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New Evidence for Palaeoproterozoic Tectono-Magmatic Activities in the Southern Prince Charles Mountains, East Antarctica

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Abstract: We present new U-Pb zircon (SHRIMP) data on rocks from Mt Newton and Cumpston Massif in the southern Prince Charles Mountains. Our data demonstrate that Mt Newton was affected by a newly proposed Palaeoproterozoic "Newton" Orogeny at c. 2100-2200 Ma. Sedimentation, felsic volcanism (c. 2200 Ma), metamorphism and folding, followed by granite intrusion (c. 2100 Ma), suggest development of a trough or aulacogene in the area during the early Palaeoproterozoic. An orthogneiss from Cumpston Massif yielded an age of c. 3180 Ma for granitic protolith emplacement, which is in good agreement with many U-Pb zircon ages from similar rocks in the southern Mawson Escarpment. A syn- to late-tectonic muscovite-bearing pegmatite from Cumpston Massif yielded a c. 2500 Ma date of emplacement, which indicates early Palaeoproterozoic activity in this block, probably in response to a tectono-magmatic episode in the Lambert Terrane bordering the Ruker Terrane in the northeast. The correlation of tectono-magmatic events in both the Ruker and Lambert terranes of the southern Prince Charles Mountains provides evidence for their common evolution during the Proterozoic.

Zusammenfassung: Es werden neue U-Pb-Zirkon-Alter (SHRIMP) von Gesteinsproben von Mt. Newton und Cumpston-Massiv aus den südlichen Prince Charles Mountains vorgelegt. Die Daten zeigen, dass Mt. Newton von der paläoproterozoischen Newton-Orogenese vor 2100-2200 Ma betroffen war. Sedimentation, felsischer Vulkanismus (ca. 2200 Ma), Metamorphose und Auffaltung, gefolgt von Granitintrusionen (ca. 2100 Ma), sprechen für eine Entwicklung in einem Trog oder Aulakogen während des frühen Paläoproterozoikums. Ein Orthogneiss vom Compston-Massiv ergab ein Alter von ca. 3180 Ma für die Intrusion des granitischen Protolith. Dies ist in guter Übereinstimmung mit vielen U-Pb-Zirkon-Altern ähnlicher Gesteinen des südlichen Mawson Escarpment. Ein syn- bis spättektonischer Muskovit führender Pegmatit vom Cumpston-Massiv lieferte ein Intrusionsalter von ca. 2500 Ma. Dies zeigt eine früh-paläoproterozoische Aktivität für diesen Block an, wahrscheinlich eine Reaktion auf eine tektono-magmatische Episode im Lambert Terrane, das das Ruker Terrane im Nordosten begrenzt. Die Korrelation tektono-magmatischer Ereignisse in den Ruker und Lambert Terranes der südlichen Prince Charles Mountains liefert Beweise für ihre gemeinsame Entwicklung während des Proterozoikums.

INTRODUCTION

The southern Prince Charles Mountains (SPCM) are composed mainly of rock associations raging from Neoproterozoic to Palaeoarchaen (c. 3400-3500 Ma), and these may be the most ancient plutonic and metamorphic rocks (unaffected by subsequent tectonothermal events) exposed in the Antarctic. Some authors (e.g. KAMENEV 1993) consider this area as a granite-greenstone terrane stabilized by the end of the Archaean, but later works (PHILLIPS et al. 2006) showed the development of later geological processes in some particular localities. In the SPCM, the rock exposures are concentrated in relatively large, but isolated mountain blocks (Fig. 1) of varying lithology and structure, which impedes direct geological correlations throughout the area. However, detailed geological and geochronological studies of these separate localities can provide a tectono-stratigraphic basis for such correlations and better understanding of the geological composition and structure of this region.

In 2002/2003 the Prince Charles Mountains Expedition of Germany and Australia (PCMEGA) collected new geological data from an extensive area in the SPCM. In this study we present new isotopic data on rocks collected from Mt Newton and Cumpston Massif, for which no U-Pb zircon isotopic data were available, and address the so far enigmatic relationships between the different terranes in the SPCM.

REGIONAL GEOLOGICAL BACKGROUND

The structure of the Prince Charles Mountains (PCM) has been described in terms of two tectonic provinces (TINGEY 1991, FITZSIMONS 2003 among others): the Meso to Early Neoproterozoic Rayner Province in the north and the Archaean Ruker Province in the south (Fig. 1). MIKHALSKY et al. (2001) described Mesoproterozoic volcano-plutonic Fisher Terrane in the central PCM and KAMENEV (1993) and MIKHALSKY et al. (2006) distinguished a separate Palaeoproterozoic Lambert Terrane in the Mawson Escarpment on the basis of lithology and isotopic age data. PHILLIPS et al. (2006) included both the Lambert and Ruker Terranes within a single Ruker Province.

The southern Prince Charles Mountains (SPCM) are underlain by thick metasedimentary sequences tectonically interleaved with orthogneisses; the strata are locally cut by abundant mafic dykes. Geological investigations (TINGEY 1991, MIKHALSKY et al. 2001 and references therein) showed that the Ruker Terrane rocks are generally of low to medium metamorphic grade (greenschist to amphibolite facies), unlike in other areas of Mac Robertson Land to Princess Elizabeth Land. TINGEY (1982a, 1991) divided the metamorphic rocks in the SPCM into the granitic basement (the Mawson Orthogneiss and at least part of the Menzies Series) and overlying metasediments (the Menzies, Ruker and Sodruzhestvo series) of Archaean to Neoproterozoic age.

The geological history of the Ruker Terrane (Fig. 2) goes back to c. 3400 Ma (MIKHALSKY et al. 2006a), i.e., the initial geological processes were Early Archaean, which is also indicated

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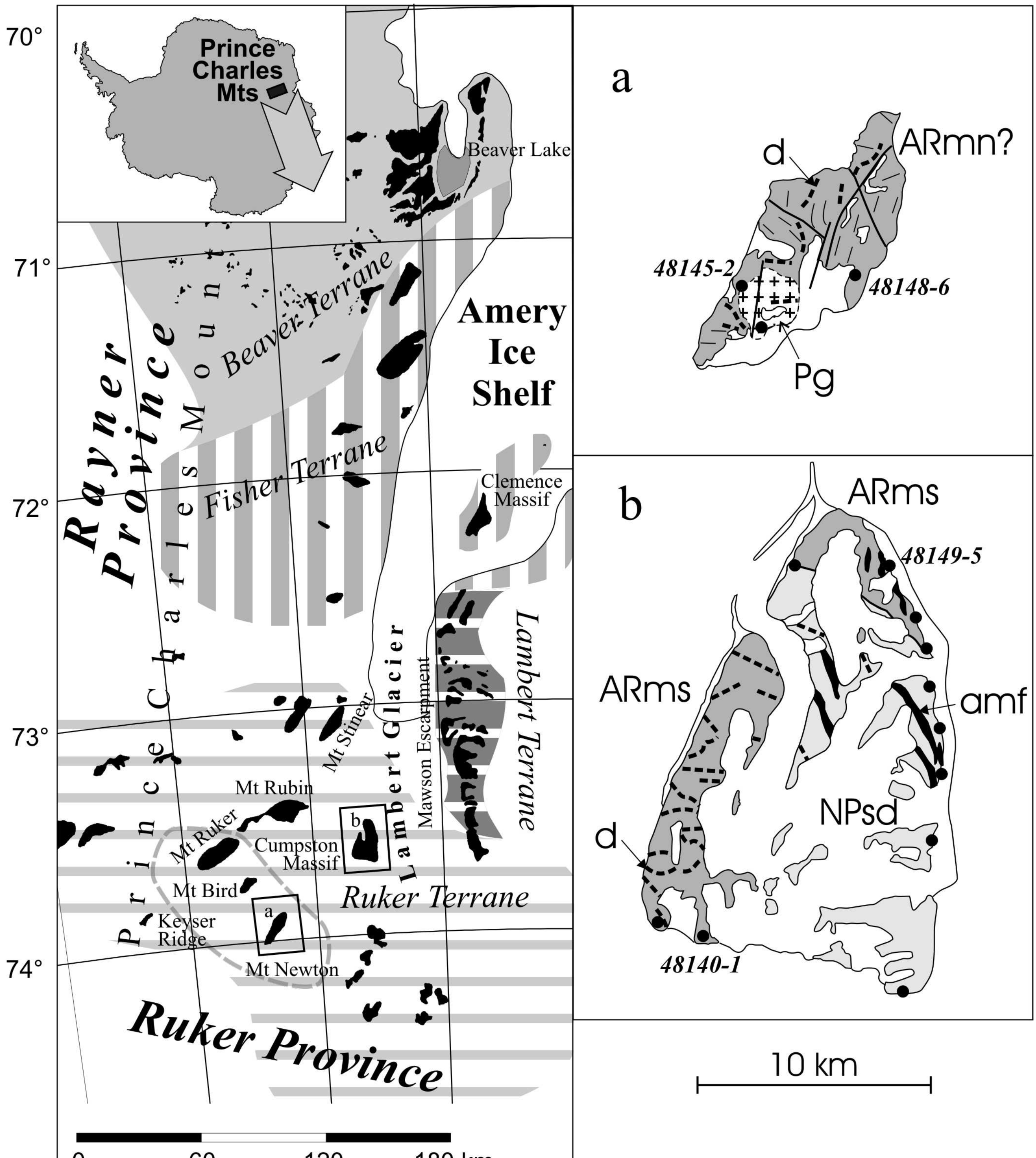

Fig. 1: Major tectonic subdivisions in the Prince Charles Mountains (MIKHALSKY et al. 2006b). The Rayner Province (FITZSIMONS 2003) includes the Lambert and the Fisher terranes of MIKHALSKY et al. (2006b), and the Ruker Province (PHILLIPS et al. 2006) includes the Lambert and the Ruker terranes of MIKHALSKY et al. (2006a). Thick grey broken contour outlines the area occupied by the Ruker Group metasediments (PHILLIPS et al., 2006). In the insets are shown schematic geological maps of Mt. Newton (inset a) and the Cumpston Massif (inset b) modified from (TINGEY 1975, 1982b). ARmn = the Archaean Menzies Series, ARms = the Archaean Mawson Orthogneiss, NPsd = the Neoproterozoic Sodruzhestvo Series, Pg = pegmatite/granite, amf = amphibolite, d = mafic dyke. Bold dots stand for the localities visited by the authors, and the relevant numbers for the samples collected.

Abb. 1: Die großen tektonischen Einheiten in den Prince Charles Mountains (MIKHALSKY et al. 2006b). Die Rayner Province (FITZSIMONS 2003) umfasst die Beaver und Fisher Terranes von MIKHALSKY et al. (2006b) und die Ruker Province (PHILLIPS et al. 2006) umfasst die Lambert und Ruker Terranes von MIKHALSKY et al. (2006 a). Die graue, unterbrochene Linie begrenzt das Vorkommen der Ruker Group Metasedimente (PHILLIPS et al. 2006). Die Ausschnitte zeigen schematische geologische Karten von Mt. Newton (Ausschnitt a) und vom Cumpston Massif (Ausschnitt b), modifiziert nach TINGEY (1975, 1982b). ARmn = archaische Menzies Serien, ARms = archaischer Mawson Orthogneis, NPsd = neoproterozoische Sodruzhestvo Serien, Pg = Pegmatit/Granit, amf = Amphibolit, d = mafischer Gang. Die schwarzen Punkte markieren die von den Autoren aufgesuchten Lokalitäten, die Zahlen entsprechen den Probennummern.

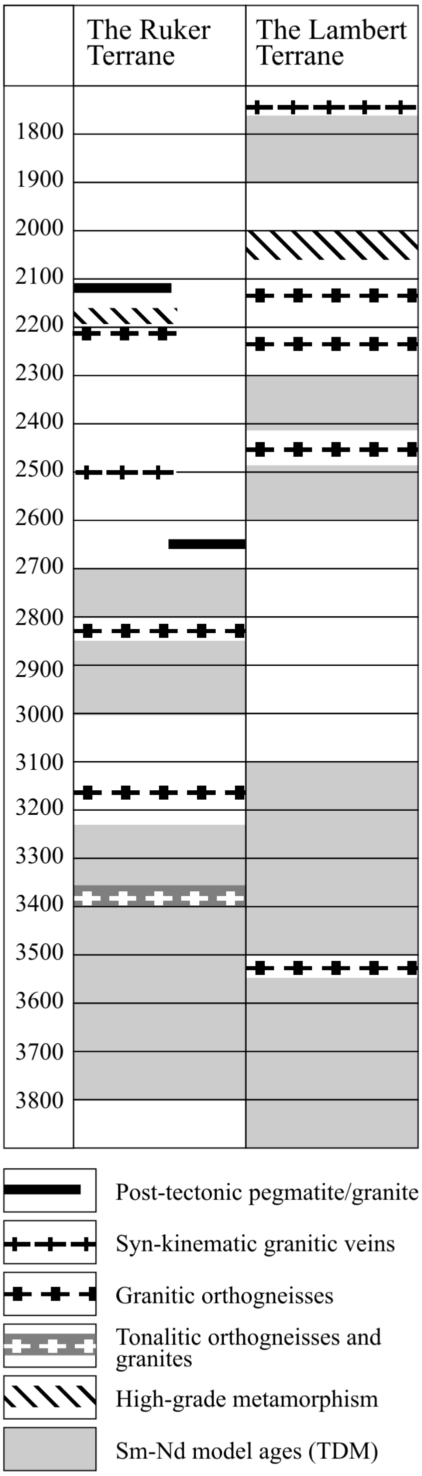

Fig. 2: Main tectono-magmatic events in the Ruker and Lambert terranes. Data sources: Boger et al. 2006, 2008, Mikhalsky et al. 2006a, Phillips et al. 2008, and this paper. Partly orthogneiss protolith emplacement may have been accompanied by metamorphism. Half symbol reflects an event developed only locally. This may be also the case for most events in the Lambert Terrane.

Abb. 2: Die wichtigsten tektono-magmatischen Ereignisse im Ruker und Lambert Terrane. Daten aus: Boger et al. 2006, 2008, Mikhalsky et al. 2006a, Phillips et al. 2008, und dieser Arbeit. Teilweise ist vermutlich die Intrusion der Orthogneis-Protolithe von Metamorphose begleitet worden. Die halblangen Symbole stehen für Ereignisse, die sich nur lokal ausgewirkt haben. Dies mag für die meisten Ereignisse im Lambert Terrane der Fall sein.

by Sm-Nd model ages (up to 3.9-3.8 Ga) (Mikhalsky et al. 2006b). Emplacement of trondhjemite, probably derived by melting of mafic rocks, occurred at c. 3390-3380 Ma (orogenic episode 1) and granite intrusion at c. 3180-3160 Ma (orogenic episode 2) (Boger et al. 2001, 2006, Mikhalsky et al. 2006a). Tectonic shearing observed in the southern Mawson Escarpment and dated by Boger et al. (2006) at c. 2790 Ma completed a 2900-2800 Ma orogenesis (orogenic episode 3). The minimum age of deformation was constrained by an age of c. 2645 Ma for an undeformed pegmatite in the southern Mawson Escarpment (Boger et al. 2006). On the basis of a detrital zircon U-Th-Pb study, Phillips et al. (2006) distinguished five lithostratigraphic units within their Ruker Province: the Menzies Group (Mesoarchaean, <3200 Ma), the Stinear Group (Neoarchaean, <2800 Ma), the Ruker Group (Early Palaeoproterozoic, 2100-2500 Ma), the Lambert Group (Palaeo- to Mesoproterozoic, <2100 Ma), and the Sodruzhestvo group (<950 Ma). Each of these has distinct metamorphic and deformational features.

The central and northern Mawson Escarpment (the Lambert Terrane) is underlain by high-grade orthogneiss (mostly biotite-quartz-feldspar gneiss) and paragneiss. Recent geochronological work by Boger et al. (2001, 2006, 2008), Mikhalsky et al. (2006a), and Corvino et al. (2008) demonstrated that this area experienced its own distinct geological history. The tectono-magmatic evolution of the Lambert Terrane covers a time span largely between 3520 Ma and 1740 Ma (Fig. 2). Ages of 3520 ±20 Ma, 2470 ±10 Ma and 2420 ±20 Ma were obtained for granite-gneiss sheets and larger bodies (extrusion ages and pre-tectonic granitoid emplacement). Sedimentation during the early Palaeoproterozoic (?2400-2200 Ma) was suggested for some paragneisses. A prominent feature of the Lambert Terrane, especially its northernmost parts, is the presence of thick mafic metamorphic piles (composed of mafic hornblende schist or metagabbro), spatially associated with paragneiss and marble, and locally containing tectonically dismembered blocks of ultramafic rocks. The emplacement age of this ultramafic-mafic complex is unknown, but zircon ages between 2400 and 2150 Ma were obtained for an amphibolite (metagabbro) sample (Corvino et al. 2008). Subsequent orogenic events include syn-tectonic felsic vein injection at c. 2220 ±60 Ma. An age of c. 2120 Ma was obtained for emplacement of an orthogneiss protolith; metamorphism was dated at c. 2065-2000 Ma. A thick swarm of deformed late-tectonic leucocratic felsic veins was injected at c. 1740 Ma. Geological events in the range 1600-1800 Ma, 2100-2300 Ma, and up to 2780 Ma are indicated by inherited zircon ages from a number of samples.

LOCAL GEOLOGY

Mt. Newton is a 5 x 13 km hilly-topped block (Fig. 1a). It was reported to consist of high-grade garnet-sillimanite gneiss, biotite gneiss, hornblende gneiss, quartzite, calc-silicate schist and mafic sills, intruded by a pegmatite plug, as depicted in the 1 : 250,000 geological map (Tingey 1975) (Fig. 1). An Archaean age for the initial metamorphism was suggested, and pegmatite was thought to have been emplaced at ca 2050 Ma (Rb-Sr whole-rock age, Tingey 1982a). Similar lithologies are indicated on the 1 : 500,000 geological map (Tingey 1982b), and high-grade garnet-sillimanite gneiss and orthopyroxenebearing metabasite are described as forming pockets or rafts within the pegmatite. The other rocks experienced retrograde chlorite–chloritoid grade metamorphism ascribed to an Early Palaeozoic event.

We made three short helicopter landings on Mt. Newton (Fig. 1a), and found folded metasediments in the central eastern part, and mafic schist containing pegmatite in the southwestern part. Metasediments are represented by thin muscovite-bearing quartzite and actinolite-albite layers, commonly containing opaque-rich (hematite) bands. The strata are folded into small upright folds with axes and mineral lineations plunging to the southwest at moderate angles (Fig. 3a,b). The metasediments contain layers of felsic gneiss (sample 48148-6) and weakly-foliated pegmatitic muscovite-bearing granite, which are thought to represent felsic volcanics and pre-tectonic granite, respectively.

In the poorly-exposed flat southwestern part of Mt. Newton, muscovite garnet-bearing granite (sample 48145-2; Fig. 3c), pegmatite and gneissic pegmatite crop out. A gneissic pegmatite contains prismatic ortho-amphibole pseudomorphs, which include a few orthopyroxene relics. A few scattered outcrops of mafic biotite ±garnet-bearing hornblende-plagioclase schist and leuco- to mesocratic biotite-bearing quartz–plagioclase migmatitic gneiss were found.

Cumpston Massif is a c. 12 x 20 km triangular flat-topped block (Fig. 1b) composed of basement orthogneisses and poorly metamorphosed, presumably Neoproterozoic, cover of

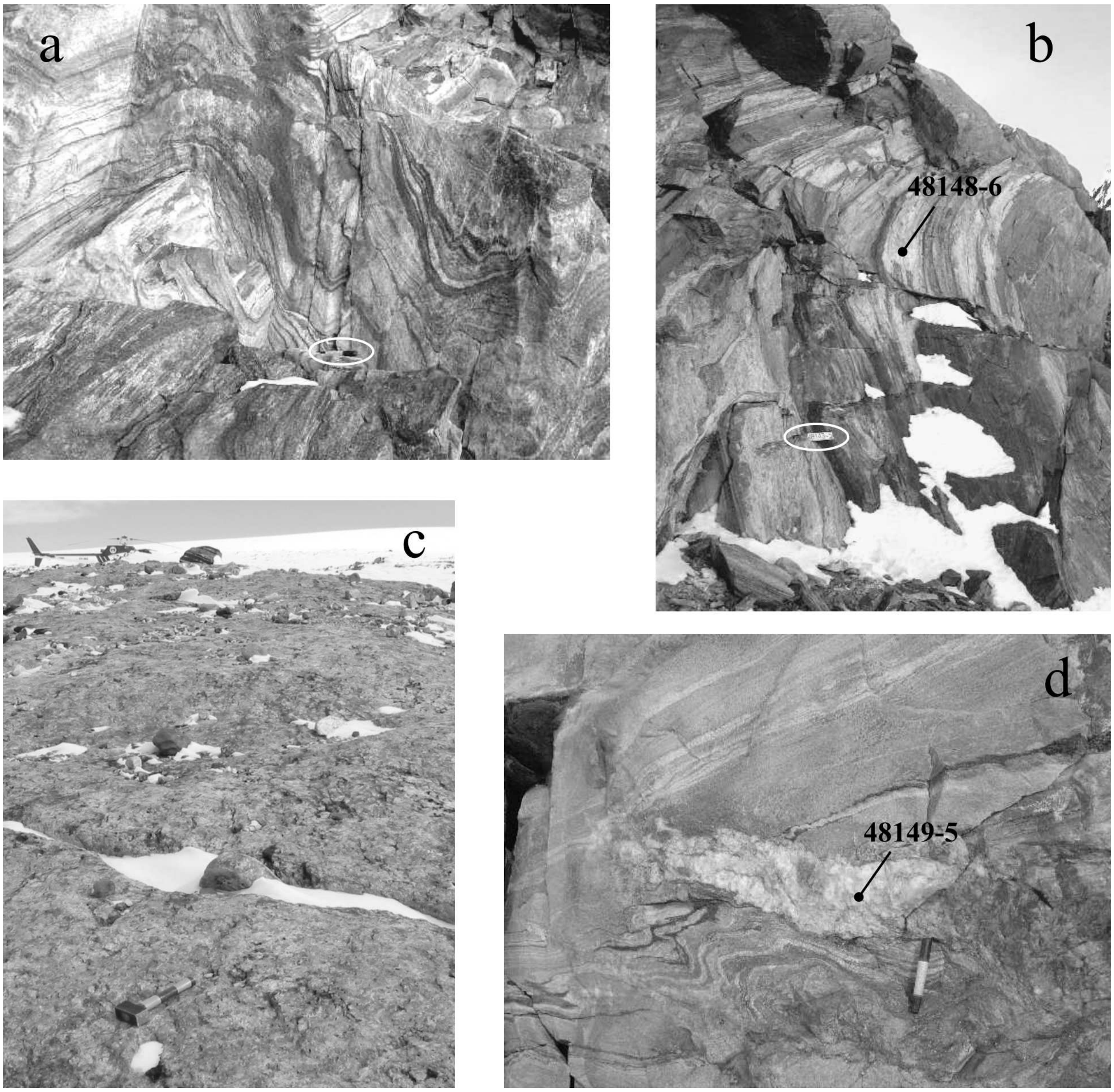

Fig. 3: Views of the localities and rocks studied. a-c = Mt. Newton; a = folded quartzite (locality 48148), b = intercalated quartzite, felsic gneiss, and schist (locality 48148), c = granite outcrop on flat top Mt. Newton; d = pegmatite in the north-eastern Cumpston Massif (locality 48149). In a and b white oval embrace markers for scale.

Abb. 3: Bilder der Lokalitäten und der untersuchten Gesteine: a-c = Mt. Newton, a = gefalteter Quarzit (Lokalität 48148), b = Wechselfolge von Quarzit, leukokraten Gneisen und Schiefer (Lokalität 48148), c = Granitaufschluss auf dem ebenen Gipfelbereich von Mt. Newton; d = Pegmatit aus dem nordöstlichen Cumpston Massif (Lokalität 48149); In a und b kennzeichnet ein weißes Oval einen Markierstift als Maßstab.

metasediments. The latter are thrust over basement in the northern part of the massif and are faulted against it in the western part. Earlier investigators described the basement rocks as biotite gneiss, granitic gneiss or gneissic granite intruded by variously deformed and metamorphosed mafic dykes (TINGEY 1975). The structure of Cumpston Massif was studied in detail by PHILLIPS et al. (2005). We made a few foot traverses along the northeastern slope of the massif and a few helicopter landings in other parts (Fig. 1b). The basement orthogneisses range widely in terms of mineral and chemical composition. In the southwestern part of Cumpston Massif the basement is represented by strongly folded biotite syeno-granitic (sample 48140-1) to alkali feldspathic gneisses, occasionally containing titanite and fluorite. Khaki-green biotite and titanite form lensoid aggregates with equal proportions of quartz, and may represent secondary material after earlier mafic minerals (pyroxenes?). Fluorite forms rare small isometric grains. These rocks have major and trace element compositions similar to the calc-alkalic ferroan hornblende-bearing Archaean orthogneisses in the southern Mawson Escarpment and other localities of the Ruker Terrane (MIKHALSKY et al. 2006a and unpubl. data). In contrast, plagioclase-rich rocks (trondhjemite, tonalite) crop out in the northeastern part of Cumpston Massif. They show considerable secondary alteration (saussurite, carbonate) and contain accessory biotite, muscovite, titanite and magnetite. They also show some distinctive geochemical features, such as higher Al_2O_3, lower TiO_2, lower LILE, large negative Nb anomalies, and very low Y. Similar felsic gneisses and granites have been found at Clemence Massif and Mt. Ruker (CORVINO et al. 2005, and unpubl. data). In the northeastern part of Cumpston Massif, thin coarse-grained muscovite-bearing pegmatite veins occur (sample 48149-5). These were intruded roughly along the axial planes of small-scale tight or isoclinal folds in the gneisses (Fig. 3d). Similar pegmatites may form concordant lenses within the gneiss. These features suggest that the pegmatites were locally derived and were syn-tectonic or emplaced shortly after the main deformation event in this area.

U-Pb DATA

Zircon recovered from samples from Mt. Newton and from Cumpston Massif was studied for its U-Pb ratios. The measurements were carried out with a SHRIMP-II ion microprobe at the Centre of Isotopic Research (VSEGEI, St. Petersburg, Russia). Zircon grains were hand selected and mounted in epoxy resin, together with chips of the TEMORA (Middledale Gabbroic Diorite, New South Wales, Australia) and 91500 reference zircons. Each analysis consisted of five scans through the mass range, the spot diameter was about 18 µm and the primary beam intensity about 4 nA. The Pb/U ratios were normalized relative to a value of 0.0668 for the $^{206}Pb/^{238}U$ ratio of the TEMORA reference zircons, equivalent to an age of 416.75 Ma (BLACK et al. 2003). Uncertainties given for individual analyses (ratios and ages) are at the one σ level, whereas uncertainties in calculated concordia ages are reported at the two σ level. The results are listed in Table 1.

Two samples were collected from Mt. Newton. A felsic gneiss (sample 48148-6), representing a thin (~1 m) layer intercalated with quartzite and other metasediments, is from the central eastern part of the area. Zircon grains are 70-120 µm across and are of rounded elongated shape (Fig. 4a). They show inhomogeneous inner structures in the cathodoluminescence images (CL), but no clear cores or rims could be distinguished. Twelve analyses on twelve grains were obtained, nine of which are nearly concordant and form a more-or-less coherent cluster. All analyses show high U (500-800 ppm) and very low Th (1-80 ppm). Th/U are low (<0.15), possibly pointing towards metamorphic origin, although the grains shape suggests a magmatic origin. Ten analyses form a poorly constrained regression line, with an upper intercept at c. 2225 ±110 Ma and a lower intercept at c. 1400 Ma (Fig. 4 a). Eight nearly concordant analyses give a weighted mean $^{206}Pb/^{238}U$ age of 2157 ±18 Ma. These data show that Mt. Newton experienced a magmatic event (acidic volcanism) at c. 2150-2200 Ma and a subsequent thermal overprint.

Sample 48145-2 is a coarse-grained muscovite-garnet granite from the southwestern slope. The zircon grains are large (mostly 200-300 µm), and short-prismatic (l = 1.2-1.5, l being the length/width ratio) or rarely long-prismatic (l up to 5.0) (Fig. 4b). Many grains are somewhat corroded and original facets rounded. No clear oscillatory zoning patterns were observed optically, but the CL of some grains show inner zoning. Six analyses on six grains were obtained and all show consistently very high U (mostly 2000-2500 ppm, and analysis 4.1 is 7700 ppm) and low Th (30-114 ppm), resulting in very low Th/U (0.01-0.05). This may be a geochemical feature of the parent magma or a metamorphic feature, although the grain shape argues against the latter. None of the analyses is concordant, but the discordance is not very large. Five analyses form an elongated cluster, and the sixth analysis (4.1) is strongly reversely discordant. Together the six analyses define a regression line, with an upper intercept at 2117 ±11 Ma and a lower intercept at recent time. Excluding analysis 4.1 the other five analyses define a regression line with an upper intercept at c. 2150 Ma, and a lower intercept at c. 1350 Ma. The data are thus indicative of probably two geological events, the first in the Palaeoproterozoic (possibly granite emplacement at c. 2120-2150 Ma) and a subsequent poorly constraint Meso- to Neoproterozoic event (thermal overprint accompanied by Pb loss).

Two rock units were sampled at Cumpston Massif. Sample 48140-1 was collected from a thick granite gneiss sequence in the southwestern part of the massif. Zircon grains are 100-250 µm large, of well-crystallized short prismatic shape (Fig. 5a), and most display well developed oscillatory zoning. Nine analyses on nine grains were obtained. All the analyses show high Th/U between 0.4-0.6 and are variously discordant. The data yielded a 7-point regression line (Fig. 5a), with an upper intercept at c. 3168 Ma and a lower intercept at c. 1200 Ma, with large uncertainties. Three nearly concordant analyses give a weighted mean $^{207}Pb/^{206}Pb$ age of 3180 ±12 Ma. The latter age is the best estimate of the time of emplacement for the granitic protolith of this rock.

Sample 48149-5 was collected in the northeastern part of the massif from a muscovite-bearing pegmatite, which intruded concordant with the fold axial planes in the host rocks. Zircon grains are long prismatic, up to 400 µm across, and may contain oval cores with thin oscillatory zoning mantled by high-U rims (Fig. 5b). Eight analyses on five grains were obtained: three of the rims, and five of the cores. The rim analyses (3.2, 4.2, 5.2) have very high U (>3000 ppm) and low Th (<15 ppm), and hence very low Th/U (<0.01). The core

Spot	% $^{206}Pb_c$	ppm U	ppm Th	^{232}Th /^{238}U	ppm ^{206}Pb*	(1) ^{206}Pb /^{238}U age	D %	(1) $^{207}Pb^*$ /^{235}U	±%	(1) $^{206}Pb^*$ /^{238}U	±%	err corr
					Mt. Newton							
48148-6*	Felsic gneiss											
1.1	0.29	537	2	0.00	182	2134	0	7.14	1.7	0.3925	0.89	0.515
2.1	0.54	664	3	0.00	229	2167	-2	7.29	1.8	0.3995	0.83	0.464
3.1	0.49	601	73	0.13	218	2257	-1	8.17	1.6	0.4193	0.85	0.515
4.1	0.35	719	86	0.12	232	2051	8	7.18	1.4	0.3746	0.79	0.548
5.1	0.10	830	60	0.07	264	2024	9	7.06	1.3	0.3689	0.86	0.660
6.1	0.49	831	5	0.01	290	2187	-5	7.20	1.8	0.4038	0.86	0.477
7.1	1.62	450	24	0.05	132	1866	7	5.68	3.9	0.3357	1.10	0.284
8.1	0.32	556	1	0.00	202	2122	0	7.15	1.7	0.3922	0.89	0.455
9.1	0.48	861	2	0.01	224	2187	0	7.62	1.7	0.4038	0.86	0.466
10.1	0.13	782	78	0.10	244	2151	6	7.72	1.4	0.3974	0.82	0.568
11.1	0.52	611	74	0.13	221	2217	2	8.01	1.5	0.4073	0.84	0.515
12.1	0.56	764	2	0.00	235	2089	6	7.66	2.7	0.3972	0.83	0.344
48145-2^	Granite											
2.1	0.21	2571	30	0.01	831	2.054.8	2	6 745	0.43	0.37541	0.25	0.590
1.1	0.29	2444	32	0.01	799	2.072.8	2	6 861	0.46	0.3793	0.29	0.633
6.1	0.27	2316	52	0.02	759	2.079.1	1	6 837	0.45	0.3806	0.30	0.668
3.1	0.07	2111	96	0.05	695	2.090.6	2	6 984	0.40	0.3831	0.26	0.658
5.1	0.19	2453	54	0.02	813	2.100.0	1	6 969	0.52	0.3851	0.42	0.804
4.1	0.01	7729	114	0.02	2.7	2.199.1	-3	7 409	0.26	0.40654	0.21	0.798
					The Cumpston Massif							
48140-1**	Granite-gneiss											
1.1	--	226	123	0.56	111	2912	7	18.88	2.1	0.571	1.9	0.874
2.1	0.08	191	92	0.50	100	3069	3	20.68	2.1	0.61	1.9	0.902
3.1	0.06	213	89	0.43	90.2	2584	15	14.96	2	0.493	1.9	0.932
4.1	0.02	255	132	0.53	101	2444	22	13.93	2.4	0.461	2.3	0.944
5.1	--	1144	667	0.60	495	2629	22	17.56	1.8	0.5037	1.8	0.970
6.1	--	226	120	0.55	122	3152	1	21.8	1.9	0.631	1.8	0.960
7.1	0.03	194	104	0.55	109	3249	-2	22.36	2	0.655	1.9	0.954
8.1	0.01	1308	731	0.58	487	2322	32	13.84	2	0.4336	2	0.989
9.1	--	227	105	0.48	129	3270	-3	22.59	2	0.661	1.9	0.961
48149-5^	Pegmatite											
3.2	0.02	3485	9	0.00	699	1.352.6	24	3 481	0.45	0.23345	0.29	0.649
5.2	0.01	3821	14	0.00	827	1.448.0	21	3 901	0.38	0.25185	0.26	0.685
4.2	0.03	3871	10	0.00	881	1.515.0	20	4 209	0.53	0.26493	0.25	0.474
3.1	0.02	2418	773	0.33	725	1.928.5	16	6 977	0.42	0.3487	0.29	0.691
4.1	0.36	301	36	0.12	106	2.21	8	8.79	1.2	0.4088	0.70	0.605
5.1	2.01	1145	358	0.32	419	2.246.7	7	9.04	1.1	0.4170	0.43	0.374
2.1	0.54	457	21	0.05	167	2.273	7	9 307	0.91	0.4228	0.57	0.627
1.1	0.29	397	28	0.07	146	2.286	6	9 228	0.84	0.4256	0.52	0.625

Tab. 1: U-Pb analyses of zircons from granite, gneiss, and pegmatite samples in Mt. Newton and Cumpston Massif. Errors are 1-sigma; Pb_c and Pb^* indicate the common and radiogenic portions, respectively; (1) = common Pb corrected using measured ^{204}Pb. Errors are 1-sigma; Pb_c and Pb^* indicate the common and radiogenic portions, respectively. D% – discordance; D = 100 * {[age($^{207}/_{206}$)] / [age($^{206}/_{238}$)] - 1}. Error in Standard calibration was: * 0.73 %, ** 1.16 %, ^ 0.32 %.

Tab. 1: U-Pb-Analysendaten von Zirkonen aus Granit-, Gneis- und Pegmatitproben von Mt. Newton und dem Cumpston Massif.

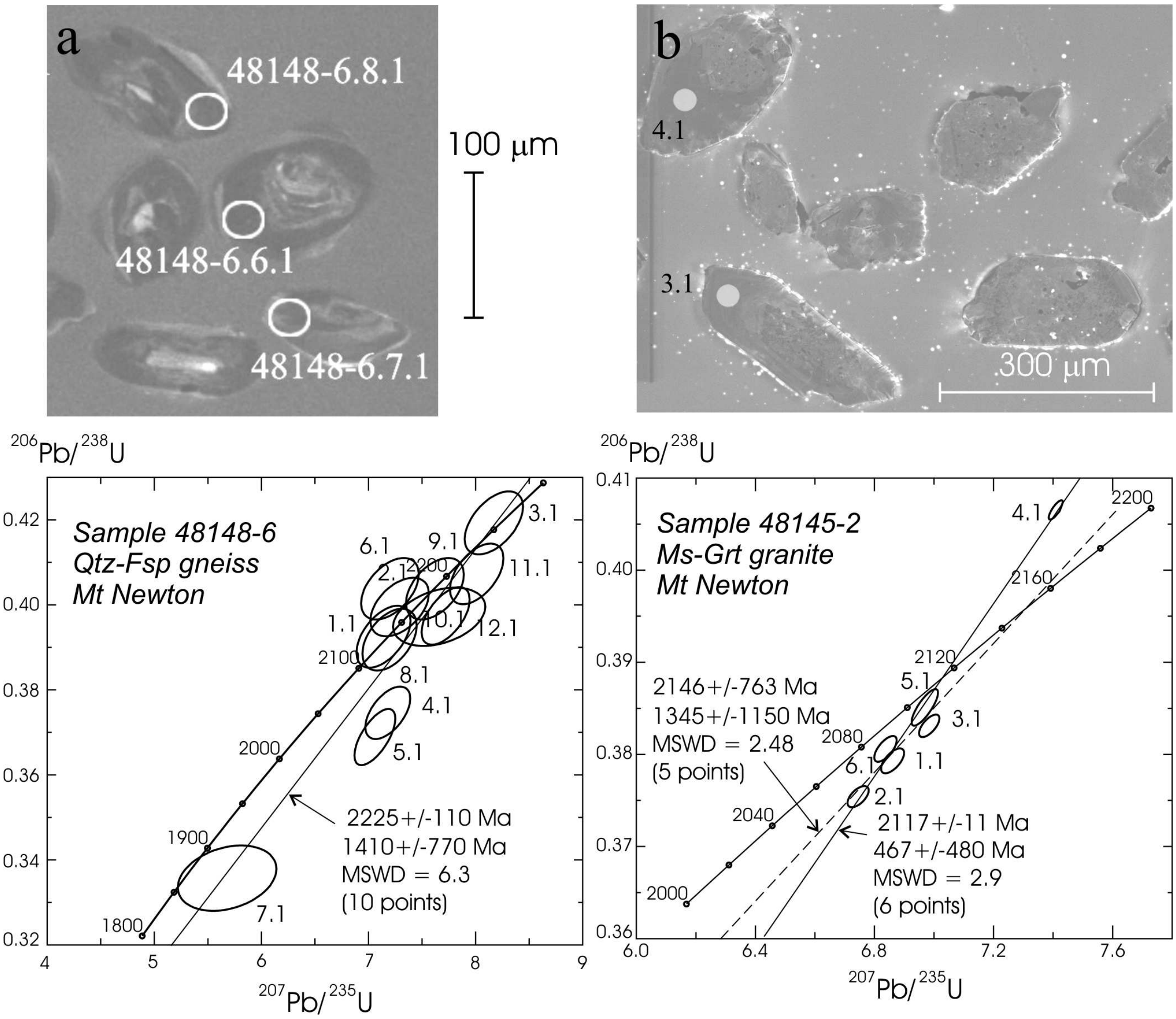

Fig. 4: The cathodoluminescent images of zircon and U-Pb Concordia plots for the rocks from Mt. Newton. a = sample 48148-6 (felsic gneiss), b = sample 48145-2 (granite).

Abb. 4: Kathodenlumineszenz-Bild eines Zirkons und U-Pb-Konkordiadiagramm für Gesteine von Mt. Newton: a = Probe 48148-6 (leukokrater Gneis), b = Probe 48145-2 (Granit).

analyses have much higher Th/U ranging from 0.05-0.33, suggestive of a magmatic origin for these grains. The three rim analyses are highly discordant, with low $^{206}U/^{238}Pb$ ages (1400-1500 Ma). The core analyses are also essentially discordant, although with a much higher $^{206}U/^{238}Pb$ ages (1900 Ma, and 2200-2300 Ma). A regression line drawn through all eight points has an upper intercept at 2511 ±78 Ma and a lower intercept at 1113 ±60 Ma (Fig. 5b). These two dates may reflect either an inherited source age (c. 2500 Ma) and the pegmatite crystallisation age (c. 1100 Ma), or alternatively pegmatite crystallisation and a thermal/metamorphic overprint. At the present stage of study we cannot completely exclude either option, but it is more likely that the zircon rims represent recrystallization and were formed as the result of fluid infiltration which was not accompanied by a geologically significant process (apart from widespread mineral retrogression). In view of the Rb-Sr muscovite age of 2580 Ma obtained from a pegmatite at Mount Stinear (Tingey 1991), an age of c. 2500 Ma for syn- to late-tectonic pegmatite emplacement at Cumpston Massif appears more probable.

DISCUSSION AND CONCLUSIONS

Our data show that the Mt. Newton block experienced a Palaeoproterozoic (c. 2100-2200 Ma) tectonothermal event which was previously only hinted at by the post-tectonic pegmatite Rb-Sr ages (Tingey 1982). The zircon morphology points to a magmatic origin, but some metamorphic reworking cannot be excluded, even though no overgrowths could be distinguished. We believe this age reflects a magmatic (probably volcanic) event, which was probably shortly followed by metamorphism and folding. The mineral assemblages of this sample and a few other rocks collected from this locality do not provide any evidence for a high-grade metamorphic event reported from this area by other authors (Tingey 1991, Mikhalsky et al. 2001). In contrast, gneissic pegmatites in the southwestern part of Mt. Newton do indeed contain orthopyroxene relics. This may reflect the occurrence of different lithotectonic units in the eastern and western parts of the block. It is worth mentioning that on the 1 : 250,000 geological map of the area (Tingey 1975) a major fault system is shown running north-northeast, separating the Mt. Newton block into two domains.

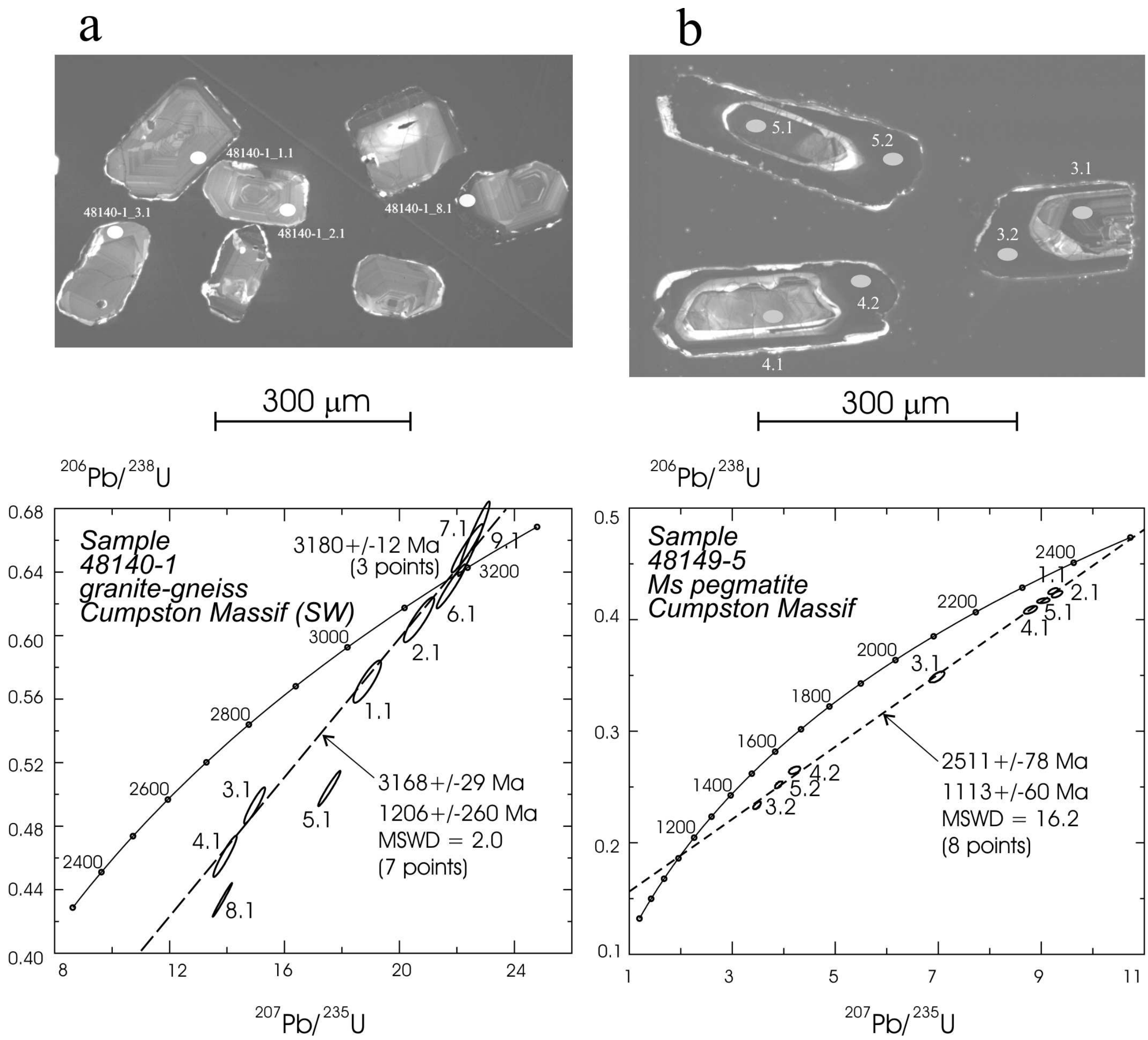

Fig. 5: The cathodoluminescent images of zircon and U-Pb Concordia plots for the rocks from the Cumpston Massif. a = sample 48140-1 (granite-gneiss), b = sample 48149-5 (muscovite-bearing pegmatite).

Abb. 5: Kathodenlumineszenz-Bild eines Zirkons und U-Pb-Konkordiadiagramm für Gesteine vom Cumpston Massif: a = Probe 48140-1 (Granitgneis), b = Probe 48149-5 (Muskovit führender Pegmatit).

The occurrence of Palaeoproterozoic rocks at eastern Mt. Newton fits well the lithotectonic scheme proposed by PHILLIPS et al. (2006). These authors suggested that Palaeoproterozoic (2500-2100 Ma) metasedimentary cover rocks of the Ruker Series crop out at Mt. Ruker, Mt. Bird and Mt. Newton (and likely also at Keyser Ridge, as suggested by MIKHALSKY et al. (2001) on lithological grounds). The c. 2200 Ma event could thus be a prominent tectono-thermal event which may be referred to as the Newton Orogeny. The emplacement of garnet-bearing granite at c. 2120 Ma probably reflects the waning stage of this orogeny. The gneissic appearance of some garnet-bearing granitic rocks at Mt. Newton suggests that the dated granite may be late- rather than post-tectonic.

The rocks in Cumpston Massif were less affected by Palaeoproterozoic activity. The pegmatite vein which we dated at c. 2500 Ma is a syn- to late-tectonic intrusion in ?Archaean gneisses, and its mode of occurrence suggests syn-tectonic intrusion. So far no tectonic activity of this age has been reported from basement rocks elsewhere in the Ruker Terrane (Mawson Orthogneiss), the only dated rocks being post-tectonic pegmatites (c. 2580-2650 Ma, TINGEY 1982, BOGER et al. 2006). Our finding shows that, at least locally, the latest Archaean-Early Palaeoproterozoic event was of a pervasive nature. At the same time, it should be noted that the dated pegmatite was collected from the northeastern part of Cumpston Massif, and the gneissic host rocks in this domain are clearly distinct from similar rocks cropping out in the southwestern domain. This implies that these two domains may represent different lithotectonic units. The southwestern domain (c. 3180 Ma) correlates with the Mawson Orthogneiss, both on lithology and age grounds (ROLAND & MIKHALSKY 2007), while the northeastern domain may correspond with the Palaeoproterozoic Lambert Terrane, or show the effects of prominent tectono-thermal reworking.

Ages of c. 2000-2200 Ma have been reported from the Lambert Terrane in the central and northern Mawson Escarpment, although only a few samples yielded precise ages and conclusive interpretations (MIKHALSKY et al. 2006a, CORVINO et al. 2008). The newly obtained ages correspond well with ages from the Lambert Terrane, supporting a suggestion that the Mt. Newton block may be part of the Lambert Terrane. However, magnetic anomaly data (DAMASKE & MCLEAN 2005) show that Mt. Newton is situated within a prominent magnetic field unit which also includes Mt. Ruker and Mt. Rubin, localities also remarkable for their post-Archaean evolution (PHILLIPS et al. 2007). Thus, it is more likely that this part of the SPCM is basically composed of a Palaeoproterozoic supracrustal sequence, deformed and metamorphosed during the Newton Orogeny (c. 2100-2200 Ma).

Our data demonstrate that this middle Palaeoproterozoic event affected not only the northern part of the SPCM (the Lambert Terrane of MIKHALSKY et al. 2001), but was also developed in its southern part (Ruker Terrane) in the form of sedimentation, felsic volcanism, metamorphism and folding followed by granite intrusion. These features may point to the development of a depositional basin (aulacogene?) in the SPCM between 2500-2100 Ma ago.

Palaeoproterozoic tectonic activity is not well documented in Antarctica, except within the c. 1.7 Ga Mawson Continent (MC; FANNING et al. 1995; Fig. 6). This is thought to include the Gawler Craton of South Australia, George V Land, Adélie Land, and the Miller Range in the central Transantarctic Mountains. Its geological history includes various events dated at c. 3150-2950, 2700-2350, 2000, and 1850-1700 Ma (FITZSIMONS 2003, and references therein). These ages roughly correspond to those obtained for the Lambert Terrane and our new ages from the Ruker Terrane, thus suggesting that the SPCM can be correlated with the MC. However, the Newton Orogeny in the SPCM (2100-2200 Ma) is about 400 Ma older than the final late-Palaeoproterozoic orogeny within the MC and the Ruker Terrane rocks have generally older Sm-Nd model ages (MIKHALSKY 2008). FITZSIMONS (2003) concluded that one or more Cambrian sutures may lie between the Mawson Block and the areas west of the Bunger Hills (Fig. 6), thus separating Antarctica into at least two major tectonic regions. Taking into account that the Ruker and Lambert terranes are bounded to the north by the Mesoproterozoic Rayner Province (including the Fisher Terrane), which may partly correlate with the Fraser Complex of the Albany-Fraser Orogen (MIKHALSKY et al. 2006b), their correlation with the MC may be a reasonable suggestion. However, there is a large sub-glacial gap between the SPCM and the MC, so any correlation can only be speculative. Alternatively, a tentative correlation with somewhat older Western Australia Cratons, such as the Palaeoproterozoic Capricorn Orogen with zircon ages of 2550-2450 Ma, 2000-1960 Ma, 1830-1780 Ma, and 1670-1620 Ma (CAWOOD & TYLER 2004), might be proposed.

The Palaeoproterozoic ages in the Ruker Terrane are relevant to the issue of the collisional nature of the Early Palaeozoic orogeny in this region of East Antarctica. It was recently suggested that the southern and northern parts of the SPCM (i.e., approximating to the Ruker and Lambert terranes of MIKHALSKY et al. 2006a) existed as separate lithospheric entities before continental collision during late Neoproterozoic to Cambrian time (BOGER et al. 2001). However, the observed correlation of Palaeoproterozoic tectonomagmatic events in both the Ruker and Lambert terranes of the SPCM provides evidence for their common rather than separate, evolution during the Proterozoic.

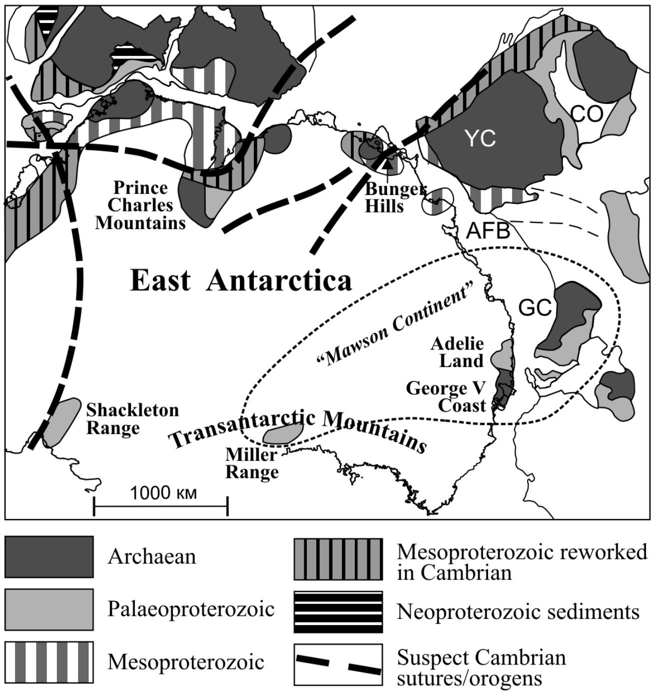

Fig. 6: Sketch map of the Archaean and Palaeoproterozoic rocks in East Antarctica and surrounding continents (DOBMEIER & RAITH 2003, MYERS et al. 1996). Suspect Cambrian sutures/orogens after FITZSIMONS (2003). AFB = Albany–Fraser Belt, GC = Gawler Craton, CO = Capricorn Orogen, YC = Yilgarn Craton.

Abb. 6: Kartenskizze der archaischen und paläoproterozoischen Gesteine der Ostantarktis und benachbarter Kontinente (DOBMEIER & RAITH 2003, MYERS et al. 1996). Vermutete kambrische Suturen/Orogene nach FITZSIMONS (2003). AFB = Albany–Fraser Belt, GC = Gawler Craton, CO = Capricorn Orogen, YC = Yilgarn Craton.

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