

**APPENDIX 2b:**

**EL 2506**

**SOUTH HORN**

**1998**

**MASON GEOSCIENCE PTY LTD**

**PETROGRAPHIC REPORT**

**#2452**


COPY 1 [initials] ✓  
COPY 2 [initials]

## **Mason Geoscience Pty. Ltd.**

ACN 063 539 686

*Petrological Services for the  
Minerals Exploration and Mining Industry*

PO Box 78, Glenside SA 5065, Australia  
141 Yarrabee Road, Greenhill SA 5140, Australia  
Ph: +61-8-8390-1507 Fax: +61-8-8390-1194  
e-mail :drmason@interconnect.com.au

REPORT TITLE	<b>Petrographic Descriptions for Fourteen Drill Core Rock Samples from the Lower Cahill Formation (Arnhem Land, Northern Territory)</b>
REPORT #	2452
CLIENT	AFmeco Mining and EXploration Pty Ltd
ORDER NO.	PO# 3582
CONTACT	Mr Daniel Alonso
REPORT BY	Dr Douglas R. Mason
SIGNED	 for Mason Geoscience Pty. Ltd.
DATE	13 July 1998

## **Petrographic Descriptions for Fourteen Drill Core Rock Samples from the Lower Cahill Formation (Arnhem Land, Northern Territory)**

### **SUMMARY**

#### **1. Rock Samples**

- Fourteen drill core rock samples from Lower Cahill Formation (Arnhem Land, Northern Territory) have been studied using petrographic and staining methods.

#### **2. Brief Results**

- Rock names and mineralogy are summarised in TABLE 1.
- Metamorphism
  - All samples display granoblastic metamorphic textures, locally porphyroblastic, with moderate to strong foliation.
  - Mineralogical layering or banding is common.
  - Grain size and mineral assemblages suggest that the rocks have recrystallised in response to a dynamic regional metamorphic event in the amphibolite facies, as supported by the occurrence of olive green hornblende in calc-silicate and metaluminous quartzo-feldspathic rocks, the presence of assemblages containing staurolite, garnet and sillimanite in pelitic rocks, and the stability of muscovite in quartzo-feldspathic and pelitic assemblages.
  - Calc-silicate sediments (drill hole ALG05, ALG06) recrystallised to assemblages of hornblende, plagioclase, quartz, garnet, biotite, opaques, sphene and zoisite. These rocks may be broadly classified as 'para-amphibolite'. Quartz-rich bands in these rocks recrystallised to quartz, plagioclase, hornblende, garnet, apatite, biotite and clinozoisite.
  - Semi-pelitic sediments (drill hole ALG06) recrystallised to assemblages of plagioclase, biotite, quartz and garnet.
  - Pelitic sediments (drill hole ALG06, SHD016) recrystallised to relatively coarse-grained porphyroblastic and mineralogically banded assemblages of biotite, quartz, muscovite, plagioclase, sillimanite, staurolite, garnet, and tourmaline.
  - Quartzo-feldspathic rocks of uncertain primary origin (drill hole ALG06, KPE01) have recrystallised to medium-grained assemblages of plagioclase, quartz, K-feldspar, and biotite. Some contain hornblende, and others contain muscovite and possible cordierite (now altered, see below).
- Alteration
  - Some samples remain fresh, but some display selective pervasive retrogressive alteration of particular phases.
  - Plagioclase commonly displays partial to severe alteration, in some samples by a fine-grained phyllosilicate of probable illitic clay composition, and in other samples (deeper parts of SHD016) by sericite.

- Biotite in some samples has suffered partial to severe replacement by chlorite  $\pm$  sericite  $\pm$  leucoxene.
- Inferred cordierite, where present, has been completely replaced by chlorite.
- Garnet in some samples displays partial to severe replacement by chlorite.
- Staurolite, where present, displays partial replacement by fine-grained phyllosilicate.
- In drill hole SHD016, alteration intensity appears to increase with depth.

**TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY**

SAMPLE	ROCK NAME	MINERALOGY*		
		Primary**	Metamorphic/alteration***	Veins
ALG05, 51	Laminated hornblende-quartz-garnet schist	-	Hbl,qtz,gar,pla,opq,spn,pre,zoi,sph	Cal,pre,qtz
ALG05, 60.7	Layered calc-silicate meta-sediment:			
“	• Laminated hornblende-plagioclase schist	-	Hbl,pla,qtz,zoi,spn,opq; Ser	Pre
“	• Zoisite-quartz-hornblende schist	-	Zoi,qtz,hbl,opq	-
ALG05, 118.6	Hornblende-plagioclase-quartz-garnet schist	-	Hbl,pla,qtz,gar,bio,opq	Chl,opq,cal
ALG05, 133.1	Partly-retrogressed biotite-garnet quartzo-feldspathic schist	-	Mus,qtz,pla,bio,gar,opq; Chl,opq,leu,cla	Kf,cal,qtz
ALG06, 76.8	Weakly retrogressed biotite-muscovite quartzo-feldspathic schist	Zir	Pla,qtz,mus,bio,apa,leu/rut; Chl,cla	Cal
ALG06, 84.8	Partly retrogressed muscovite-staurolite-garnet gneiss	-	Qtz,mus,bio,gar,stau,pla,tou,rut; Cla,chl,opq,flu	Cal,sph
ALG06, 147.9	Layered meta-sediment:			
“	• Plagioclase-biotite-quartz semi-pelitic schist	-	Pla,bio,qtz,gar; Cla,opq	-
“	• Plagioclase-hornblende-biotite-quartz calc-silicate schist	-	Pla,hbl,bio,qtz,gar; Cla	-
“	• Quartz-plagioclase-hornblende-apatite calc-silicate band	-	Qtz,pla,hbl,gar,apa,bio,clz	-
KPE01, 288.9	Biotite-hornblende quartzo-feldspathic gneiss	Zir	Pla,qtz,Kf,bio,hbl,spn,apa; Cla,chl,zoi	-
KPE01, 291.4	Moderately retrogressed biotite(-hornblende) quartzo-feldspathic gneiss	Zir	Pla,qtz,Kf,bio,hbl,apa; Cla,chl,cal	-
KPE01, 307	Weakly retrogressed biotite(-hornblende) quartzo-feldspathic banded gneiss	Zir	Pla,qtz,bio,Kf,hbl,apa,spn; Cla,pre,zoi	Zoi
SHD016, 160.4	Partly retrogressed banded biotite-muscovite(-?cordierite) quartzo-feldspathic gneiss	Zir	Pla,qtz,bio,Kf,mus,apa	Cla,chl
SHD016, 168	Moderately retrogressed banded biotite-muscovite-garnet-sillimanite gneiss	-	Bio,qtz,sill,mus,tou; Ser,chl,opq	-
SHD016, 195.3	Strongly retrogressed feldspar-biotite-sillimanite-garnet gneiss	-	Qtz,sill,Kf,bio,gar; Ser,chl,leu,cal	-
SHD016, 207.3	Strongly retrogressed banded feldspar-biotite-sillimanite-garnet gneiss	-	Qtz,bio,sill,gar; Ser, chl,cal,opq,leu	-

cont

## NOTES ON TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

### 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:

Apa = apatite; bio = biotite; cal = calcite; chl = chlorite; cla = undifferentiated clay (possibly illitic); clz = clinozoisite; flu = fluorite; gar = garnet; hbl = hornblende; Kf = K-feldspar; leu = leucoxene; mus = muscovite; opq = undifferentiated opaque minerals; pla = plagioclase; pre = prehnite; qtz = quartz; rut = rutile; ser = sericite; sill = sillimanite; sph = sphalerite; spn = sphene; stau = staurolite; tou = tourmaline; zir = zircon; zoi = zoisite.

## 1. INTRODUCTION

Fourteen drill core rock samples were received from Mr Daniel Alonso (AFmeco Mining and EXploration Pty Ltd, Darwin, Northern Territory) on 17 June 1998.

It was indicated that the samples originate from Amhem Land, where they are considered to represent the Lower Cahill Formation. Particular requests were:

- i) To prepare a thin section and routine petrographic description for each sample (service codes PETRO 2.1 or 2.2 as appropriate).
- ii) To stain each sample offcut for K-feldspar.

Preliminary results were provided by facsimile to Mr Alonso at the Darwin office of AFMEX on 2 July 1998. Subsequent telephone discussion of the results with Mr Alonso confirmed that colour macrophotographs of drill core and colour photomicrographs of thin sections should be included in the final report. This report contains the full results of this work.

## 2. METHODS

The drill core samples were examined in hand specimen and marked for section preparation. Where possible, section planes were oriented more-or-less perpendicular to the principal structure through the rock. Standard thin sections were obtained from an external commercial laboratory (T. & S. Bradley, Eastwood, New South Wales).

At Mason Geoscience Pty Ltd, conventional transmitted polarised light microscopy was used to prepare the routine petrographic descriptions.

Preliminary petrographic observations suggested that K-feldspar was present in some samples. For confirmation, each section offcut was stained for K-feldspar using the conventional sodium cobaltinitrite method. Each offcut was etched in HF for ~10 seconds, rinsed in water, covered with freshly made saturated solution of sodium cobaltinitrite for ~30 seconds, and finally rinsed. This procedure generates a bright yellow stain where K-feldspar occurs in the rock. The results are provided in TABLE 2, and are also given under Hand Specimen description in the individual petrographic descriptions.

**TABLE 2: RESULTS OF STAINING FOR K-FELDSPAR**

SAMPLE	RESULT*	COMMENTS
ALG05, 51	Negative	K-feldspar absent.
ALG05, 60.7	Negative	K-feldspar absent.
ALG05, 118.6	Negative	K-feldspar absent.
ALG05, 133.1	Positive	Minor K-feldspar concentrated in discordant and concordant veinlets.
ALG06, 76.8	Negative	K-feldspar absent.
ALG06, 84.8	Negative	K-feldspar absent.
ALG06, 147.9	Negative	K-feldspar absent.
KPE01, 288.9	Positive	Moderately abundant K-feldspar as ragged disseminated grains, but concentrated in indistinct felsic band.
KPE01, 291.4	Positive	Moderately abundant K-feldspar, concentrated in indistinct felsic bands.
KPE01, 307	Positive	Moderately abundant K-feldspar, distributed as ragged grains but concentrated in coarser felsic bands.
SHD016, 160.4	Positive	Moderate K-feldspar distributed as small ragged grains (but note additional false stain by absorption of stain into altered feldspar grains)
SHD016, 168	Negative	K-feldspar absent.
SHD016, 195.3	Positive	Moderately abundant K-feldspar in paler bands.
SHD016, 207.3	Negative	K-feldspar absent.

\*: Positive = Yellow stain for K-feldspar observed under binocular microscope.

Negative = No yellow stain for K-feldspar observed under binocular microscope.

### 3. PETROGRAPHIC DESCRIPTIONS

The petrographic descriptions are provided in the following pages. Macrophotographs of offcuts and photomicrographs are included at the beginning of each sample description.

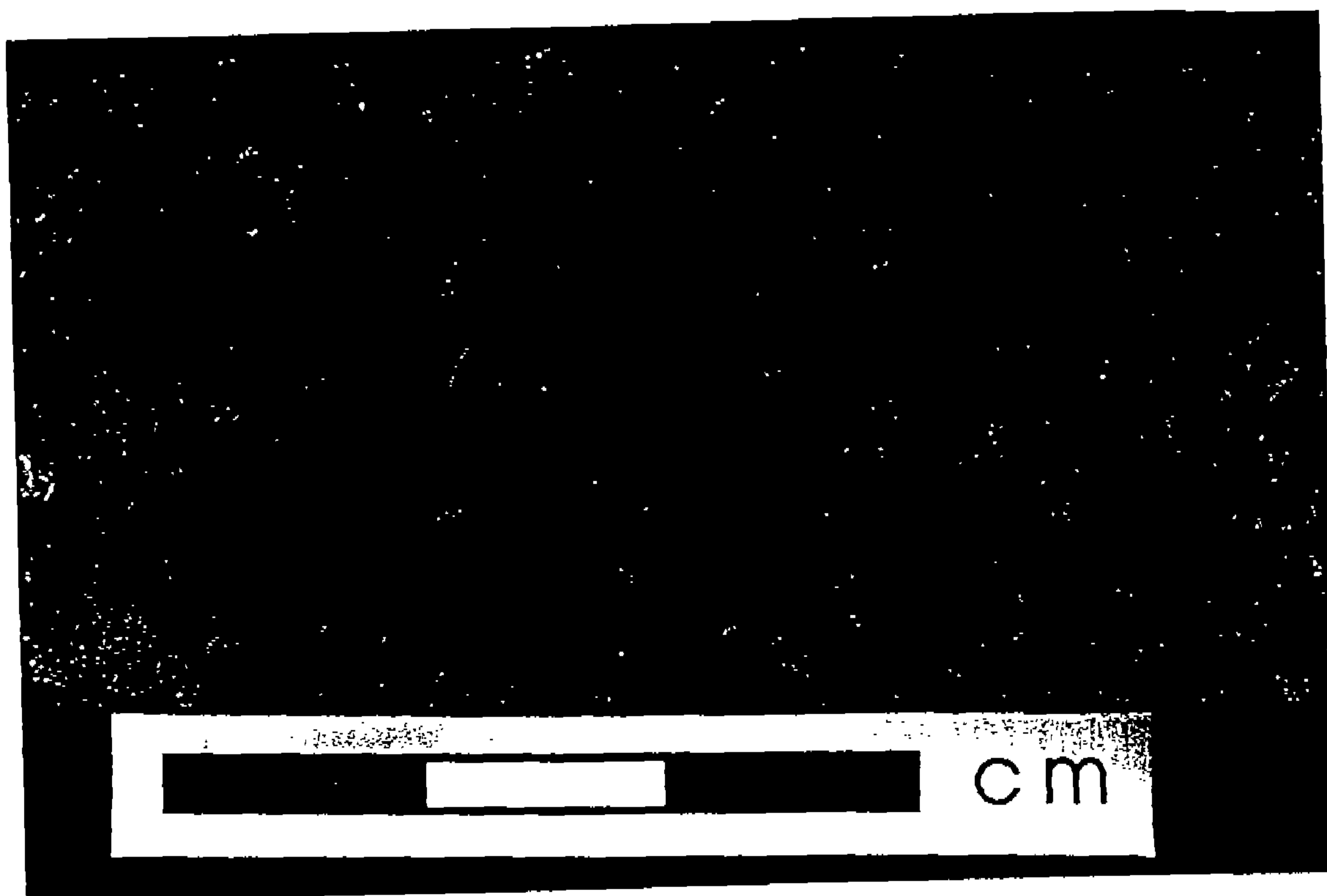


PLATE 1. SAMPLE ALG05, 51 (Macrophotograph of sawn core, wet, bar for scale; Film 1 Frame 1)  
This hornblende-rich meta-sedimentary rock contains sparsely distributed small dark pink garnet grains, and sulphide (lustrous metallic yellow 'pyrite') in disseminated ragged aggregates and uncommon thin discontinuous stringers (far right).



PLATE 2. SAMPLE ALG05, 51 (Transmitted plane polarised light x5 Film 2 Frame 0)  
In this calc silicate meta sediment, hornblende (green) forms subhedral prisms in a fold structure, accompanied by garnet (equant high relief colourless crystal, lower left) and opaques (black, in fold hinge centre right)

SAMPLE : ALG05, 51 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG05, 51

HAND SPECIMEN : The drill core sample represents a dark greenish grey crystalline rock in which indistinct thin lamination is defined by thin felsic laminae. Small equant dark pink garnet grains are sparsely scattered through the rock, and uncommon thin fractures cut the rock. Lustrous aggregates of sulphide are disseminated through the rock and locally are concentrated along discontinuous fractures. Small reddish brown grains (?sphalerite) are sparsely disseminated and locally concentrated along thin fractures.

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : **Laminated hornblende-quartz-garnet schist**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Hornblende	48	Metamorphic
Quartz	30	Metamorphic
Garnet	12	Metamorphic
Plagioclase	5	Metamorphic
Opaques	2	Metamorphic
Sphene	1	Metamorphic
Prehnite	<1	Metamorphic / vein filling
Zoisite	Tr	Metamorphic
Sphalerite	Tr	Metamorphic
Calcite	Tr	Vein filling
Quartz	Tr	Vein filling

In thin section, this sample displays a foliated granoblastic metamorphic texture with indistinct lamination modified by folding.

Hornblende is abundant, occurring as subhedral prismatic crystals ~0.2-1.0 mm long, pleochroic from brownish green through blue-green to pale straw brown. The pleochroism suggests it is a genuine Al- and Ti-rich hornblende. It is distributed throughout the rock, but is concentrated in indistinct laminae that display local tight folding.

Quartz is moderately abundant, occurring mostly as anhedral equant grains ~0.1-0.2 mm in size, forming a granular mosaic between the larger hornblende crystals. It tends to be concentrated in indistinct laminae between the hornblende-rich laminae. Larger quartz grains up to ~1.5 mm in size are concentrated in polycrystalline pods or patches within the trace of the lamination.

Garnet occurs in significant amount as subhedral equant crystals ~0.4-1.0 mm in size. They are scattered throughout the rock, but locally are concentrated in particular laminae. The garnet displays a very pale off-yellow colour. Some garnet crystals display sinuous trails of inclusions ('rolled' garnet), suggesting rotation of the garnet crystals during metamorphic deformation.

Plagioclase is uncommon, forming small ragged grains in granoblastic relationship with quartz and hornblende. It tends to occur in restricted areas and particular laminae, and is absent from much of the rock.

Opaques occur in minor amount in different forms:

- i) Some occurs as relatively large porous aggregates of subhedral equant cubic crystals (probably pyrite).
- ii) Some occurs as angular grains (possibly ?chalcopyrite) in loose aggregates associated with prehnite. Locally, these grains are concentrated in the folded hornblendic laminae, or in the fold hinge zones.
- iii) Some occurs as small ragged granules (probably ilmenite) in cores of sphene aggregates.

Sphene occurs in minor amount as fine-grained microgranular aggregates scattered through the rock, locally entrained within particular hornblendic laminae.

Prehnite occurs as anhedral grains and patches that commonly mantle opaque grains and aggregates. Elsewhere, larger subradiating prehnite aggregates fill indistinct veins that cut the lamination.

Zoisite is uncommon, forming small subhedral crystals closely associated with prehnite, but also occurring as discrete crystals in quartz-rich pods.

Sphalerite occurs in trace amount as small anhedral grains with characteristic deep dark red colour in plane transmitted light, and isotropic optical behaviour under crossed polarisers. The sphalerite occurs in close association with opaques.

Calcite is rare, forming ragged clear unstrained twinned grains in indistinct veins with associated subradiating prehnite and unstrained euhedral small quartz crystals.

#### INTERPRETATION:

This sample has suffered dynamic regional metamorphism in the amphibolite facies, generating the foliated granoblastic assemblage observed above. The opaque phases (including sulphides) are considered to have formed as part of the metamorphic assemblage. It remains uncertain whether the sulphide components were introduced during metamorphism or represent precursor components. During metamorphism, folding of lamination and rotation of garnet porphyroblasts occurred. Following cessation of directed stress, indistinct veinlets were filled by unstrained calcite + prehnite + quartz.

Note that the rock cannot properly be termed 'amphibolite' (= metamorphic hornblende + plagioclase rock), because plagioclase is very low to absent. It is essentially a hornblende + quartz + garnet rock.

The nature of the precursor rock has been obscured by complete metamorphic destruction of all primary minerals and primary textures. The nature of the mineralogical layering remains conjectural: it may represent metamorphic segregation in response to strain, or relict primary compositional lamination.

Two possible precursors are suggested: a mafic igneous precursor, or a calc-silicate sedimentary precursor. A chemical sedimentary origin is supported by the presence of lamination which is folded, the scarcity of plagioclase (and therefore low Na), and the estimated bulk rock composition from assumed mineral compositions (~58% SiO<sub>2</sub>, ~15% total FeO, ~12% Al<sub>2</sub>O<sub>3</sub>, ~7% CaO, ~6% MgO).

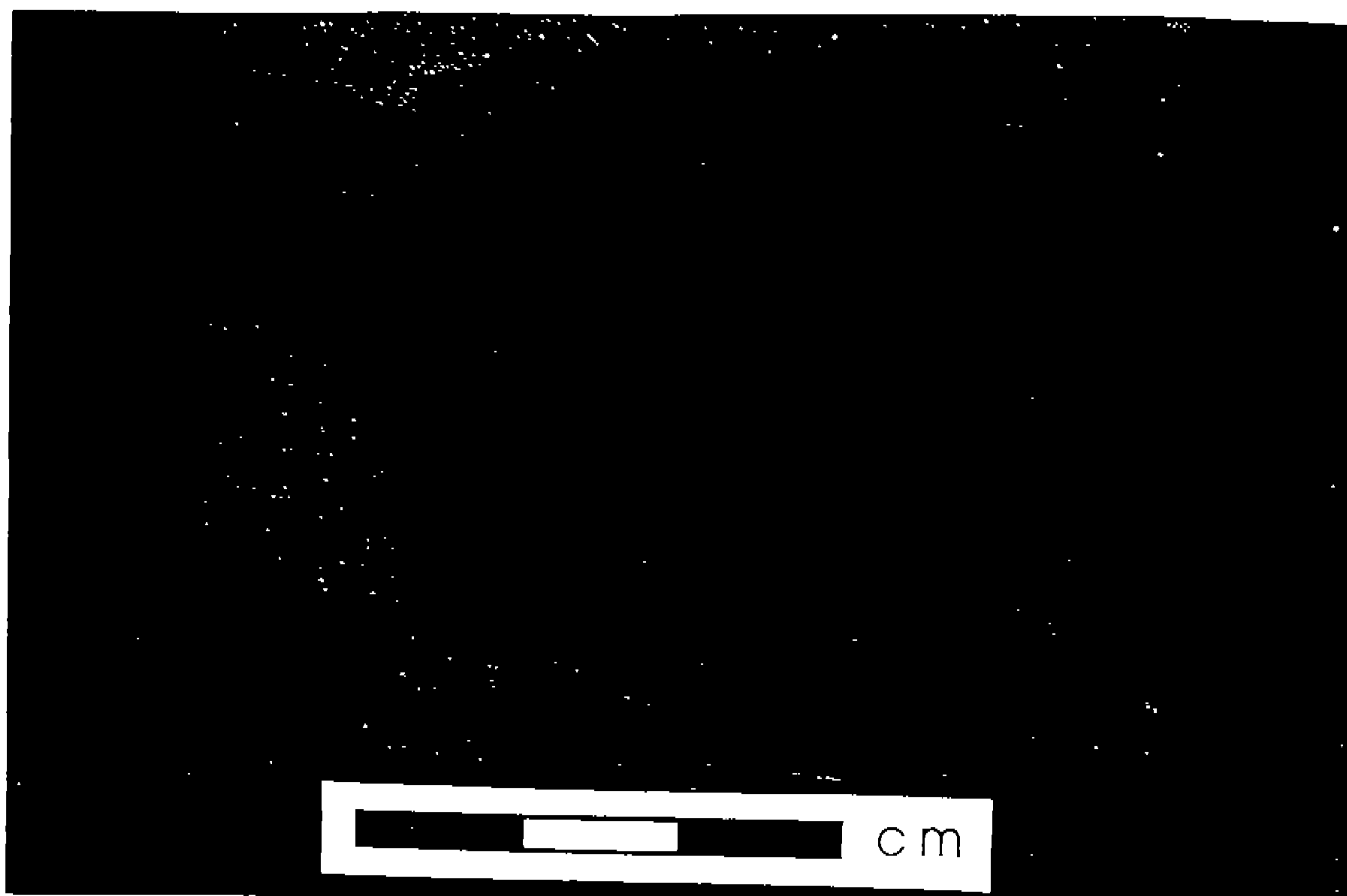


PLATE 13 - ALG05, 60" (Macro photograph of sawn core, wet, bar for scale, Film 1 - Frame 2)  
 In this calc silicate meta sediment, mineralogical layering (oriented WNW - ESE - paler and darker greys) is defined by hornblende + plagioclase in the darker layers, and zoisite + quartz in the paler layer.

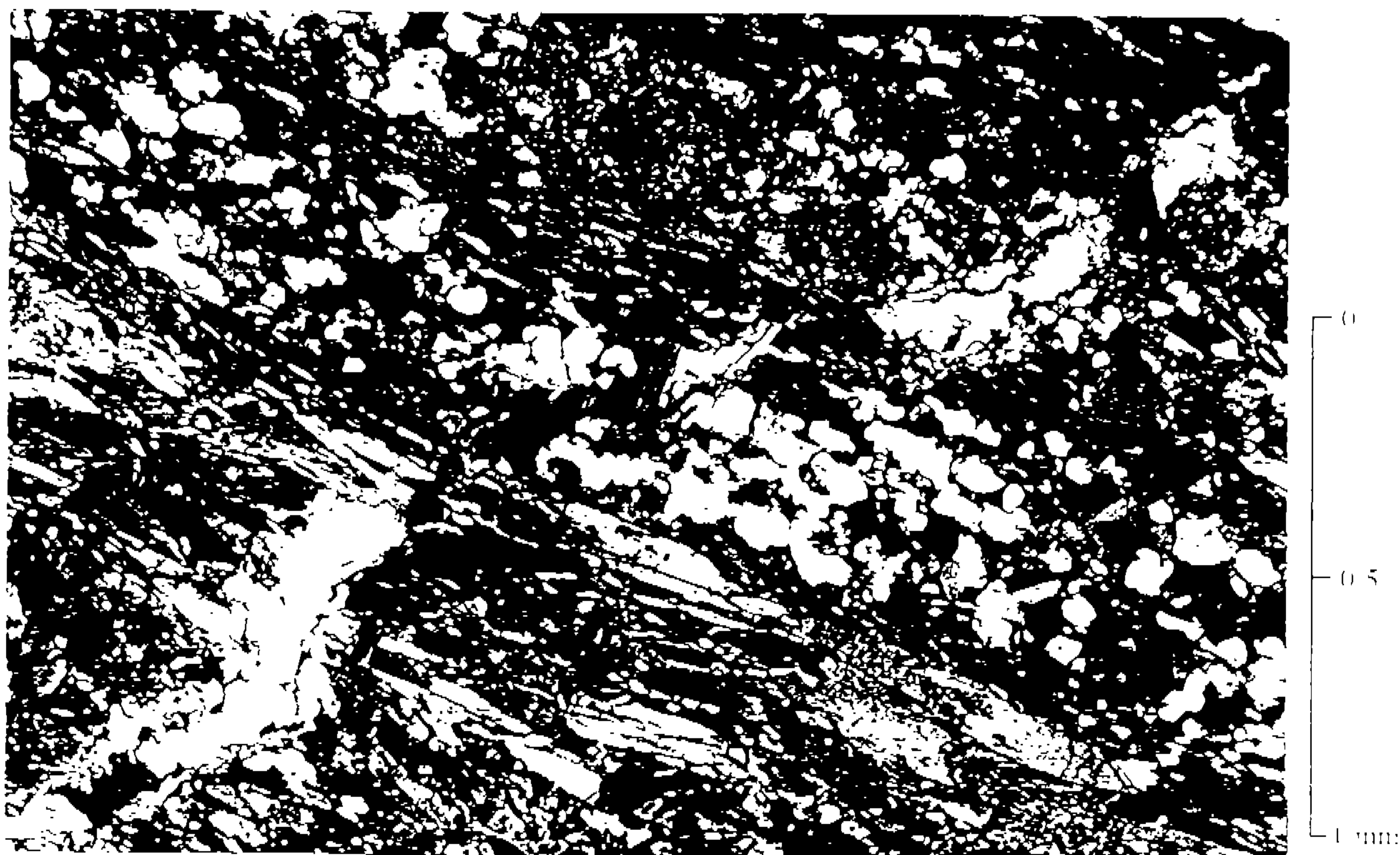


PLATE 14 - SAMPLE ALG05, 60" (Transmitted light, crossed polarisers, x5, Film 2 - Frame 1)  
 A thin section filled by pelinite (bright yellow - blue - oriented N45 - 52° E) - a laminated calc silicate meta sediment composed mainly of hornblende (lined blue - yellow - red - green - oriented N.W. - S) and plagioclase (small equant grain - white to pale grey).

SAMPLE : ALG05, 60.7 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG05, 60.7

HAND SPECIMEN : The drill core rock sample represents a layered rock characterised by darker greenish grey and paler grey layers of centimetre thickness. The darker layers display thin internal lamination.

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : Layered calc-silicate meta-sediment:  
Laminated hornblende-plagioclase schist  
Zoisite-quartz-hornblende schist

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Laminated hornblende-plagioclase schist</u>		
Hornblende	55	Metamorphic
Plagioclase (incl. sericite)	30	Metamorphic (incl. retrogressive alt'n)
Quartz	10	Metamorphic
Zoisite	3	Metamorphic
Sphene	<1	Metamorphic
Opaques	Tr	Metamorphic
Prehnite	Tr	Fracture filling
<u>Zoisite-quartz-hornblende schist</u>		
Zoisite	50	Metamorphic
Quartz	40	Metamorphic
Hornblende	10	Metamorphic
Opaques	Tr	Metamorphic

In thin section, this sample displays a fine-grained foliated granoblastic metamorphic texture with mineralogical layering and lamination (thin layering).

Laminated hornblende-plagioclase schist displays an internally laminated foliated granoblastic texture. Hornblende is abundant, occurring as small acicular crystals ranging ~0.1-1.0 mm long. They tend to be concentrated in thin laminae ~0.2-0.6 mm thick, and display a preferred orientation subparallel to the lamination. Pleochroism from olive green to pale buff brown suggests a genuine Al- and Ti-rich composition.

Plagioclase is the other principal phase, occurring as small equant anhedral grains that display twinning and normal compositional zoning. They tend to be concentrated in thin laminae, similar in thickness to the hornblende-rich laminae. Some plagioclase displays partial replacement by turbid clouds of very fine sericite.

Quartz occurs in moderate amount as small equant anhedral grains similar in size to plagioclase. It tends to be concentrated in particular laminae, and may be absent from some plagioclase-rich laminae.

Zoisite occurs in minor amount as small anhedral to stumpy prismatic grains that display the characteristic anomalous interference colours and parallel extinction of this phase. It is restricted to the plagioclase-rich laminae, and is absent from the hornblende laminae.

Sphene occurs in minor but significant amount as fine-grained turbid pale brown microgranular aggregates that are elongated in the trace of the foliation. The aggregates tend to be concentrated in particular hornblende laminae. Opaques (probably ilmenite) occur as small ragged grains in the cores of some sphene aggregates. A trace of opaques (possibly sulphide) also occurs as small ragged disseminated grains unrelated to sphene.

Prehnite occurs in trace amount as small anhedral grains that fill indistinct fractures cutting the lamination.

Zoisite-quartz-hornblende schist displays an equigranular granoblastic texture with weak foliation defined by aligned small subhedral pleochroic green hornblende crystals. Most of the rock is composed of small subhedral to anhedral equant grains of zoisite and quartz ~0.1-0.2 mm in size. Opaques occur in trace amount as small anhedral grains and microgranular aggregates.

#### INTERPRETATION:

This sample has suffered complete recrystallisation in response to regional metamorphism in the amphibolite facies. This generated the observed foliated granoblastic assemblages in different layers: hornblende + plagioclase + quartz + minor zoisite + others in the darker layers, and zoisite + quartz + minor hornblende in paler layers. The dominance of hornblende + plagioclase in the darker layers allows use of the term 'amphibolite' (para-amphibolite, see next).

No primary minerals or textures are preserved to aid identification of the precursor rock. However, a layered calc-silicate sedimentary precursor is inferred from the metamorphic mineral assemblage and the presence of mineralogical layering. The extent to which primary layering has been modified by metamorphic deformation remains unevaluated.

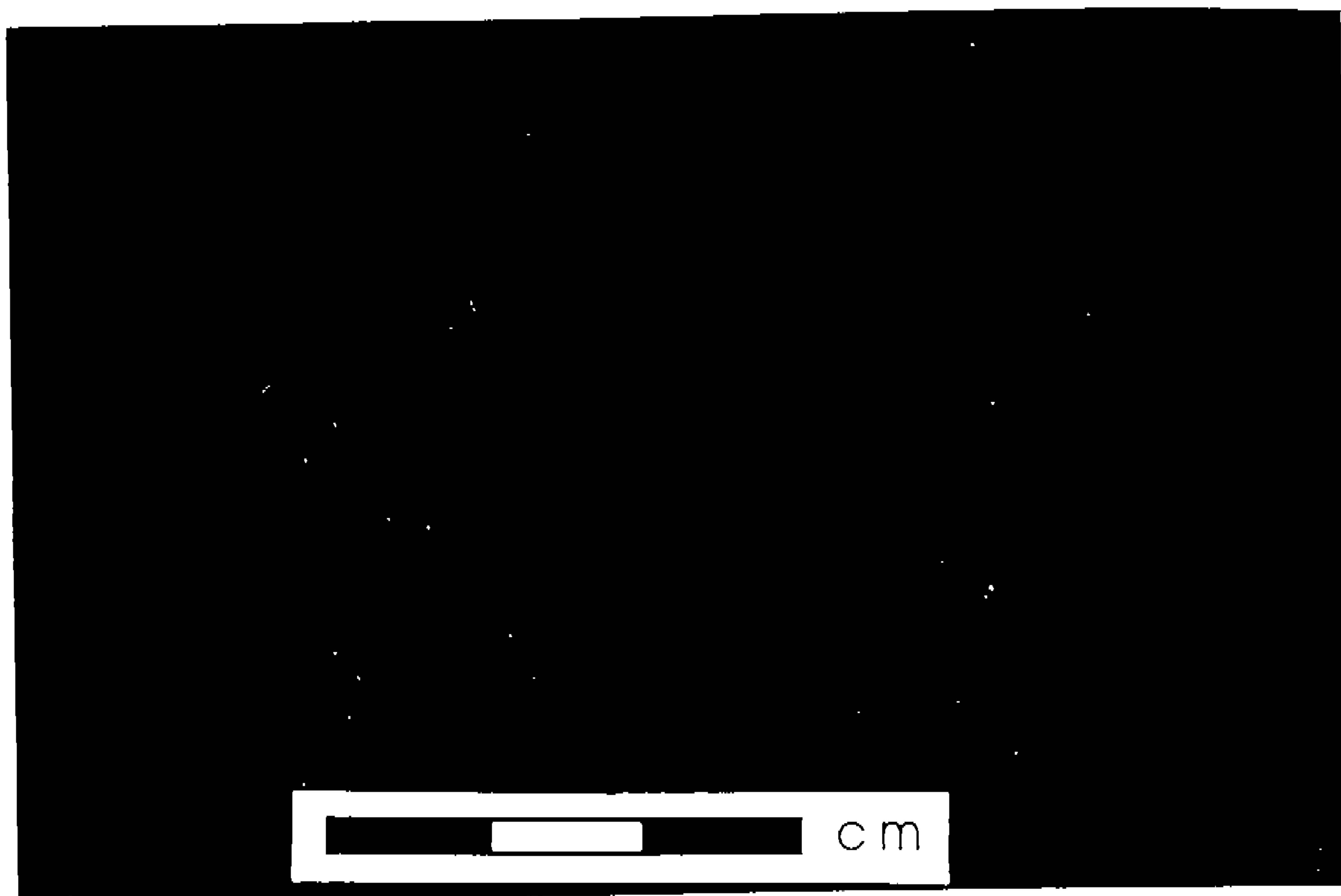


PLATE 5: SAMPLE ALG05-118.6 (Macrophotograph of sawn core, wet bar for scale Film 1 Frame 3) In this calc silicate meta sediment, small garnet crystals (paler spots) are uniformly distributed through a darker matrix of mainly hornblende, plagioclase and quartz. The larger pink patches at upper right are saw marks.



PLATE 6: SAMPLE ALG05-118.6 (Transmitted plane polarised light x5 Film 2 Frame 3) Rolled inclusion trails of quartz and opaques occur in a garnet porphyroblast (off white, centre) that lies in a foliated assemblage of hornblende (green), biotite (brown flake) and felsic minerals (colourless quartz and plagioclase).

SAMPLE : ALG05, 118.6 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG05, 118.6

HAND SPECIMEN : The drill core sample represents a fine-grained foliated dark greenish grey crystalline rock with uniformly distributed small pale pink garnet crystals. Cutting the foliation are minor thin discontinuous lustrous sulphide veinlets.

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : Hornblende-plagioclase-quartz-garnet schist

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Hornblende	63	Metamorphic
Plagioclase	15	Metamorphic
Quartz	10	Metamorphic
Garnet	5	Metamorphic
Biotite	5	Metamorphic
Opagues (disseminated)	1	Metamorphic
Opagues	Tr	Fracture filling
Chlorite	Tr	Fracture filling
Calcite	Tr	Fracture filling
Prehnite	Tr	Fracture filling

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

Hornblende is abundant, occurring as subhedral acicular crystals ~0.2-1.0 mm long whose strong preferred orientation contributes to definition of a strong structure through the rock. A single tight fold, at an acute angle to the foliation, is developed. Pleochroism from olive green to very pale buff brown confirms a genuine Al- and Ti-rich hornblende composition.

Plagioclase occurs in moderate amount as tiny anhedral grains that form small microgranular mosaics elongated in the trace of the foliation. Quartz accompanies the plagioclase as similar small anhedral grains ~0.1-0.2 mm in size.

Garnet builds small equant subhedral porphyroblasts ~1 mm in size, with very pale off-yellow colour. They are scattered sparsely through the rock, and some display sinusoidal trails of quartz inclusions ('rolled' garnets) indicating rotation of the crystals during growth in the directed stress regime of the metamorphic event.

Biotite occurs in minor amount as small but well-crystallised flakes, pleochroic from reddish tan brown to very pale straw yellow. They are aligned in the trace of the foliation, and are uniformly distributed through the rock with local tendency to be concentrated in thin laminae.

Two types of opagues are distinguished:

- i) Most occurs as small equant crystals (probably ilmenite) sparsely disseminated through the rock.

- ii) A trace of opaques occurs as very fine-grained aggregates concentrated in thin discordant fractures, variously through-going and discontinuous. This may be a sulphide (?pyrite).

Some of the thin fractures are filled by fine-grained pleochroic green chlorite in massive mats, and a trace of similar chlorite fills uncommon thin fractures in the garnet porphyroblasts. A trace of clear sparry calcite accompanies the chlorite and opaques in the thin fracture fillings.

#### INTERPRETATION:

This sample has suffered complete recrystallisation in response to dynamic regional metamorphism in the amphibolite facies. This generated the observed foliated granoblastic porphyroblastic assemblage of hornblende + plagioclase + quartz + garnet + biotite + trace opaques. The term 'para-amphibolite' could be loosely used for this rock. During metamorphic deformation, garnet porphyroblasts overgrew a foliation and then suffered rotation during progressive deformation. Late thin fractures were filled by the lower-grade assemblage of chlorite + opaques + calcite, and a trace of chlorite filled thin fractures in garnet porphyroblasts.

No primary minerals or textures are preserved to aid identification of the precursor rock. The mineral abundances suggest a calc-silicate sedimentary precursor.

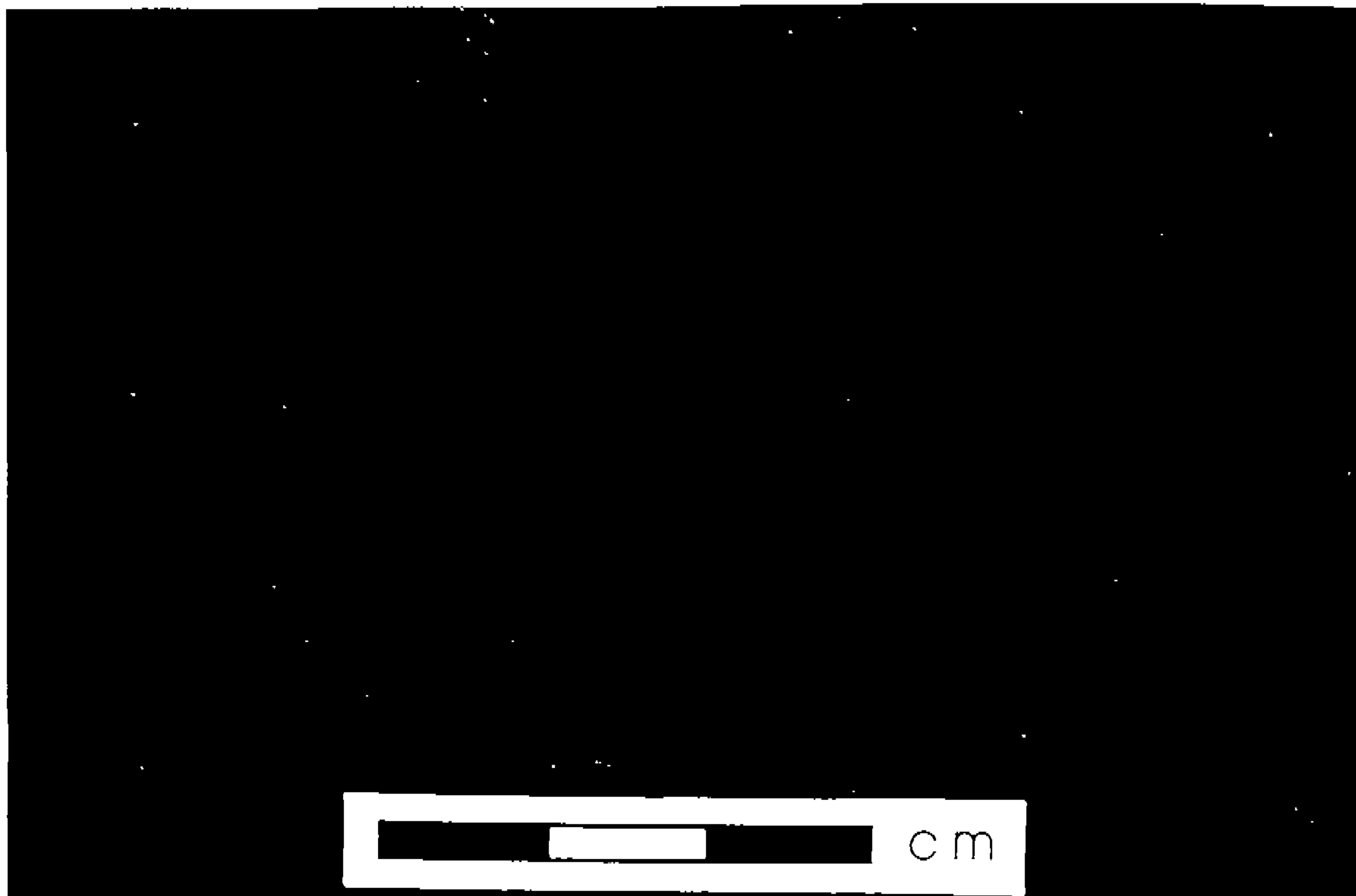


PLATE 7. SAMPLE ALG05-1331 (Macro photograph of sawn core wet bar for scale. Film 1 Frame 4). This grey foliated rock represents an aluminous quartzofeldspathic metamorphic rock.

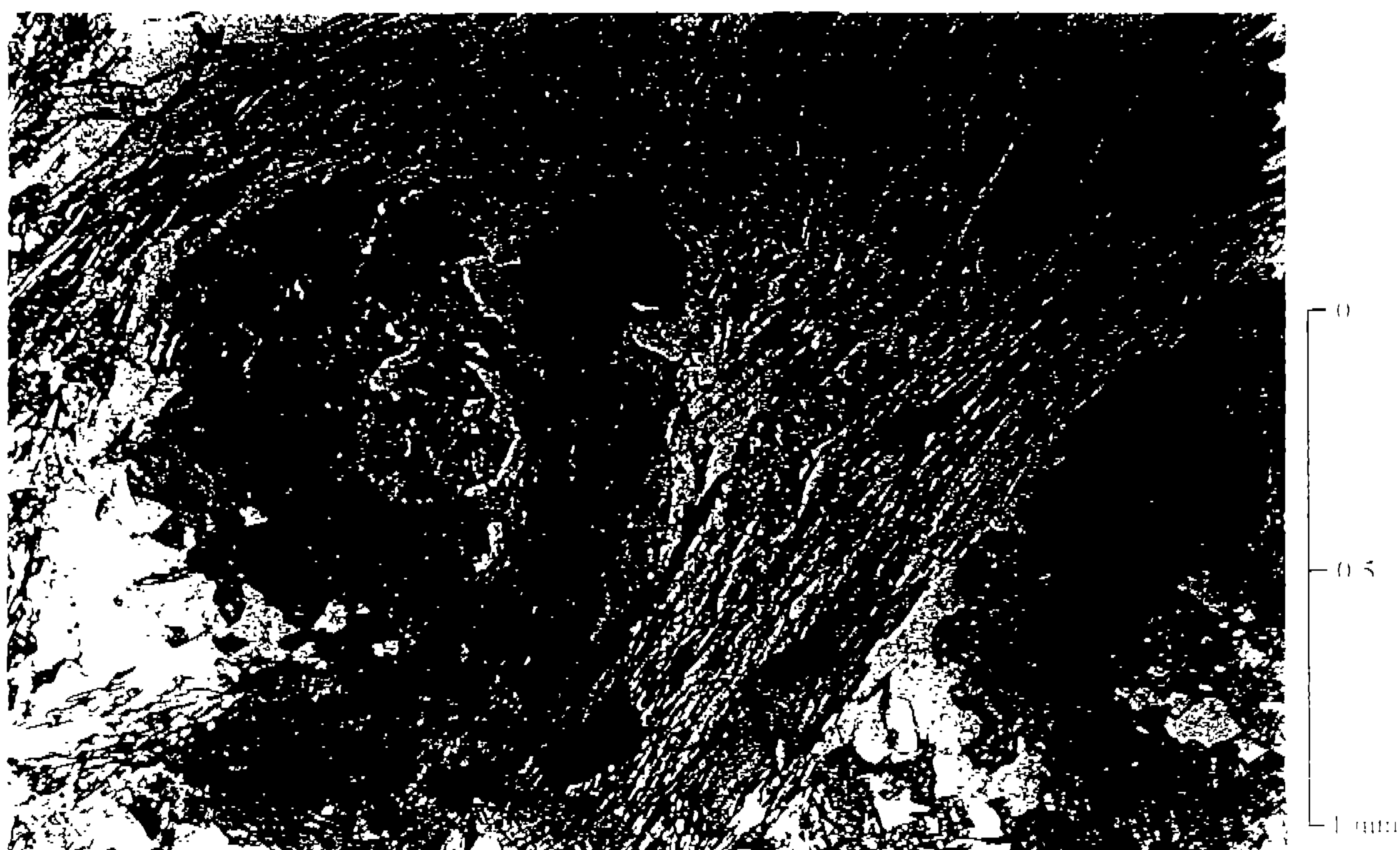


PLATE 8. SAMPLE ALG05-1331 (Transmitted plane polarised light x5. Film 2 Frame 4). In the quartzofeldspathic schist, alteration chlorite (dark green) has partially replaced garnet porphyroblast (center left, lower right) that lie in a strongly foliated matrix of muscovite (aligned colourless flakes) and quartz (all colourless clear grains).

SAMPLE : ALG05, 133.1 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG05, 133.1

HAND SPECIMEN : The drill core sample represents a compositionally uniform grey schistose rock with foliation defined by thin dark micaceous foliae. Uncommon small lustrous silvery sulphide lenticles (pyrite) lie in the trace of the foliation.

The section offcut accepted a weak positive yellow stain for K-feldspar, indicating it occurs in minor amount in thin discordant and concordant fracture fillings.

ROCK NAME : **Partly-retrogressed biotite-garnet quartzo-feldspathic schist**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Muscovite	30	Metamorphic
Quartz	25	Metamorphic
Plagioclase (incl. trace ?illite)	25	Metamorphic (incl. retrogressive alt'n)
Biotite	7	Metamorphic
Garnet	1	Relict metamorphic
Chlorite	12	Retrogressive alteration
Opakes	Tr	Retrogressive alteration
Leucoxene	Tr	Retrogressive alteration
K-feldspar	Tr	Fracture filling
Calcite	Tr	Fracture filling
Quartz	Tr	Fracture filling

In thin section, this sample displays a strongly foliated granoblastic metamorphic texture, modified by partial retrogressive alteration.

Muscovite is abundant, occurring as flakes ~0.2-0.6 mm long. They tend to be concentrated in foliae, and a strong foliation is defined by the preferred orientation of the foliae and the flakes within the foliae.

Quartz and plagioclase occur as small equant anhedral grains ~0.2 mm in size, forming an equigranular granoblastic mosaic between the muscovite foliae. The quartz is quite clear, but plagioclase displays incipient replacement by minute phyllosilicate flecks (possibly illitic clay).

Biotite occurs in significant amount as small but well-crystallised flakes ~0.2-0.4 mm long, pleochroic from tan brown to very pale straw yellow. They tend to occur in the granoblastic quartz-feldspar 'bands' between the muscovite-rich foliae, and their preferred orientation contributes to definition of the foliation.

Garnet forms equant subhedral porphyroblasts ~1-1.5 mm in size and off-yellow in colour, scattered through the rock. All have suffered partial to complete replacement by pleochroic green chlorite plates and aggregates, leaving relict garnet kernels in some crystal sites. Similar chlorite occurs in significant amount as discrete aggregates of flakes scattered through the rock. Locally, chlorite flakes have grown across the foliation.

Opaques occur in different forms:

- i) Most occurs as fine-grained aggregates elongated in the trace of the foliation, but closely associated with chlorite aggregates. This appears to be retrogressive alteration opaque material (probably pyrite as observed in hand specimen).
- ii) A trace of opaque material occurs as tiny specks, aggregates and diffuse clouds within muscovite foliae. These opaques may be carbonaceous materials (graphite).

Leucoxene occurs in trace amount as microgranular aggregates, pseudomorphous after precursor elongate crystals (?ilmenite) aligned in the trace of the foliation.

Cutting the rock are tortuous veinlets of irregular width, variably filled by fine-grained microgranular K-feldspar, larger clear sparry grains of unstrained calcite, and small euhedral quartz crystals.

#### INTERPRETATION:

This sample has suffered deformation and recrystallisation in response to regional metamorphism in the amphibolite facies. This generated the observed foliated granoblastic assemblage of muscovite + quartz + plagioclase + biotite + garnet + minor opaques (?graphite, ?ilmenite).

A subsequent retrogressive alteration event affected the rock. Chlorite formed ragged aggregates and replacements of garnet, and thin irregular fractures were filled by assemblages of K-feldspar, calcite and quartz. A trace of phyllosilicate (possibly illitic clay).

The nature of the precursor rock has been obscured by the effects of metamorphism. No primary minerals or textures are preserved, but an aluminous quartzo-feldspathic precursor is inferred.

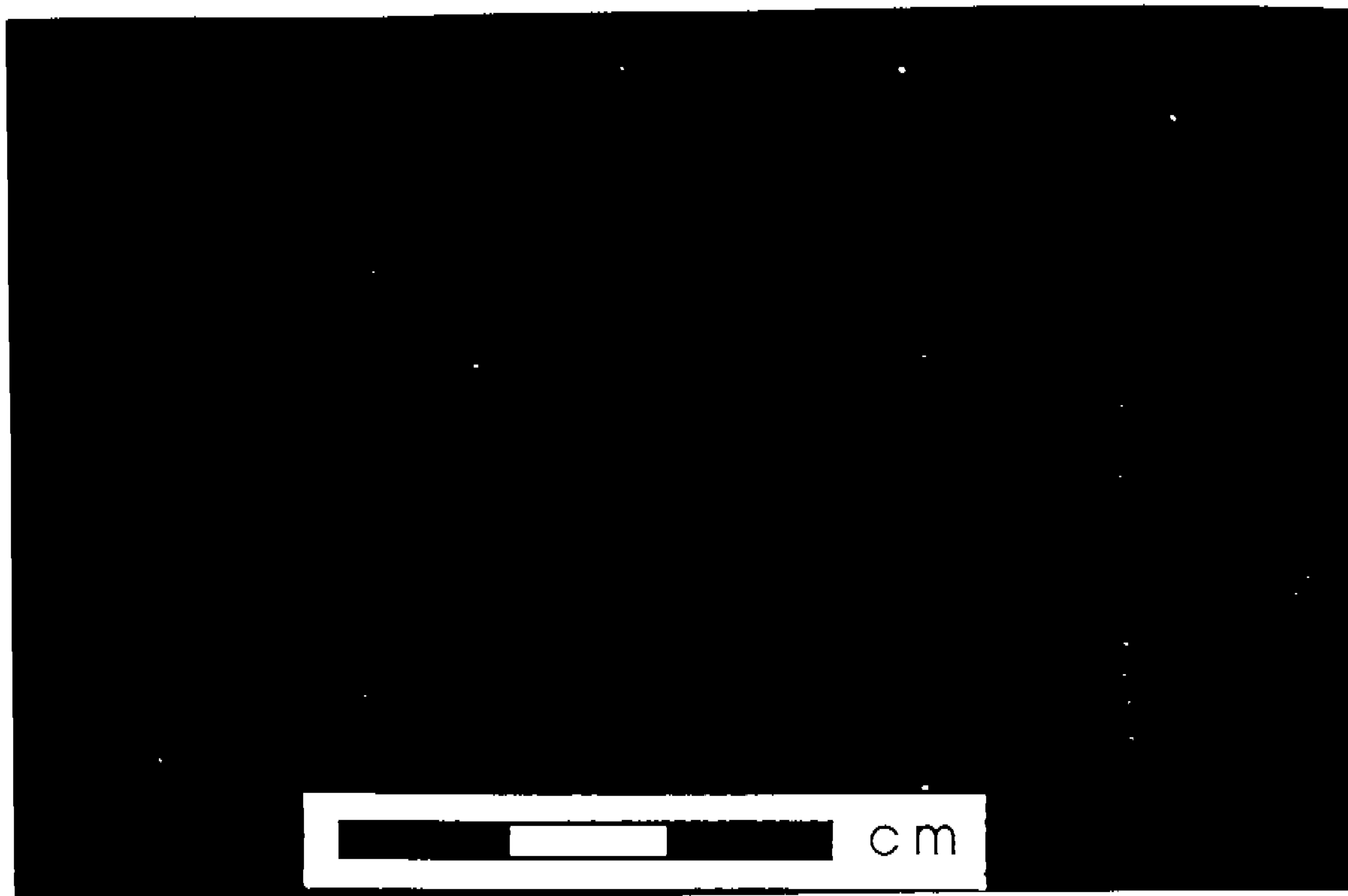


PLATE 9. SAMPLE ALG06-76.8 (Macrophotograph of sawn core, wet, bar for scale. Film 1. Frame 5). This quartzofeldspathic schist contains ragged larger feldspar grains (pale patches) that lie in a foliation defined by aligned phyllosilicate flakes (thin dark foliae).

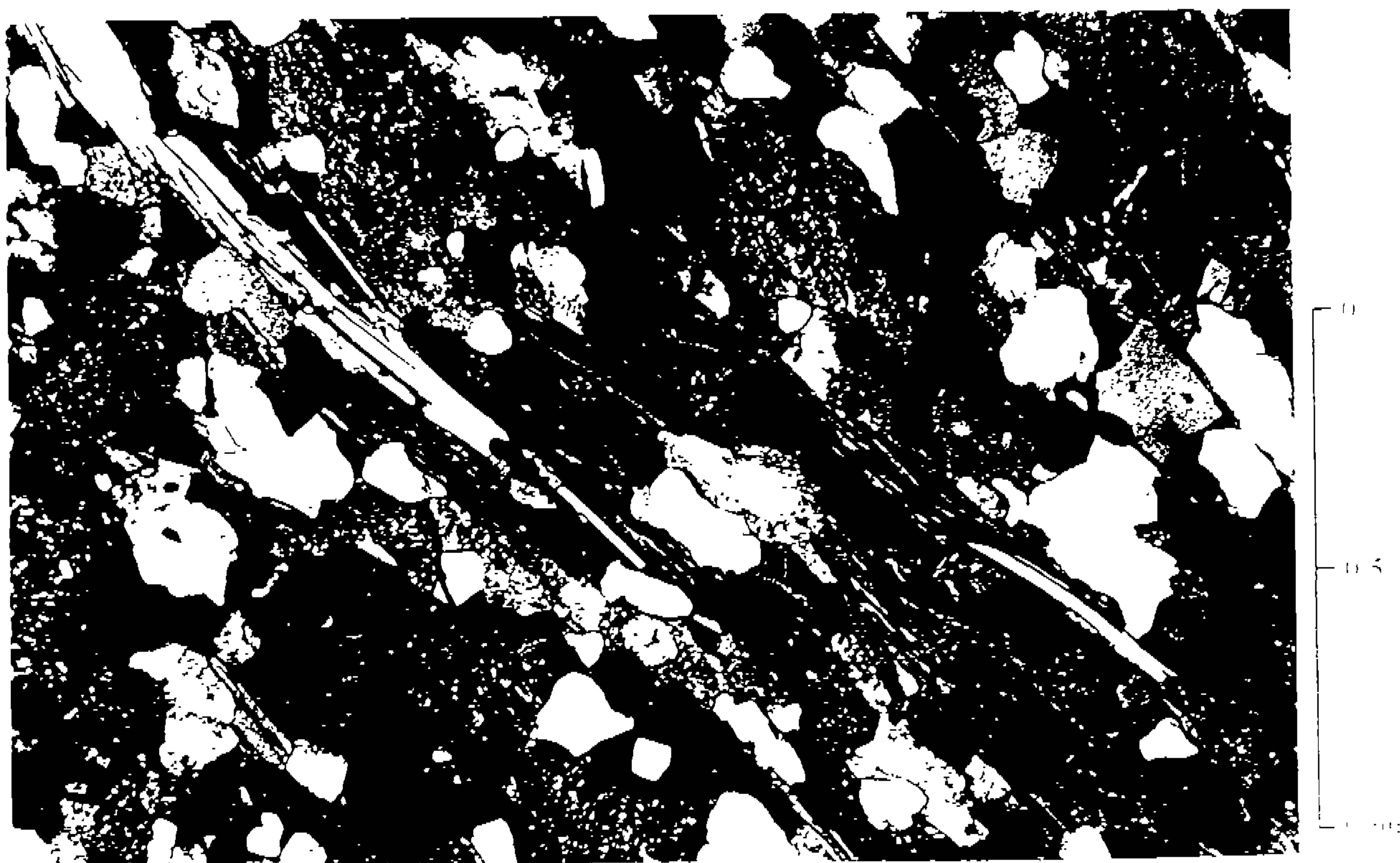


PLATE 10. SAMPLE ALG06-76.8 (Transmitted light, crossed polarisers, x5. Film 2. Frame 6). In this quartzofeldspathic schist, quartz (white to grey) and microcline (yellow to blue - cyan, fresh, but plagioclase (dull grey) is partly replaced by illitic clay (minute pale flecks) and biotite (reddish brown, centre, lower right) is partly replaced by chlorite (anomalous blue, centre).

SAMPLE : ALG06, 76.8 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG06, 76.8

HAND SPECIMEN : The drill core sample represents a compositionally uniform grey crystalline rock containing scattered indistinct cream feldspar grains. A strong foliation is defined by small dark mica flakes, and lustrous white mica flakes are evident on broken foliation surfaces.

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : **Weakly retrogressed biotite-muscovite quartzo-feldspathic schist**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase (incl. minor ?illite)	55	Metamorphic (incl. retrogressive alt'n)
Quartz	35	Metamorphic
Muscovite	5	Metamorphic
Biotite	3	Metamorphic
Apatite	Tr	Metamorphic
Leucoxene/rutile	Tr	Metamorphic
Zircon	Tr	Relict primary
Chlorite	1	Alteration
Calcite	Tr	Alteration / fracture filling

In thin section, this sample displays a foliated granoblastic metamorphic texture, with possible faint preservation of precursor feldspar grains.

Plagioclase is abundant, occurring in two forms:

- i) Some occurs as larger subhedral blocky grains and subrounded grains ~1-1.5 mm in size. They are uniformly distributed throughout the rock, and have suffered incipient replacement by fine flecks of phyllosilicate (possibly illitic clay). These grains may present relict primary plagioclase crystals, but this remains uncertain.
- ii) Some occurs as smaller anhedral grains that form a granoblastic mosaic with quartz. These grains clearly are metamorphic in origin.

Quartz is moderately abundant, occurring as anhedral grains ~0.2-0.4 mm in size. Most are equant, but larger grains tend to be elongated in the trace of the foliation.

Muscovite occurs in moderate amount as well-crystallised flakes ~0.4-0.8 mm long. They are distributed throughout the rock, but tend to be concentrated in thin foliae which wrap around the larger plagioclase grains. Uncommon smaller muscovite flakes form replacement flakes within the larger plagioclase grains.

Biotite forms small well-crystallised flakes ~0.2-0.4 mm long, pleochroic from reddish tan grown to very pale straw yellow. Some flakes have suffered partial to complete replacement by pleochroic green chlorite with associated minute turbid dark leucoxene granules.

Apatite is rare, occurring as small equant subhedral grains <0.2 mm in size.

Zircon is rare, forming tiny euhedral terminated crystals enclosed within plagioclase grains.

Uncommon thin fractures cut the rock, and are filled by clear sparry calcite.

#### INTERPRETATION:

This sample has suffered recrystallisation and deformation in response to regional metamorphism. This generated the granoblastic foliated assemblage of plagioclase + quartz + muscovite + biotite + trace apatite + leucoxene/rutile. The assemblage is not grade-specific, confirming only that the grade reached middle greenschist facies. The grain size, however, is supportive of a higher grade of metamorphism (e.g. amphibolite facies).

The nature of the precursor rock has been obscured, but it most likely formed as an aluminous quartzo-feldspathic rock which contained moderately large subhedral plagioclase crystals.

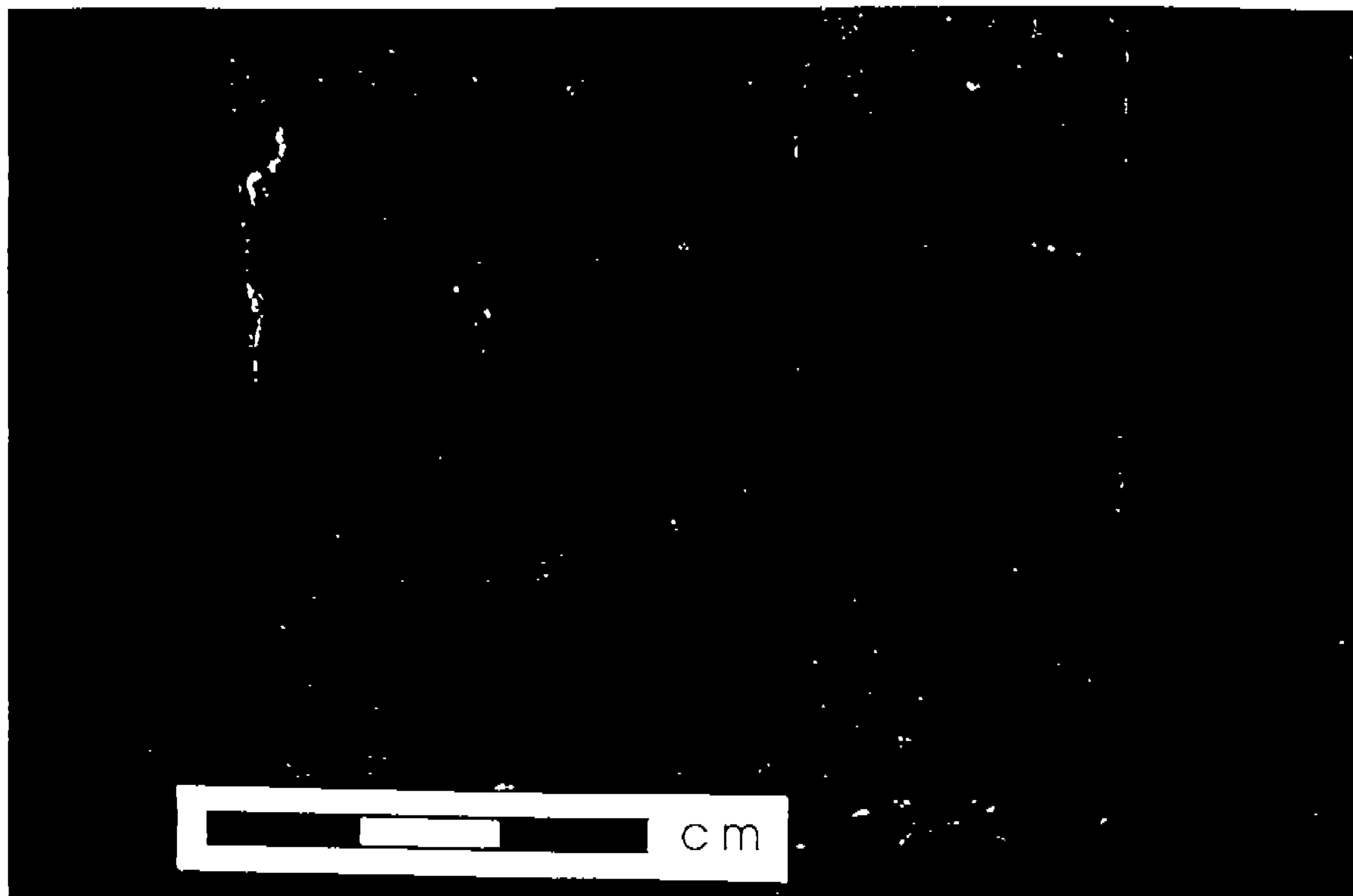


PLATE 11. SAMPLE ALG06/848. Macro photograph of sawn core, wet, bar for scale. (Film 1, Frame 6). Two different portions of this pelitic gneiss illustrate strong foliation and mineralogical layering. At left and lower right, larger grains of garnet (pale pink) and staurolite (dark brown) are distinguishable.

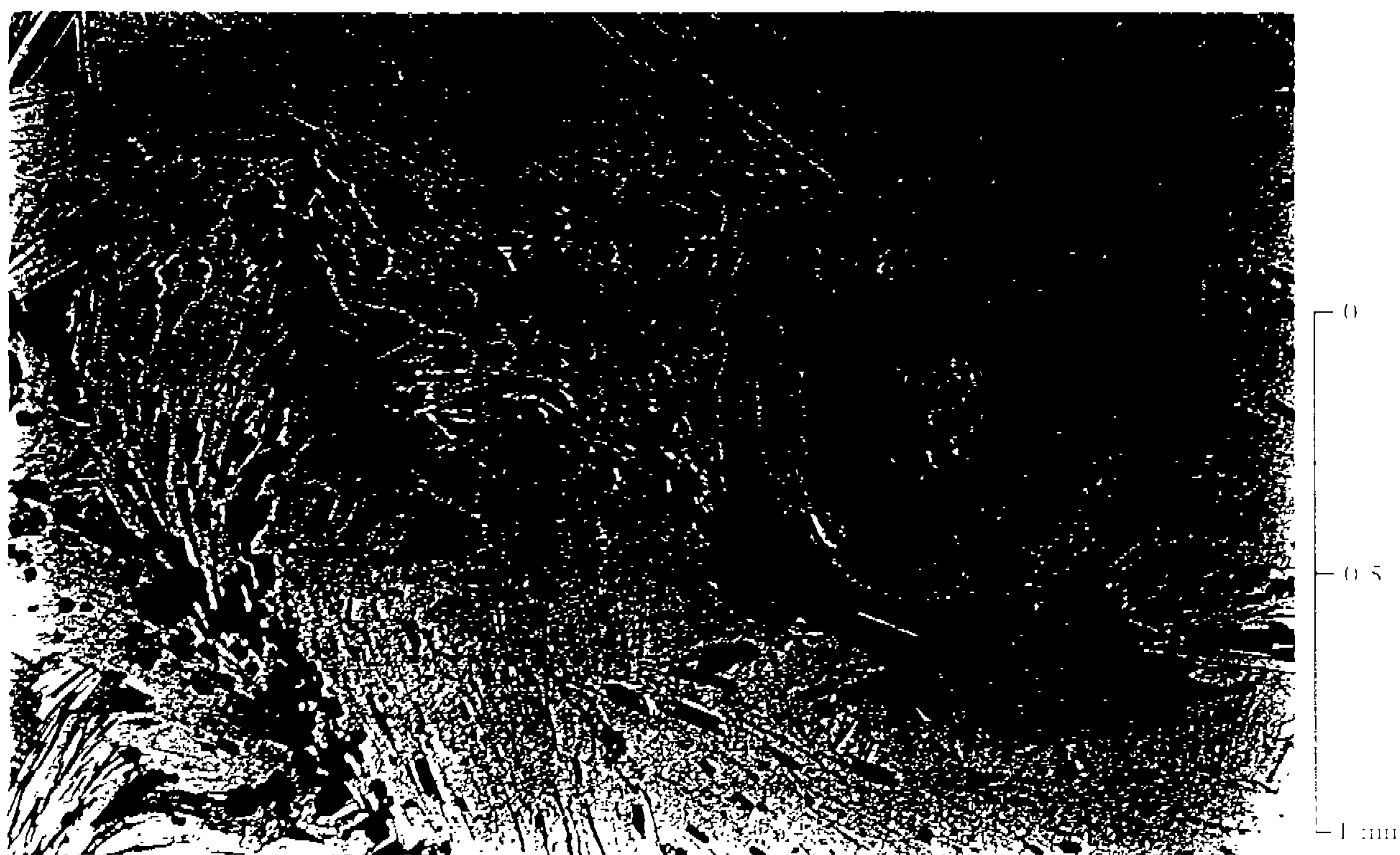


PLATE 12. SAMPLE ALG06/848. Transmitted plane polarised light (x5, Film 2, Frame 7). In this partly retrogressed gneiss, drab green alteration chlorite mantles an equant garnet porphyroblast (upper right), which lies in a foliated matrix of muscovite (colourless, aligned flakes) and small, bright zirconium crystals (dark green).

SAMPLE : ALG06, 84.8 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG06, 84.8

HAND SPECIMEN : The drill core sample represents a gneissic metamorphic rock composed of strongly foliated grey matrix through which are scattered pink garnet grains and dull brown staurolite grains. Yellow alteration patches lie in the trace of the foliation, and a thick white quartz vein lies subparallel to the foliation.

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : **Partly retrogressed muscovite-staurolite-garnet gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	48	Metamorphic
Muscovite	30	Metamorphic
Biotite	5	Metamorphic
Garnet	5	Metamorphic
Staurolite (incl. ?illite)	5	Metamorphic (incl. alteration)
Plagioclase (incl. ?illite)	5	Metamorphic (incl. alteration)
Tourmaline	Tr	Metamorphic
Rutile	Tr	Metamorphic
Chlorite	1	Alteration
Fluorite	Tr	Alteration
Opakes	Tr	Alteration
Calcite	Tr	Fracture filling
Sphalerite	Tr	Fracture filling

In thin section, this sample displays a coarse-grained foliated granoblastic metamorphic texture, with irregular to banded distribution of minerals.

Quartz is abundant. Much occurs in a single band composed of large anhedral grains ~1-4 mm in size. Smaller anhedral quartz grains are intergrown with other phases elsewhere through the rock, and tiny ragged grains form nests of inclusions in cores of some garnet crystals.

Muscovite is moderately abundant. It forms well-crystallised flakes up to ~1 mm long, mostly concentrated in dense mats aligned in the trace of the foliation. Biotite flakes, pleochroic from tan brown to pale yellow, are intimately interleaved with the muscovite. Some biotite flakes have suffered partial replacement by drab green pleochroic chlorite, and larger clean aggregates of chlorite flakes are located at margins of garnet grains.

Garnet forms equant subhedral to euhedral crystals ~1.5-3.0 mm in size. They are very pale pink in colour, and some display rolled trails of quartz inclusions suggesting the rock suffered deformation during the metamorphic recrystallisation event.

Staurolite occurs as large equant pleochroic yellow grains, intergrown with quartz in a reticulated texture. Many have suffered partial to complete replacement by dense mats of very fine-grained phyllosilicate phase (possibly illitic clay).

Plagioclase builds large anhedral grains, partly to completely replaced by very fine-grained dense clouds of phyllosilicate (possibly illitic clay).

Tourmaline occurs in trace amount as tiny equant crystals, pleochroic in drab brownish green colours. The tourmaline is sprinkled uniformly through a dense muscovite-rich band, and is absent elsewhere.

Rutile occurs as small subhedral grains sprinkled through the muscovite-rich areas of the rock.

Fluorite is uncommon, forming dense bulbous drab pale mauve aggregates intergrown with chlorite in dense chlorite patches, and intergrown with fine-grained sericite mats after plagioclase.

Opaques are uncommon, occurring as small angular grains and ragged aggregates in close association with alteration sericite and chlorite.

Calcite occurs in trace amount as anhedral clear grains that fill uncommon fractures cutting the rock.

Sphalerite is observed as rare small ragged grains, variably colourless to pale orange-yellow and characteristically isotropic, aligned along a fracture through a sericite-altered plagioclase grain.

#### INTERPRETATION:

This sample represents a gneissic metamorphic rock of broadly pelitic composition. It has suffered recrystallisation and deformation in response to medium-grade regional metamorphism in the amphibolite facies, generating the foliated assemblage muscovite + quartz + biotite + garnet + staurolite + plagioclase + minor tourmaline + rutile. Coarse-grained quartz-rich bands are considered to represent metamorphic segregations.

The rock body has suffered partial retrogressive alteration, generating minor amounts of illitic clay + chlorite + opaques + fluorite. Thin fractures were filled by calcite and rare sphalerite.

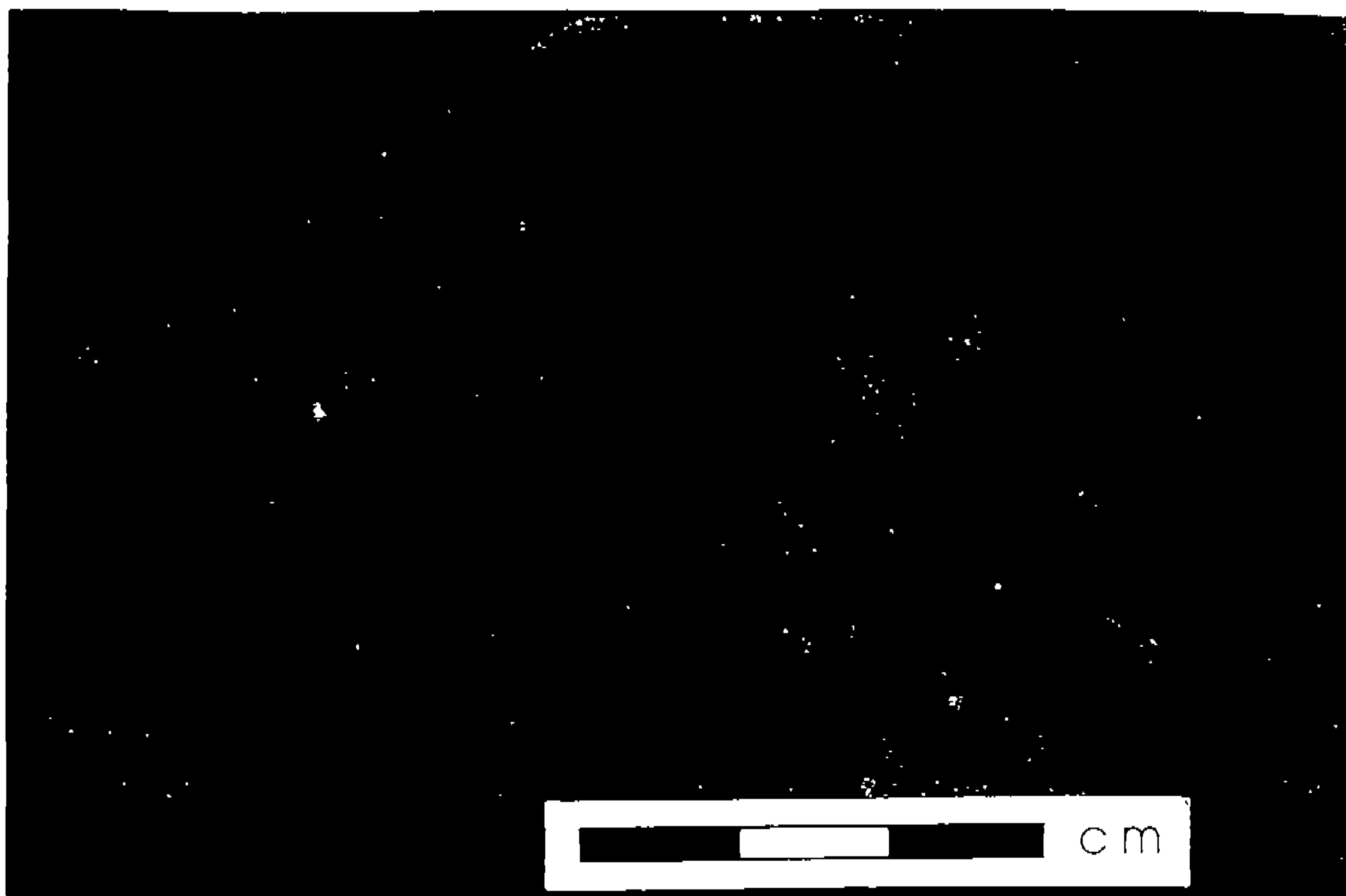


PLATE 14 SAMPLE ALG06, 147.9 (Macro photograph of sawn core (wet bar for scale, Film 1, Frame 8). In this layered meta-sediment a discontinuous felsic band (pale grey, mainly quartz and plagioclase) separates darker bands of semi-pelitic (mainly plagioclase and biotite) and calc-silicate (plagioclase, hornblende, biotite-quartz) compositions. Pink garnet porphyroblasts are evident.

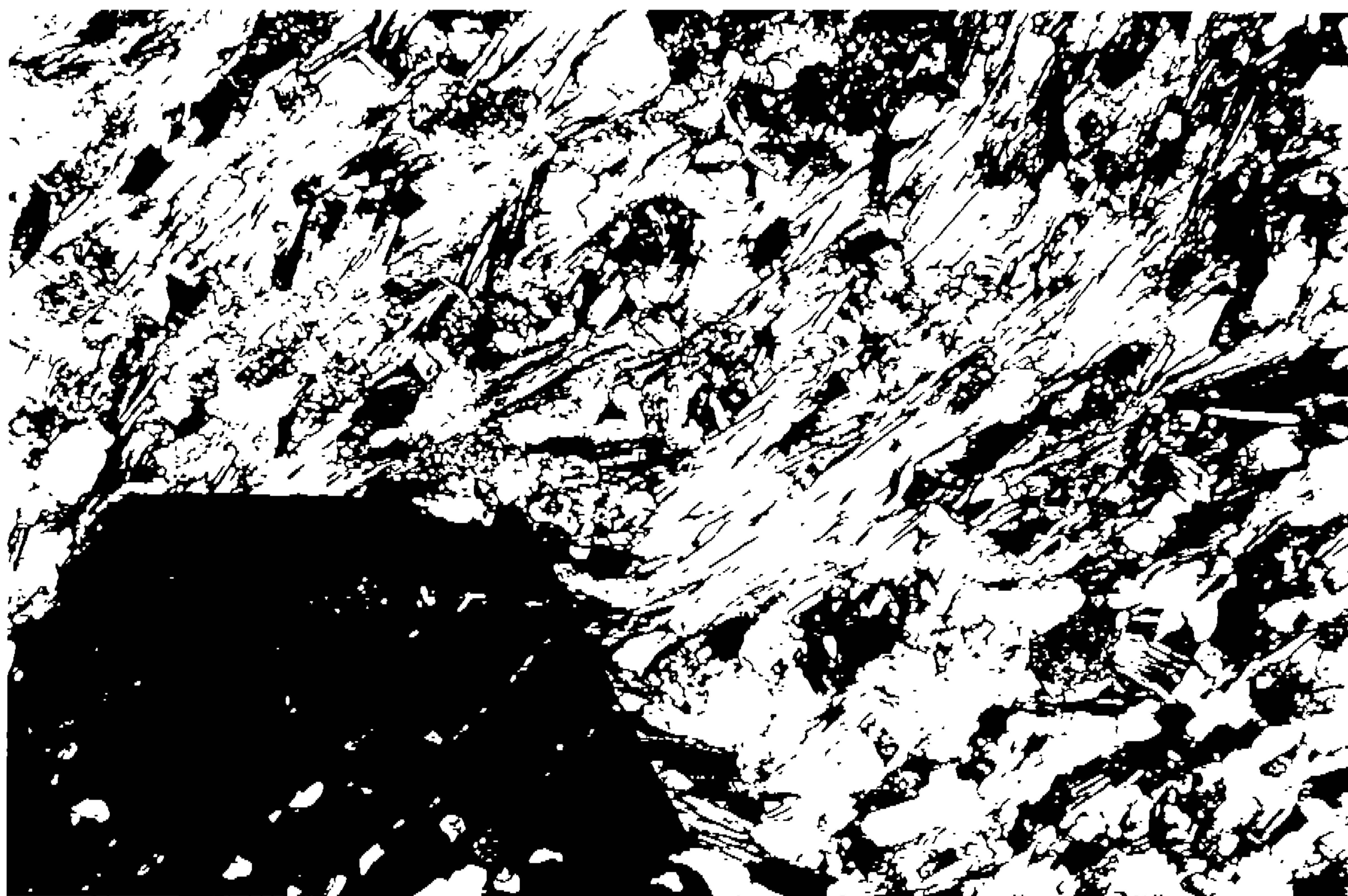


PLATE 15 SAMPLE ALG06, 147.9 (Transmitted light (crossed polariser), x5, Film 2, Frame 9). In this view of meta-semi-pelite, foliated biotite flakes (high order colour) and a garnet porphyroblast (black, bottom left) remain fresh, but plagioclase grains (equant grey grains) have suffered incipient replacement by minute clay flecks (pale yellow).

SAMPLE : ALG06, 147.9 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : ALG06, 147.9

HAND SPECIMEN : The drill core sample represents a dark green to black, strongly foliated rock that contains sparsely scattered pink garnet crystals and thick to thin discontinuous felsic bands or pods.

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : **Layered meta-sediment:**  
**Plagioclase-biotite-quartz semi-pelitic schist**  
**Plagioclase-hornblende-biotite-quartz calc-silicate schist**  
**Quartz-plagioclase-hornblende-apatite calc-silicate band**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Plagioclase-biotite-quartz semi-pelitic schist</u>		
Plagioclase (incl. ?illite)	55	Metamorphic (incl. alteration)
Biotite	40	Metamorphic
Quartz	3	Metamorphic
Garnet	2	Metamorphic
Opaques	Tr	?Metamorphic / ?alteration
<u>Plagioclase-hornblende-biotite-quartz calc-silicate schist</u>		
Plagioclase (incl. ?illite)	35	Metamorphic (incl. alteration)
Hornblende	25	Metamorphic
Biotite	20	Metamorphic
Quartz	20	Metamorphic
Garnet	Tr	Metamorphic
<u>Quartz-plagioclase-hornblende-apatite calc-silicate band</u>		
Quartz	48	Metamorphic
Plagioclase	40	Metamorphic
Hornblende	5	Metamorphic
Garnet	3	Metamorphic
Apatite	2	Metamorphic
Biotite	1	Metamorphic
Clinozoisite	Tr	Metamorphic

In thin section, this sample displays an equigranular foliated granoblastic metamorphic texture, with coarser grain size in the felsic band.

Plagioclase-biotite-quartz semi-pelitic schist contains abundant equant anhedral grains of plagioclase, partly replaced by small flakes and patches of a phyllosilicate phase (possibly illitic clay). Uncommon large patches several millimetres in size are composed entirely of plagioclase as coarse-grained polycrystalline aggregates.

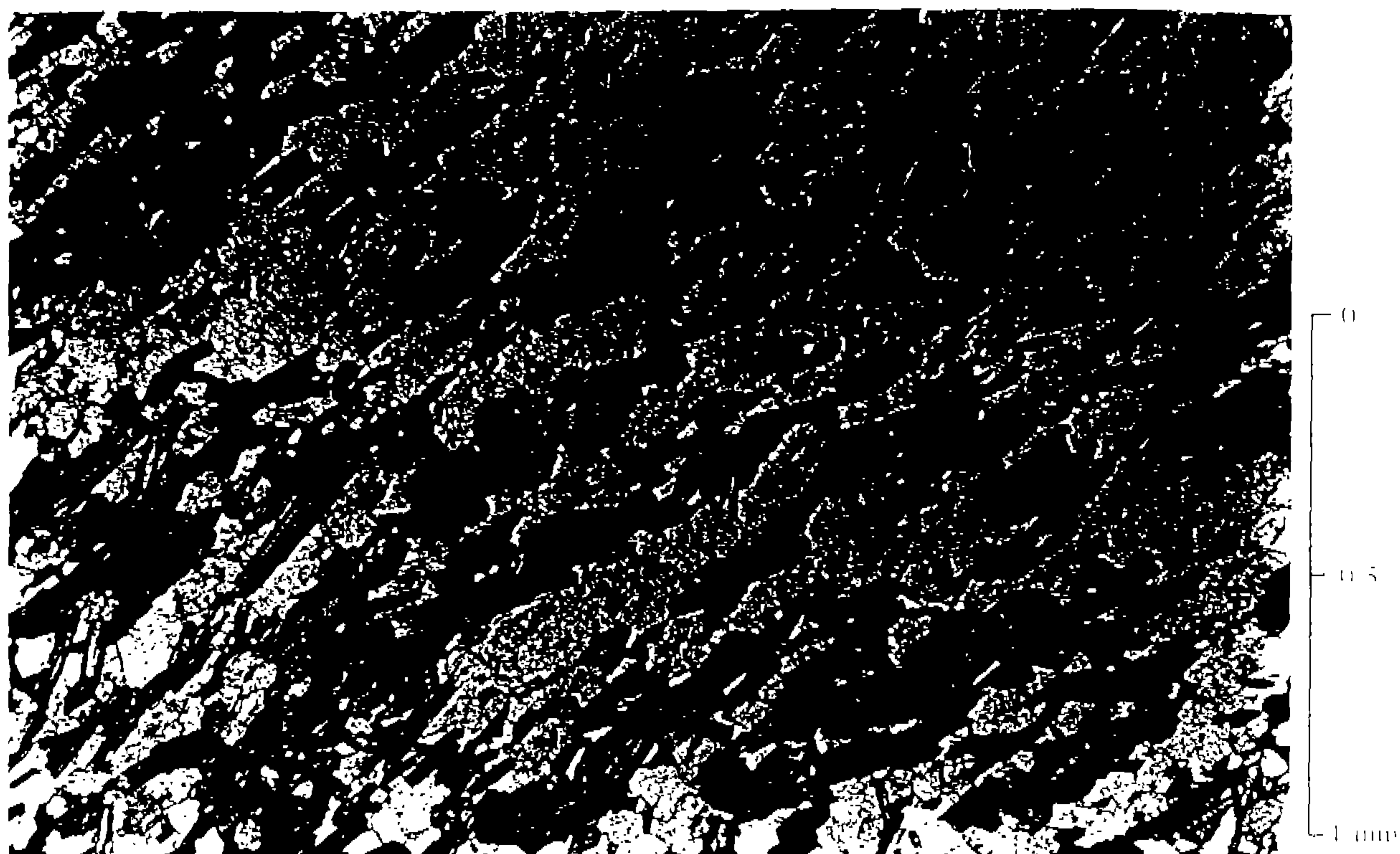


PLATE 16 SAMPLE ALG06-147-9 (Transmitted plane polarised light x5 Film 2 Frame 10)

This view shows the meta calc silicate band of this sample (contrast with the meta calc pelite band PLATE 15). Hornblende (green) and biotite (brown) are aligned in a strong foliation oriented NE-SW. Felsic grains (colourless) are plagioclase and quartz.

Biotite is abundant, occurring as pleochroic reddish tan brown to very pale yellow flakes whose preferred orientation defines a moderately strong foliation subparallel to compositional layering in the rock. The foliation locally tends to be misoriented. Quartz occurs as small clear anhedral grains, sparsely and irregularly distributed through the rock. Garnet is uncommon, forming euhedral porphyroblastic crystals ~2 mm in size, but restricted to the vicinity of the quartz-rich band.

Opaques occur in trace amount as rare aggregates of grains.

Plagioclase-hornblende-biotite-quartz calc-silicate schist displays an equigranular foliated granoblastic texture, with small anhedral plagioclase grains partly replaced by sericite, pleochroic olive green to pale yellow-brown subhedral hornblende crystals aligned in the trace of the foliation, aligned pleochroic reddish tan brown to very pale yellow biotite flakes, and small anhedral clear quartz grains.

Garnet forms very pale pink euhedral porphyroblastic crystals in the vicinity of the quartz-rich band.

Quartz-plagioclase-hornblende-apatite calc-silicate band is dominated by large anhedral grains of quartz, and small anhedral plagioclase grains that tend to be concentrated in plagioclase-rich bands. Pleochroic olive green to very pale yellow-brown hornblende tends also to be concentrated in monomineralic laminae. Biotite forms pleochroic flakes scattered irregularly through the band. Apatite builds euhedral equant crystals, characteristically colourless with high relief and very low birefringence. Garnet occurs as scattered euhedral crystals, some containing cores of granular clinozoisite aggregates.

#### INTERPRETATION:

This sample represents a layered sedimentary rock, with layers variably of semi-pelitic to calc-silicate compositions and siliceous compositions. The layered sedimentary sequence suffered complete recrystallisation in response to regional metamorphism in the amphibolite facies. Layers recrystallised to assemblages that reflect their primary compositions:

- i) Semi-pelitic layers recrystallised to assemblages of plagioclase + biotite + minor quartz + garnet.
- ii) Calc-silicate layers recrystallised to assemblages of plagioclase + hornblende + biotite + quartz + minor garnet.
- iii) Siliceous calc-silicate layers recrystallised to assemblages of quartz + plagioclase + minor hornblende + biotite + garnet + apatite + clinozoisite.

Note that, although the rock has the appearance of a uniform dark green rock with a siliceous 'vein', there is a significant mineralogical distinction between the two dark bands: one is hornblende-free and quartz-poor, whilst the other is hornblende-rich and quartz-rich. The quartz-rich 'vein' is interpreted to represent primary compositional layering, which separates the two compositionally distinct dark layers.

Minor retrogressive alteration has affected the rock, mainly in the form of incipient illitic clay alteration of plagioclase. A trace of opaques formed in some layers, but its relationship to alteration is unclear.

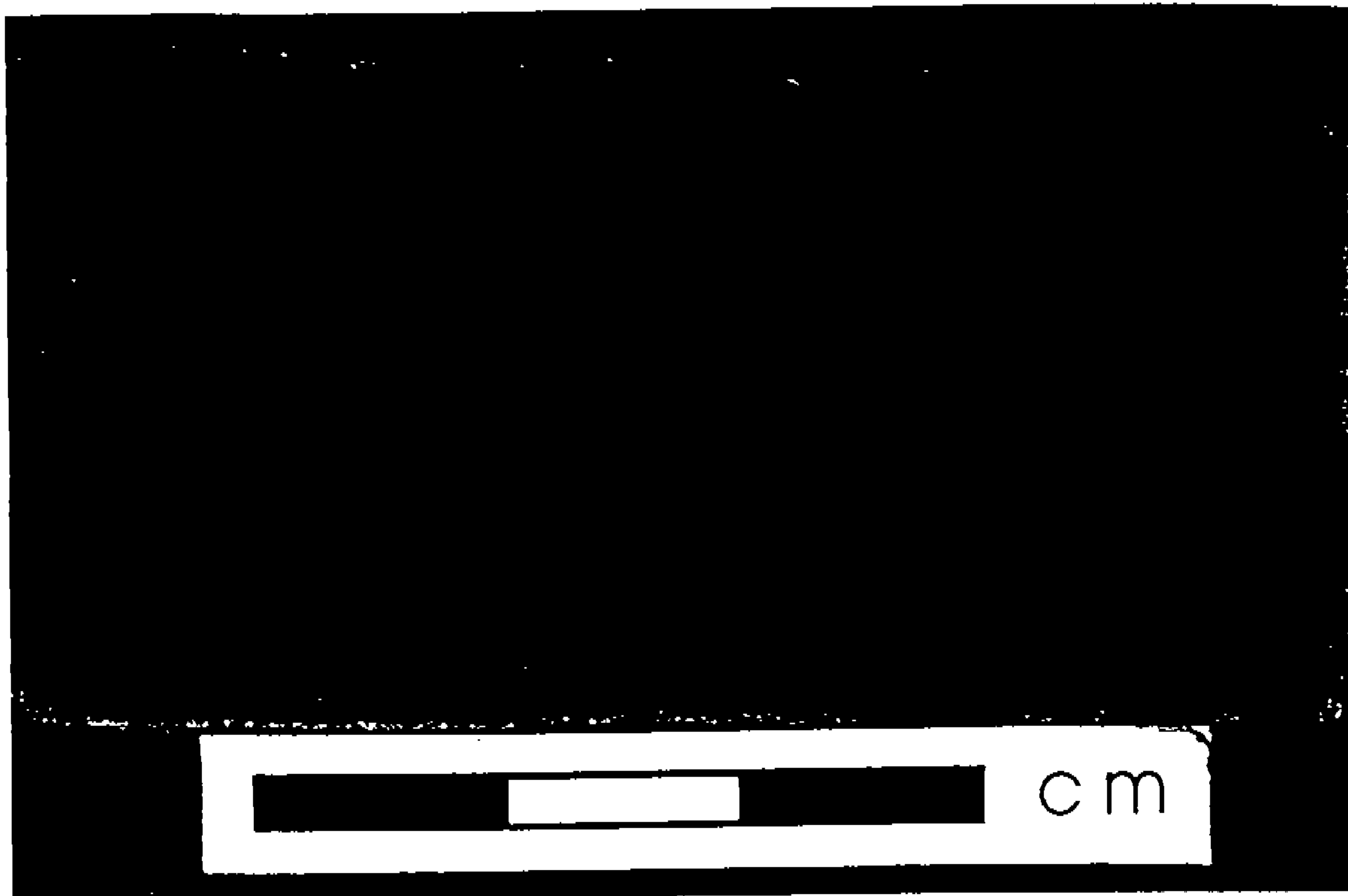


PLATE 17 SAMPLE KPL01, 288.9 (Macro photograph of sawn core, wet, bar for scale. Film 1 Frame 9) In this quartzofeldspathic gneiss, indistinct banding (oriented NW-SE) is defined by variable abundances of plagioclase, quartz, K-feldspar, biotite and hornblende.

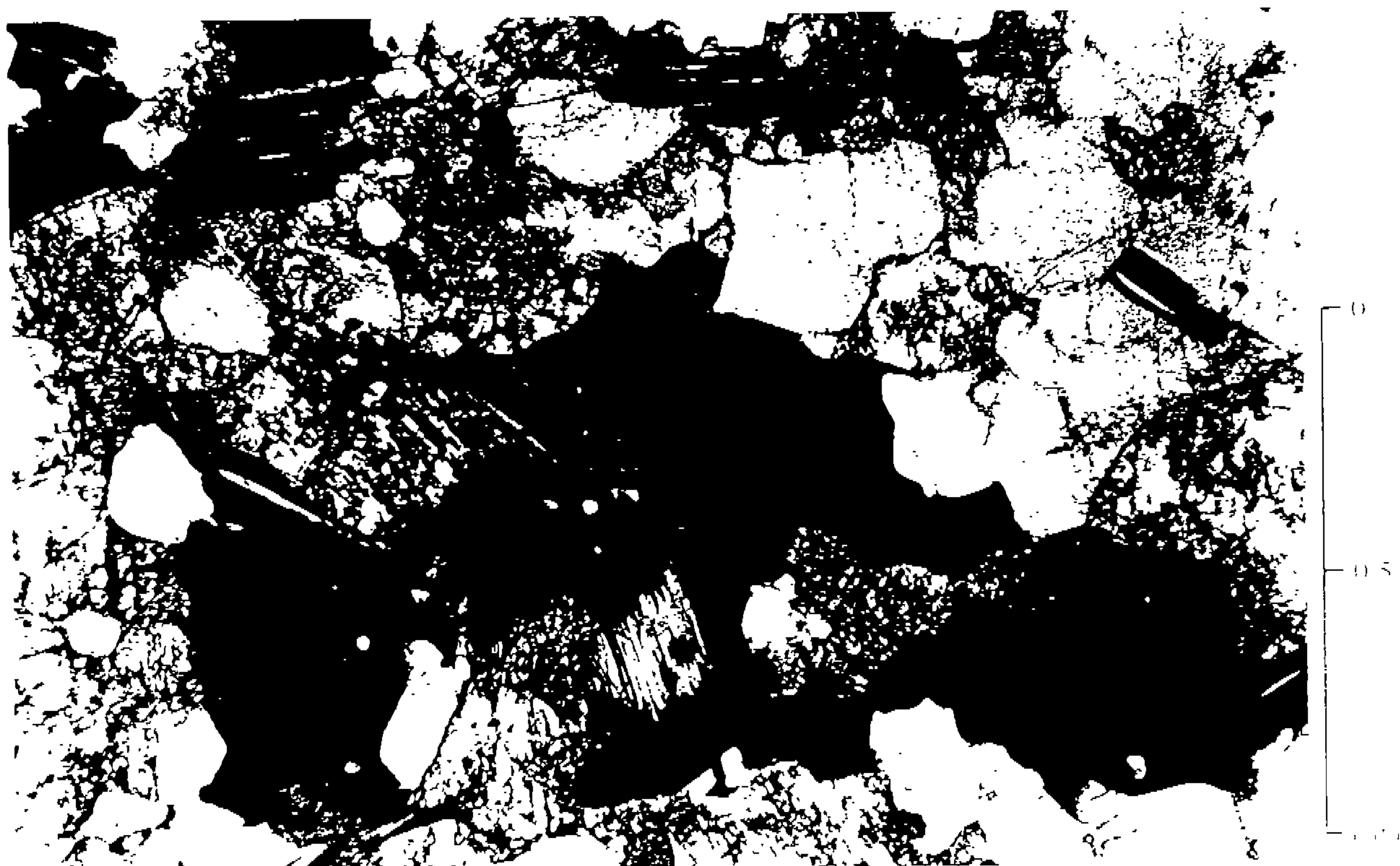


PLATE 18 SAMPLE KPL01, 288.9 (Transmitted plane polarized light x5. Film 2 Frame 11) In this quartzofeldspathic gneiss, plagioclase (pale, with fine, wavy grains) have suffered in situ dissolution, but quartz (colorless), hornblende (dark green) and biotite (brown) remain fresh.

SAMPLE : KPE01, 288.9 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : KPE01, 288.9

HAND SPECIMEN : The drill core sample represents a compositionally uniform grey crystalline rock composed of equant grey felsic grains and small black aligned ferromagnesian grains that define a foliation through the rock.

The section offcut accepted a positive yellow stain for K-feldspar, confirming it occurs in moderate abundance as ragged disseminated grains concentrated in an indistinct band.

ROCK NAME : **Biotite-hornblende quartzo-feldspathic gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase (incl. ?illite, ?zoisite)	40	Metamorphic (incl. alteration)
Quartz	35	Metamorphic
K-feldspar (microcline)	10	Metamorphic
Biotite (incl. trace chlorite)	8	Metamorphic (incl. alteration)
Hornblende	5	Metamorphic
Sphene	Tr	Metamorphic
Apatite	Tr	Metamorphic
Zircon	Tr	?Relict primary / ?metamorphic

In thin section, this sample displays a medium-grained granoblastic metamorphic texture with weak foliation, and only weak selective retrogressive alteration.

Plagioclase is moderately abundant, forming equant anhedral to subhedral grains ~0.4-1.0 mm in size. Some display twinning but compositional zoning is absent. All display partial replacement by small fibrous phyllosilicate flakes and patches (possibly illitic clay), and minor small grains and aggregates of an epidote-group mineral (probably zoisite).

Quartz is moderately abundant, occurring as equant anhedral grains with somewhat lobate shapes, ~0.4-1.0 mm in size. They display only weak shadowy strain extinction.

K-feldspar is moderately abundant, forming anhedral interstitial clear grains scattered somewhat irregularly through the rock. They display the combined albite and pericline twinning that is characteristic of microcline.

Biotite occurs in significant amount as well-crystallised flakes ~0.4-1.0 mm long, distributed more-or-less uniformly through the rock but aligned in the trace of a foliation. Their pleochroism from red to pale yellow suggests a strongly reduced composition. Some biotite flakes have suffered partial replacement along cleavage traces by pleochroic green chlorite.

Hornblende occurs in minor amount as anhedral grains ~0.2-1.0 mm in size. They are scattered through the rock, but locally are concentrated in small monomineralic aggregates aligned in the trace of the foliation. Pleochroism from olive brownish green to very pale buff brown confirms a genuine Al- and Ti-rich hornblendic composition.

Sphene is present in trace amount as small lobate grains in close association with hornblende and biotite.

Apatite occurs as small equant subhedral crystals, mostly in interstitial quartz.

Zircon occurs in trace amount as small euhedral stumpy terminated crystals, located within quartz, plagioclase and biotite. Some display growth zoning.

#### INTERPRETATION:

This sample has suffered metamorphic recrystallisation under amphibolite facies conditions during a regional metamorphic event. This generated the observed foliated granoblastic assemblage of plagioclase + quartz + K-feldspar + biotite + hornblende + trace apatite + sphene.

The nature of the precursor rock has been obscured by the metamorphic effects, but it appears to have been broadly quartzo-feldspathic in composition. Small zoned zircon crystals appear to represent the only preserved primary phase. The euhedral shape of the zircon crystals is consistent with a primary igneous origin.

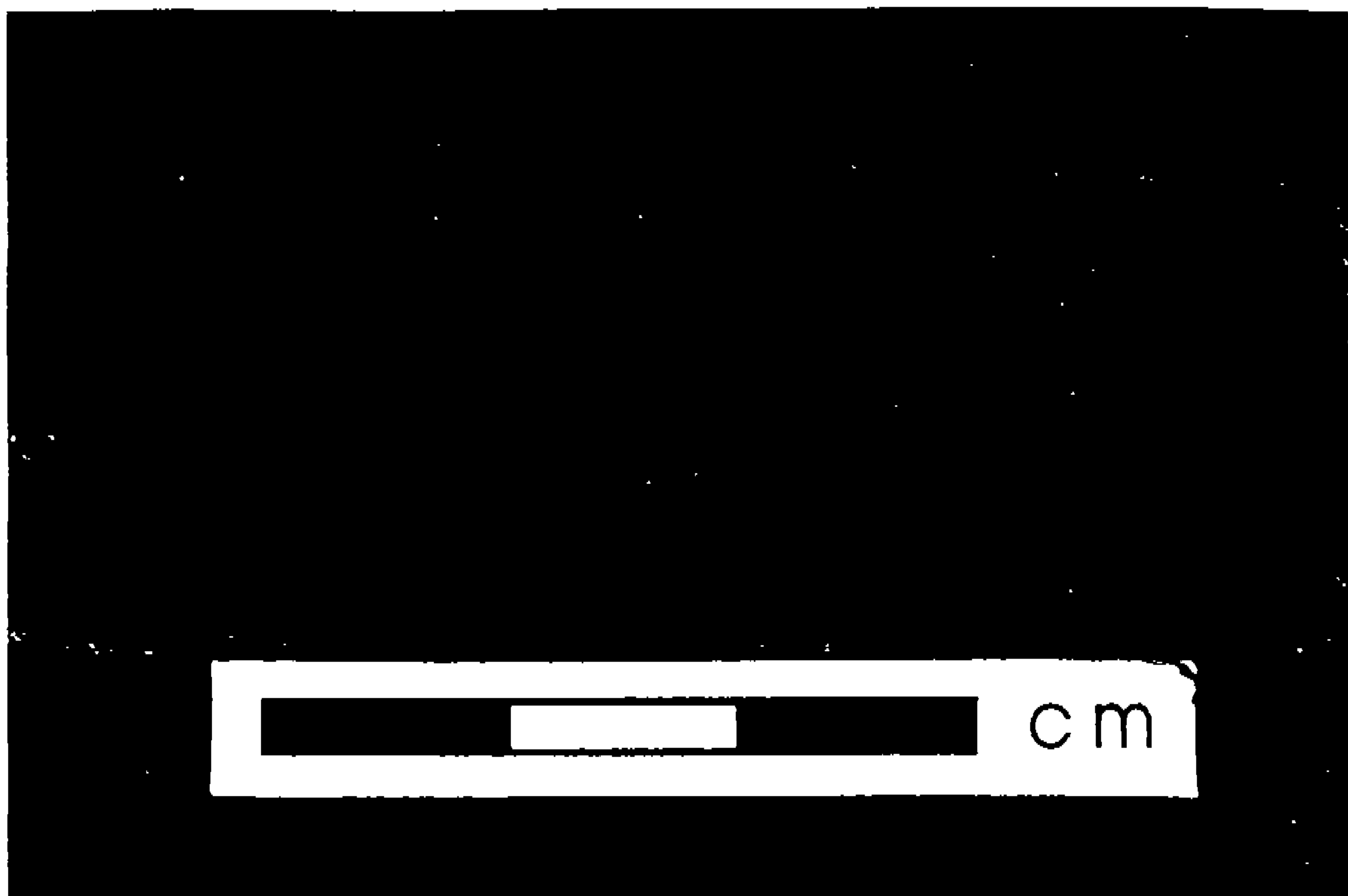


PLATE 19 SAMPLE KPI 01-2914 (Macro photograph of sawn core - wet, bar for scale - Film 1 - Frame 10). In this quartzofeldspathic gneiss, indistinct mineralogical banding (oriented NW-SE) is defined by concentrations of K-feldspar (white) and plagioclase (pink) in felsic bands. Note the pinkish colour of the retrogressed plagioclase grains (mainly illitic clay, but also with minor submicroscopic hematite to give the pink colour).

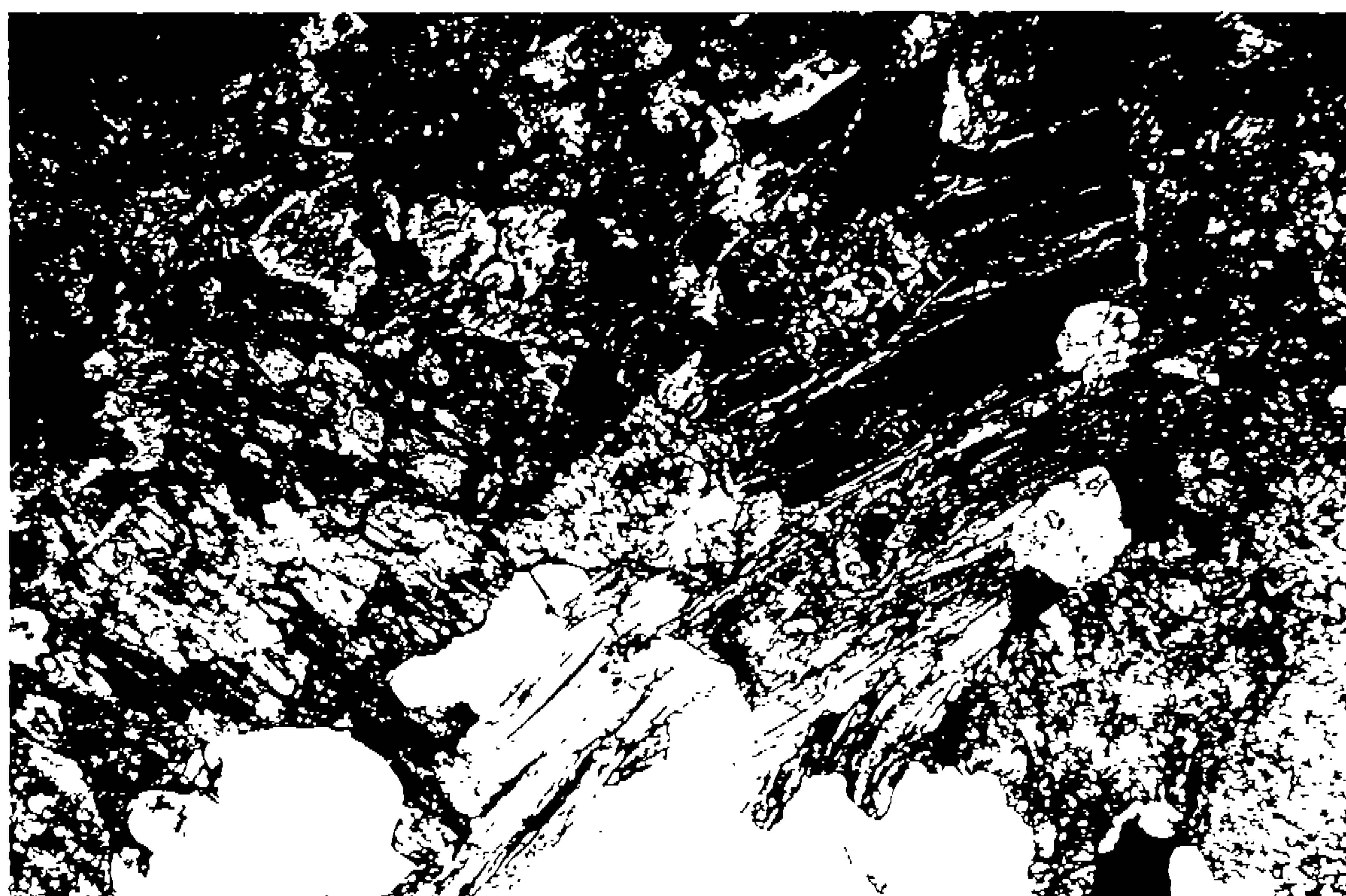


PLATE 20 SAMPLE KPI 01-2914 (Transmitted light - crossed polarizers with condenser x5 - Film 2 - Frame 12). In this view of quartzofeldspathic gneiss, biotite (centre-right) - reddish brown flake - and quartz (bottom - white) remain fresh, but hornblende (large anhedral grain - top-left) is partly replaced by chlorite and small irregular carbonate grains, and plagioclase (centre-far-right) is partly replaced by minute Fe-clay.

SAMPLE : KPE01, 291.4 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : KPE01, 291.4

HAND SPECIMEN : The drill core sample represents a medium-grained crystalline rock composed of abundant pale pink felsic grains, with indistinct mineralogical banding defined by concentrations of white grains and mafic grains. A moderate foliation is defined by preferred orientation of aligned mafic grains and felsic bands.

The section offcut accepted a positive yellow stain for K-feldspar, confirming it occurs in moderate abundance in indistinct felsic bands.

ROCK NAME : **Moderately retrogressed biotite(-hornblende)  
quartzo-feldspathic gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase (incl. ?illite)	45	Relict metamorphic (incl. alteration)
Quartz	25	Metamorphic
K-feldspar (microcline)	20	Metamorphic
Biotite	5	Metamorphic
Hornblende (incl. chlorite, calcite)	5	Relict metamorphic (incl. alteration)
Apatite	Tr	Metamorphic
Zircon	Tr	?Relict primary / ?metamorphic

In thin section, this sample displays a medium- to coarse-grained granoblastic texture with weak foliation, modified by selective alteration.

Most of the rock is composed of a medium- to coarse-grained granoblastic mosaic of anhedral grains ~1-2 mm in size of plagioclase (severely replaced by massive fine-grained phyllosilicate mats, possibly illitic clay, with a trace of submicroscopic hematite), clear unstrained quartz, and K-feldspar with combined albite and pericline twinning characteristic of microcline.

Biotite forms pleochroic reddish brown to pale yellow flakes mostly ~0.5-1.0 mm long, whose weak preferred orientation contributes to a structure through the rock. Most are quite fresh, but some have suffered incipient alteration along cleavage traces by green chlorite.

Hornblende formed large anhedral grains up to ~3 mm in size, partly moulded on plagioclase grains. The hornblende is pleochroic in greens, but has suffered severe replacement by fine-grained drab green chlorite and ragged small calcite grains and aggregates.

Apatite forms small stumpy colourless prisms, in quartz and in biotite flakes.

Zircon occurs in trace amount as small euhedral stumpy terminated crystals, mainly located in quartz and biotite.

#### INTERPRETATION:

This sample has suffered recrystallisation under regional metamorphic conditions in the amphibolite facies. This generated the observed foliated granoblastic assemblage of plagioclase +

quartz + K-feldspar + biotite + hornblende + minor apatite. All primary mineralogical and microtextural features have been destroyed, except perhaps for accessory primary zircon which may have survived the metamorphic event. The precursor rock is inferred to have been broadly quartzo-feldspathic in composition. Subsequent retrogressive alteration generated phyllosilicate (illite) after plagioclase, and chlorite + calcite after hornblende.

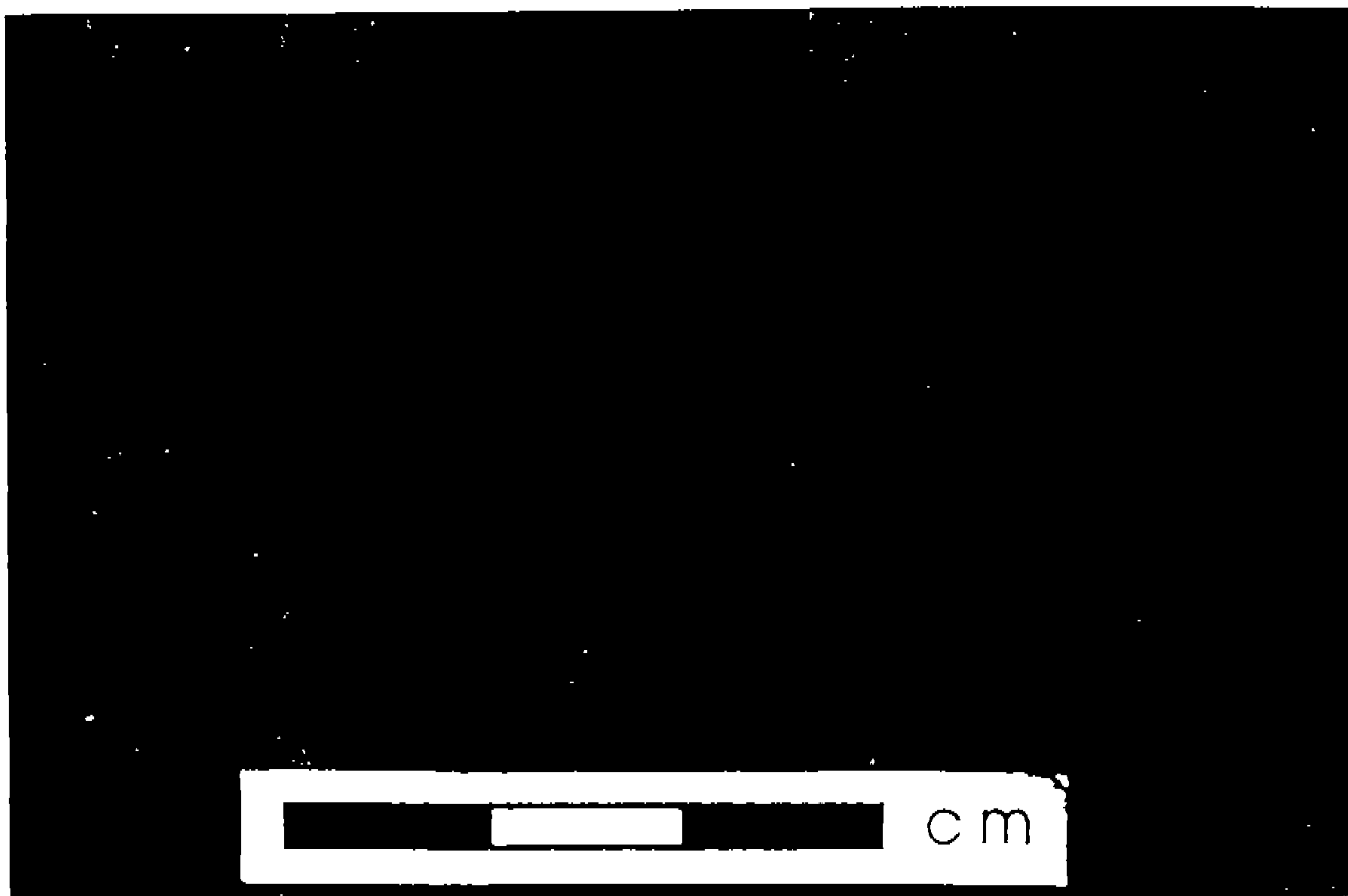


PLATE 21. SAMPLE KPI 01 - 307 (Macrophotograph of sawn core, wet, bar for scale. Film 1 Frame 11) In this quartzofeldspathic gneiss, banding is defined by variable abundances of plagioclase, quartz, biotite and minor K-feldspar and hornblende.



PLATE 22. SAMPLE KPI 01 - 307 (Transmitted light, crossed polarisers, x5. Film 2 Frame 13) In this weakly altered quartzofeldspathic gneiss, prehnite (bright blue-red, yellow at centre and upper right) forms alteration lenses in the cleavage trace of biotite flake. Illite clay forms tiny alteration flecks in plagioclase grains (scattered through view). Hornblende (grains at lower left) and quartz (whites) remain fresh.

SAMPLE : KPE01, 307 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : KPE01, 307

HAND SPECIMEN : The drill core sample represents a medium-grained grey crystalline rock, with a moderately strong structure defined by indistinct felsic bands and aligned dark ferromagnesian grains.

The section offcut accepted a positive yellow stain for K-feldspar, confirming it occurs in moderate abundance as disseminated ragged grains concentrated in coarser felsic bands.

ROCK NAME : **Weakly retrogressed biotite(-hornblende) quartzo-feldspathic banded gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase (incl. ?illite, prehnite, epi.)	52	Metamorphic (incl. alteration)
Quartz	30	Metamorphic
K-feldspar (microcline)	5	Metamorphic
Biotite (incl. chlorite)	10	Metamorphic (incl. chlorite)
Hornblende	2	Metamorphic
Apatite	Tr	Metamorphic
Sphene	Tr	Metamorphic
Zircon	Tr	?Relict primary / ?metamorphic
Epidote (?clinozoisite)	Tr	Fracture filling

In thin section, this sample displays a medium-grained granoblastic metamorphic texture, modified by weak selective alteration.

Plagioclase occurs in moderate abundance as equant anhedral grains ~0.4-2.0 mm in size. They are twinned but not zoned, and most have suffered partial replacement by fine fibrous phyllosilicate flakes (possibly illitic clay), and minute microgranular aggregates (an epidote-group mineral, possibly zoisite). Rarely, plagioclase has suffered partial replacement by ragged small grains and patches of prehnite (colourless, first order yellow to red interference colours, parallel extinction).

Quartz forms anhedral grains that range in size ~0.2-2.0 mm in size (mostly ~0.4-1.0 mm). Although distributed throughout the rock, it is more abundant and forms larger grains in indistinct felsic bands parallel to foliation. All of the quartz grains display weak shadowy strain extinction.

K-feldspar (microcline) occurs in minor amount as anhedral clear grains similar in size to the plagioclase and quartz. Combined albite and pericline twinning ('tartan' twinning) is commonly developed.

Biotite forms well-crystallised flakes ~0.4-1.0 mm long, pleochroic from reddish brown to very pale yellow (reduced composition). It is distributed throughout the rock, but is less abundant in the indistinct felsic bands. A preferred orientation of the biotite contributes to a structure through the rock, parallel to the indistinct mineralogical banding. A trace of chlorite forms around margins and along cleavages of some flakes, and prehnite (colourless, with first order interference colours) forms swollen lensoidal fillings in the cleavage traces of some biotite flakes.

Hornblende occurs in minor amount as anhedral grains ~0.2-1.0 mm in size, pleochroic from olive green to pale buff brown. They are sparsely scattered through the rock.

Apatite occurs in trace amount as small colourless stumpy crystals located in quartz, plagioclase and biotite.

Sphene is rare, forming small angular grains at margins of some biotite flakes.

Zircon is uncommon, forming small euhedral prismatic crystals located in quartz and biotite. Some display growth zoning.

Uncommon thin discontinuous fractures cut the rock, and are filled by an epidote-group mineral (possibly clinozoisite).

#### INTERPRETATION:

This sample has suffered recrystallisation and mild deformation under regional metamorphic conditions in the amphibolite facies. This has generated the observed granoblastic assemblage of plagioclase + quartz + K-feldspar + biotite + hornblende + minor apatite + sphene. The olive green colour of the hornblende supports amphibolite facies of metamorphism. During metamorphism, indistinct mineralogical banding and mild foliation developed. Subsequent weak selective alteration generated minor illitic clay + epidote-group mineral + prehnite after plagioclase, and traces of prehnite + chlorite after biotite.

The nature of the precursor rock has been obscured by the effects of metamorphism. It is inferred to have been a quartzo-feldspathic rock, and a granitoid is supported by the size, shape and abundance of relict accessory zircon crystals. If it was a granitoid, then it was metaluminous such as an I-type granitoid (rather than peraluminous such as an S-type), as indicated by the presence of hornblende in the metamorphic assemblage.

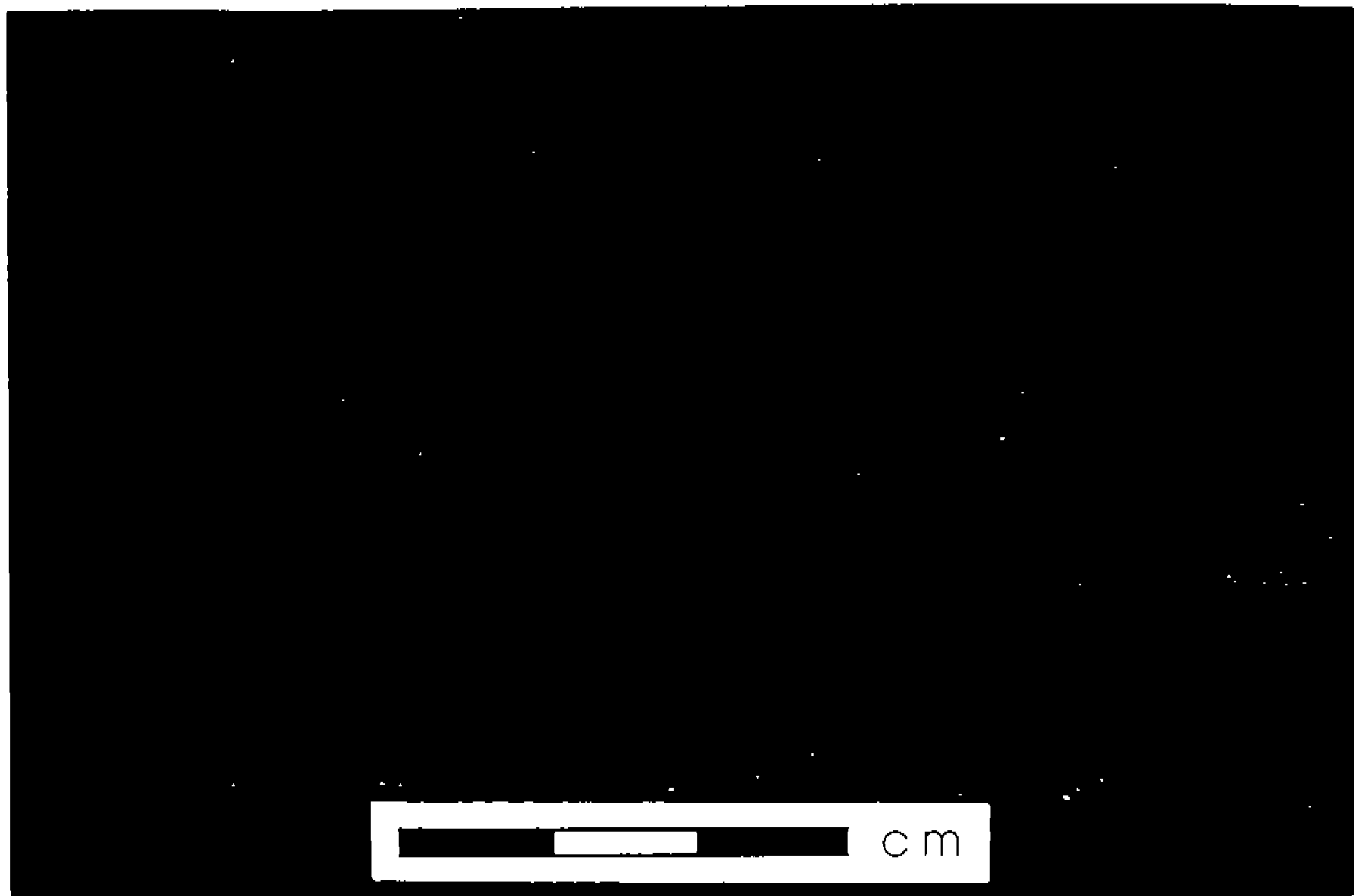


PLATE 23 SAMPLE SHD016-1604 (Macro photograph of sawn core - wet, but for scale - Film 1 - Frame 14) In this faintly banded quartzofeldspathic gneiss, pale yellowish colour of felsic grains arise from illitic alteration of plagioclase.

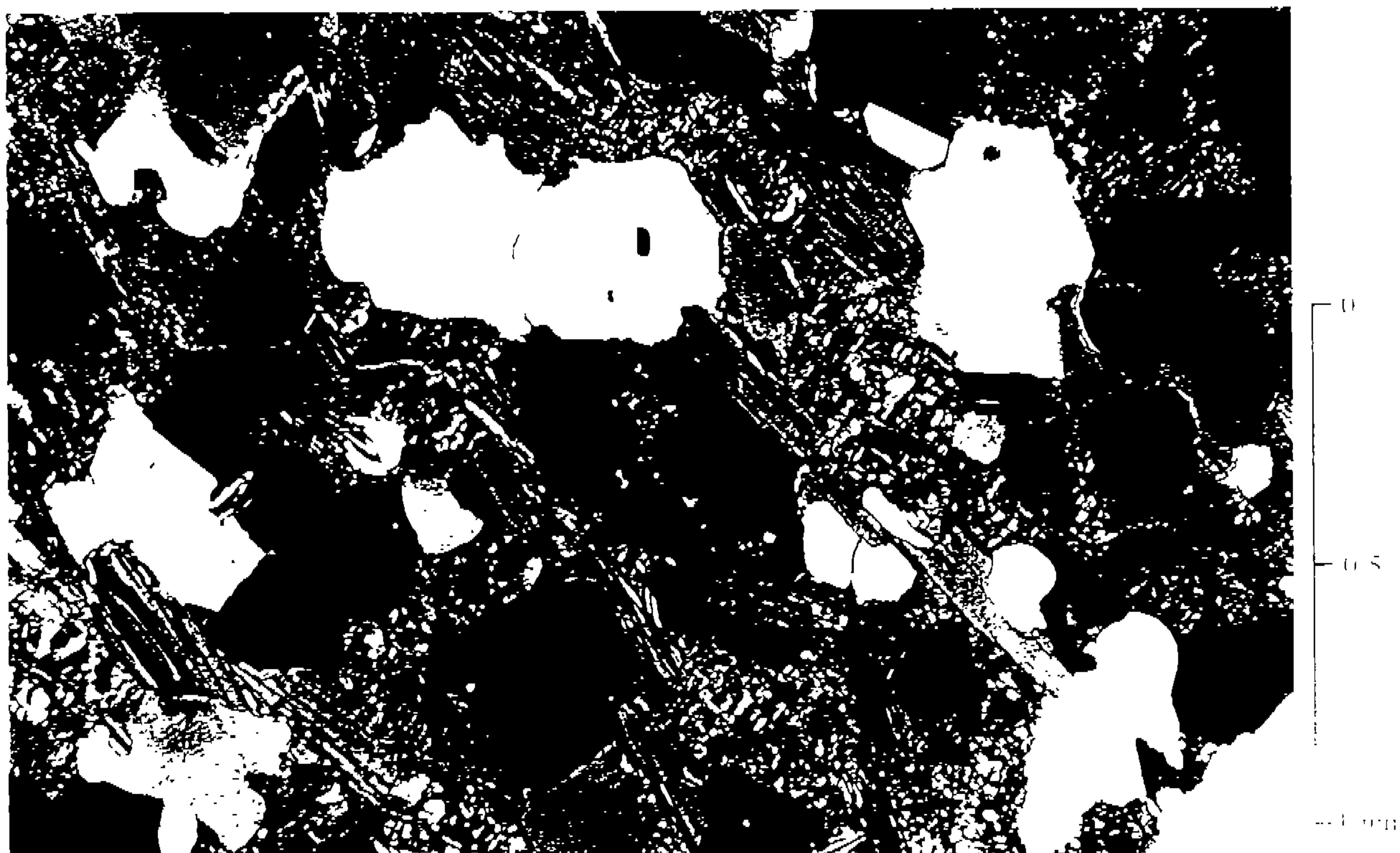


PLATE 24 SAMPLE SHD016-1604 (transmitted light - crossed polarisers - x5 - Film 2 - Frame 14) In this quartzofeldspathic gneiss, illitic clay (tiny yellowish flecks) has completely replaced anhydrous plagioclase grains (now dull mats). Foliated biotite (pink to green flake - oriented  $\sim 2-8^\circ$ ) and quartz (white to grey equant grains) remain fresh.

SAMPLE : SHD016, 160.4 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : SHD016, 160.4

HAND SPECIMEN : The drill core sample represents a fine- to medium-grained crystalline rock composed of waxy grey felsic grains and dark ferromagnesian flakes. A structure is defined by alignment (foliation) of the ferromagnesian flakes, and indistinct mineralogical banding subparallel to foliation defined by variable abundance of ferromagnesians.

The section offcut accepted a positive yellow stain for K-feldspar, indicating it occurs as disseminated ragged grains. Note that altered plagioclase has absorbed the stain, giving an additional false positive stain.

ROCK NAME : **Partly retrogressed banded biotite-muscovite(-?cordierite) quartzo-feldspathic gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Plagioclase	1	Relict metamorphic
Quartz	55	Metamorphic
K-feldspar (microcline)	5 (0-10)	Metamorphic
Biotite (incl. chlorite)	15	Metamorphic (incl. alteration)
Muscovite	2	Metamorphic
Apatite	Tr	Metamorphic
Zircon	Tr	?Metamorphic / ?relict primary
Phyllosilicate (?illitic clay)	21	Alteration
Chlorite	1	Alteration (after ?cordierite)

In thin section, this sample displays an equigranular granoblastic metamorphic texture, with weak foliation and indistinct mineralogical lamination, modified by selective alteration.

Plagioclase was abundant, occurring as anhedral grains ~0.2-0.5 mm in size that are partly moulded on equant quartz grains. All of the plagioclase grains have suffered severe replacement by fine-grained mats of phyllosilicate (probably illitic clay), leaving only rare ragged plagioclase relicts in some grain sites.

Quartz is abundant, occurring as equant anhedral grains distributed more-or-less uniformly through the rock. It is virtually unstrained.

K-feldspar (microcline) occurs in moderate amount in part of the rock (the paler band), where it forms anhedral clear subpoikiloblastic grains up to ~1 mm in size that have enclosed small ovoid quartz grains.

Biotite is moderately abundant, forming well-crystallised flakes ~0.2-0.6 mm long, pleochroic from reddish tan brown to pale straw yellow (i.e. a reduced composition). A moderate preferred orientation of the biotite defines a foliation through the rock. Most flakes are fresh, but some display partial replacement by pleochroic pale green chlorite. Chlorite also occurs as replacement aggregates with minor muscovite, pseudomorphous after rounded grains similar in size to the feldspar and quartz grains that may have been cordierite but none is preserved.

Muscovite occurs in minor amount as relatively well-crystallised flakes, similar in size to biotite and locally interleaved with biotite. Elsewhere it occurs discretely.

Apatite occurs in minor amount as small subhedral equant grains.

Zircon is uncommon, forming tiny subhedral to subrounded grains in quartz and in biotite.

#### INTERPRETATION:

This sample has suffered recrystallisation under regional metamorphic conditions, generating the equigranular granoblastic assemblage of quartz + plagioclase + biotite ± K-feldspar + minor muscovite + apatite. Cordierite may have formed in minor amount. Mineralogical banding is defined by presence of K-feldspar and lesser biotite in indistinct bands subparallel to a moderate foliation. The mineral assemblage is not specific for a particular metamorphic grade, but it is consistent with the amphibolite facies.

Identification of the precursor rock is difficult, owing to complete loss of primary minerals and texture. However, it is considered to have been broadly quartzo-feldspathic in composition, and was peraluminous. The presence of mineralogical banding and the high abundance of quartz support a clastic sedimentary precursor.

Subsequent to metamorphism, low-grade alteration has resulted in virtually complete replacement of plagioclase by a fine-grained phyllosilicate phase (possibly illitic clay), chlorite has replaced ?cordierite, and biotite suffered incipient replacement by chlorite.



PLATE 25. SAMPLE SHD016-168 (Macro photograph of sawn core, wet bar for scale. Film 3 Frame 5). In this partly retrogressed pelitic gneiss, mineralogical banding is defined by aligned thin foliae of sillimanite and biotite (thin dark foliae) and altered plagioclase grains (pale yellow). A large equant grain of garnet (lower left) is replaced by drab dark green chlorite.



PLATE 26. SAMPLE SHD016-168 (Transmitted light, crossed polars x5. Film 2 Frame 15). Dense mats of fibrolitic sillimanite (pale yellow, oriented NW-SE) are aligned on the trace of the foliation with associated biotite and sericite. Note the elongation of the quartz grains (pale grey) in the high strain zone within pelitic gneiss.

SAMPLE : SHD016, 168 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : SHD016, 168

HAND SPECIMEN : The drill core sample represents a laminated gneissic rock composed of subparallel foliated dark grey to black micaceous bands and intervening felsic bands (some waxy pale yellow). The foliation wraps around large round dark green grains (altered garnet porphyroblasts).

The section offcut failed to accept the stain for K-feldspar, suggesting it is absent.

ROCK NAME : **Moderately retrogressed banded biotite-muscovite-garnet-sillimanite gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Biotite	20	Relict metamorphic
Quartz	10	Metamorphic
Sillimanite (fibrolite)	5	Metamorphic
Muscovite	1	Metamorphic
Tourmaline	Tr	Metamorphic
Sericite	54	Alteration
Chlorite	10	Alteration
Opagues	Tr	Alteration

In thin section, this sample displays a partly preserved coarse-grained granoblastic strongly foliated metamorphic texture with mineralogical lamination, modified by moderately strong selective and pervasive alteration.

Biotite was abundant, forming strongly foliated mats of pleochroic reddish tan brown to pale yellow flakes concentrated in parallel laminae, and better-crystallised plates in felsic bands. Much of the biotite has been replaced variably by pleochroic pale green chlorite, and by tiny diffuse flecks and patches of sericite.

Quartz occurs in moderate amount as large anhedral grains ~1-3 mm in size. They tend to be concentrated in quartz-rich laminae, and most grains are elongated in the trace of the foliation and lamination. Most grains are virtually unstrained.

Sillimanite occurs in minor amount as fine fibrous dense mats (fibrolite), in places interleaved with biotite, but elsewhere forming dense swirled mats in cores of altered garnet grains.

Tourmaline is uncommon, forming subhedral ragged aggregates pleochroic in drab greens, within biotite-rich laminae.

White mica occurs in different forms:

- i) Some occurs in minor amount as relatively well-crystallised flakes and plates of muscovite that are considered to represent a metamorphic phase.

- ii) Most occurs as tiny randomly oriented flecks of sericite that form dense replacements after biotite, after large ragged patches of ?plagioclase (but none is preserved for confirmation), and as thin trellisworks filling microcracks in quartz.

Chlorite occurs in two sites:

- i) Some occurs as replacements of biotite flakes.
- ii) Some occurs as dense pale green mats that are pseudomorphous after large ovoid grains (probably garnet, but none is preserved for confirmation).

Opaques are uncommon, forming fine-grained granular aggregates located in chlorite- or sericite-altered areas of the rock.

#### INTERPRETATION:

This sample has suffered complete recrystallisation under regional metamorphic conditions, generating the strongly foliated and laminated assemblage of biotite + quartz + ?plagioclase + garnet + sillimanite + minor muscovite + tourmaline. The mineral assemblage is consistent with the amphibolite facies; there are no mineralogical reasons to indicate progression into the granulite facies. The mineral assemblage suggests a pelitic sedimentary precursor rock.

Subsequent invasion of the rock by hydrothermal fluids caused selective and pervasive low-grade alteration to the assemblage sericite + chlorite + trace opaques.

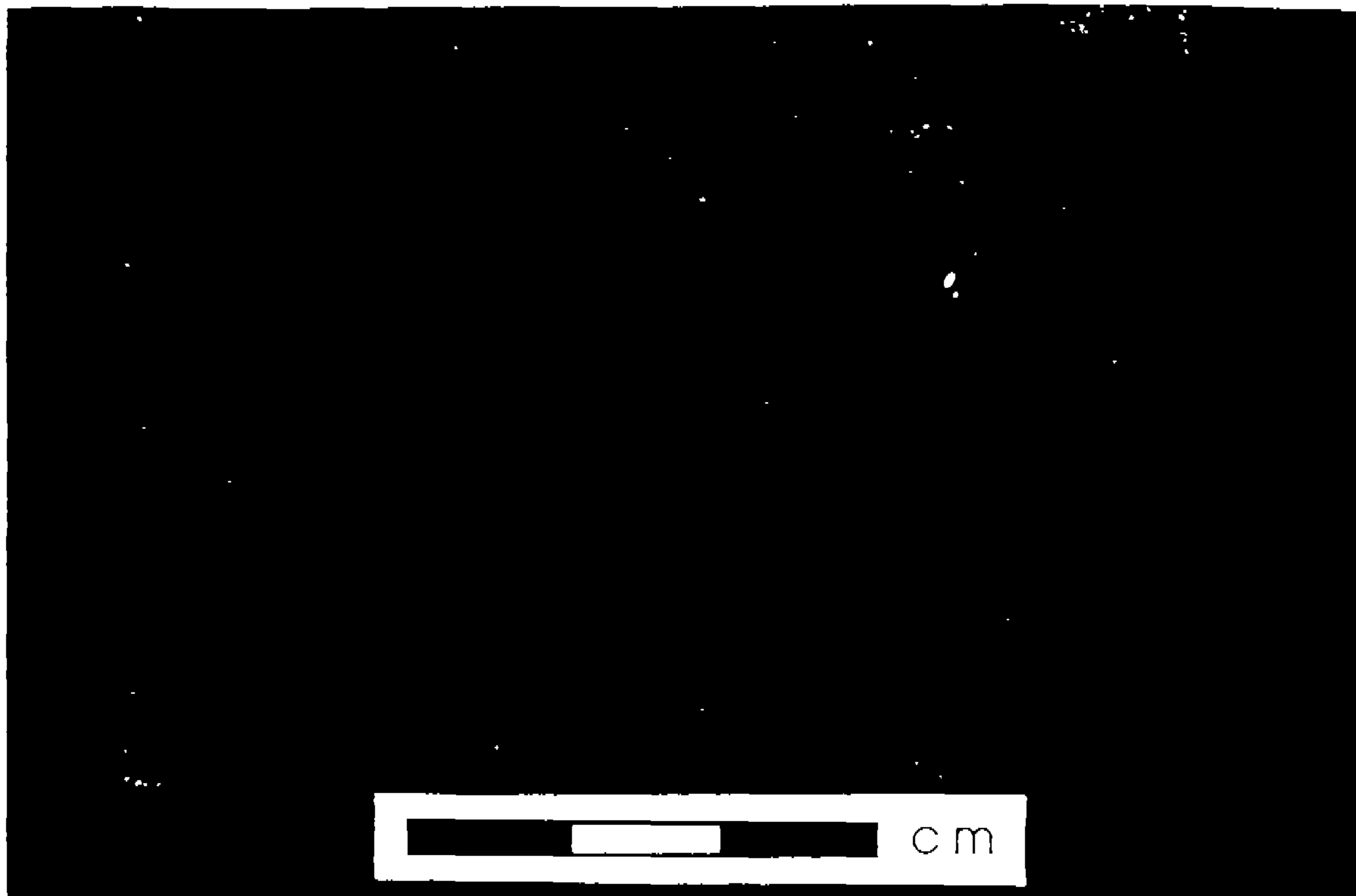


PLATE 27. SAMPLE SHD016, 1953 (Macro photograph of sawn core (wet), bar for scale, Film 1 Frame 17). In this altered pelitic gneiss, thin dark foliac of sillimanite and biotite contribute to definition of the banding and foliation.

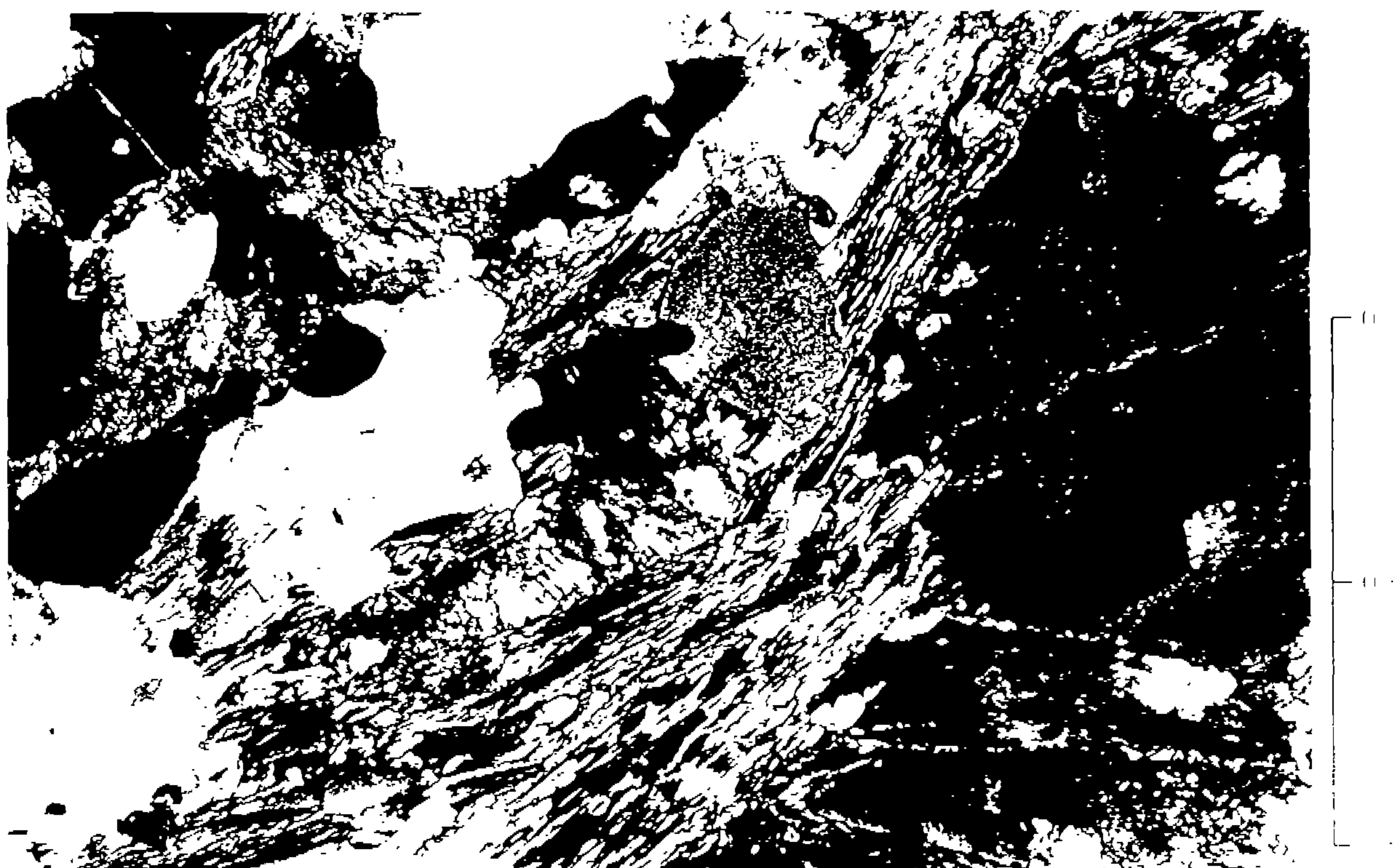


PLATE 28. SAMPLE SHD016, 1953 (Transmitted light, crossed polars, x5, Film 2 Frame 17). In this view of a lower strain zone in pelitic gneiss, alteration chlorite and sericite (after biotite) and sericite (after plagioclase) are moderately abundant. Feldspar (dark grey, far right) and quartz (white to pale grey) remain fresh.

SAMPLE : SHD016, 195.3 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : SHD016, 195.3

HAND SPECIMEN : The drill core sample represents a waxy dull grey crystalline rock, with a strong foliation defined by thin wispy dark foliae.

The section offcut accepted a positive yellow stain for K-feldspar, confirming it occurs in minor amount.

ROCK NAME : **Strongly retrogressed feldspar-biotite-sillimanite-garnet gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	40	Metamorphic
Sillimanite (fibrolite)	5	Metamorphic
K-feldspar (microcline)	2	Metamorphic
Biotite	Tr	Relict metamorphic
Garnet	Tr	Relict metamorphic
Sericite (incl. muscovite)	30	Alteration
Chlorite	20	Alteration
Calcite	<1	Alteration
Leucoxene	Tr	Alteration

In thin section, this sample displays a foliated granoblastic metamorphic texture, with stronger foliation in wispy laminae, modified by selective pervasive alteration.

Quartz is abundant, occurring as equant anhedral subrounded grains ~0.4-1.0 mm in size. In thin bands ~2mm wide, quartz grains are much more elongate (aspect ratios up to ~5:1), suggesting higher strain in these bands.

Sillimanite occurs in moderate amount as very fine fibrolitic mats, concentrated in foliae in the thin high-strain zones with elongate quartz grains. These are the darker foliae observed in hand specimen.

K-feldspar (microcline) is present in minor amount, forming anhedral grains up to ~1 mm in size and displaying the characteristic combined albite and pericline twinning ('tartan' twinning) of this phase. It is distributed irregularly through the rock, being concentrated in poorly-defined bands. This contributes to mineralogical banding of the rock.

Garnet formed uncommon equant subhedral grains, but has suffered almost complete replacement by chlorite, leaving ragged small kernels of garnet (colourless, high relief, isotropic).

Biotite formed well-crystallised flakes ~0.4-1.0 mm in size, distributed more-or-less uniformly through the rock except in the sillimanite-quartz bands. All biotite flakes have suffered severe replacement by intergrown drab green chlorite and sericite, with accessory turbid microgranular leucoxene. Only small ragged flecks of brown biotite are preserved.

Sericite is abundant, and occurs in different sites:

- i) Most occurs as fine-grained dense pseudomorphous replacements of anhedral grains up to ~1 mm in size. These most likely were mainly plagioclase, but none is preserved for confirmation.
- ii) Fine sericite and better-crystallised muscovite occur as replacements of biotite crystals.

Calcite is uncommon, forming small ragged replacement patches in some altered ?plagioclase grains.

#### INTERPRETATION:

This sample has suffered complete recrystallisation in response to a regional metamorphic event, generating the assemblage ?plagioclase + quartz + biotite + sillimanite + K-feldspar + minor garnet. The assemblage is consistent with the amphibolite facies, and a pelitic sedimentary precursor rock is inferred. The sillimanite formed preferentially in thin zones of higher strain, characterised by fibrolite foliae and elongated quartz grains, that were distributed more-or-less regularly through the rock.

Subsequent invasion of the rock by hydrothermal fluids resulted in quite strong selective pervasive alteration. Plagioclase was completely replaced by sericite, biotite suffered severe replacement by chlorite + sericite/muscovite + leucoxene, and garnet was severely replaced by chlorite.



PLATE 29 SAMPLE SHD016, 207.3 (Macro photograph of sawn core - wet - bar for scale, Film 1 - Frame 19). In this altered pelitic gneiss, mineralogical banding is defined by alternating concentrations of felsic minerals (pale yellow - sericite after plagioclase, with quartz) and mafic minerals (chloritised biotite with sillimanite).

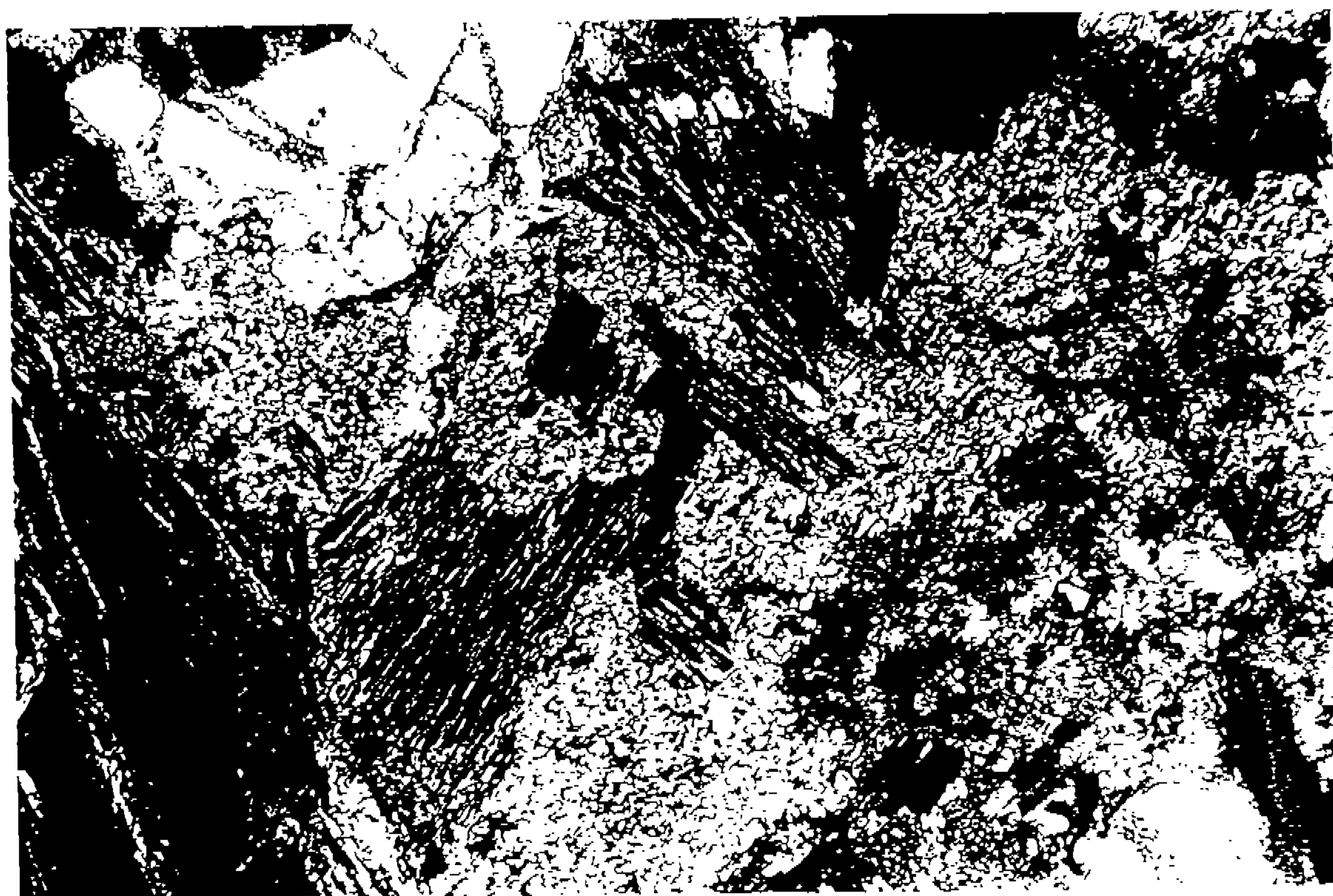


PLATE 30 SAMPLE SHD016, 207.3 (Transmitted light - crossed polarisers - x5, Film 2 - Frame 18). In this pelitic gneiss, alteration sericite (tiny yellow fleck) and minor ragged carbonate grains (high pastel colours - lower right) form a dense replacement mat. Chlorite (anomalous blue - lower left - centre top) has completely replaced biotite flakes. Quartz (pale grey - top - bottom right) remains fresh.

SAMPLE : SHD016, 207.3 (Lower Cahill Formation, Arnhem Land, NT)

SECTION NO. : SHD016, 207.3

HAND SPECIMEN : The drill core sample represents a banded gneissic rock composed of strongly foliated dark grey bands and granular paler yellowish-grey bands.

ROCK NAME : **Strongly retrogressed banded feldspar-biotite-sillimanite-garnet gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	52	Metamorphic
Biotite	10	Relict metamorphic
Sillimanite (fibrolite)	2	Metamorphic
Garnet	Tr	Relict metamorphic
Sericite	25	Alteration
Chlorite	10	Alteration
Calcite	<1	Alteration
Opauques	Tr	Alteration
Leucoxene	Tr	Alteration

In thin section, this sample displays a strongly foliated granoblastic metamorphic texture, with mineralogical banding, modified by selective pervasive alteration.

Quartz is abundant, occurring as anhedral grains in different forms:

- i) Most occurs as large grains ~1-3 mm in size that are concentrated in the felsic, biotite-poor bands. These grains are more-or-less equant in form, and display little or no strain.
- ii) Some occurs as smaller grains up to ~0.4 mm in size. These grains occur in the biotite-rich and sillimanite-bearing bands. These quartz grains are elongate in shape, with aspect ratios up to ~3:1). Although their elongate shapes indicate development under stress, annealing has removed all signs of strain within each grain.

Biotite was abundant. It was concentrated in strongly foliated dense mats that contribute to the structure through the rock, and better-crystallised discrete foliated flakes formed in minor amount in the felsic bands. All of the biotite flakes have suffered partial to complete replacement by fine-grained sericite and slightly coarser-grained muscovite, and by optically continuous pale green chlorite with associated microgranular leucoxene aggregates.

Sillimanite occurs in minor amount as strongly foliated fibrolitic laminae that occur within the biotite-rich bands.

Garnet formed equant but anhedral grains up to ~1 mm in size, sparsely and irregularly scattered through the rock. All grains have suffered severe replacement by pleochroic drab green chlorite, leaving relict ragged cores of colourless isotropic garnet.

Sericite is abundant. Much occurs as fine-grained massive replacement aggregates after ragged precursor grains (probably mainly plagioclase). Some sericite occurs as fine alteration patches in the biotite-rich bands.

Calcite is uncommon, forming ragged alteration patches associated with sericite.

Opauques are rare, forming small ragged aggregates very irregularly scattered through the rock.

#### INTERPRETATION:

This sample has suffered complete recrystallisation in response to regional metamorphism in the amphibolite facies. This generated a foliated banded assemblage of quartz + ?plagioclase + biotite + sillimanite + garnet. Banding was defined by concentration of biotite + sillimanite (darker bands in hand specimen) and quartz + feldspar (paler bands in hand specimen). Stronger foliation of the darker bands (including elongation of quartz grains) indicates that these bands accepted a higher degree of strain during metamorphic recrystallisation. The mineralogy is consistent with a pelitic sedimentary precursor rock.

Subsequent invasion of the rock by hydrothermal fluids generated the low-grade alteration assemblage of sericite + chlorite + trace leucoxene + calcite + opaques.