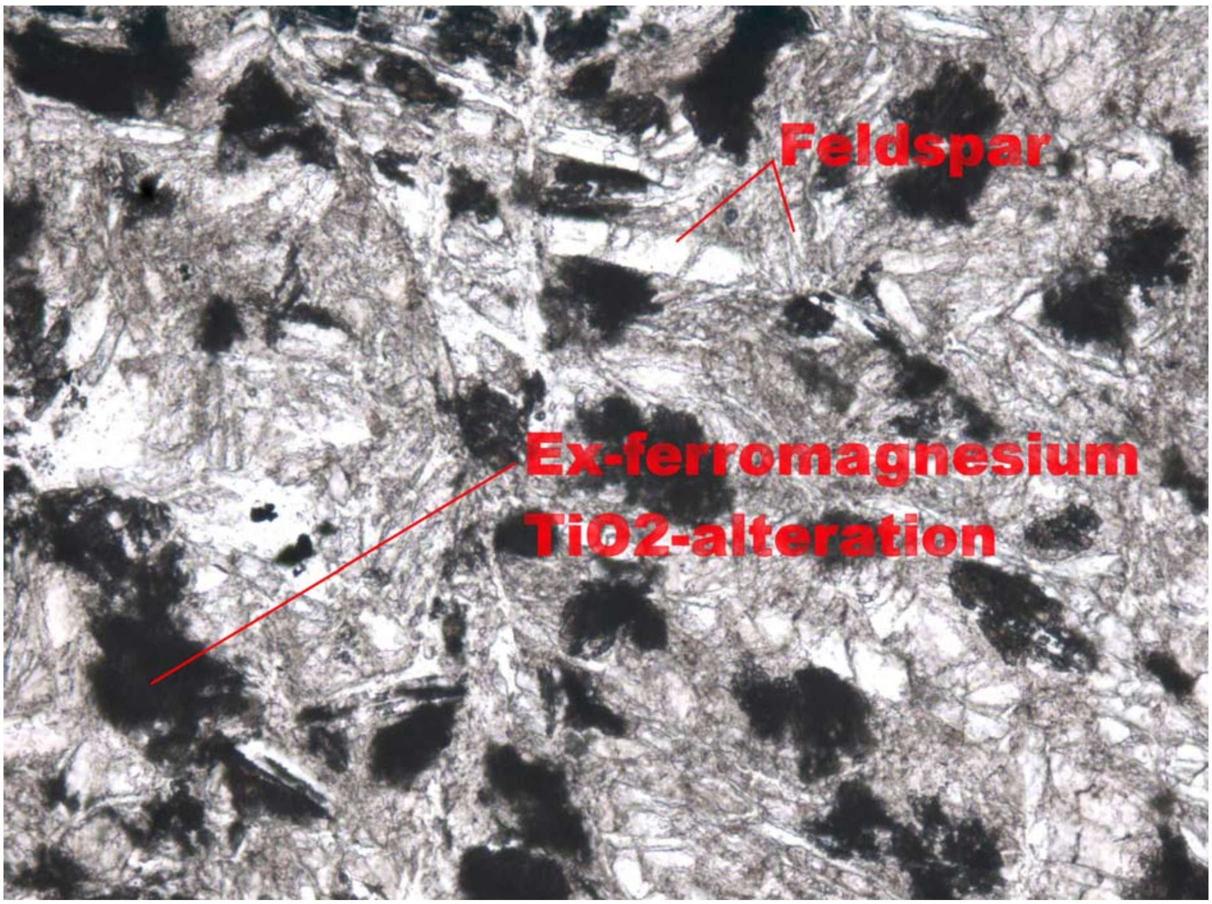

Figure 25. Specimen MM07 DD05 - 168.70-168.95. Basalt fragment. WOF c1.4mm.

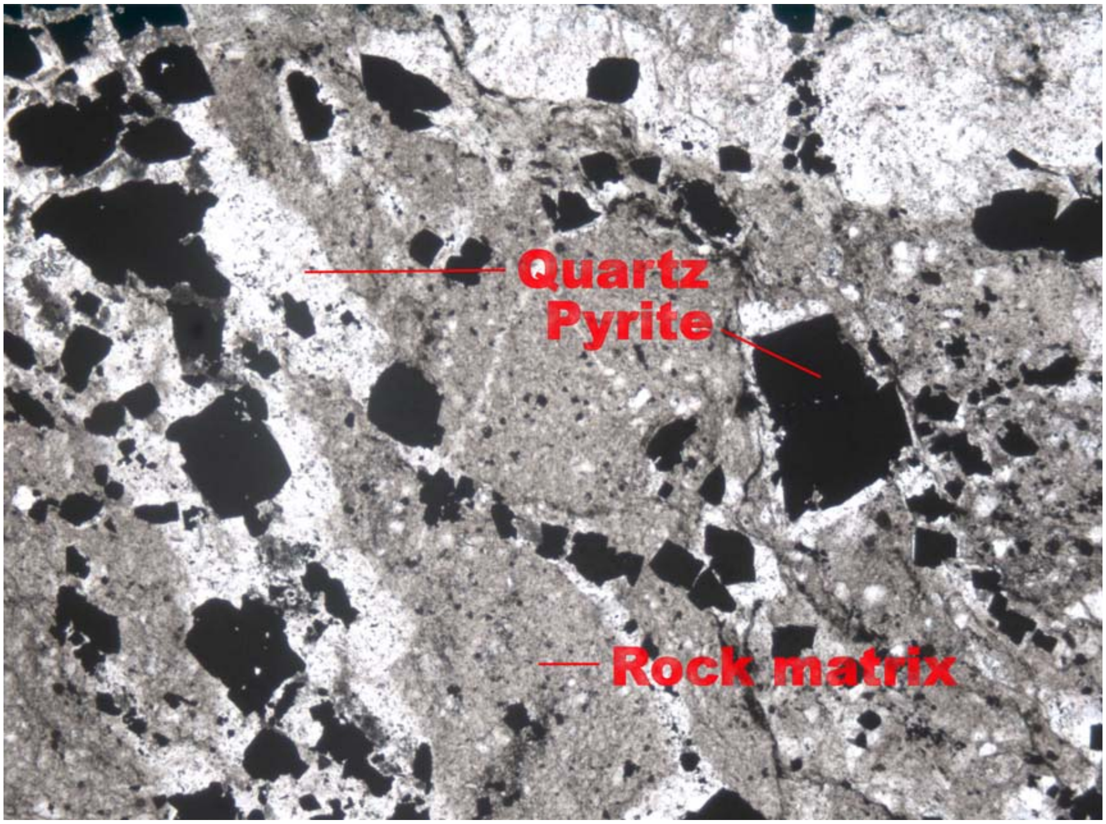

Figure 26. **Specimen MM07 DD05 - 118.70-118.95. Quartz-sulphide veins. WOF 5.6mm.**

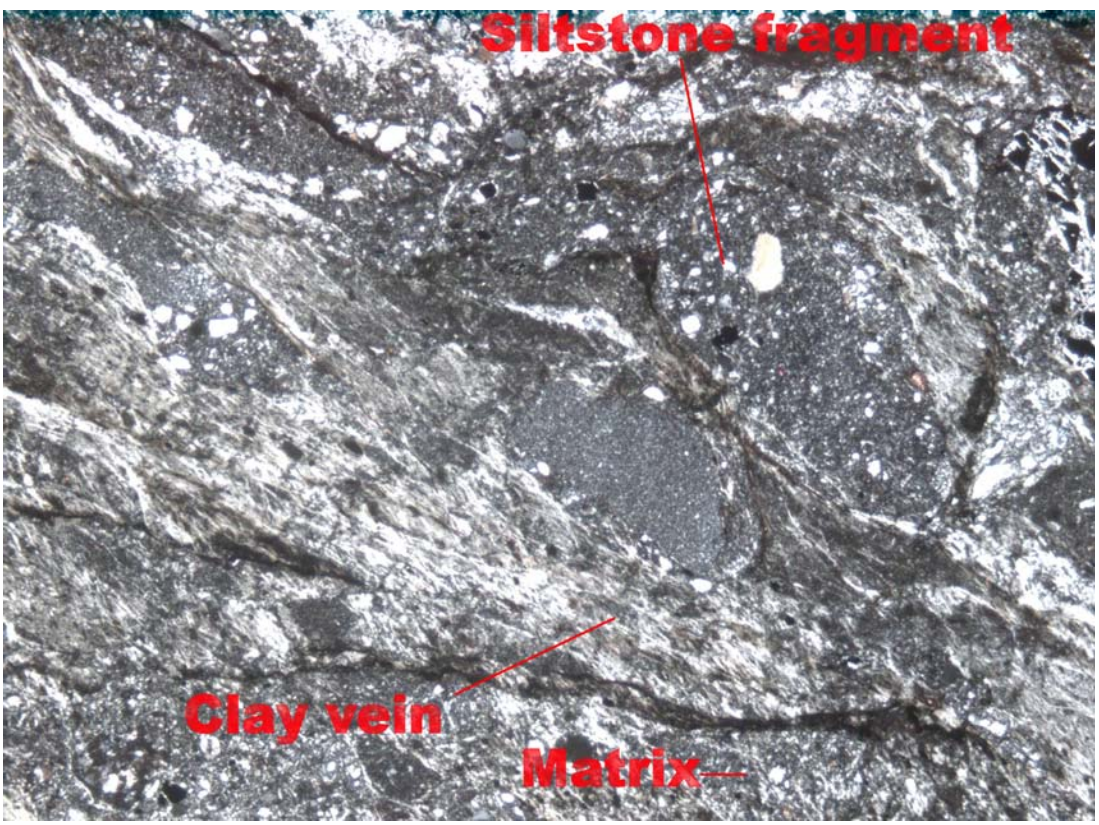

Figure 27. **Specimen MM07 DD05 - 168.70-168.95. Clay vein. WOF 5.6mm.**

Specimen MM07 DD05 (171.18-171.43m).

Altered porphyritic dolerite/basalt (argillised) *(Figure 28). Hand specimen.*

A 24cm core strip of relatively uniform textured fine grained pale grey/buff rock (altered). Some 5-10% vague white spots (1-2mm scale) scattered throughout are thought to be ex-feldspar phenocrysts and smaller equally vague dark spots are probably ex-mafic phenocrysts (altered). The entire rock is altered (sericitised ± clay) and the lack of quartz suggests a mafic igneous origin (basalt?).

A subtle network (2-3%) of discontinuous white carbonate (1mm wide) veinlets is present.

Similar darker (more siliceous) streaks/veinlets are present (possible more bedding parallel?) – these are cut by the white carbonate veins. Fine sulphide (pyrite, ?sphalerite) is present in the darker veinlets (trace amounts only) in granular sub-millimeter grain format.

Petrology (Figure 29).

The rock is porphyritic igneous and extremely altered. Phenocrysts constitute some 40-50% of the rock within a coarse (100-500 micron) matrix. The prominent phenocrysts are ex-feldspar (equant to elongate 0.50-2.0mm), sometimes clustered. These are not clay altered.

The original ferromagnesium mineral is also very clay altered, with 0.50mm crystals representing some 10-20%? phenocrysts. Trace quartz is present. The altered matrix consist of clay/"sericite", with remnant ferromagnesium minerals (amphibole? pyroxene?) and abundant TiO_2 alteration compounds.

Clay veins (100-200 micron wide) are common.

Sulphides occur in rare (50 micron wide) quartz ± pyrite ± chalcopyrite veinlets, overprinted along the margins by carbonate veining. Late quartz/carbonate (100 micron wide) veins are present which cut the above sulphide bearing veins.

Comment.

The rock although extremely altered (argillic) would have been porphyritic dolerite/basalt. The timing of clay alteration is not clear with respect to sulphides and carbonate veining (possibly early??).

Figure 28. Specimen MM07 DD05 - 171.18-171.43. Altered porphyritic dolerite. WOF c24cm.

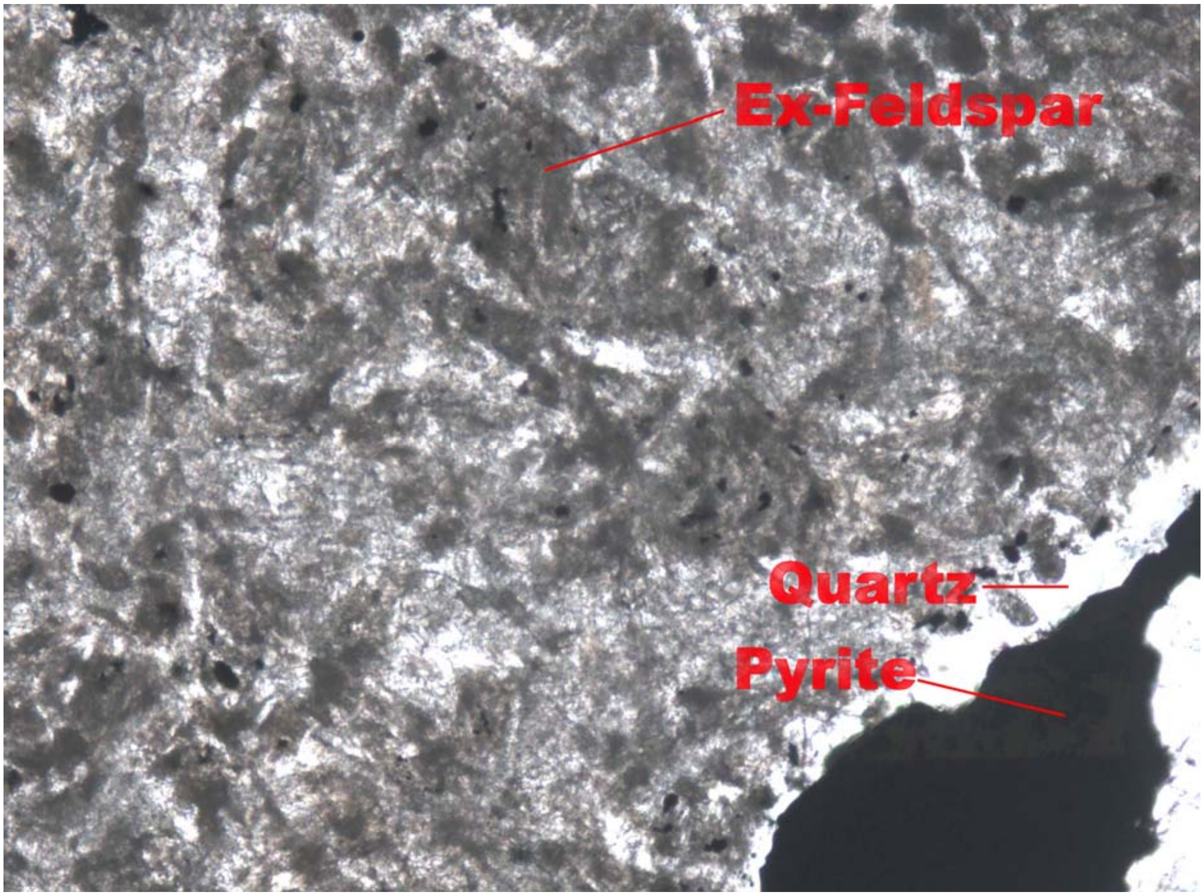

Figure 29. **Specimen MM07 DD05 - 171.18-171.43. Altered porphyritic dolerite. WOF 1.4mm.**

Specimen MM07 D005 (173.25-173.60m).

Altered dolerite, quartz veins, and dark clay veins *(Figure 30).*

A 30cm strip of core composed of conspicuous buff layers (5-6) separated by wispy 1-2cm foliated irregularly bordered dark zones. Within the darker zones are fragments?, wisps of the paler buff materials seemingly flattened/sheared. The dark zones are composed of quartz wispy vein like material with dark soft wisps/streaks – seem like carbonaceous materials disrupted by quartz subsequent to deformation? The pale buff zones (1-3cm wide) are speckled with dark flecks some of which are discontinuous quartz veinlets (wavy). However the majority are soft and range from elongate (1-2m) spindles, discontinuous cracks?, oblongs and occasional ovoids. The texture is hieroglyphic in places and it is unclear at hand specimen scale whether the rock is igneous or sedimentary. At one end a 2-3cm zone illustrates an increasingly shear/high strain style texture within the pale buff unit which becomes grey/green sericitised in a grey soft 'sericite' matrix. The origin of most of the features within the core strip remains unclear from visual inspection. A late white carbonate vein cross cuts both pale/and dark units, at a 30^o, 40^o angle, approximately parallel to the $30\text{-}40^o$ fabric defined by the darker wispy units. Minor granular carbonate is present in the wispy zones.

Petrology.

Host rock.

The host rock is extremely altered and even residual textures are difficult to see. The rock appears to have been porphyritic igneous with some 10-15 %(possibly more) phenocrysts, now defined by rectangular 300-500 micron outlines composed of fine clay ± carbonate, presumed to be ex-feldspar. A few very vague more elongate outlines may have been ferromagnesium in origin. The matrix is extremely cloudy with extremely vague elongates stick-like outlines just visible (200 microns long), these are now clay-carbonate and interpreted as ex-feldspar, possibly trachytic textures. Considerable amounts (10-15%) of TiO_2 spots are present (20-30 microns), occasionally present in veins? – discontinuous grain trails (10x400/500 microns). Also present are larger (300 micron) carbonate spots. No quartz was recorded and the rock seems to be altered porphyritic basalt/dolerite.

Veins.

Clay veins (Figure 31).

The darker wispy components on the rock are large clay veins (up to 3mm wide) occurring in a general shear fabric format, with fine fibrous clay. One prominent anastomosing example occurs along a 'basalt' – quartz vein contact, seems slightly later than the bulk clay and is a paler colour on the rock.

Quartz? Veins.

The clay veins cut over a coarse granular fabric of quartz grains (100-200 micron). There is also some finer granular silica (5 microns) of unclear origin (possibly rock? – cut by the coarser quartz?).

The coarser quartz is suspected as vein quartz and contains sulphides in elongate 1.0 x 0.5mm formats. Some of the quartz appears broken prior to sulphide deposition? The sulphide is pyrite as 200-600 micron grains, many of which have crystal faces. Chalcopyrite spots are present (100-200 microns, in quartz.

Carbonate.

Carbonate is also present, although its relationship with the clay veins is unclear (cut by clay??) seems the coarse carbonate vein style material.

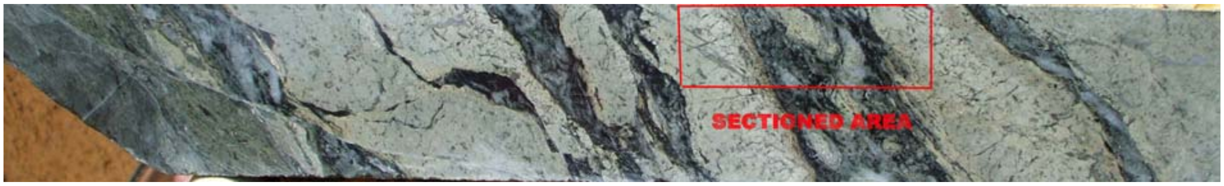

Figure 30. **Specimen MM07 DD05 - 173.25-173.60. Altered porphyritic dolerite, quartz veins, and dark clay veins. WOF c30cm.**

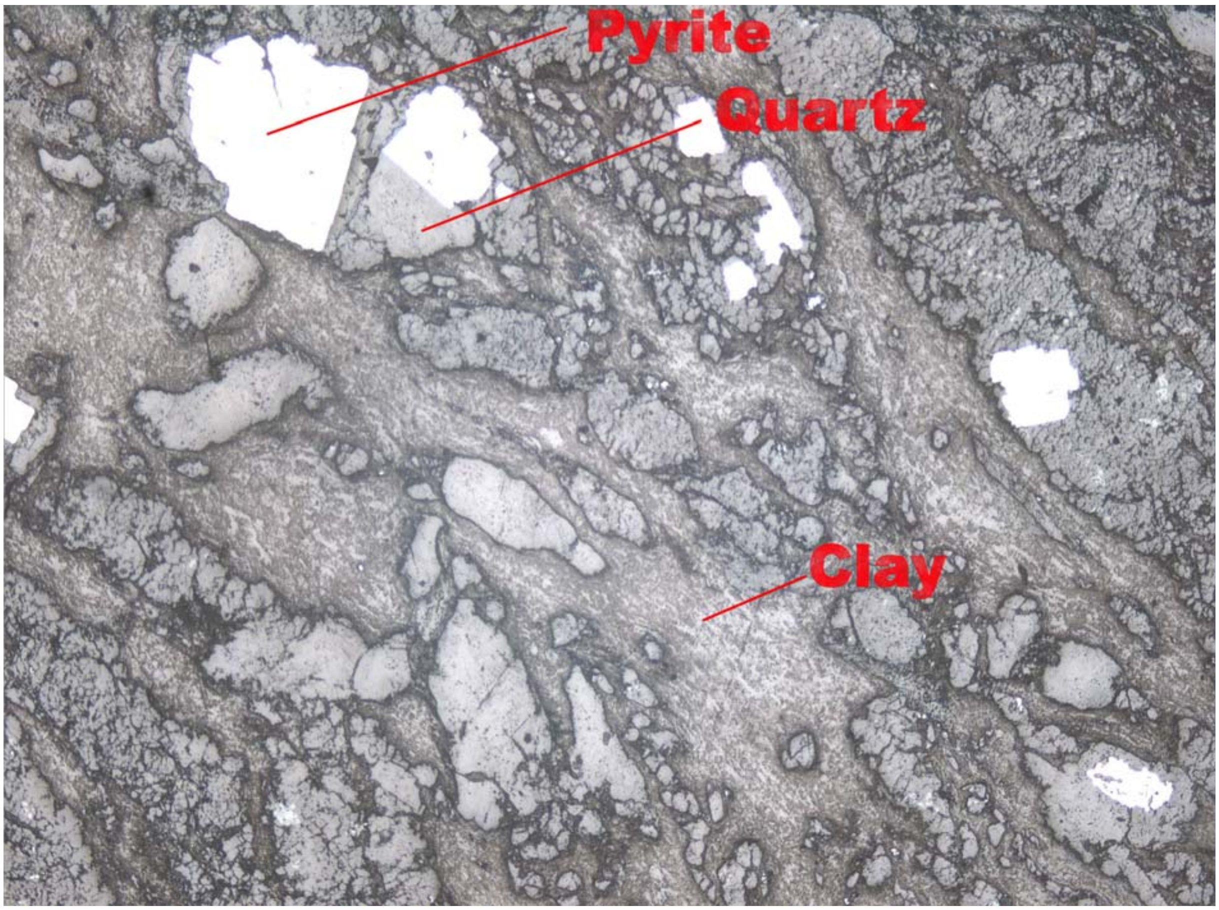

Figure 31. **Specimen MM07 DD05 - 173.25-173.60. Broken quartz-sulphide vein, with clay overprint. WOF 5.6mm.**

Specimen MM07 DD05 (175.0-175.25).

Altered porphyritic dolerite/basalt + deformed quartz-sulphide vein. *Hand specimen (Figure 32).*

A 20cm core strip composed of 80% pale buff material similar to that in 173.25-173.60, cut by dark/pale grey veinlets (20%).

The buff rock is argillised/sericitised (soft) but retains a clear fine grained porphyritic texture. Phenocrysts (10-15%) at the 1.0mm scale are clearly visible as aligned mostly elongate rectangular crystals together with occasional ovoid shapes. These are now completely altered (sericite/clay) but would have included feldspars. Quartz seems low or absent in phenocrysts format. The unit appears to have been deformed with prominent phenocrysts alignment. The matrix is pale and occasionally coarsely granular (0.5mm grains of ex-feldspar). The rock looks like fine grained felsic (rhyolitic?), but quartz content seems too low, and alteration effects may have lightened the colour of a more mafic origin.

The dark veins range from 1.0cm to 1.0mm and from continuous to discontinuous. Several appear to be bent/mildly contorted suggesting a pre-deformation origin. They are composed of pale grey fine quartz, and within one 1.0cm wide example two generations of quartz are visible. An early grey infill silica is broken and overprinted by veinlets of slightly paler quartz. Minute late carbonate is also present in cracks.

Discontinuous sulphide cracks (pyrite grains @ 0.5mm) appear to cut over both quartz generations.

More massive granular pyrite (1.0cm blebs/grain aggregates) occur within quartz veins (sulphide timing unclear).

Other veins contain fine dark soft (?sericite), some of which is cut by grey quartz. No alteration occurs adjacent to the veins. Some late pale brown sericite stringers appear to cut the quartz veins (sub-parallel along the vein margins). Late white carbonate (1.0m) veins – infill only – cut the quartz veins.

Petrology.

The rock is altered porphyritic igneous, with some 15-20%? phenocrysts at the 0.5-1.50 micron scale.

The phenocrysts are ex-feldspar and define the rock foliation, they are now all clay altered.

The matrix consists of some 60% altered ex-feldspar (50-200 microns) now all clay but defining a trachytic style texture. The remaining 40% is essentially TiO_2 spots (leucoxene) at 5-20 microns plus traces of chalcopyrite (20 micron) and pyrite (up to 100 micron). The unit contains a different finer texture than a similar rock type described from 171.18-171.43m. The rock texture suggests an original basalt/dolerite classification. The quartz-sulphide veins (Figure 33) are composed of :-

Quartz – 100-200 micron grain size, mostly recrystallised and including fibrous formats in and around pyrite domains. Some clay veins cut the quartz.

Sulphides – the sulphides comprise some 25% of the vein and include:

Pyrite (98%), crystalline, seems broken in places with quartz in-between.

Chalcopyrite (2%) – 20-50 microns, on edges of pyrite, as inclusions in pyrite, more prolific in quartz where it occurs alone interstitially.

A late carbonate vein (1mm wide) is present (cuts clay).

Figure 32. Specimen MM07 DD05 - 175.0-175.25. Altered porphyritic dolerite/basalt, + deformed quartz-sulphide veins. WOF c20cm.

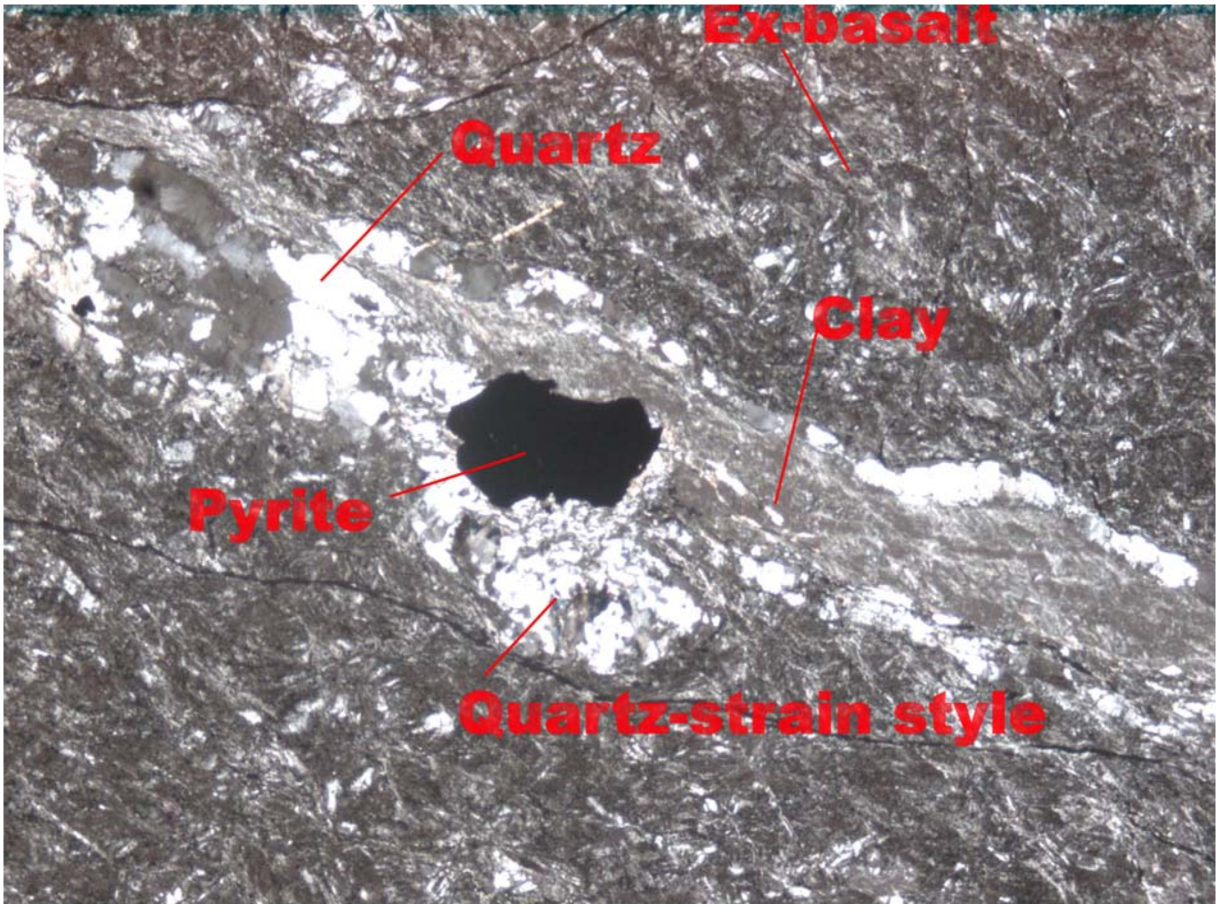

Figure 33. Specimen MM07 DD05 - 175.0-175.25. Altered dolerite/basalt, deformed quartz vein + sulphides, with clay vein overprint. WOF c5.6mm.

Specimen MM07 DD05 (176.73-177.03m).

Altered porphyritic dolerite/basalt + deformed quartz-sulphide veins. *Hand specimen (Figure 34).*

A 30cm cores strip similar to 175.0-175.25, with increased veining.

The host rock is the pale buff unit previously described (175.0-175.25m and 173.25-173.60m) with less visible phenocrysts, and less evidence of deformation via phenocrysts alignment. Considerable portions of the granular (500 micron) matrix are visible and the granules are very diffuse edged. Sericite altered with pearly effects in places. Hieroglyphic textures are present.

The unit contains a stockwork style of ore extremely irregularly shaped/bordered dark quartz, ?sericite, sulphide veinlets. The infill veinlets pinch and swell over centimeter lengths ranging from 1.0cm to 1.0mm in widths. Some post formation deformation is possibly, although the shapes could just be normal brittle fracture ± differential fluid pressure in origin. There is no alteration and the infill components are grey silica, dark soft ?sericite/chlorite pyrite, and sphalerite (pale brown-low iron). Pyrite is the dominant sulphide (say 10% of veins) in granular and massive-granular formats. The largest pyrite clumps are around 1.0cm scales. Sphalerite is also granular in 1.0mm or less aggregates. Sphalerite content of the rock is less than 1.0%, with granules at 100 micron scales.

Petrology (Figures 35-37).

The rock is essentially identical to 175.0-175.25, with considerably more clay veining overprinting the quartz-sulphide veins.

Sulphides.

The sulphides in a deformed/recrystallised quartz consist of some 80-85% pyrite, 15-20% sphalerite, and 0.5% chalcopyrite. The pyrite is coarse grained, frequently with crystal faces, and ranges from 0.5-1.5mm in size. Many grains seem broken with quartz separating the fragments.

Sphalerite is iron poor/pale yellow in colour, and interstitial to quartz at 0.5-3.0mm scales (it is probably granular in detail, 50 micron scale). Chalcopyrite occurs:

(a) Interstitial to quartz grains (150 micron)
(b) Interstitial to sphalerite (60 microns)
(c) On pyrite edges (60 micron).

Figure 34. Specimen MM07 DD05 - 176.73-177.03. Altered dolerite/basalt with deformed quartz-sulphide-veins. WOF c30cm.

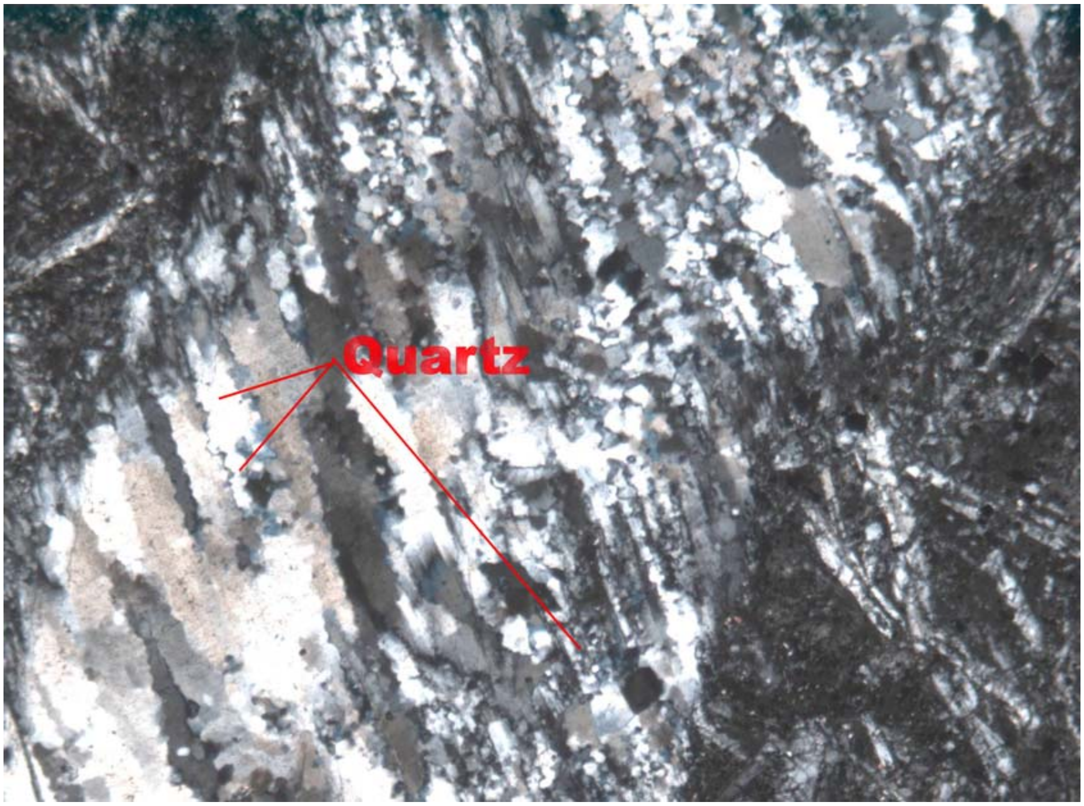

Figure 35. Specimen MM07 DD05 - 176.73-177.03. Deformed quartz vein in basalt/dolerite. WOF c2.8mm.

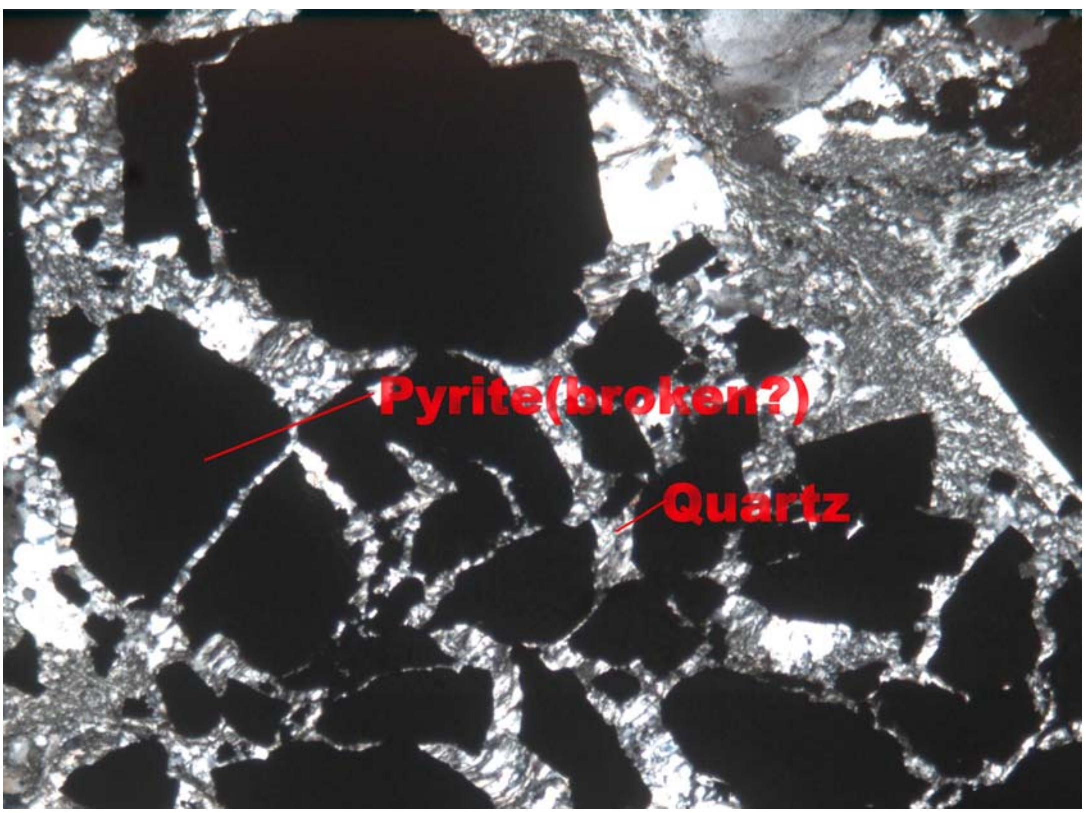

Figure 36. Specimen M07 DD05 - 176.73-177.03. Broken pyrite with fibrous (deformation) quartz in between fragments. WOF c1.4mm.

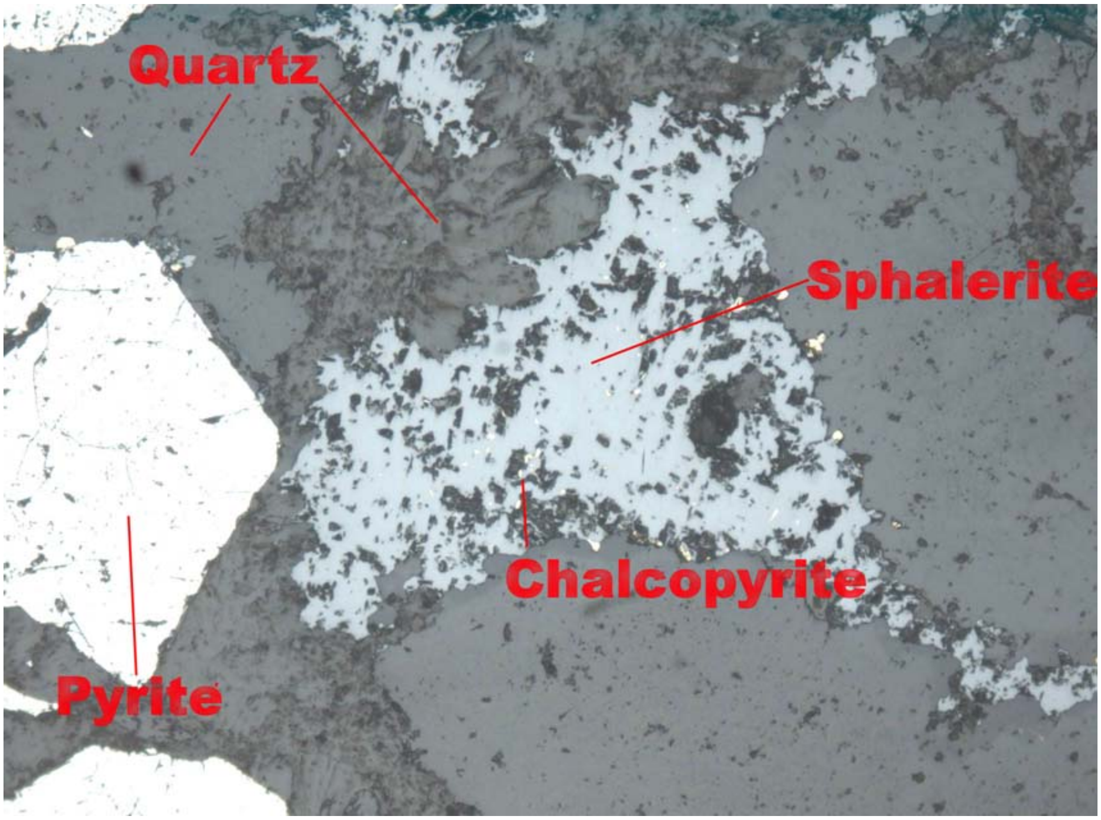

Figure 37. **Specimen MM07 DD05 - 176.73-177.03. Pyrite, sphalerite, chalcopyrite, quartz. WOF 1.4mm.**

Specimen MM07 DD05 (180.45-180.70m).

Altered (sericitised/argillised) – porphyritic monzonite. *Hand specimen (Figure 38).*

A fine grained igneous rock with porphyritic texture, with suspected moderate sericitic and argillic alteration.

The rock contains some 20-30% phenocrysts at the 1.0mm scale including quartz (grey ovoid) ex-feldspar (white-vaguely bordered altered-sericite clay) and ex-ferromagnesium minerals (dark, spots and elongate-altered – sericite/chlorite?). Quartz phenocrysts are at around 10% of the rock, suggesting a felsic origin (monzonite/granite).

There is no discernable alignment of phenocrysts and the rock seems undeformed. The texture is different to the previous porphyritic units, with no evidence of deformation, coarse matrix, and higher quartz contents. Paler zones are probably argillic alteration. No obvious pyrite.

Petrology (Figure 39).

The rock is porphyritic igneous with some 30-40% phenocrysts (0.5-3.0mm). The phenocrysts are:

> **Quartz** – 10-15% of the rock, with rounded crystals, many of which are mildly resorbed. They range from 0.5-2.0mm. Some quartz grains have fine marginal (40-100 micron) rims of small K-spar crystals.
>
> **Feldspar** – some 40% of the rock, equant to mildly elongate, occasional multiple twinning – is visible beneath the extensive alteration (sericite – illite, carbonate), but no symmetrical examples were available for compositional measurement. Most grains are untwined, and simple twinning is common. Grains range from 0.5-3.0mm.
>
> **Ferromagnesium** minerals – 8-12% of the rock, now totally altered to sericite-muscovite ± TiO_2 compounds, carbonate, chlorite and traces of pyrite and chalcopyrite. Some of the shapes suggest presence of amphiboles originally.

Some coarse clusters of carbonate grains (3.0mm) are present, and the coarse (50 micron scale) matrix is composed of muscovite/sericite, clouded-blurred feldspars (possibly K-spar?), with no quartz. A zircon accessory was noted.

Classification is difficult without feldspar data, but the 10-15% quartz suggests something in the monzonite range. The main alteration would classify as sericitic.

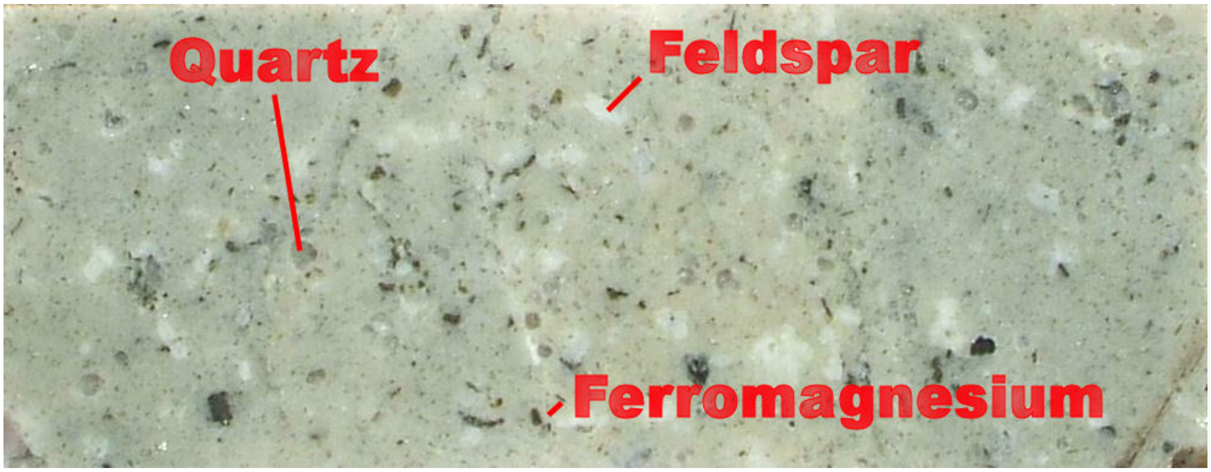

Figure 38. **Specimen MM07 DD05 - 180.45-180.70m. Altered monzonite. WOF c6cm.**

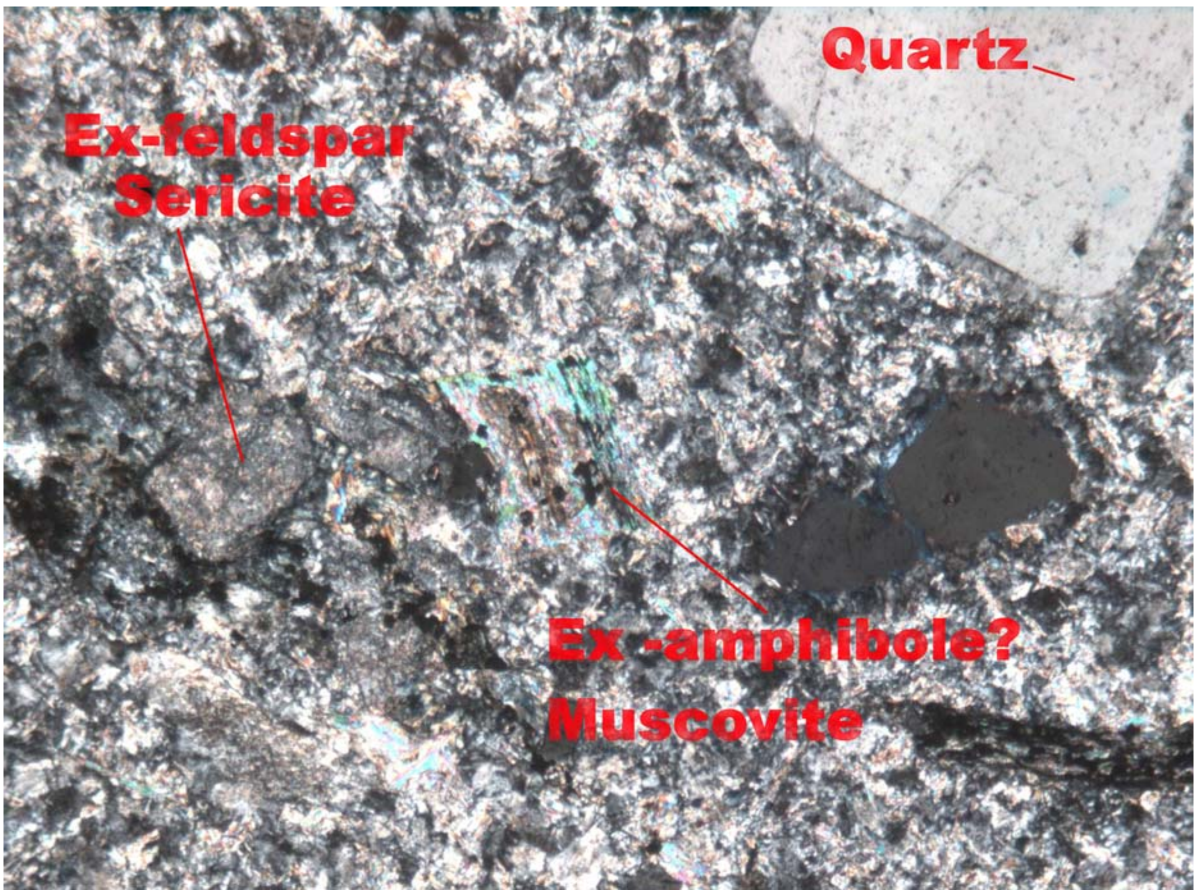

Figure 39. **Specimen MM07 DD05 - 180.45-180.70. Altered monzonite. WOF c2.8mm.**