Terra Antartica
2007, **14**(1), 31-41

Granitoid Diversity in the Southern Prince Charles Mountains: Geological and Petrographic Features

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Abstract - Granitic rocks in the southern Prince Charles Mountains vary widely in both composition and field appearance. Generally, the granitoids form syn- to post-tectonic sheet-like bodies. Variously deformed (pre-tectonic) basement granitoids also occur as large bodies. Subvertical dykes occur in many localities, and sporadically form dense networks grading into larger bodies with only scarce rafts of the country rocks. In a few localities concentrated in the Fisher Glacier area stock-like bodies occur. The deformation style also varies widely. Variously deformed granitic bodies prevail in the northern Mawson Escarpment and nearly undeformed granites occur in the Fisher Glacier area. The granite structure varies from homogeneous, equigranular to augen or highly stretched gneissic.
Two distinct gneissic rock groups occur in the southern Mawson Escarpment: biotite or hornblende–biotite granite-gneiss, and orthopyroxene-bearing granite-gneiss. The latter was probably formed during a charnockitisation process or may be magmatic, as no biotite break-down reaction has been preserved and some rocks reveal apparently magmatic structures. In the Cumpston Massif plagioclase-rich orthogneisses containing magnetite and fluorite occur. More calcic gneisses predominate in Clemence Massif.
The presumed Early Palaeozoic granitoids form three distinct groups. The granites in the northern Mawson Escarpment are biotite and rarely biotite–garnet or biotite–hornblende-bearing, in Harbour Bluff mostly muscovite–garnet-bearing, and elsewhere in the southern Prince Charles Mountains mostly muscovite or muscovite–biotite-bearing. Distinctive granitic rocks crop out on Landing Bluff (Prydz Bay coast), where they are more mafic (biotite) and contain essential amounts of accessory allanite, titanite, and fluorite. These rocks cannot be correlated with granites in the southern Prince Charles Mountains, which suggests different origins for the granites in these two regions.

INTRODUCTION

The Prince Charles Mountains (PCM) reveal the best exposed cross section through the East Antarctic Shield, extending for more than 500 km along the drainage basin of the Lambert Glacier–Amery Ice Shelf system. Two major tectonic provinces have been distinguished in the northern and in the southern PCM (Tingey 1982, 1991, Kamenev et al., 1993, Fitzsimons, 2003, Mikhalsky et al., 2006). The Meso- to Neoproterozoic Beaver and Mesoprotorozoic Fisher Terranes occupy the northern PCM, and the Archaean Ruker Terrane (Boger et al., 2006) and Palaeoproterozoic Lambert Terrane (Mikhalsky et al., 2006) occupy the southern PCM. These terranes are composed of highly variable lithologies, with granite (*s.l.*[1]) and granite-gneiss (along with metasediments) being the most common rock types forming the basement of these terranes. In the Ruker Terrane the granitic basement is overlain by a highly deformed metasedimentary cover (Phillips et al., 2005). Both the Lambert Terrane and the Ruker Terrane granitic basement rocks seem to have experienced some Early Palaeozoic tectonism. A prominent feature of the southern PCM is the widespread occurrence and, in some areas, abundance, of younger, presumably Early Palaeozoic granites that were considered to be post-tectonic or anorogenic (Sheraton et al., 1996). The major tectonic subdivisions, and sampling localities are shown in figure 1.

The age of the granites in the southern PCM has been determined as Archaean (*c.* 2700-2800 Ma, Rb-Sr isochron ages by Tingey, 1982, 1991, which most likely are metamorphic ages, and *c.* 3000 Ma, U–Pb bulk zircon data, Mikhalsky et al., 2001) or early Palaeozoic (*c.* 500 Ma, Rb–Sr whole-rock isochron and mica model ages, Halpern & Grikurov, 1975, Tingey, 1991). Boger et al. (2006) dated pre-tectonic granitoid rocks at *c.* 3185–3155 Ma and Mikhalsky et al. (2006) reported tonalite–trondhjemite emplacement at *c.* 3390–3380 Ma. A number of late Archaean to early Proterozoic ages were obtained for pegmatites from the southern PCM. Rb–Sr muscovite ages of 2580 Ma (Mount Stinear), 1708 Ma and 1995 Ma (deformed pegmatites at Keyser Ridge), and a model age of muscovite of about 2100 Ma has been obtained on a pegmatite at Mount Newton (Tingey, 1991). Recent SHRIMP zircon studies by Boger et al. (2001) showed early Palaeozoic ages of syn-, and post-tectonic granitic vein injections (*c.* 510 and 490 Ma, respectively) in the

[1]Granite *sensu largo* means phaneritic igneous rock dominated by quartz and feldspars.

Fig. 1 - The southern Prince Charles Mountains tectonic subdivisions, and locality map.

central Mawson Escarpment (Philpot Bluff). Granite in western Prydz Bay coast was dated at *c.* 500 Ma (Tingey, 1991, and references therein).

The main goal of our study is to distinguish the key geological and petrographical features of the southern PCM granites (including orthogneisses and not or poorly deformed granites) and to make a comparison between Early Palaeozoic granites from the Prydz Bay area. We do not include in our study the pegmatitic rocks from the Ruker Terrane, because the ages of these rocks are not well constrained, with some of them were dated Archaean while the other might be of Early Palaeozoic age (Tingey, 1982), which may cause a confusion considering the composition of these rocks altogether. This paper will be followed by a contribution on the geochemical composition and age of these rocks. In the present paper we try to distinguish geologically distinct rock groups, which may be of different origin or even represent different terranes, and this will be checked by dating and geochemical studies. We also outline some important field findings, summarize the available geological data and define objects for the further research.

GEOLOGICAL FEATURES

Granitic rocks in the southern PCM vary widely in both composition and field appearance. Variably deformed basement granitoids occur as large bodies sometimes making up cliffs up to a few hundred metres high (Fig. 2 A) and up to several kilometres across (*e.g.*, Mt. Ruker). However, such large bodies seem to be relatively rare as compared to the northern PCM and the Prydz Bay area (where they are younger). More often basement granitoids form pre- to syntectonic or syn- to late-tectonic sheet-like bodies some metres to decametres thick, which occur conformably intercalated with metasediments (Fig. 2 B) and rarely mafic rocks. In other localities a similar layering occurs at centimetre to decimetre scale reflecting migmatisation. A layered appearance of the granitic bodies is not common, but was observed in some localities (*e.g.*, Clemence Massif, McCue Bluff, Rimmington Bluff). Granitic gneisses are mostly medium to coarse-grained rocks of grey or rarely pinkish grey and occasionally greenish-brown colour. Subvertical dykes up to 10-20 m thick occur in many localities (Fig. 2 C), and sporadically form dense networks grading into larger bodies with only scarce rafts of the country rocks enclosed within them (Fig. 2 D). In a few localities larger, stock-like bodies occur (*e.g.*, Mts Stinear, Newton, McCauley, Dummett). In these locations, apart from Mt Dummett (personal communication from C.J.L. Wilson), the granitoids do not show any significant deformation patterns or structures either on outcrop scale or in thin section, and they are not cut by presumed Proterozoic mafic dykes (Tingey, 1991). Therefore these rocks are suggested to have Early Palaeozoic crystallisation ages.

The deformation style also varies widely. Nearly undeformed granites of both Archaean and early Palaeozoic age occur sporadically. The basement granite structure varies from equigranular, homogeneous to poorly developed augen (Fig. 3 A) and to highly stretched gneissic structure with relict feldspar porphyroclasts within wide shear zones (Fig. 3 B). Apparently syn-tectonic, gneissose granitoids may appear as slightly deformed masses (Fig. 3 C). Granitic material also forms isoclinally folded and sheared migmatite veins in the northern Mawson Escarpment (the Lambert Terrane) (Fig. 3 D), but these veins were not included in the present study.

Granitic basement rocks crop out in the northern and south-western parts of Cumpston Massif. In the

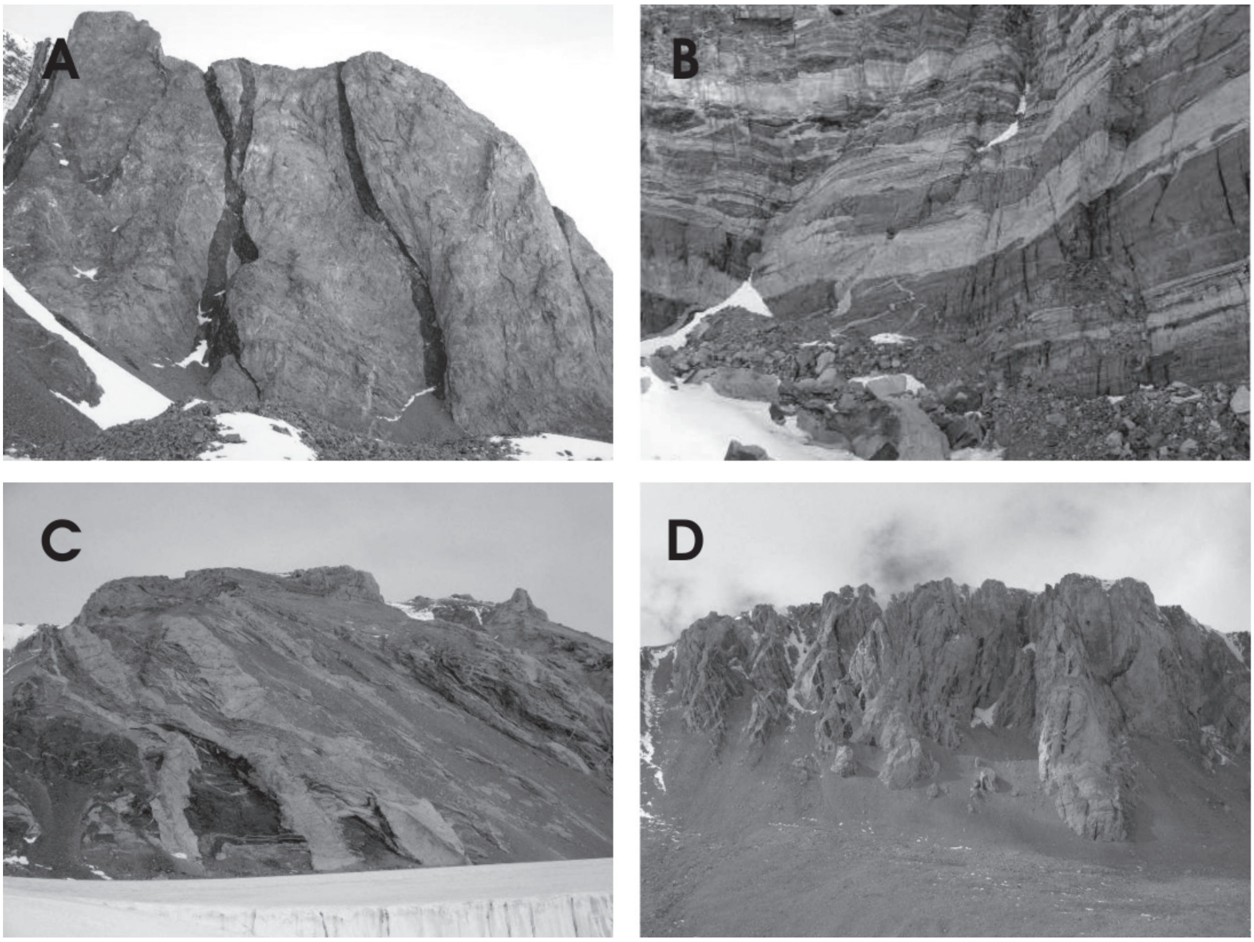

Fig. 2 - Granitoids in the southern PCM: (A) presumed Archaean granite in Mt. Rymill (north), cut by mafic dykes, (B) granitic sheets in Clemence Massif, (C) presumed Early Palaeozoic granite-pegmatite dykes in Rofe Glacier area, (D) dense stockwork of veins and dykes in Harbour Bluff, dated at c. 500 Ma by Tingey (1982). Outcrop height in A, C, D – 100–200 meters, in B – a few tens of meters.

former area the granite-gneisses and mafic rocks, presumably dykes, are highly sheared and folded, and the rocks are retrogressed, whereas in the latter the rocks are much less deformed and contain a dyke swarm composed of mafic schistose amphibolite, which indicates a strong, but coaxial strain pattern.

In the southern Mawson Escarpment (McCue Bluff) layered orthogneisses in a few outcrops show a spectacular change in colour from typical light grey to light or dark greenish-brown, with the "colour front" clearly cross-cutting the rock foliation. The colour front may be accompanied by similar "veins" intruding the protolith (Fig. 3 E). The field appearance strongly resembles occurrences of initial charnockitization in Dronning Maud Land (Mikhalsky & Weiser, 2004) or elsewhere in the former Gondwanaland continents. However, in a nearby locality a coarse-grained apparently magmatic charnockite (Fig. 4 A) was sampled from the scree, although it was clear that such rocks had come from the adjacent very steep cliff. Another rock in the same locality shows essential foliation (Fig. 4 B) suggestive of a considerable deformation of the charnockite. On the other hand, in the same area subconcordant orthopyroxene-bearing pegmatite bodies locally occur within pyroxene-bearing mafic rocks (Fig. 3 F, G), which suggests high-grade metamorphic conditions, maybe transitional from amphibolite to granulite facies. It is noteworthy that the granulite facies rocks are known from the northern Mawson Escarpment, but have never been reported from the southern Mawson Escarpment, although relict granulite assemblages were found in a few localities elsewhere in the Ruker Terrane (Mikhalsky et al., 2001, and references therein).

In many localities in the northern Mawson Escarpment granite and pegmatite veins and dykes are composed of very coarse-grained mica-quartz-feldspar rocks and have no tectonic overprint; biotite crystals may be up to 0.5 in length (Fig. 3 H). However, some felsic dykes and veins which cut across the foliation of the country rocks may bifurcate into a network of subparallel veins or form apophyses intruding the country rocks, with substantial deformation (shearing and small-scale folding) affecting both the country rocks and apophyses. Thus, many granitic dykes or veins in the northern Mawson Escarpment may not be truly post-tectonic.

PETROGRAPHIC FEATURES

The petrography of the crystalline (Archaean) basement rocks and presumed Early Palaeozoic granitic veins and stocks which intrude the basement is

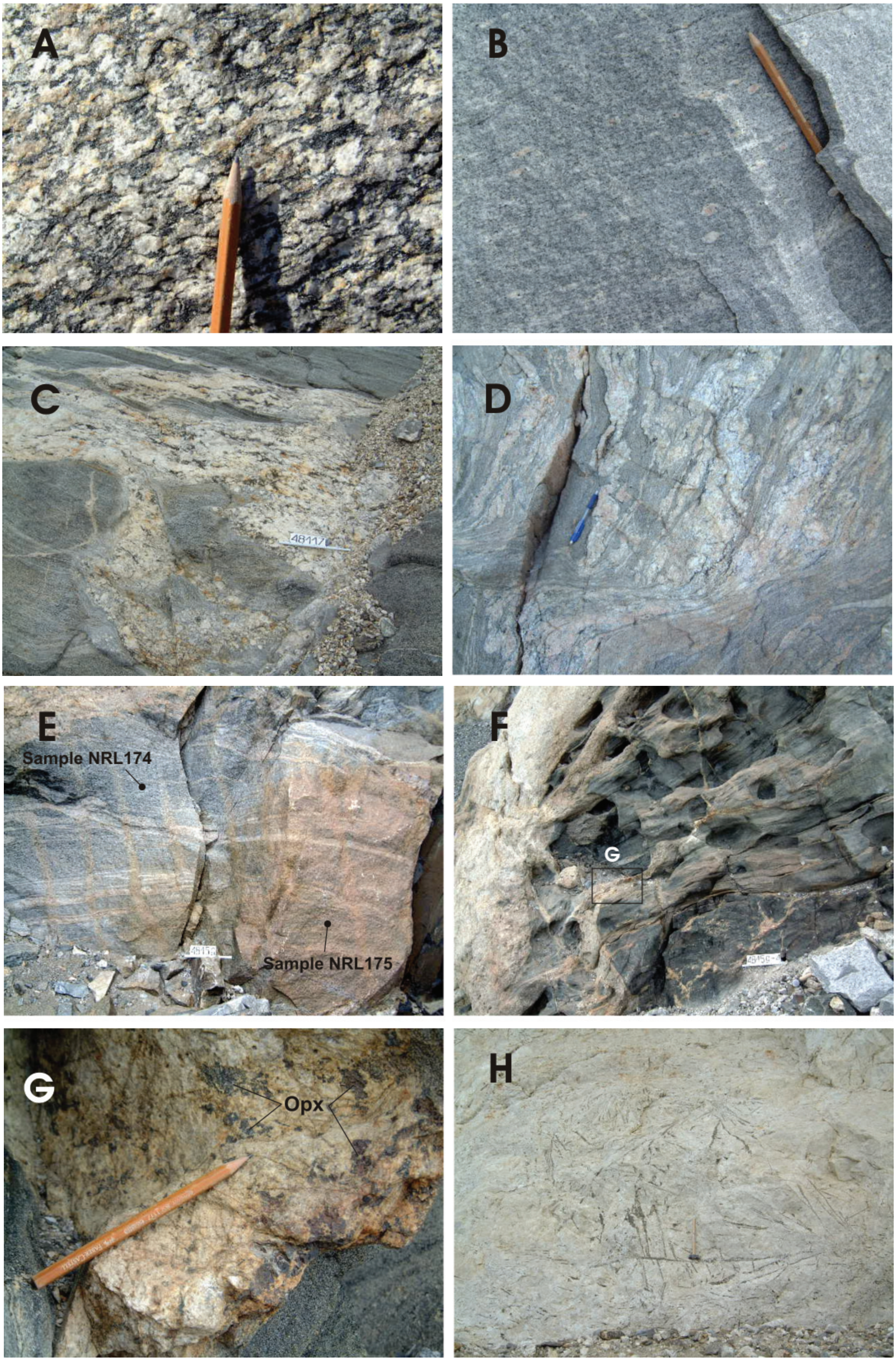

Fig. 3 - Outcrop appearance of granitic rocks in the southern PCM: (A) augen gneiss (deformed granite) in Rimmington Bluff, (B) highly sheared granite-gneiss in Cumpston Massif, note relict feldspar porphyroclasts, (C) syn-tectonic injections, Rofe Glacier area, (D) strongly deformed granitic injections cut by a dextral shear zone, (E) orthogneisses exhibiting the colour change probably due to fluid infiltration along subvertical vein-like zones, which may have been accompanied by charnockitisation process, McCue Bluff, (F) orthopyroxene-bearing pegmatite in mafic metamorphic rocks in McCue Bluff, (G) coarse orthopyroxene grains in pegmatite shown in F, (H) very coarse-grained biotite pegmatite in Rofe Glacier area; biotite packages are same size as a hammer (55 cm long) serving scale.

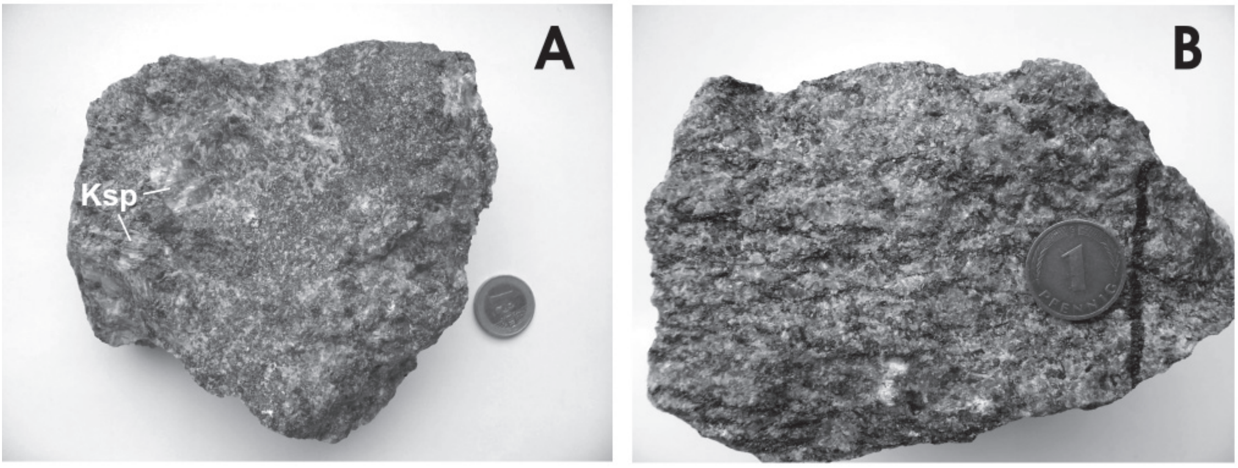

Fig. 4 - Charnockitic samples from McCue Bluff: (A) coarse-grained porphyric rock, NRL178; note potassium feldspar phenocrysts (Ksp), (B) foliated rock of similar bulk composition, with strongly stretched potassium feldspar porphyroclasts, NRL177.

described below. The petrographic terms and notation follow MacKenzie et al. (1982) and Bard (1986). The study was performed with a polarizing microscope, and plagioclase composition was estimated using a petrographic approach. About 100 thin sections were studied. The principal petrographic features of rocks from different areas are summarised in table 1.

ARCHAEAN BASEMENT GRANITOIDS AND ORTHOGNEISSES

In *Cumpston Massif* granitic rocks are highly deformed (sheared and folded), with a generally strongly developed gneissose structure. In the south-western part of the massif the rocks are mostly biotite-bearing quartz syenite to alkali feldspar

Tab. 1 - A summary of petrographic data.

Group	General composition	Mafic minerals	Accessory minerals	Predominate textures
		Presumed Early Palaeozoic granitoids		
North Mawson Escarpment	Leucocratic monzogranitic to sienigranitic, Ksp>Pl>Qtz	Bt, ±Grt, ±Hbl	±All, ±Zrn, ±Ap, ±Mnz	Heterogranular or aplitic
Harbour Bluff	Leucocratic monzogranitic to syenogranitic, Ksp>Qtz>Pl	Grt, ±Ms	Bt, Hbl, Ttn	Porphyric (Ksp)
Fisher Glacier area and southwards	Leucocratic syenogranitic, Ksp>Pl>Qtz	Ms, ±Bt, ±Grt	All, Mnz, ±Tur	Heterogranular to porphyric (Pl, Ksp)
Landing Bluff	Mesocratic (M up to 15) granitic, Ksp≈Pl≈Qtz	Bt, Ttn	All, Fl	Heterogranular, euhedral
		Basement orthogneisses and granitoids		
Cumpston Massif, southwestern part	Leucocratic syenogranitic to alkali feldspathec granitic, Ksp>Qtz>>Pl	Bt	±Fl, ±Ttn, ±OM	Heterogranular to porphyroblastic
Cumpston Massif, northeastern part	Leucocratic trondhjemitic, Pl>Qtz>>Ksp	Bt, Ms	Ttn, OM	Heteroblastic to porphyroclastic
Mawson Escarpment, southern part	Leucocratic quartz syenitic, Ksp>Qtz≈Pl	Bt, ±Hbl	Ttn, Zrc, All	Heteroblastic to porphyroclastic
Mawson Escarpment, southern part	Leucocratic to mesocratic (M up to 25) syenogranitic to monzodioritic	(Opx), Bt, ±Grt	Mnz, Zrc	Heteroblastic to porphyroclastic
Clemence Massif	Leococratic to mesocratic (M up to 10), Pl>Qtz>>Ksp	Bt, ±Grt	±OM	Heterogranoblastic
Mt Ruker	Leucocratic granitic to granodioritic	Bt	Zrc, Ttn	Heterogranular, porphyric (Ksp or Pl)
Mt Rymill	Mesocratic (M 5–10) quartz syenitic to syenogranitic, Ksp>>Qtz≈Pl	Hbl, ±Bt	All, OM	Equigranular to heterogranular
Mt Stinear	Leucocratic monzogranitic, Ksp≈Pl>Qtz	Hbl, ±Bt	All, Mnz, Ttn	Porphyroblastic (Pl)

Notes - Mineral abbreviations after Kretz (1983); OM is opaque mineral; M is colour index; ± denotes sporadical occurrence; brackets denote relict.

granite-gneisses consisting of quartz (10-30 vol.%, shown as % hereafter), potassium feldspar (up to 70%) and minor plagioclase, or magnetite-biotite bearing plagiogneisses comprising quartz (10-40%), microcline (10-20%) and plagioclase (50-70%, An_{30}). Syenitic gneisses have highly heterogranular to heteroblastic texture, partly porphyroclastic with microcline porphyroclasts up to 4x4 mm across, strongly framed[1]; mylonitic textures are commonly developed. Mafic minerals are minor constituents and include khaki-green biotite and titanite, which forms lensoid aggregates with equal proportions of quartz and may represent secondary material after the earlier mafic minerals (amphibole?). In one sample fluorite occurs as abundant small oval or squared grains as inclusions in potassium feldspar and within the matrix. Larger accessory titanite grains are usually present. In the north-western part of Cumpston Massif plagioclase-rich rocks (60–70%, $An_{20–22}$) occur, and those have experienced strong secondary alteration (saussurite, carbonate, muscovite).

In the *southern Mawson Escarpment* the basement granitoids vary widely both in composition and deformation style. Petrographically at least two rock types may be distinguished:

1) Biotite and hornblende–biotite gneisses of quartz syenitic (quartz 15-20, plagioclase 10-15, potassium feldspar 60-65%) to granodioritic (quartz 20-40, plagioclase 40-45, potassium feldspar 10-30%) composition, which were sampled mainly from Rimmington Bluff and further south in the Mawson Escarpment; however, a few biotite gneiss samples were also collected from McCue Bluff and near the eastern extremity of Tingey Glacier.
2) Orthopyroxene-bearing gneisses of syenogranitic (quartz 15-30, plagioclase 10-15, potassium feldspar ~70%) to monzodioritic (quartz 5-15, plagioclase 60-65, potassium feldspar 20-25%) composition, which were sampled from McCue Bluff.

The plagioclase composition in both rock types is An_{30-32} in biotite and hornblende–biotite gneisses, and An_{20-25} in the orthopyroxene-bearing gneisses. The structure of both types is mostly highly gneissose and sometimes layered, and the texture highly heteroblastic to porphyroclastic, generally with a medium- to fine-grained matrix enclosing larger porphyroclasts. Porphyroclasts are rarely framed (showing marginal cataclasis and recrystallisation), although mylonitic textures are commonly developed within the matrix. The rock texture thus varies from slightly framed granitic (Fig. 5 A) to highly sheared or even mylonitic (Fig. 5 B). The matrix has an anhedral, granolepidogranoblastic texture with the grain boundaries slightly interlocking; a slight polygonal pattern is rarely developed. The observed compositional variations may be due at least partly to the presence of scarce porphyritic megacrysts which strongly influence the bulk modal composition seen in thin sections. Both types may contain porphyroclasts of potassium feldspar and plagioclase (up to 10 mm in size), which look like phenocrysts in less deformed varieties.

Biotite and hornblende–biotite rocks are relatively leucocratic with a colour index mostly ranging from 1 to 5, and rarely up to 10. In the latter case hornblende and biotite are accompanied by titanite and an opaque phase to form lens-shaped aggregates in association with fine-grained quartz. Hornblende is usually emerald green and biotite is khaki green; they form fine-grained prisms and flakes, respectively. Zircon and allanite are the accessory phases in some rocks. Generally similar lithologies occur in the northern part of *Mt. Stinear.*

Orthopyroxene-bearing rocks are somewhat more mafic, with the colour index ranging from 3-4 to 20-25. Orthopyroxene was found only in darker-coloured, greenish-brown to light brown rocks. The adjacent light-coloured grey rocks are biotite gneisses with traces of hornblende. Orthopyroxene usually forms small colourless to pinkish grains of irregular shape (Fig. 5 C) in the gneissic varieties. It forms porphyric isometric prismatic grains (2x2 mm; Fig. 5 D) in coarse-grained rocks which contain large rounded megacrysts of white or yellowish potassium feldspar, features typical of magmatic charnockite (e.g., Roland, 2004). In the gneisses small orthopyroxene grains occur in close spatial association with quartz, quartz + biotite, or quartz + opaque phase, and the phase relationships point to replacement of orthopyroxene by biotite and quartz (Fig. 5 E). In a few samples garnet also occurs as atoll-structure aggregates in association with fine-grained quartz and plagioclase, and was probably formed at the expense of orthopyroxene or orthopyroxene and biotite (Fig. 5 F). In hand specimen such garnet-bearing rocks have more homogeneous structures than garnet-free gneisses, so the garnet-bearing rocks seem to loose their gneissosity. Biotite may constitute up to 20% of the rock volume. It is brownish-green to reddish-brown, and may contain relict orthopyroxene inclusions. Monazite and zircon are the usual accessories. As the polygonal texture is only a rare, poorly developed feature, it might be suggested that the overall texture and composition of these rocks (strongly sheared in many cases) does not correspond to a granulite-facies metamorphic event. The apparent lack of orthopyroxene in the surrounding rocks is surprising and may be accounted for by its complete consuming during the hydration. On the other hand, the charnockitization process may have been responsible for the formation of orthopyroxene, in this case representing an advanced stage of it (completed rather than initial charnockitization).

Somewhat different lithologies occur in *Clemence Massif.* In the north-eastern part of the massif biotite plagiogneisses of tonalite to granodiorite composition predominate. The rock texture is heterogranoblastic,

[1] *Framed texture: rock with protoclasis or beginning of cataclasis characterized by its microcrystalline mortar cementing porphyroclasts (Bard, 1986).*

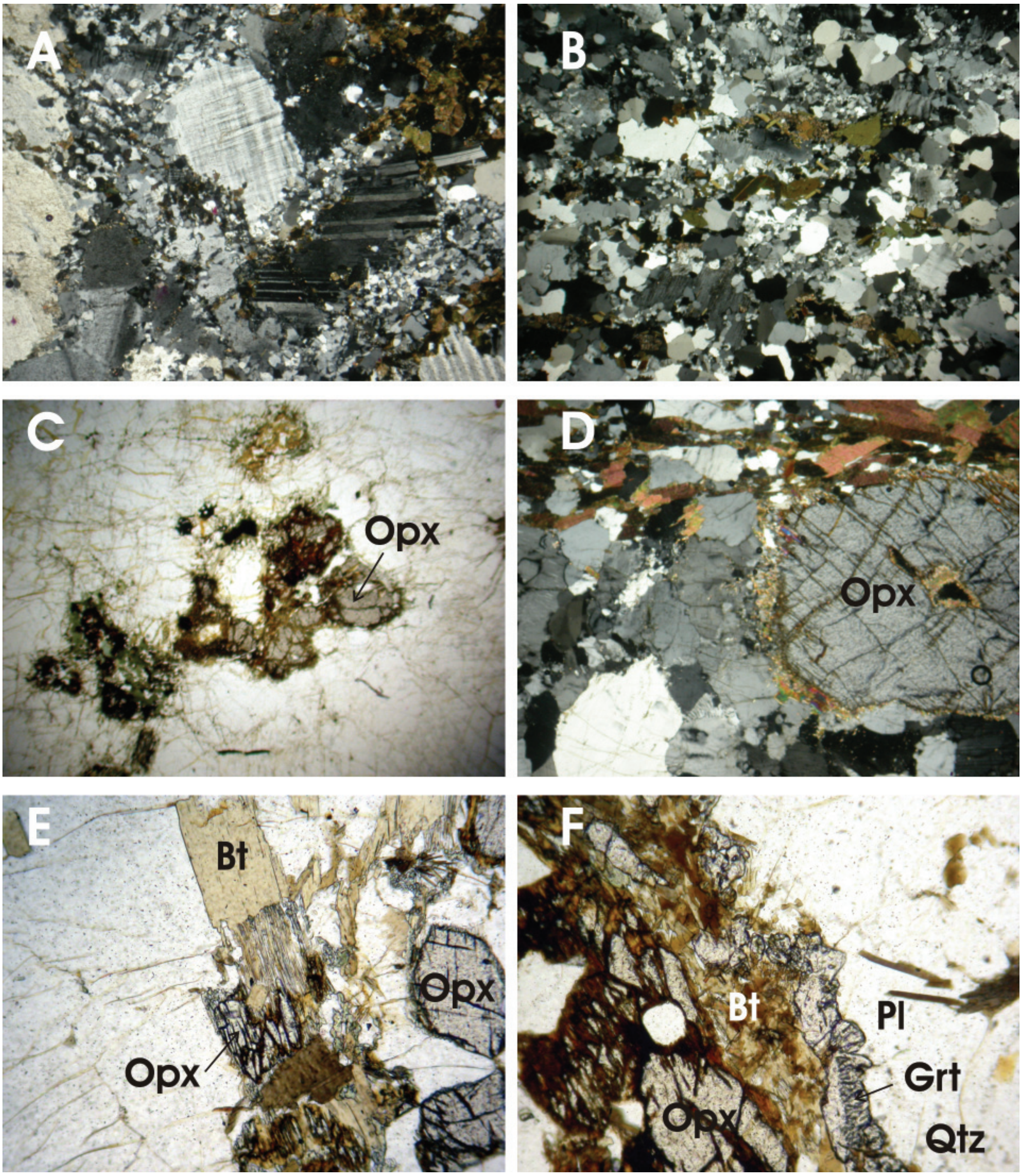

Fig. 5. Microphotographs of selected orthogneisses from the southern PCM: (A) granitoid with slight blastocataclastic (framed) structure, Mt Rymill, NRL 100, (B) hornblende granite-gneiss, highly sheared, with relict plagioclase porphyroclast, Mt Stinear, NRL 88, (C) orthopyroxene-bearing orthogneiss, southern Mawson Escarpment, NRL 179, (D) orthopyroxene megacryst in quartz – feldspar matrix of charnockite, McCue Bluff, NRL 177, (E) biotite replacing orthopyroxene in charnockite, McCue Bluff, NRL 178, (F) garnet developed around biotite replacing orthopyroxene, McCue Bluff, NRL 178. View area approximately 5x7.5 mm (B, C), 2.5x3.7 mm (A, D) and 0.6x1 mm (E, F).

mainly coarse- to medium-grained, subhedral to anhedral, with a weak gneissosity; no clear polygonal texture was apparent, but some rocks contain plagioclase grains forming "Y" junctions. The rocks are composed of quartz (20-35%), plagioclase (An_{25-30}, 55-70%) and potassium feldspar (≤ 25% or lacking). The colour index varies between 2-3 and 5-10, with reddish-brown biotite being the most common mafic constituent. Garnet may occur as rare atoll grains, and opaque minerals form small anhedral, sometimes abundant grains. Secondary minerals include chlorite (after biotite), muscovite and sericite, and saussurite after plagioclase. Other rock types in Clemence Massif include felsic gneisses of biotite quartz monzonite and garnet leucogranite composition, but, from field observations, these rock types are only subordinate.

Two lithologies were observed in the granitic pluton in *Mt Ruker* (its north-eastern part): biotite granite and biotite granodiorite. The biotite granite has a heterogranular, mostly coarse-grained, porphyric, subhedral to euhedral texture. It contains large tabular (up to 5x10 mm) microcline-perthite phenocrysts enclosed in a matrix of quartz (20-30%), plagioclase (An_{30-32}, 25-30%) and microcline (40-50%). Quartz forms mosaic aggregates of small grains tending to fill the interstices between feldspar grains. Plagioclase forms euhedral tabular grains and was probably the first phase to have crystallised. Biotite constitutes up to 5% of the rock volume. It is fine-grained, brown or "dusty" green, and tends to fill the interstices, forming aggregates with quartz and secondary muscovite, carbonate, and epidote. Zircon is an accessory mineral. Biotite granodiorite contains plagioclase phenocrysts enclosed in a groundmass of quartz (15-20%), plagioclase (An_{30-35}, ~75%) and microcline (5-10%). Biotite flakes form fibrous masses in association with quartz and epidote, which may have been formed at the expense of clinopyroxene. Titanite is an accessory mineral. Secondary alteration is strongly pronounced, plagioclase being largely replaced by saussurite and biotite by chlorite.

In *Mt Rymill* (both northern and southern parts) hornblende±biotite quartz syenite to syenogranite crops out. The rocks have an equigranular medium-grained to heterogranular medium- to fine-grained, subhedral to anhedral, slightly framed texture. They are composed of quartz (15-25%), plagioclase (An_{22-25}, 10-15%) and perthitic microcline (55-65%). Mafic minerals are relatively abundant (5-10%). Dark green or bluish-green hornblende is the major constituent, and forms subhedral prismatic grains often containing small quartz inclusions, apparently replacing some early magmatic mineral phase (pyroxene?). An opaque mineral (titanomagnetite?) occurs sporadically, and is replaced by titanite and leucoxene. Interstitial brown biotite forms secondary fine-grained aggregates. Allanite grains are abundant. Granite-gneisses of broadly similar syenitic composition crop out in the southern part of Mt Rymill, but there biotite, rather than hornblende, occurs. The rocks are more leucocratic, and they are far more deformed than those in the northern part.

PRESUMED EARLY PALAEOZOIC GRANITOIDS

In the Rofe Glacier area and on Barkell Platform (*northern Mawson Escarpment*) granitoid veins and dykes, which are presumably of Early Palaeozoic age, are mainly composed of fine- to medium-grained leucocratic rocks of monzogranite to syenogranite composition. Coarser-grained rocks are found in larger bodies. Major rock forming minerals are cross-twinned perthitic microcline (40-50%), sodic plagioclase (An_{22-28}, 25-35%) and quartz (15-30%). The rock structure is basically heterogranular and aplitic. Feldspars form subhedral to anhedral grains with interlocking grain boundaries. Quartz forms irregular blebs or is xenomorphic. It rarely forms elongated grains which define a slight gneissosity. In most rocks the major rock-forming minerals seem to have crystallised simultaneously, but in a few rocks quartz seems to have been the first phase to crystallise. Mafic minerals are mostly represented by small biotite flakes, partly replaced by chlorite and opaque minerals, or rarely by larger tabular, probably early crystallised grains and sparse hornblende crystals (Fig. 6 A). Garnet occurs in a few samples, and forms atoll to hollow coarse grains (1-4 mm) with abundant quartz inclusions, and is surrounded by quartz grains. Accessories are allanite, zircon, apatite, and monazite, but these occur only sporadically. The rocks are generally fresh, but biotite is sometimes replaced by chlorite. An unusual cordierite-bearing pegmatite (Fig. 6 F) was found within orthopyroxenite in Lawrence Hills. Apart from quartz, this coarse-grained rock contains 10–20% cordierite and sporadic grains of potassium feldspar and orthopyroxene.

In Harbour Bluff (*central Mawson Escarpment*) granitic veins and dykes are composed of generally similar lithologies (leucocratic monzogranite to syenogranite), but coarse-grained rocks are more common, and the rock structure is mostly porphyric with large microcline phenocrysts (up to 8-10 mm). A distinctive feature of these rocks is the relative abundance of garnet (up to 1-2%), and muscovite also occurs in most samples (Fig. 6 B). Accessory biotite, hornblende and titanite may be present. Biotite, when present, is replaced with cryptic secondary products.

On *Mts McCauley* and *Dummett* (Fisher Glacier area) muscovite-bearing granite (syenogranite) occurs. This is a mostly heterogranular to porphyric, coarse- to medium-grained rock, with rare plagioclase phenocrysts (up to 2x2 mm) enclosed in a nearly isogranular euhedral to subhedral matrix of microcline, plagioclase and quartz. Plagioclase (An_{25-28}) and muscovite are the first phases to have crystallised. Muscovite forms either large (up to 1 mm) or fine-grained flakes and tabular grains, and makes up to 10-15%. Biotite occurs only as rare small flakes. Allanite and monazite are rare accessories. Quite similar muscovite-bearing granite at *Wilson Bluff* contains microcline phenocrysts, highly corroded tabular reddish-brown biotite, irregularly shaped muscovite (Fig. 6 C), and a few small tourmaline crystals. Muscovite-garnet-bearing leucogranite in *Mt Newton* has a quartz monzonite composition (quartz 10-15%, plagioclase 30-35% (An_{30}), microcline 45-50%) and a heterogranular, predominantly coarse-grained, subhedral, cataclastic texture. Quartz forms irregular oval grains of highly variable size (0.5-7 mm) and was probably the first to have crystallised. The rock contains coarse-grained garnet (atoll to hollow crystals, 10-15%; Fig. 6 D), and singular tabular muscovite grains, which are altered to sericite rosettes within some fractures cutting across the rock fabric, and a few pale green flakes of biotite. Otherwise the rocks are not altered. At some localities within the granite pluton in Mt Newton very garnet-rich varieties occur. Garnet is up to 10 cm large and may constitute up to volume 30% of the rock. Similar, but

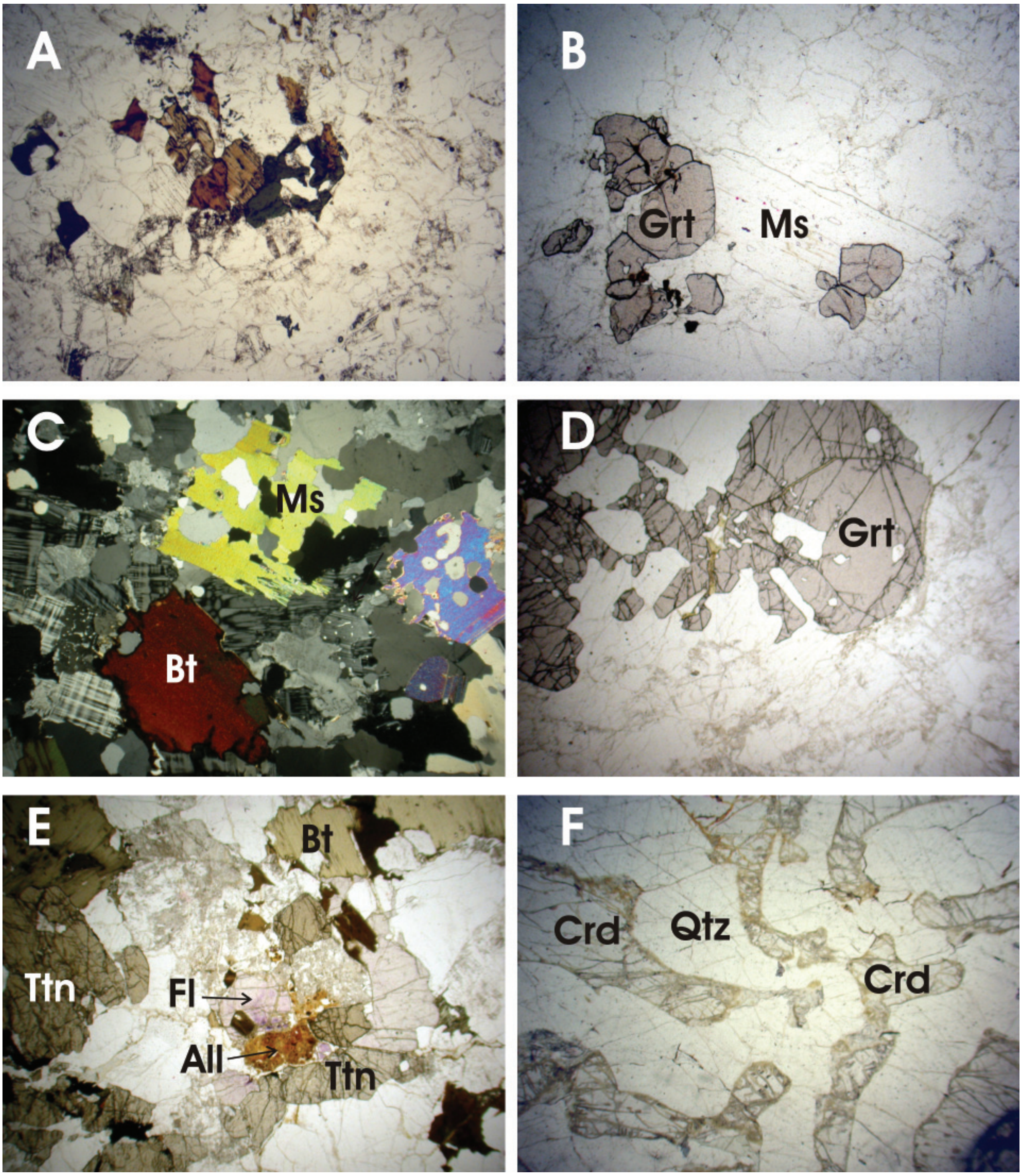

Fig. 6 - Microphotographs of presumed Early Palaeozoic granitic rocks from the southern PCM and Landing Bluff: (A) biotite-hornblende aplite, Rofe Glacier, NRL 61, (B) garnet–muscovite granite, Manning Glacier, NRL 72b, (C) biotite–muscovite granite, Wilson Bluff, NRL 146, (D) (muscovite)-garnet quartz monzonite, Mt Newton, NRL 136, E) biotite granite, Landing Bluff, NRL 217, F) cordierite-bearing pegmatite, Lawerence Hills, 48113-12. View area approximately 5x7.5 mm (A, C–F) and 2.5x3.7 mm (B).

with a higher plagioclase/potassium feldspar ratio, muscovite-garnet granitoid occurs on *Mt. Borland*. On *Mt. Creswell* muscovite±biotite±garnet granite occurs as large gently dipping dykes. The rocks have a coarse-grained pegmatoid texture, but in some instances the rocks exhibit deformation and gneissose texture. Crystallization of plagioclase, potassium feldspar and quartz occurred simultaneously, which suggests that the rocks are of near-minimum melt composition.

The Early Palaeozoic granitic pluton in *Landing Bluff* area (Tingey, 1991, and references therein) was visited only briefly during the PCMEGA. At the landing site it is composed of biotite granite. The rocks have a heterogranular, generally phaneritic, euhedral texture. They are composed of quartz (25-40%), plagioclase (An_{33-35}, 20-30%) and microcline (30-40%). The colour index ranges from 5 to 15, with biotite being the most common phase. It is greenish-brown, and forms coarse tabular grains or plates (up to 3 mm), isomorphic with plagioclase and quartz. Large titanite and metamict allanite grains are abundant. Fluorite forms large, but rare grains of irregular shape (Fig. 6 E).

DISCUSSION AND CONCLUSIONS

The petrographic features of most of the samples point to an igneous, most likely plutonic origin, that is these rocks are orthogneisses. In spite of the wide development of initial blastocataclasis and common mylonitic fabrics, relict magmatic textures may be observed. The presence of two petrographically distinct orthogneiss types in the southern Mawson Escarpment point to a complex composition and structure for this part of the Ruker Terrane. The observed features of orthopyroxene-bearing rocks suggest that orthopyroxene may be of either magmatic origin, or developed through a charnockitization process, or both. There is no evidence for a biotite breakdown reaction preserved in the rocks, which puts doubt on the secondary origin of orthopyroxene, unless the reaction was complete. Moreover, orthopyroxene is apparently being replaced by biotite, and the latter reacts to form garnet. The apparent euhedral shape of orthopyroxene also argues for a magmatic origin. However, it must be noted that orthopyroxene is lacking in the grey gneisses in contact with the orthopyroxene-bearing greenish-brown gneisses (Fig. 3 E). This may be difficult to reconcile with a magmatic origin of orthopyroxene in these gneisses. It should be noted that the texture of the brownish "veins" cutting the foliation and gneissosity are more homogeneous and apparently less sheared. Therefore the formation of orthopyroxene co-eval with the observed colour change due to a fluid infiltration cannot be completely discounted in this locality (Fig. 3 E). However, in this case complete, rather than initial, charnockitization must have taken place. Nevertheless, the presence of true magmatic charnockites in this area (unfortunately, not seen in an outcrop) is well indicated by the rock structure and texture (if anything definitive can be said about that most enigmatic rock type – charnockite). Thus, at this stage of the investigation it is most likely that both magmatic and "incipient" charnockites occur in the southern Mawson Escarpment, with the development of the latter maybe triggered by the intrusion of the magmatic charnockite. The presence of orthopyroxene-bearing pegmatites indicates the high-grade conditions of these processes. Clearly, additional mineralogical studies are needed to constrain the geological history in this area.

Different lithologies (plagioclase-rich tonalitic to granodioritic rocks) occur in Clemence Massif, which suggests that this massif may represent a separate crustal block. Similar lithologies are well exposed in the central PCM (Fisher Massif and nearby localities, Mikhalsky et al., 1996), so a possible correlation with the Mesoproterozoic rocks of that area should be investigated. Yet another orthogneiss type occurs in Cumpston Massif, in the south-western part of which the rocks contain magnetite and fluorite. The latter is a characteristic of A-type granitoids, which were reported to form much of the southern Mawson Escarpment, along with some other localities within the Ruker Terrane (Sheraton et al., 1996). However, fluorite has not been reported from these areas before, thus this massif may represent a separate block, although the widespread mafic dykes provide some indirect evidence for a correlation with the southern Mawson Escarpment.

The Archaean granite on Mt Ruker and yet undated granite on Mt Rymill also reveal systematic differences, which again points to the compositional heterogeneity of the granite-gneiss basement in the Ruker Terrane.

The orthogneisses from the Ruker Terrane and the Lambert Terrane show prominent differences in chemical composition (Mikhalsky et al., 2006). The Ruker Terrane rocks are more sodic and less enriched in most trace elements than the Lambert Terrane rocks. In many discrimination diagrams the Lambert Terrane and Ruker Terrane rocks plot in different, although sometimes partly overlapping, fields, as will be discussed in the subsequent presentation. The chemical composition of the Lambert Terrane rocks suggests that they have calc-alkaline features and likely originated, broadly speaking, in orogenic environments (a magmatic arc at a continental margin or a mature volcanic arc) as opposed to anorogenic environments. These features are not typical for the Ruker Terrane rocks, which have compositions comparable to within-plate types with some features in common with A-type granites.

The younger, presumably Early Palaeozoic, granitic rocks in the three areas studied in more detail (the northern Mawson Escarpment, the central Mawson Escarpment, and the Fisher Glacier area) show systematic petrographic differences, which may indicate consistent compositional differences between the source regions in these three domains or different melt crystallisation histories. Many rocks, particularly those in the central Mawson Escarpment and in the Fisher Glacier area, contain muscovite or muscovite and garnet, but no cordierite has been detected. It may be that not all of these rocks were necessarily derived from (meta)sedimentary precursors, that means they may be not of only S-type. White et al. (1986) showed that locally peraluminous granites may result from contamination of metaluminous I-type, or could even be derived by partial melting of igneous sources with fractionation enhancing the peraluminous nature of such magmas. Nonetheless, the granites of the southern PCM share some common petrographic features: rather leucocratic compositions with the colour index very rarely exceeding 5–10, general lack of hornblende, commonly garnet-bearing, and generally rare accessory minerals (titanite, monazite, allanite, and zircon in particular; an exception is provided by granitic rocks within mafic to ultramafic slabs in the Rofe Glacier area which contain abundant accessory allanite, monazite, apatite, and zircon).

The widespread occurrence of muscovite in the southern areas of the region may also indicate that these granitoids crystallised at a different crustal level compared to the biotite granitoids in the northern

Mawson Escarpment, and further research is needed to evaluate the crystallization conditions. However, an important feature of the granites in the northern Mawson Escarpment is their close spatial association with granite sheets and leucosome veins (although of unknown age), which occur concordant to the country rock structure, and are sometimes folded. Thus, the field observations provide evidence for syn- to late-tectonic, rather than post-tectonic, emplacement of many granites in the northern Mawson Escarpment. These observations imply granite emplacement at considerable depth, which may also be very close to the level of granite melt segregation and extraction. Thus, it may be concluded that the area of the northern Mawson Escarpment may represent a separate crustal block with a distinctive geological history.

The Cambrian granitoids of Landing Bluff have a quite distinct mineral composition. Therefore, these rocks cannot be correlated with any of the southern PCM granitoids even given the wide compositional variation of the latter. The granites in the eastern Amery Ice Shelf area are of well-established A-type (Sheraton & Black, 1988; Sheraton et al., 1996). Thus, the coastal area at Prydz Bay/Amery Ice Shelf and the southern PCM may have experienced different tectonic processes in the Early Palaeozoic, resulting in the development of distinct granite suites.

The most important topics and objects for further studies are:

1) Petrogenesis, ages and palaeotectonic environments of the basement orthogneisses, especially in Cumpston Massif and Clemence Massif, where juvenile subduction-derived granitoids may be present,
2) Nature, origin and age of charnockitic rocks and related processes,
3) Petrogenesis, ages and palaeotectonic environments of different late- to post-tectonic granites, with particular emphases on the source region, crystallisation conditions and relations between the rocks mineral and chemical compositions,
4) Correlation of Early Palaeozoic granites in the southern PCM with similar rocks elsewhere in the Lambert Glacier – Amery Ice Shelf region,
5) Isotopic protolith age mapping based on Sm–Nd whole rock data.

Acknowledgements - We thank J.W. Sheraton and S. Rocchi for their constructive reviews and improvement of the language. This work was made possible in part by a grant from the Deutsche Forschungsgemeinschaft to EVM. This study was partly supported by the Russian governmental Federal Program "World Ocean", subprogram "Antarctica".

REFERENCES

Bard J.P., 1986. *Microtextures of igneous and metamorphic rocks*. D. Reidel Publishing Company, 264 p.

Boger S.D., Wilson C.J.L. & Fanning C.M., 2001. Early Paleozoic tectonism within the East Antarctic Craton: the final suture between east and west Gondwana? *Geology*, **29,** 463-466.

Boger S.D., Wilson C.J.L. & Fanning C.M. 2006. An Archaean province in the southern Prince Charles Mountains, East Antarctica: U–Pb zircon evidence for c. 3170 Ma granite plutonism and c. 2780 Ma partial melting and orogenesis. *Precambrian Research*, **145**, 207–228.

Fitzsimons I.C.W., 2003. Proterozoic basement provinces of southern and southwestern Australia, and their correlation with Antarctica. In: Yoshida, M. et al. (eds.), *Proterozoic East Gondwana: supercontinent assembly and breakup, Geol Soc London, Spec. Publ.*, **206**, 93–130.

Halpern M. & Grikurov G.E., 1975. Rubidium–strontium data from the southern Prince Charles Mountains. *Antarctic Journal of the United States*, **10**, 9–15.

Kamenev E.N., Andronikov A.V., Mikhalsky E.V., Krasnikov N.N. & Stüwe K., 1993. Soviet geological maps of the Prince Charles Mountains. *Australian Journal of Earth Sciences,* **40**, 501–517.

Kretz R. 1983. Symbols for rock-forming minerals. American Mineralogist, 68, 277–279.

MacKenzie W.S., Donaldson C.H. & Guilford C., 1982. *Atlas of igneous rocks and their textures*. Longman, 148 p.

Mikhalsky E.V. & Weiser T. 2004. Incipient charnockite or hydrated granulite in the Conradgebirge in Central Dronning Maud Land, Antarctica? In: Paech H.-J- (ed.), *International GeoMaud Expedition of the BGR to Central Dronning Maud Land in 1995/96 – Geological Results. Geologisches Jahrbuch*, **B 96**, 293–305.

Mikhalsky E.V., Sheraton J.W., Laiba A.A. & Beliatsky B.V., 1996. Geochemistry and origin of Mesoproterozoic metavolcanic rocks from Fisher Massif. *Antarctic Science,* **8**, 85–104.

Mikhalsky E.V., Sheraton J.W., Laiba A.A. et al., 2001. Geology of the Prince Charles Mountains, Antarctica. *AGSO Bulletin*, **247**.

Mikhalsky E.V., Beliatsky B.V., Sheraton J.W. & Roland N.W. 2006. Two distinct Precambrian terranes in the southern Prince Charles Mountains, East Antarctica: SHRIMP dating and geochemical constraints. *Gondwana Research*, **9**, 291–309.

Phillips G., Wilson C.J.L. & Fitzsimons I. 2005. Stratigraphy and structure of the southern Prince Charles Mountains (East Antarctica). *Terra Antartica*, **12**(2), 69–86.

Roland N.W., 2004. Early Palaeozoic granite–charnockite magmatism in Central Dronning Maud Land, East Antarctica: petrography, geochemistry and plate tectonic implications. In: Paech H.-J- (ed.), International GeoMaud Expedition of the BGR to Central Dronning Maud Land in 1995/96 – Geological Results. *Geologisches Jahrbuch*, **B 96**, 187–231.

Sheraton J.W. & Black L.P., 1988. Chemical evolution of granitic rocks in the East Antarctic Shield, with particular reference to post-tectonic granites. *Lithos*, **21**, 37-52.

Sheraton, J.W., Tindle, A.G. & Tingey, R.J., 1996. Geochemistry, origin, and tectonic setting of granitic rocks of the Prince Charles Mountains, Antarctica. *AGSO Journal of Australian Geology and Geophysics*, **16**, 345–370.

Tingey R.J., 1982. The geologic evolution of the Prince Charles Mountains—an Antarctic Archean cratonic block. In: Craddock, C. (ed.), *Antarctic Geoscience*, University of Wisconsin Press, Madison, 455–464.

Tingey R.J., 1991. The regional geology of Archaean and Proterozoic rocks in Antarctica. In: Tingey, R.J. (ed.), *The geology of Antarctica*, Clarendon Press, Oxford, 1–58.

White A.J.R., Clemence J.D., Holloway J.R., Silver L.T., Chappell B.W. & Wall V.J., 1986. S-type granites and their probable absence in southwestern North America. *Geology*, **14**, 115-118.