

**APPENDIX 2d:**

**EL 2505**

**CARAMAL**

**1998**

**MASON GEOSCIENCE PTY LTD**

**PETROGRAPHIC REPORT**

**#2487**

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

ACN 063 539 686

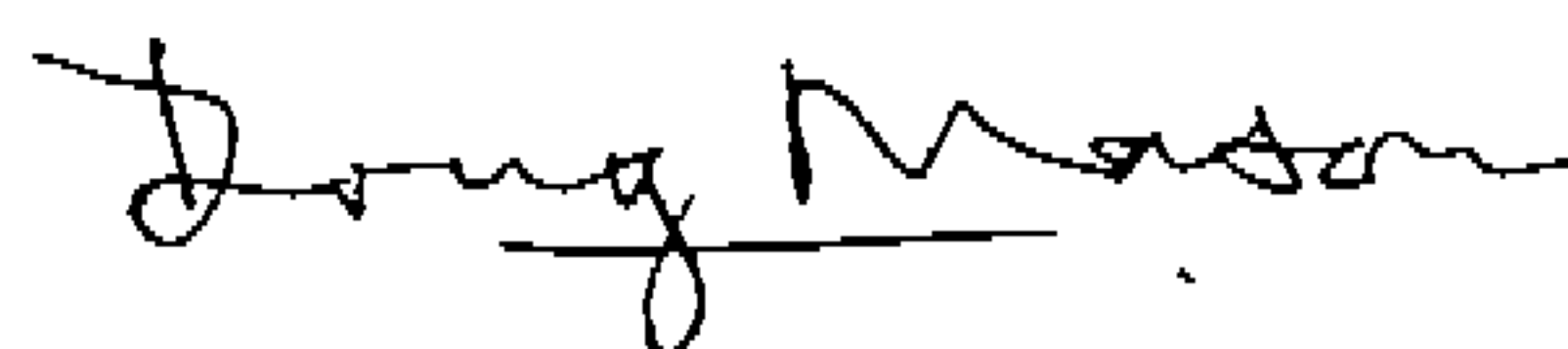
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REPORT TITLE	<b>Petrographic Descriptions for Fourteen Drill Core Rock Samples, Northern Territory</b>
REPORT #	2487
CLIENT	AFmeco Mining and EXploration Pty Ltd
ORDER NO.	3672
CONTACT	Mr John Fabray

REPORT BY	Dr Douglas R. Mason
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SIGNED



for Mason Geoscience Pty. Ltd.

DATE	13 November 1998
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## Petrographic Descriptions for Fourteen Drill Core Rock Samples, Northern Territory

### SUMMARY

#### 1. Rock Samples

- Fourteen drill core rock samples from the Northern Territory have been studied using standard petrographic methods (TABLE 1).

#### 2. Brief Results

- Primary rock types
  - Most samples represent precursor rocks of inferred sedimentary origin, including quartzose, quartzo-feldspathic, and pelitic compositions.
  - One sample (CA 54, 112.3m) represents a basaltic breccia of uncertain mode of formation, and one sample (SHRD 20, 92.5m) represents an intrusive quartz dolerite.
- Metamorphism
  - The sedimentary rock sequence suffered complete recrystallisation under amphibolite facies regional metamorphic conditions, generating new foliated granoblastic assemblages that reflected their primary bulk compositions. Many of these assemblages are now obscured by subsequent alteration (see below), but they included mineral assemblages of plagioclase, quartz, K-feldspar, biotite, muscovite, garnet and sillimanite.
  - The basaltic breccia and quartz dolerite samples did not suffer the regional metamorphic event, and therefore are inferred to be much younger than the sedimentary sequence.
- Alteration
  - All samples have suffered selective pervasive hydrothermal alteration, ranging from low-intensity (partial to good preservation of primary minerals and good preservation of primary textures) to medium-intensity (complete loss of primary minerals but partial preservation of primary texture).
  - In most samples the alteration is of chlorite-sericite-hematite type, but one sample (CA 51, 79.5m) contains alteration of chlorite-illite type and therefore appears to be of lower alteration grade.
  - Alteration intensity appears to be zonally distributed in drill hole CA 54, in which alteration intensity decreases with depth. Highest intensity of alteration is observed in the chlorite-quartz-hematite altered basaltic breccia at 112.3m, with less intense alteration in chlorite-sericite altered gneissic rocks to ~320m down-hole.
  - In drill hole SHRD 20, alteration intensity is highest in the sericite-chlorite altered quartz dolerite. Like the basaltic breccia in CA 54, the dolerite occurs at shallowest depth.
  - Veins of space-filling type are observed in some samples. In SHRD 20 (227.9m), a vein is filled by quartz + chlorite and is assumed to have formed synchronously with the pervasive wall rock chlorite-sericite-quartz alteration assemblage. In sample CA 56 (144.8m), brittle fractures were filled by the assemblage apatite + hematite, whilst quartzite wall rock has suffered selective alteration by sericite + hematite.

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

SAMPLE	ROCK NAME	MINERALOGY*		
		Primary**	Metamorphic/alteration***	Veins
CA 51, 79.5m	Chlorite-illite altered micaceous gneiss	Zir	Qtz,mus,apa,bio,zir; Chl,ill,opq,rut	-
CA 54, 112.3m	Chlorite-quartz-hematite altered basaltic breccia	-	Chl,qtz,opq(hem),spn	Qtz,chl,opq(hem),spn
CA 54, 315.6m	Chlorite-sericite altered feldspathic gneiss	?Zir	Kf,qtz,mon,zir; Chl,ser,chl,spn,opq	-
CA 54, 316.4m	Chlorite-sericite altered mica-sillimanite quartzo-feldspathic gneiss	?Zir	Qtz,Kf,mus,sill,bio,apa,zir; Chl,ser,rut	-
CA 54, 319.2m	Low-intensity sericite-chlorite altered mica-sillimanite quartzo-feldspathic gneiss	?Zir	Qtz,Kf,pla,bio,mus,sill,zir; Ser,chl,rut	-
CA 54, 324.6m	Low-intensity chlorite-sericite-carbonate altered mica-sillimanite quartzo-feldspathic gneiss	-	Pla,qtz,Kf,mus,bio,sill; Chl,ser,rut	-
CA 56, 144.8m	Apatite-hematite veined, low-intensity sericite-hematite altered quartzite	-	Qtz,mus,apa,mon,zir; Ser,opq(hem)	Apa,opq(hem)

**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; chl = chlorite; grp = graphite; hem = hematite; ill = illitic clay; Kf = K-feldspar; leu = leucoxene; mon = monazite; mus = muscovite; opq = opaque phase; pla = plagioclase; qtz = quartz; rut = rutile; ser = sericite; sill = sillimanite; spn = sphene; zir = zircon; ? = uncertain paragenesis or mineral identification.

## **1. INTRODUCTION**

Fourteen drill core rock samples were received from Mr John Fabray (AFmeco Mining and EXploration Pty Ltd, Winnellie, Northern Territory) on 19 October 1998.

Particular requests were:

- i) To prepare a thin section and routine petrographic description for each sample (service code PETRO 2.1).
- ii) To provide a macrophotograph and photomicrograph for each sample (as per previous batches).

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. Standard thin sections were obtained from an external commercial laboratory (Amdel Limited, Thebarton, South Australia).

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

Macrophotographs were taken from each drill core sample using 35mm photography including camera stand and ring flash to provide even lighting conditions. Photomicrographs were taken using standard 35mm photomicrographic equipment attached to the petrographic microscope.

## **3. PETROGRAPHIC DESCRIPTIONS**

The petrographic descriptions are provided in the following pages.

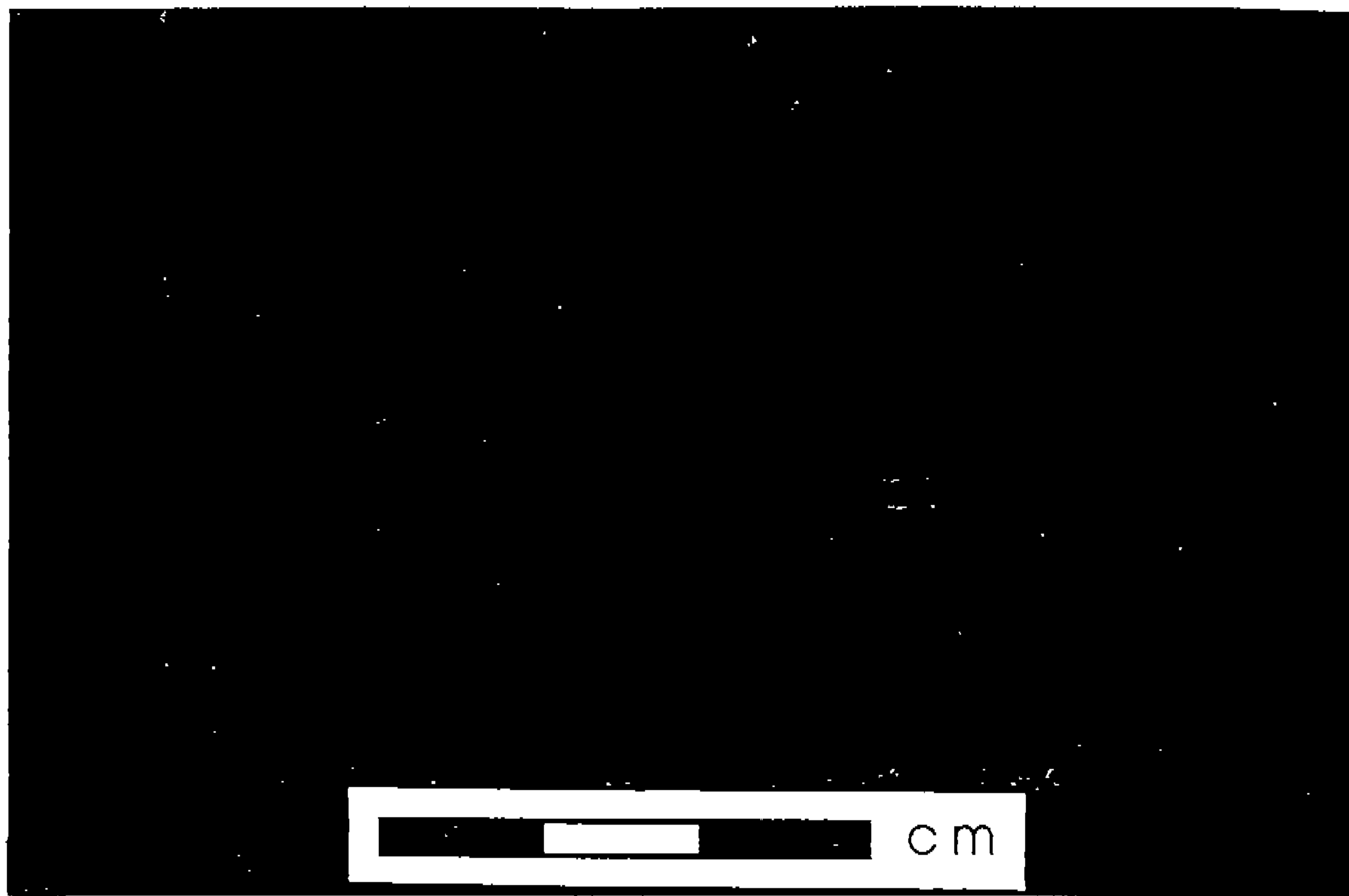


PLATE 1 SAMPLE CA 51 - 79.5m (Macro photograph sawn drill core wet film - Frame 1)

This view shows the dark greenish grey colour of this altered micaceous gneiss. Foliation is oriented NNE-SSW.

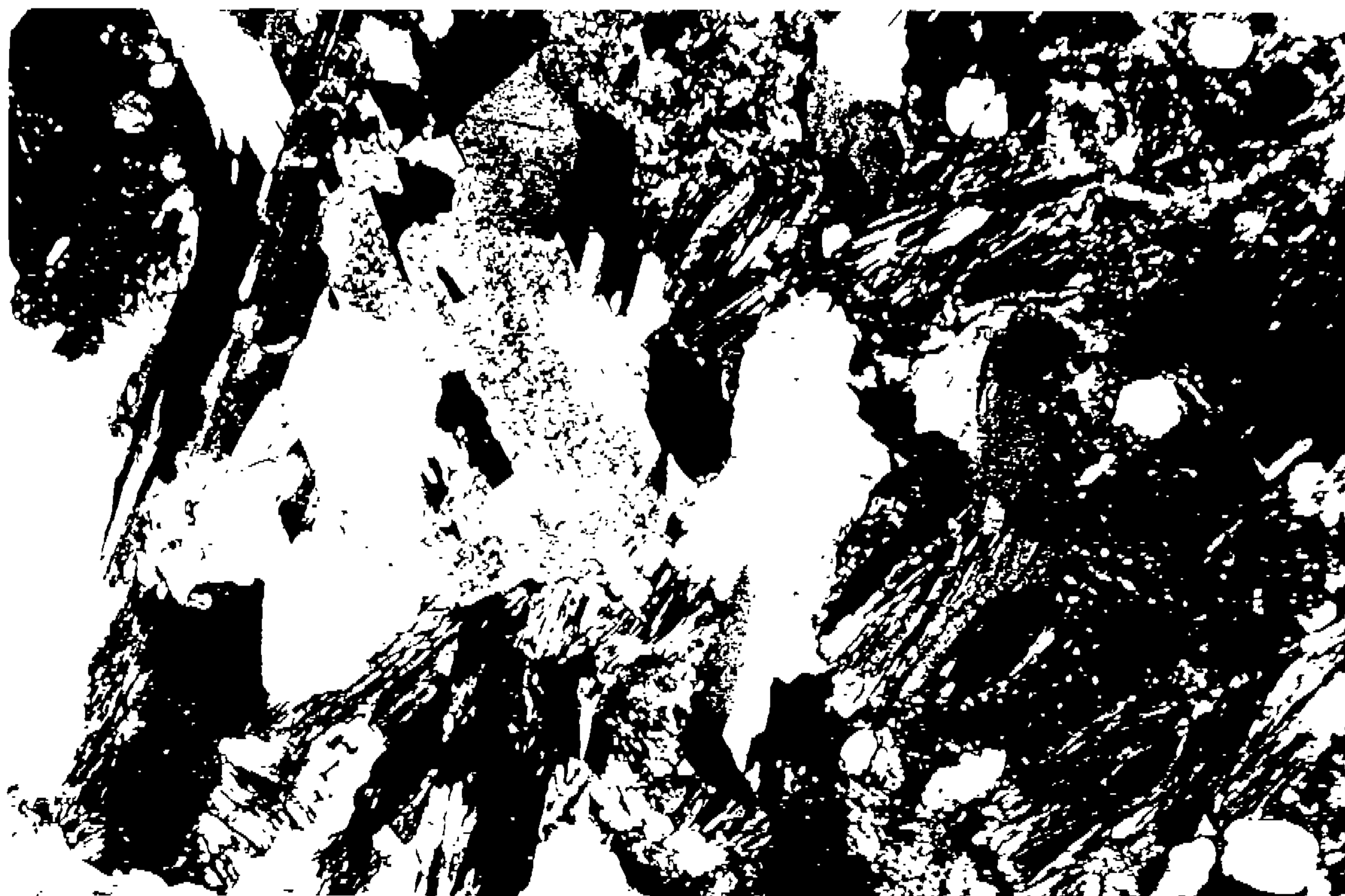


PLATE 2 - SAMPLE CA 51 - 79.5m (Photomicrograph - 20 diam. - wet film - Frame 1)

This view shows well preserved metamorphic textures (bright white quartz and green chlorite). Chlorite flakes have been replaced by chlorite (bright green).

SAMPLE : CA 51, 79.5m (Northern Territory)

SECTION NO. : CA 51, 79.5m (C71062)

HAND SPECIMEN : The drill core sample represents a medium-grained, foliated crystalline rock composed of pale green altered grains and aligned darker green flakes.

ROCK NAME : Chlorite-illite altered micaceous gneiss

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	30	Metamorphic
Muscovite	1	Metamorphic
Apatite	Tr	Metamorphic
Biotite	Tr	Metamorphic
Zircon	Tr	Metamorphic / ?relict primary
Chlorite (very pale green to colourless)	33	Alteration (after ?feldspar)
Chlorite (dark green)	20	Alteration (after biotite)
Clay (illite?)	15	Alteration (after ?feldspar)
Opagues (?hematite)	Tr	Alteration (after biotite)
Rutile	Tr	Alteration (after biotite)

In thin section, this sample displays a partly preserved foliated medium-grained granoblastic metamorphic texture, modified by moderately strong selective pervasive alteration.

Quartz is moderately abundant, occurring as anhedral grains that range widely in size from ~0.2 mm up to ~2 mm. Most are equant in shape, but some are elongated in the trace of the foliation. All of the quartz is unstrained (i.e. lacks strain effects such as shadowy strain extinction).

Muscovite occurs in minor amount as large poikiloblastic plates up to ~2 mm in size. They display the characteristic optical properties of this phase (colourless, single perfect cleavage, moderate birefringence), and some flakes display mild deformation in the form of bending.

Biotite occurs in tiny trace amount as small but well-formed flakes, perfectly preserved within single quartz grains. The biotite displays pleochroism from reddish brown to pale yellow, suggestive of a relatively reduced composition. Biotite was much more abundant in the precursor rock, forming large flakes mostly ~0.5-1.0 mm long whose strong preferred orientation contributed to a well-developed foliation through the rock. All of these biotite flakes have suffered complete replacement by pleochroic dark green chlorite with tiny rutile granules and uncommon small ragged opaque grains (some of which display deep red colour suggestive of hematite).

Two types of chlorite are distinguished:

- i) Pleochroic dark green chlorite (as described above) has completely replaced precursor biotite flakes.
- ii) Fine-grained very pale green to colourless chlorite forms fine-grained dense massive replacement patches after precursor grains of uncertain nature. The pale colour of the chlorite suggests a lower-Fe, higher-Mg composition compared with the darker chlorite after biotite. The chlorite may have replaced feldspar, but this remains uncertain owing to loss of grain shapes and lack of preserved precursor phase.

Illitic clay occurs in moderate amount as tiny colourless flecks that form dense massive replacement patches closely associated with, or intergrown with, the pale chlorite patches.

Apatite occurs in minor amount as equant subhedral grains ~0.2-0.4 mm in size. They are irregularly scattered through the rock, and locally are concentrated in loose aggregates.

Zircon occurs in trace amount as small grains. Each contains a rounded core, overgrown by a subhedral to euhedral growth-zoned rim. These grains are interpreted to represent relict primary zircon (possibly of clastic origin) overgrown by zircon of metamorphic origin.

#### INTERPRETATION:

This sample represents a gneissic metamorphic rock, originally composed of a medium-grained granoblastic assemblage of quartz, ?feldspar, foliated biotite and muscovite, and accessory apatite and zircon. Other phases may have been present (e.g. garnet). The metamorphic mineralogy and texture are consistent with recrystallisation of a primary pelitic sedimentary rock under regional metamorphic conditions in the amphibolite facies.

The rock subsequently suffered strong selective pervasive hydrothermal alteration, which generated the new assemblage of chlorite (dark green) + chlorite (pale green) + illitic clay + trace opaques (?hematite) + rutile. In detail:

- i) Biotite was replaced by dark green chlorite + rutile ± opaques (?hematite),
- ii) ?Feldspar and possibly other phases were replaced by pale green chlorite + illitic clay.

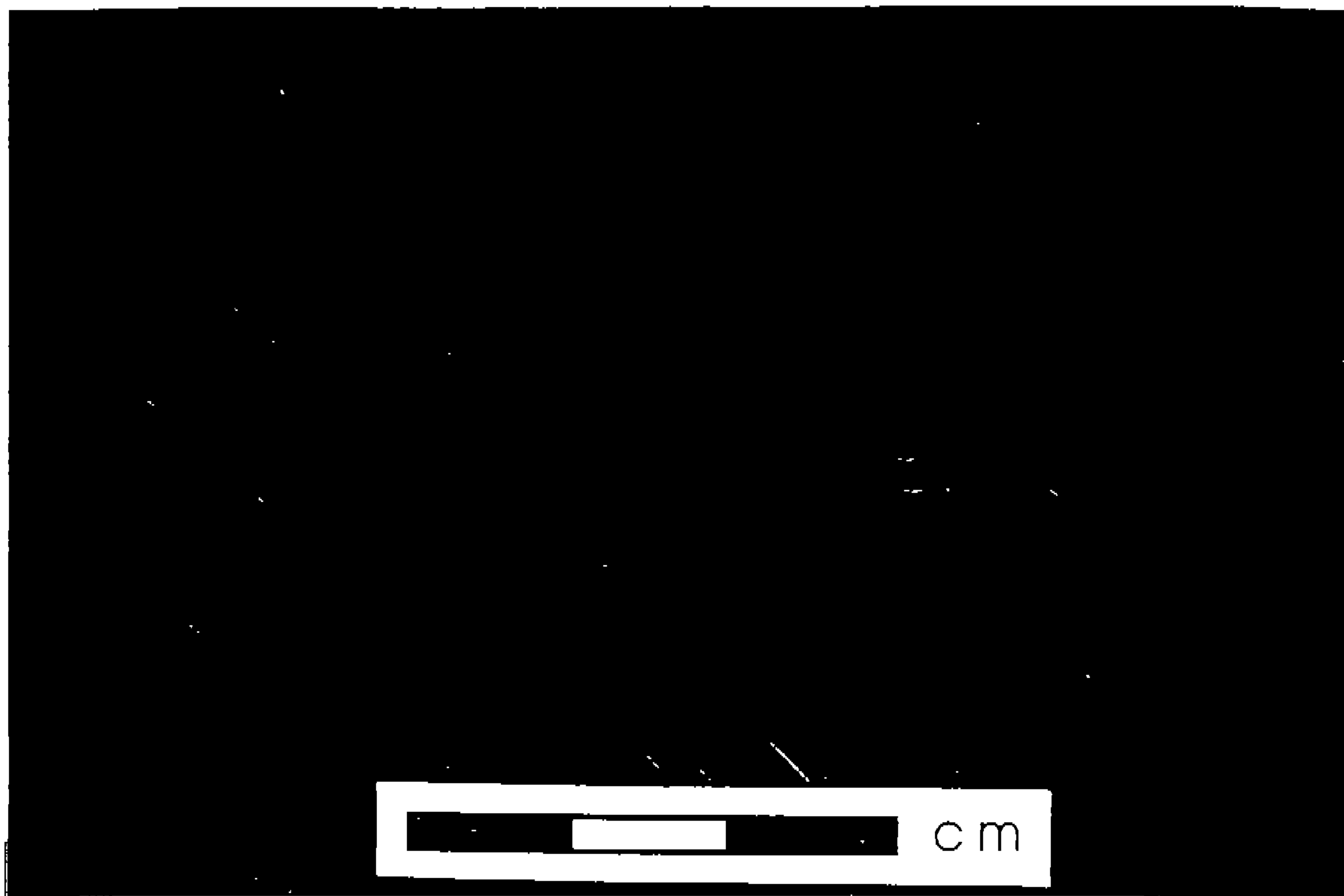


PLATE 3 SAMPLE CA 54, 112.3m (Macro photograph, sawn drill core, wet film 1, frame 3)

This altered basaltic breccia is composed of large angular closely packed fragments now replaced by chlorite with minor quartz and hematite.



PLATE 4 SAMPLE CA 54, 112.3m (Photomicrograph, transmitted plane polarized light, x5, film 2, frame 1)

This view shows the fairly preserved basaltic texture in the large (mm) fragments. Long relict plagioclase (rls) have been replaced by very fine quartz and clinopyroxene (pale elongate) (this upper left, lower right) in a matrix of chlorite (green) and hematite (very dark reddish brown). The larger breccia pores are filled by quartz (white) and chlorite (green).

SAMPLE : CA 54, 112.3m (Northern Territory)

SECTION NO. : CA 54, 112.3m (C71063)

HAND SPECIMEN : The drill core rock sample represents a fragmental rock (breccia), composed of fine-grained dark green angular rock fragments of centimetre size that are closely packed, with minor interstitial dark green to dark reddish brown matrix.

ROCK NAME : **Chlorite-quartz-hematite altered basaltic breccia**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Chlorite	90	Alteration / pore filling
Quartz	5	Alteration / pore filling
Opagues (mainly hematite)	5	Alteration / pore filling
?Leucoxene/?sphene	Tr	Alteration / pore filling

In thin section, this sample displays a very poorly-preserved massive coarse framework-supported fragmental texture, modified by strong pervasive alteration and pore-filling between the breccia fragments.

Chlorite dominates the rock, and occurs in different sites:

- i) Most occurs as tiny flakes that form a dense massive replacement mat after large precursor lithic fragments. Margins of the lithic fragments are difficult to distinguish. The chlorite is pleochroic in greens, and therefore is inferred to be Fe-rich. Rarely, optically continuous fibrous chlorite is concentrated in small equant blocky sites that represent precursor crystals ~0.2-0.4 mm in size (ferromagnesian microphenocrysts, probably olivine).
- ii) Some chlorite occurs as slightly larger, better-formed flakes concentrated in interfragment pores, where the chlorite flakes tend to form subradiating spheroidal aggregates and subradiating linings along pore margins. This chlorite displays the same pleochroism (and therefore probably is the same composition) as the pervasive replacement chlorite.

Quartz occurs in minor amount, and also occurs in two sites:

- i) Most occurs as tiny ragged grains that form microcrystalline replacement mosaics pseudomorphous after small, randomly oriented laths (plagioclase quench crystals, but no plagioclase is preserved for confirmation). The presence of the inferred small ?plagioclase laths supports identification of the precursor rock fragments as quenched basalt.
- ii) A small amount of quartz occurs as larger anhedral clear grains that fill interfragment pore spaces.

Opagues occur in minor amount, both as small ragged granules and aggregates within the chlorite-quartz altered basaltic fragments, and also as dense coarser-grained massive aggregates that fill the interfragment pores. Some of the thinner smaller opaque grains display deep red colours, suggestive of hematite but other opagues may also be present (no reflected light observations are available for confirmation).

A Ti-phase occurs as minute turbid granules disseminated sparsely through the altered lithic fragments, and also as larger turbid aggregates in the interfragment pores. The phase may be sphene, but it is too poorly crystallised for positive optical identification.

#### INTERPRETATION:

This sample represents a basaltic breccia, originally composed of closely-packed centimetre-sized basaltic rock fragments. The abundance of the fragments, their angular shapes, and the quenched primary texture of the basalt suggests that the breccia formed as a primary breccia, possibly of lava flow-breccia or tuffaceous (near-vent) breccia origin, or possibly even an intrusive vent breccia. The origin could be clarified by field relationships with related rock units. An alkali basaltic composition is supported by the presence of small ?olivine microphenocrysts, the lack of plagioclase phenocrysts, and the moderately high Ti content of the rock (inferred from significant abundance of alteration Ti-phase).

The rock has suffered invasion by hydrothermal fluids, which resulted in complete pervasive alteration of the basaltic fragments to the fine-grained assemblage of chlorite + minor quartz + opaques (mainly hematite) + Ti-phase (?sphene). At this time, the breccia pore were filled by the same assemblage (quartz + chlorite + opaques + Ti-phase).

Note that partial preservation of primary delicate basaltic quench texture indicates that the rock did not suffer the regional metamorphic event that most other samples in this suite suffered. Thus the basaltic breccia is much younger than the gneissic metamorphic rocks. Nevertheless, its alteration type and style appears to be similar to that observed in the altered gneissic rocks, suggesting both groups of rocks (the older gneisses and the younger basaltic breccia) suffered the same alteration event.

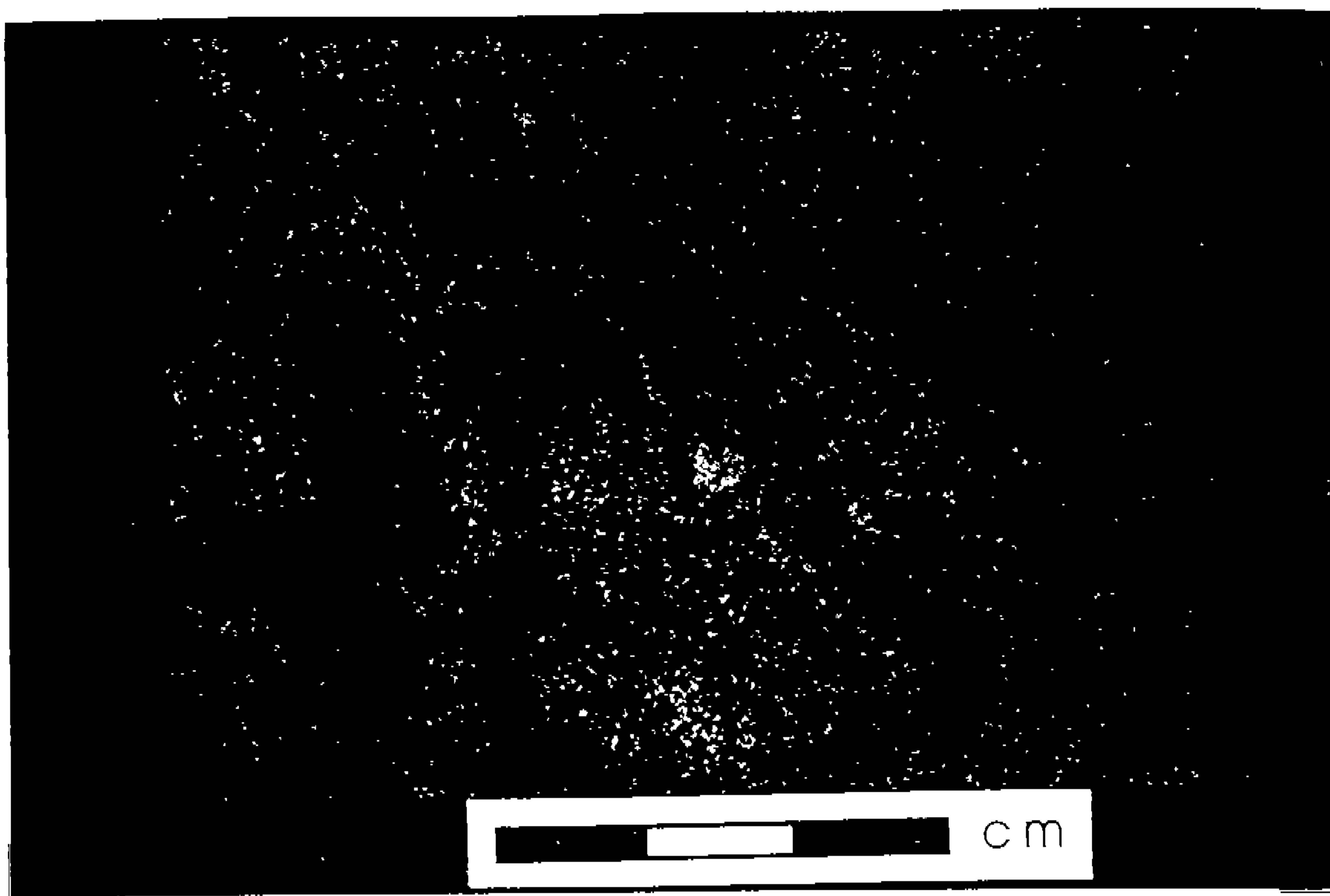


PLATE 5: SAMPLE CA 54, 315.6m (Macrophotograph, sawn drill core, wet film 1 - frame 5)

In this altered feldspathic gneiss, pale pinkish white grains of K feldspar are distributed through an altered matrix of mainly chlorite and sericite.



PLATE 6: SAMPLE CA 54, 315.6m (Photomicrograph, transmitted plane polarised light, film 2 - frame 3). Relict grains of K feldspar (colourless - light, top left) display twinning, etched by incipient chlorite alteration. The matrix is composed of alteration: dark green chlorite (centre) and paler green chlorite with intergrown patches of sericite (not observable).

SAMPLE : CA 54, 315.6m (Northern Territory)

SECTION NO. : CA 54, 315.6m (C71064)

HAND SPECIMEN : The drill core rock sample represents a medium-grained crystalline rock composed of small angular white to pale pink feldspar grains, scattered through a fine-grained pale green matrix with some darker green patches. Although apparently massive in structure, an indistinct foliation is defined by weak alignment of the dark patches.

ROCK NAME : **Chlorite-sericite altered feldspathic gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
K-feldspar (microcline)	40	Metamorphic
Quartz	2	Metamorphic
Zircon	Tr	Metamorphic / ?relict primary
Monazite	Tr	Metamorphic
Chlorite (pale green)	35	Alteration
Chlorite (dark green)	2	Alteration
Sericite	20	Alteration
Sphene	Tr	Alteration
Opauques	Tr	Alteration

In thin section, this sample displays a partly preserved massive crystalline texture, modified by moderately severe pervasive alteration.

K-feldspar is moderately abundant, occurring as large poikiloblastic grains up to ~1-4 mm in size, as well as smaller anhedral grains. They all display well-developed 'tartan' twinning (combined albite and pericline twinning), confirming identification as microcline.

Quartz occurs in minor amount as small anhedral clear grains intergrown with, or enclosed by, the K-feldspar grains.

Chlorite is abundant, and two types are distinguished:

- i) Most occurs as tiny randomly oriented flakes that form dense replacement mats throughout the rock. The mats display no preserved shapes, and no precursor mineral/s is/are preserved, so positive identification of the precursor mineral/s is impossible. However, it may have been feldspar or possibly cordierite. The pale green colour of the chlorite suggests a relatively Fe-rich composition.
- ii) A small amount of dark green pleochroic chlorite occurs as small subradiating aggregates located within the larger patches of paler green chlorite. Their darker colour suggests a more Fe-rich composition.

Sericite occurs in significant amount as fine-grained dense massive patches, commonly located within the chloritic areas of the rock.

Opauques are uncommon, occurring as small angular grains and aggregates, sparsely and irregularly disseminated through the rock.

Sphene occurs as small subhedral grains and aggregates that display the characteristic optical properties of this phase (subhedral blocky crystals, turbid dark brown colour with pleochroism, high birefringence).

Monazite occurs in minor amount as small euhedral equant crystals that display their typical moderate birefringence, but most crystals display turbid dark brown alteration from margins inwards. Some are completely altered. Locally, monazite crystals are concentrated in loose aggregates.

Zircon occurs in trace amount as small angular grains and subrounded grains with thin overgrowths.

#### INTERPRETATION:

This sample represents a medium-grained crystalline rock, originally composed of moderately abundant K-feldspar, other minerals (possibly including plagioclase), minor quartz, and accessory monazite and zircon. The rock is inferred to have crystallised in response to a regional metamorphic event in the amphibolite facies, a suggestion supported by the grain size and the structural state of the K-feldspar (the low-temperature inverted form, microcline).

The metamorphic rock was invaded by hydrothermal fluids which caused pervasive alteration to the assemblage chlorites (paler and darker types) + sericite + minor sphene + opaques. Some metamorphic phases survived this event (microcline, monazite, zircon), but much of the rock was replaced by the alteration phases.

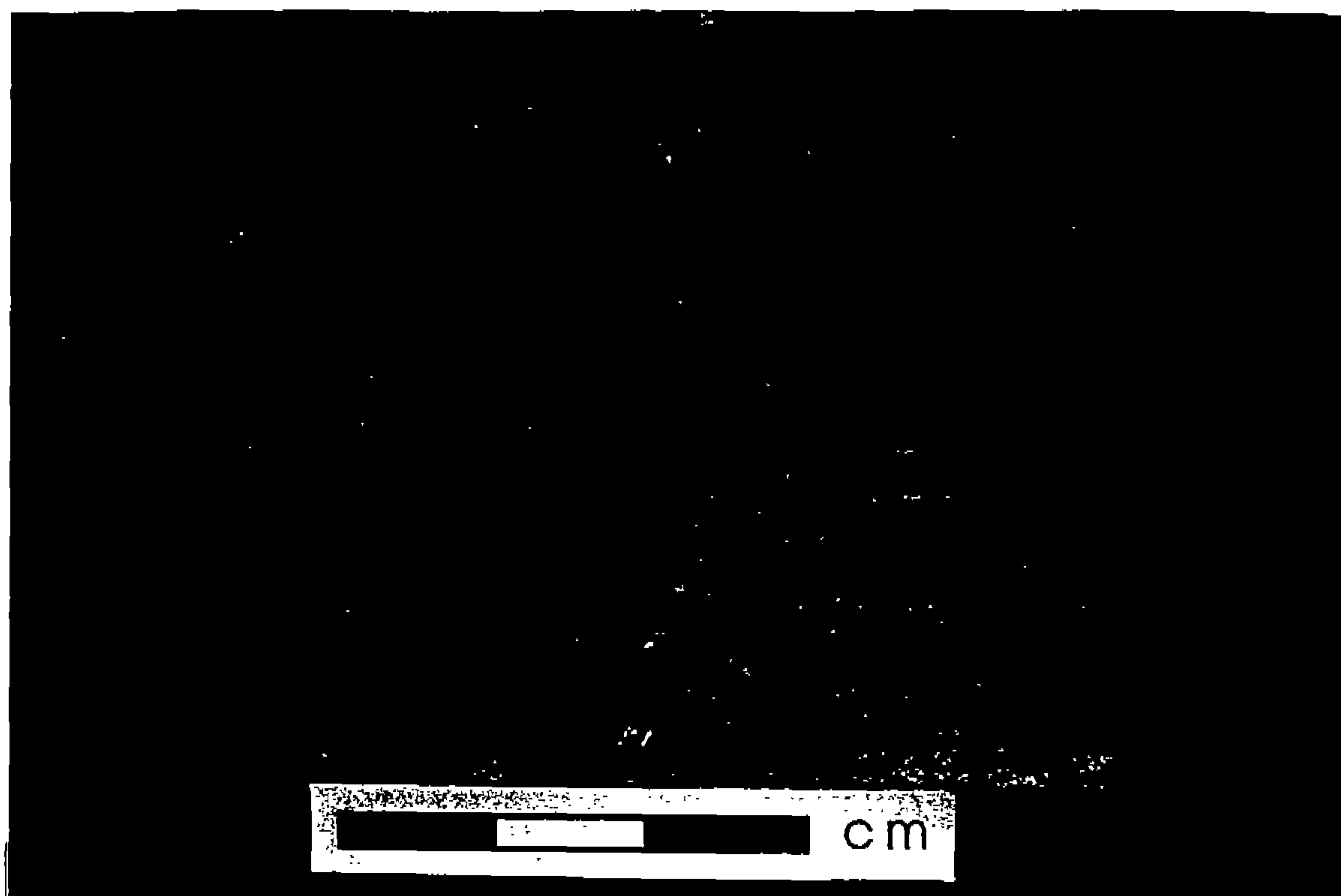


PLATE 7 - SAMPLE CA 54, 316.4m (Macro photograph - sawn drill core - wet film 1 - Frame 6). This view of altered quartzofeldspathic gneiss shows scattered large ragged yellowish green patches (silimanite bearing, top - bottom) in a matrix of K-feldspar, sericite, altered plagioclase and foliated muscovite and altered biotite flakes.



PLATE 8 - SAMPLE CA 54, 316.4m - thin section (up - transmitted light - crossed polars - x5 - Film 2 - Frame 4). This view of altered gneiss shows pre-cleaved K-feldspar grains (grey with twinning - far right - lower left), quartz (clear grey to white - top left - bottom centre) and muscovite (bright pink - centre right). Biotite flakes (aligned SW - SE) have suffered complete replacement by chlorite (drab khaki green) and plagioclase by sericite (yellowish clouds - centre left).

SAMPLE : CA 54, 316.4m (Northern Territory)

SECTION NO. : CA 54, 316.4m (C71065)

HAND SPECIMEN : The drill core rock sample represents a medium-grained gneissic rock composed of abundant pale grey to cream feldspathic grains, through which a strong foliation is defined by subparallel dark green flakes and foliae. Uncommon but large (centimetre-sized) paler yellowish cream patches are aligned in the trace of the foliation.

ROCK NAME : **Chlorite-sericite altered mica-sillimanite quartzo-feldspathic gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	39	Metamorphic
K-feldspar (microcline)	20	Metamorphic
Muscovite	3	Metamorphic
Biotite	1	Relict metamorphic
Sillimanite (fibrolite)	2	Metamorphic
Apatite	Tr	Metamorphic
Zircon	Tr	Metamorphic / ?relict primary
Chlorite (pale green)	8	Alteration (after biotite)
Chlorite (dark green)	7	Alteration (after biotite)
Sericite	20	Alteration (after ?plagioclase)
Rutile	Tr	Alteration (after biotite)

In thin section, this sample displays a medium- to coarse-grained foliated granoblastic metamorphic texture, modified by selective pervasive alteration.

Quartz is abundant, occurring as anhedral equant grains ~0.4-1.0 mm in size. Most display a moderate degree of shadowy strain extinction. Quartz is distributed non-uniformly through the rock, being more abundant in areas containing fibrolite and lacking altered ?plagioclase grains.

K-feldspar (microcline) is moderately abundant, occurring as anhedral grains ~0.4-1.0 mm in size in granoblastic relationship with quartz, muscovite and altered plagioclase and altered biotite. The K-feldspar grains display well-developed 'tartan' twinning (combined albite and pericline twinning), confirming identification as microcline.

Muscovite occurs in minor amount as well-crystallised flakes interleaved with biotite. Elsewhere, larger poikiloblastic plates are intergrown with quartz, and some of these larger flakes appear to have suffered replacement by turbid pale brownish mats of fibrolitic sillimanite (with lower birefringence than muscovite). The sillimanite mats display a moderate preferred orientation which contributes to a foliation through the rock. The sillimanite mats most likely represent the pale yellowish cream patches observed in hand specimen.

Biotite formed well-crystallised flakes ~0.4-1.0 mm long. Their preferred orientation contributes to the foliation through the rock. All have suffered partial to complete replacement by chlorite, commonly with paler (Fe-poorer) cores and darker (Fe-richer) rims. Tiny rutile granules are peppered through the chlorite. Uncommon small cleavage flakes of brown biotite are preserved in some biotite flake sites.

Sericite occurs in moderate amount as tiny randomly oriented flakes that form mats pseudomorphous after precursor equant anhedral grains ~0.5-1.0 mm in size. They may have been plagioclase, or possibly cordierite, but none is preserved for confirmation.

Apatite is present in minor amount as equant anhedral grains sparsely and irregularly scattered through the rock. They are readily identified from their characteristic optical properties (high relief, colourless, low birefringence).

Zircon is uncommon, forming small anhedral to subhedral grains with indistinct growth zoning. They may be of complex origin (e.g. relict clastic cores with metamorphic overgrowths).

#### INTERPRETATION:

This sample represents a gneissic metamorphic rock which formed by recrystallisation in response to regional metamorphic conditions in the amphibolite facies. The nature of the precursor rock has been obscured, but it may have been a pelitic sediment or quartzo-feldspathic clastic sediment. The metamorphic event generated the medium-grained foliated granoblastic assemblage of quartz + K-feldspar + ?plagioclase + biotite + muscovite + sillimanite + minor apatite + zircon.

At a later time, the rock body was invaded by hydrothermal fluids which caused selective pervasive alteration to form the new assemblage of chlorite (pale and dark types) + sericite + trace rutile. In particular, metamorphic biotite was replaced by chlorites + trace rutile, and ?plagioclase was replaced by sericite.

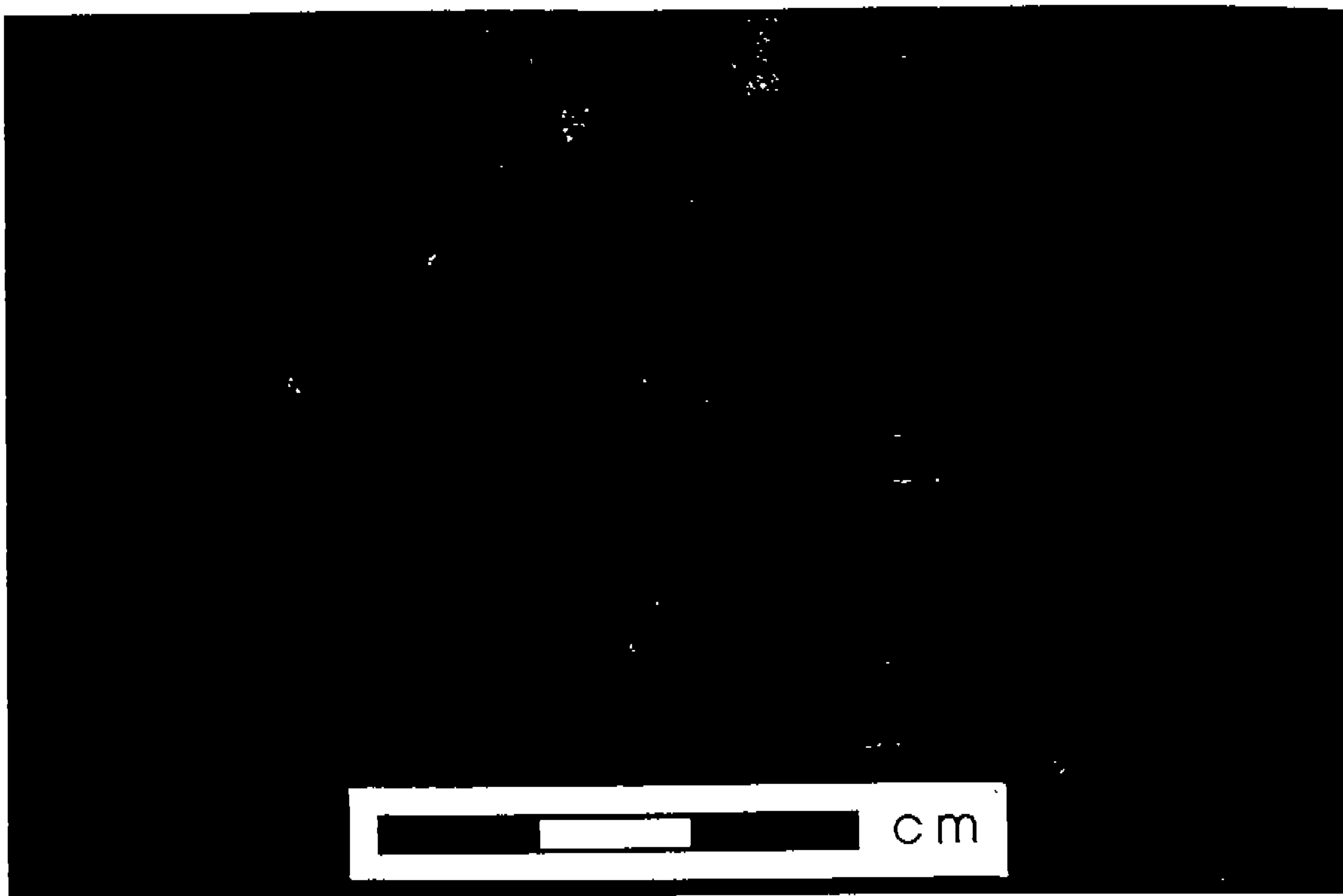


PLATE 9. SAMPLE CA 54, 319.2m (Macro-photograph, sawn drill core, wet, film 1 - Frame 7)

This view of altered quartzofeldspathic gneiss illustrates the preserved metamorphic foliation (oriented NNE-SSW) defined by aligned chlorite altered biotite flakes (dark greenish grey). Paler feldspar grains include K feldspar (pale pink) and plagioclase (white to sericite altered pale yellow).



PLATE 10. SAMPLE CA 54, 319.2m (Photo-micrograph, transmitted light, crossed polarisers, wet, film 2 - Frame 5). This view illustrates the development of fibrolitic sillimanite (fibrolitic, pale yellow-grey centre) by replacement of large (mm) covellite plates (bright yellow-pink). The aligned fibrolite and muscovite contribute to definition of the foliation through the rock.

SAMPLE : CA 54, 319.2m (Northern Territory)

SECTION NO. : CA 54, 319.2m (C71066)

HAND SPECIMEN : The drill core sample represents a medium-grained crystalline rock composed of moderately abundant pale yellowish altered feldspar grains and pale pink feldspar grains, through which a moderately strong foliation is defined by dark green altered flakes and anastomosing foliae of mica.

ROCK NAME : **Low-intensity sericite-chlorite altered mica-sillimanite quartzo-feldspathic gneiss**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
Quartz	25	Metamorphic
K-feldspar (microcline)	27	Metamorphic
Plagioclase	25	Relict metamorphic
Biotite	7	Relict metamorphic
Muscovite	2	Metamorphic
Sillimanite	1	Metamorphic
Zircon	Tr	?Relict primary / ?metamorphic
Sericite	10	Alteration (after plagioclase)
Chlorite (green, incl. trace rutile)	3	Alteration (after biotite)
Rutile	Tr	Alteration

In thin section, this sample displays a medium-grained foliated granoblastic metamorphic texture that has suffered weak selective alteration.

Quartz and K-feldspar are both moderately abundant, occurring as anhedral grains ~0.4-2.0 mm in size. The quartz grains display mild shadowy strain extinction, and the presence of 'tartan' twinning in the K-feldspar confirms its identification as microcline.

Plagioclase forms anhedral grains ~0.5-1.5 mm in size, in granoblastic relationship with quartz and K-feldspar. All of the plagioclase grains display partial replacement by tiny sericite flecks and patches. Some multiply-twinned plagioclase is preserved to confirm the identification of the phase as plagioclase.

Biotite forms well-crystallised pleochroic brown flakes ~0.5-1.0 mm long. They are distributed as single flakes and as aggregates throughout the rock, and their preferred orientation defines a moderately strong foliation through the rock. All have suffered partial to severe replacement by pleochroic green chlorite and associated minute rutile granules.

Muscovite occurs as well-crystallised flakes up to ~1 mm long. Smaller flakes tend to be interleaved with biotite flakes, and larger flakes occur independently.

Sillimanite occurs in minor amount as pale brown (but non-pleochroic) dense fibrolitic mats that form lenses of millimetre size very irregularly and sparsely scattered through the rock. They occur in association with quartz- and muscovite-rich areas.

Zircon occurs in trace amount as small subrounded to subhedral grains, some of which display thinly zoned overgrowths.

**INTERPRETATION:**

This sample represents a pelitic to quartzo-feldspathic rock (possibly of sedimentary origin) that has suffered recrystallisation in response to amphibolite facies regional metamorphism. This generated the medium-grained foliated granoblastic assemblage of quartz + K-feldspar + plagioclase + biotite + minor muscovite + sillimanite + trace zircon. Some compositional heterogeneity in the metamorphic mineral distribution was defined by areas richer in quartz + muscovite + sillimanite, and these may reflect primary compositional layering in the precursor sediment.

The rock suffered minor alteration, in which plagioclase was partly replaced by sericite and biotite was partly replaced by chlorite + trace rutile.

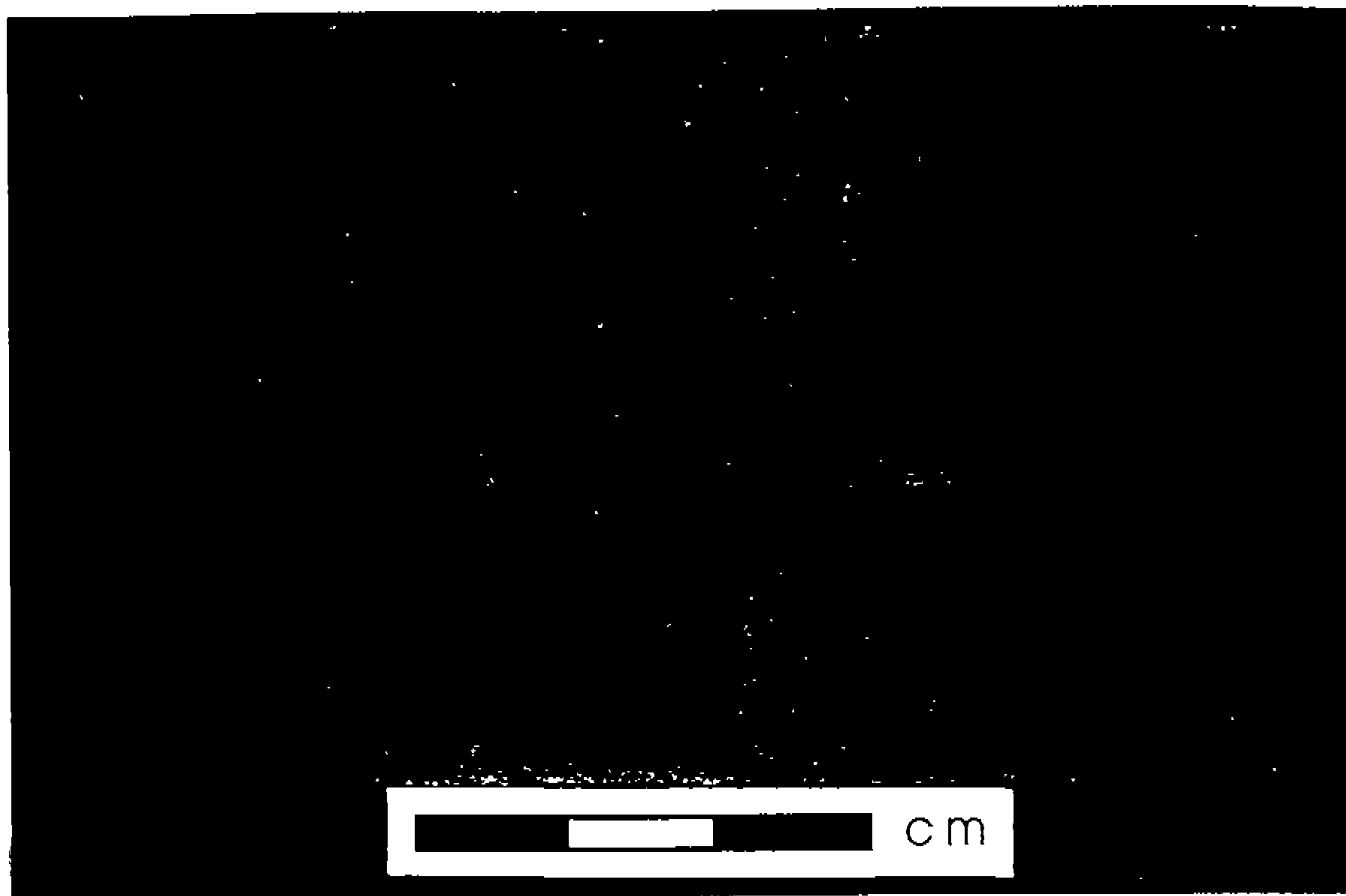


PLATE 11 SAMPLE CA 54 - 324.6m (Macro photograph, sawn drill core, wet, Film 1 - Frame 8)

This altered gneissic rock displays mineralogical layering defined by higher abundance of felsic minerals (white - mainly plagioclase, quartz and K feldspar). The darker layers contain a higher proportion of mafic minerals (now replaced by chlorite).

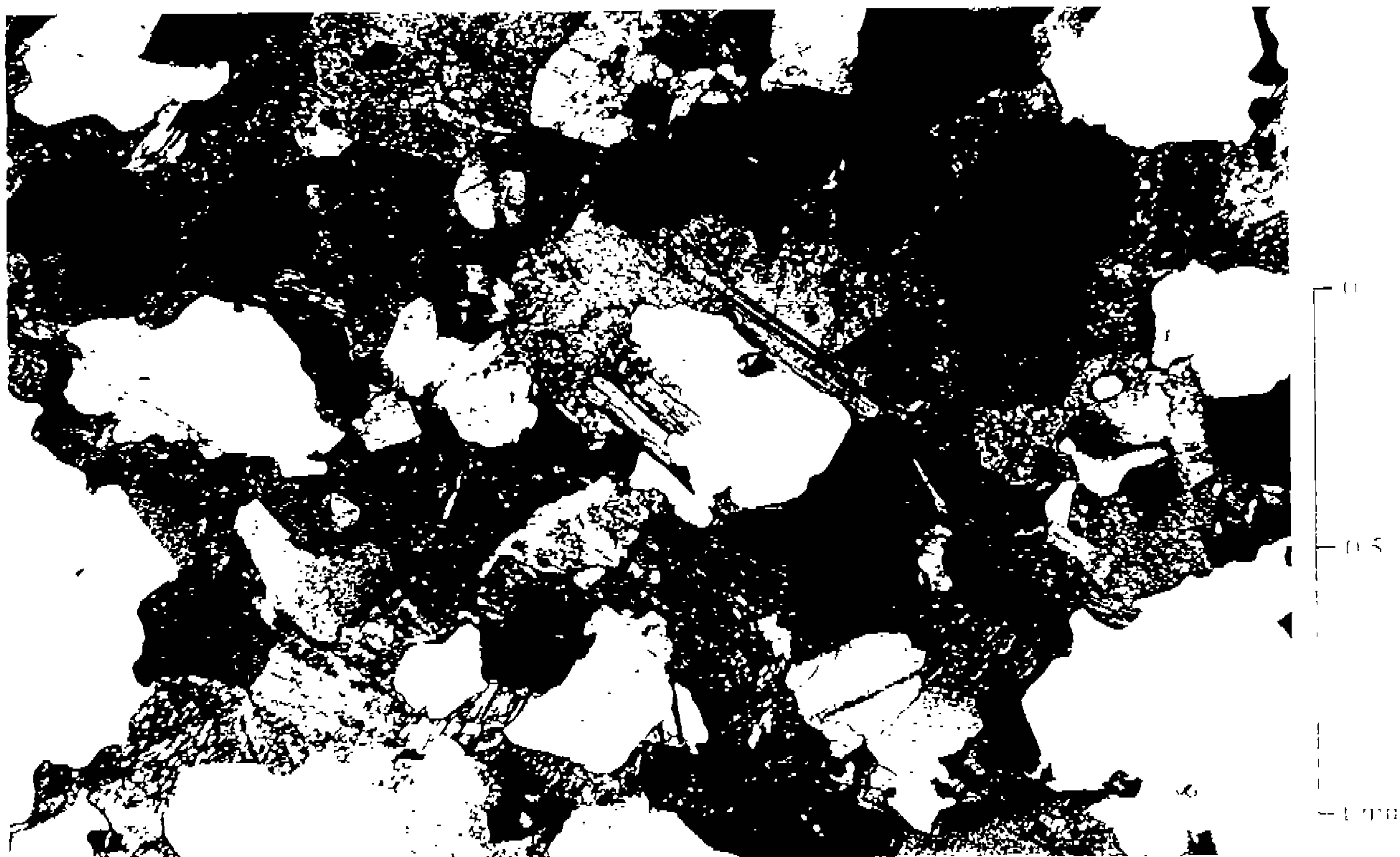


PLATE 12 SAMPLE CA 54 - 324.6m (Photomicrograph, transmitted light, crossed polars, 25x, Film 2 - Frame 7). The focus was taken in the felsic portion of the rock (see PLATE 11) and is composed of the granoblastic assemblage of plagioclase (trace tiny serrate flecks), K feldspar (dark grey, twinned, centre right) and quartz (white to pale grey). Minor (small bright flakes) (centre bottom, PLATE 11) are partly replaced by chlorite.

SAMPLE : CA 54, 324.6m (Northern Territory)

SECTION NO. : CA 54, 324.6m (C71067)

HAND SPECIMEN : The drill core sample represents a medium-grained grey crystalline rock with foliation defined by dark aligned mica flakes. A paler yellowish white band ~2-3 cm wide is oriented subparallel to the foliation. The thin section has mostly captured the paler band, with a small portion of the grey rock.

ROCK NAME : **Low-intensity chlorite-sericite-carbonate altered mica-sillimanite 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. sericite)	52	Metamorphic (incl. alteration)
Quartz	30	Metamorphic
K-feldspar (microcline)	10	Metamorphic
Muscovite	3	Metamorphic
Biotite	1	Relict metamorphic
Sillimanite	1	Metamorphic
Chlorite (incl. trace rutile)	3	Alteration (after biotite)
Carbonate (dolomite)	Tr	Alteration

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

Plagioclase is abundant, occurring as anhedral grains mostly ~0.4-1.0 mm in size. They display combined simple and multiple twinning, and all grains display some degree of replacement by small sericite flecks and patches. The plagioclase lies in granoblastic relationship with clear but weakly strained quartz grains, and clear K-feldspar grains that display the characteristic 'tartan' twinning of microcline.

Biotite occurs in minor amount as well-crystallised flakes partly to completely replaced by pleochroic green chlorite peppered with tiny rutile granules. Some partly-preserved biotite flakes are present, and biotite is more abundant in the small portion of 'grey' host rock captured near the edge of the slide. Preferred orientation of the biotite flakes defines a foliation through the rock.

Muscovite builds well-crystallised flakes similar in size to biotite. Some muscovite flakes are interleaved with biotite, but others occur discretely or in large muscovite-rich patches or elongated foliae that contribute to the foliation through the rock.

Sillimanite occurs as fibrolitic dense pale brown (but non-pleochroic) mats, limited to the muscovite-rich foliae.

Carbonate occurs in minor amount as small ragged grains intergrown with chlorite. The moderately strong double refraction suggests it is dolomite rather than calcite.

### INTERPRETATION:

This sample represents a gneissic metamorphic rock which formed in response to amphibolite facies regional metamorphic recrystallisation of a precursor rock. This generated the foliated granoblastic assemblage of plagioclase + quartz + K-feldspar + minor biotite + muscovite + sillimanite. The fibrolitic, poorly-crystallised nature of the sillimanite suggests that the rock barely reached sillimanite grade. All mineralogical and microtextural features of the precursor rock were destroyed, but it may have been a quartzo-feldspathic sedimentary rock.

Subsequently, the rock suffered weak selective alteration. Biotite suffered partial replacement by chlorite  $\pm$  carbonate + rutile, and plagioclase suffered partial replacement by sericite.

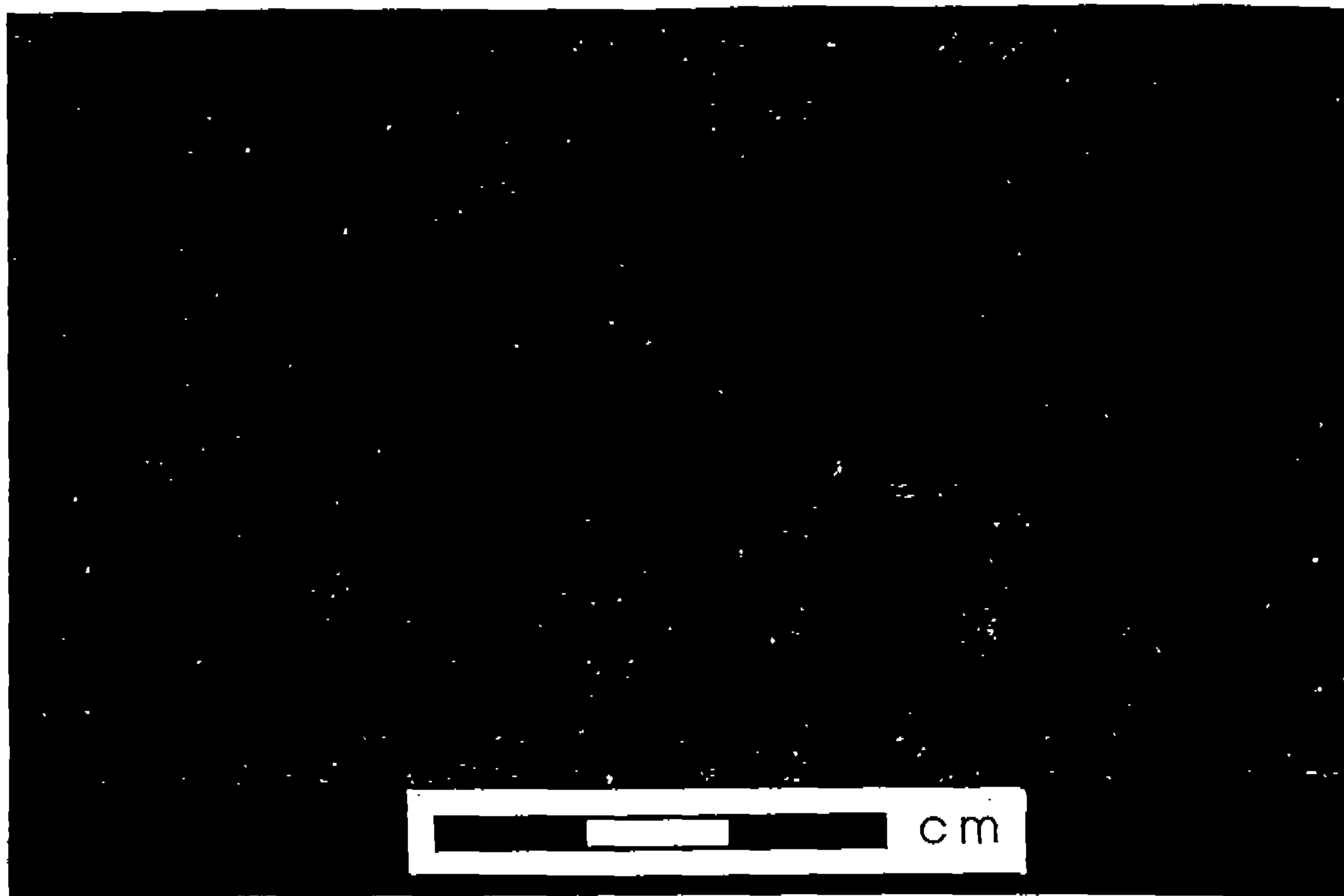


PLATE 13 SAMPLE CA 56, 144.8m (Macro photograph, sawn drill core, wet Film 1, Frame 10). Altered quartzite host rock is cut by brittle branching fractures filled by veinlets of apatite and hematite. The latter mineral is responsible for the dark pink colour of the veins.

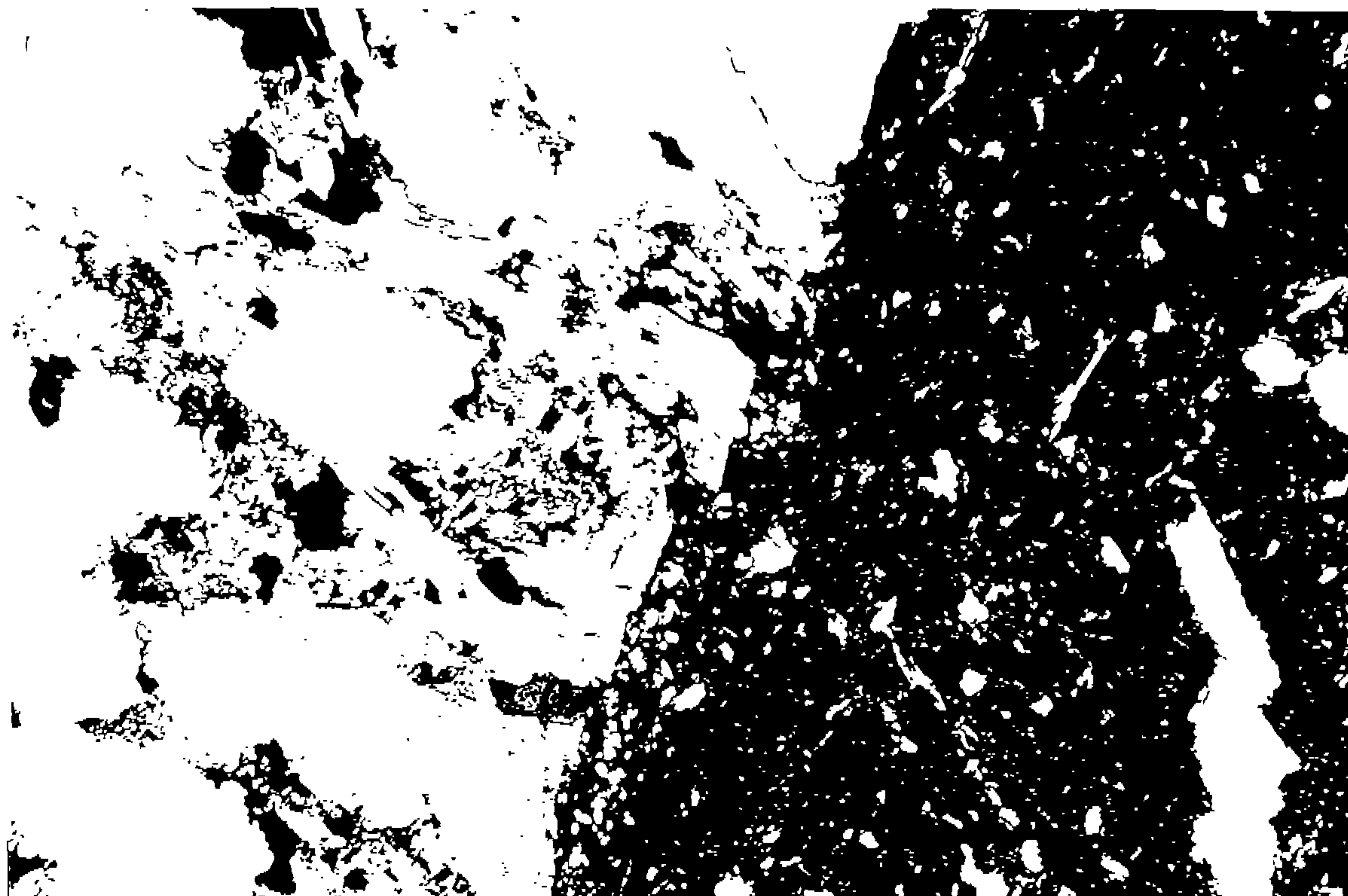


PLATE 14 SAMPLE CA 56, 144.8m (Photomicrograph, transmitted light, crossed polar,  $\times 50$ , Film 2, Frame 8). Altered quartzite (delta 15) composed of quartz (grey), muscovite (bright yellow), and fine-grained sericitic replacement patches (after olivine) (c). The vein (right) also see Plate 15, composed mostly of fine-grained apatite, hematite, and altered angular fragments of quartz, white, and muscovite, derived from the quartzite wall rock.

SAMPLE : CA 56, 144.8m (Northern Territory)

SECTION NO. : CA 56, 144.8m (C71068)

HAND SPECIMEN : The drill core rock sample represents a medium-grained massive grey crystalline rock with pervasive dull reddish brown oxidation tinge. Cutting the rock are thin fractures and thicker veins up to ~1 cm wide, filled by fine-grained massive reddish brown materials.

ROCK NAME : **Apatite-hematite veined, low-intensity sericite-hematite altered quartzite**

PETROGRAPHY :

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

<u>Mineral</u>	<u>Vol. %</u>	<u>Origin</u>
<u>Quartzite</u>		
Quartz	93	Metamorphic
Muscovite	3	Metamorphic
Apatite	Tr	Metamorphic
Monazite	Tr	Metamorphic
Zircon	Tr	Metamorphic
Sericite	2	Alteration
Opagues (mainly ?hematite)	1	Alteration
<u>Apatite-hematite vein</u>		
Apatite	80	Vein filling
Opagues (mainly ?hematite)	10	Vein filling
Muscovite	5	Wall rock fragments
Quartz	5	Wall rock fragments

In thin section, this sample displays a massive granoblastic metamorphic texture modified by selective alteration, and a massive fine-grained crystalline texture in the vein.

Quartzite is dominated by quartz, which occurs as large equant anhedral grains ~0.6-1.0 mm in size. They form a massive granoblastic mosaic throughout the rock.

Muscovite occurs as large plates up to ~1-2 mm in size scattered through the rock. Some are well-crystallised plates, and others form poikiloblastic patches.

Sericite occurs in minor amount as tiny randomly oriented flecks that have completely replaced precursor anhedral grains ~0.4-0.6 mm in size that were in granoblastic textural equilibrium with the quartz. No precursor mineral has been preserved in the sericite-altered sites, but it most likely was feldspar.

Opagues occur as ragged grains and aggregates that pepper the sericite-altered ?feldspar grain sites. The deep red colour of some of the 'opaque' grains suggests hematite is the principal phase.

Apatite occurs in trace amount as subrounded grains up to ~0.4 mm in size.

Monazite occurs as small equant subrounded to euhedral crystals, with characteristic high relief, high birefringence and inclined extinction. Zircon, although somewhat similar, displays parallel extinction to prism faces (where preserved) and some crystals contain round cores with overgrowths.

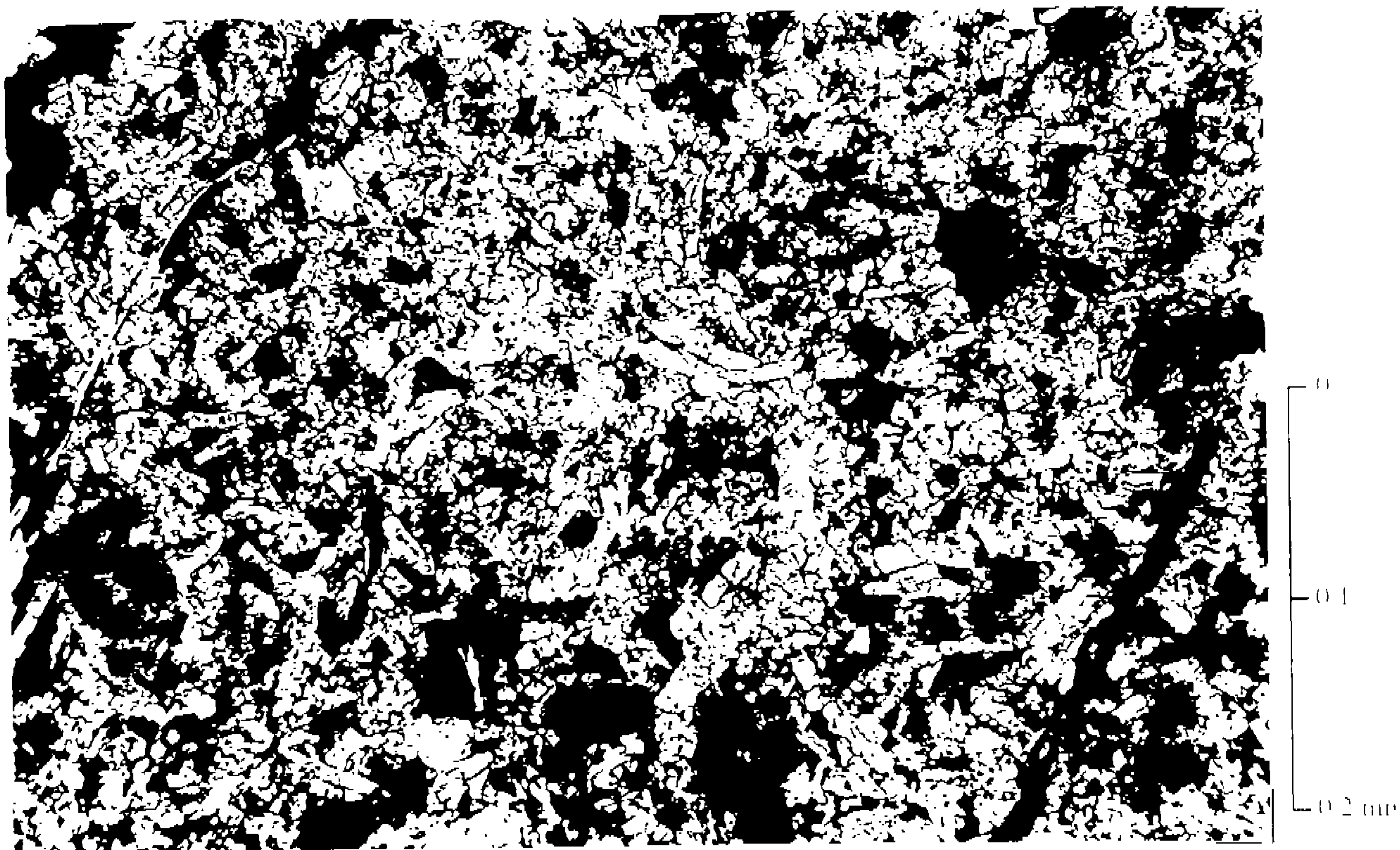


PLATE 15 SAMPLE CA 56, 1448m (photomicrograph transmitted plane polarised light x20, Film 2 Frame 9) This closer view of the vein shows abundant small apatite prisms (colourless, high relief) with interstitial ragged grains of hematite (dark reddish brown to black)

Apatite-hematite vein is composed mostly of tiny randomly oriented apatite crystals ~50  $\mu\text{m}$  long. They display the characteristic optical properties of this phase: colourless stumpy prismatic crystals with hexagonal basal sections, moderately high relief, lack of cleavage, low birefringence (first order dark greys), and parallel extinction to prism faces. The apatite forms a dense mat of small crystals throughout the veins.

Opaques (hematite) occur as small ragged grains dispersed uniformly through the apatite mat as interstitial grains. They give the veins their reddish brown colour in hand specimen.

Scattered through the veins are angular crystal fragments of quartz and platy crystals of muscovite. Both are considered to represent xenocrysts scavenged from the quartzite wall rock.

#### INTERPRETATION:

This sample represents a siliceous sedimentary rock, probably a quartz sandstone, that has suffered complete recrystallisation to form the granoblastic assemblage of quartz + minor ?feldspar + muscovite + trace apatite + monazite + zircon.

At a much later time, the rock body suffered fracturing and invasion by hydrothermal fluids. Wall rock suffered selective replacement of ?feldspar by sericite + opaques (mainly hematite). Open fractures were filled by massive apatite + opaques (mainly hematite), with fragments of quartz and muscovite scavenged from the wall rock.