Geology of the Terre Adélie Craton (135 – 146° E)

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Abstract More than 15 years of field and laboratory investigations on samples from Terre Adélie to the western part of George Vth Land (135 to 146°E) during the GEOLETA program allow a reassessment of the Terre Adélie Craton (TAC) geology. The TAC represents the largest exposed fragment of the East Antarctic Shield preserved from both Grenville and Ross tectono-metamorphic events. Therefore it corresponds to a well-preserved continental segment that developed from the Neoarchean to the Paleoproterozoic. Together with the Gawler Craton in South Australia, the TAC is considered as part of the Mawson continent, i.e. a striking piece of the Rodinia Supercontinent. However, this craton represents one of the less studied parts of the East Antarctic Shield. The three maps presented here clearly point out the extent of two distinct domains within the Terre Adélie Craton and suggest that the TAC was built up through a polyphased evolution during the Neoarchean-Siderian (*c.a.* 2.5Ga) and the Statherian (*c.a.* 1.7Ga) periods. These data support a complete re-assessment of the TAC geology and represent a valuable base for the understanding of global geodynamics changes during Paleoproterozoic times.

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Introduction

The Terre Adélie Craton (TAC) is located on the eastern part of the East Antarctic Shield (Fig. 1). Three geological maps are presented here that review some 15 years of field, petrological and geochronological investigations in Terre Adélie and western George Vth Land. A general localization map (Fig. 1) illustrates large-scale features of the TAC geology. It emphasizes the distinction of main lithotectonic domains based on rock types, structure and age of peak metamorphism (Monnier et al., 1995). A second map (Fig. 2) focuses on the easternmost domain of the craton, which corresponds to a Neoarchean polycyclic basement and the overlying Paleoproterozoic Cape Hunter basin. Finally the third map (Fig. 3) relates to the highly strained and metamorphosed Paleoproterozoic Dumont D'Urville basin which is juxtaposed to the west of the Archean domain. Furthermore, small outcrops of Rocher Mathieu and Rocher X allow extending the TAC more to the west without precision on its exact western boundary (cf. star and broken line on the inset map of Fig. 1).

Previous work

The first geological investigations were carried out during Sir Douglas Mawson's expedition in the Cape Denison during the 1911-1914 Australasian Antarctic Expedition (AAE) wintering. Stillwell (1918) and Tilley (1923) described the metamorphic rocks from the basement of Commonwealth Bay and the surrounding areas (George Vth Land). Later, in the early 1950's and 1960's, French Polar Expeditions reported new data from Terre Adélie, further West, including a preliminary geological map of the coast between Pointe Géologie and Cape Denison, and the first absolute dating of the Pointe Géologie migmatitic formations at *ca.* 1.5 Ga (Aubert de la Rüe and Tchernia, 1951; Heurtebize, 1952a, b; Bellair, 1961a, b; Bellair and Delbos, 1962).

More recently, Stüwe and Oliver (1989) attempted to integrate the previous, and scarce, data in a regional framework involving both Terre Adélie and South Australia in Rodinia and Gondwana reconstruction. Subsequently, petrological and geochronological (SHRIMP) results were obtained by Oliver and Fanning (1997, 2002) from samples collected during the 1911-1914 AAE (see below).

Finally, in the early 1990's, new field investigations were undertaken through the GEOLETA program supported by the French Polar Institute (IPEV). Detailed mapping of the Terre Adélie Craton (TAC) from 135 to 146°E together with petrological and geochronological investigations allow us to propose a complete re-assessment of the TAC basement (this paper and references therein). Moreover these results have also been used to constrain better the mechanical behaviour of the Neoarchean continental lithosphere (Duclaux et al., 2007a) and the role and distribution of fluids (Pelletier et

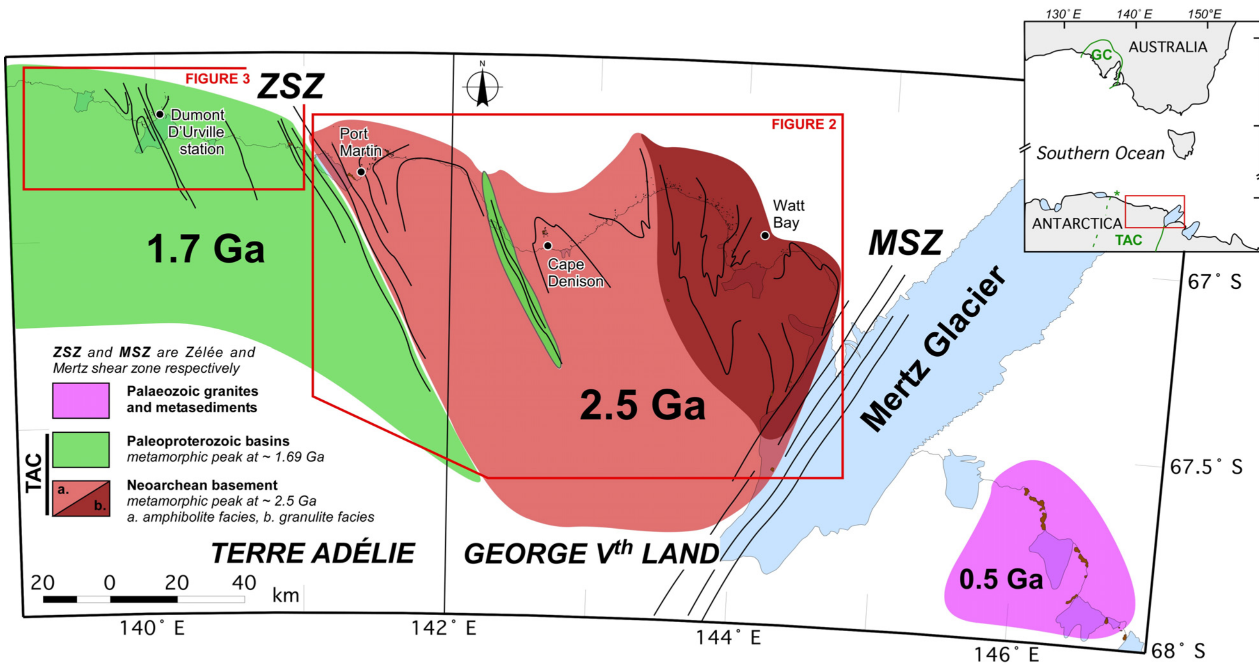

Figure 1. Geological sketch map of the Terre Adélie Craton illustrating the 2.5 and 1.7 Ga domains localization – *Projection UTM 53S*. Inset : location and limits of the Terre Adélie Craton (TAC) in East Antarctica and of the Gawler Craton (GC) in South Australia; continuous green lines : known boundaries of the Palaeoproterozoic cratons; broken green line : supposed western boundary of TAC; star : position of outcrops of the Rocher X and Rocher Matthieu.

al., 2005) during orogenic processes.

The Neoarchean basement

The Easternmost domain (Fig. 2) extends from the Zélée SZ (141°E) to the Mertz SZ (145°E) and reveals a composite Neoarchean basement, made of mainly felsic to mafic orthogneisses and granodiorites intruding subordinate metasedimentary country rocks including marbles and calc-silicates. This 2.55-2.44 Ga continental crust segment exposes two distinct tectonic units that represent two crustal sections from deep and intermediate levels equilibrated under granulites and amphibolites facies conditions respectively (Ménot et al., 2005). Within the Neoarchean gneissic basement, the Cape Hunter phyllites (see below) could be considered as remnants of a Paleoproterozoic, autochtonous, sedimentary basin. A large scale 1.7Ga thermal and tectonic overprinting was assumed by Di Vincenzo et al. (2007) on the base of Ar/Ar dating. But, according to our data (Duclaux et al., 2007b), the 1.7 Ga resetting recorded in the gneissic basement is restricted to only narrow fluid-bearing anastomosed shear zones, concentrated on the edges of the Neoarchean domain and along the Cape Hunter basin.

The Paleoproterozoic metasedimentary basins

The Western domain (Fig. 3), extending westward from the Zélée shear zone (141°E) corresponds to the highly strained and metamorphosed Paleoproterozoic Dumont d'Urville (DDU) basin. It consists in metapelitic migmatitic gneisses with subordinate metagraywackes, silicic metavolcanic rocks and mafic intrusions. Oldest crustal precursors are 2.2-2.4 Ga old (T_{DM}) with inherited zircons up to 2.8 Ga. A short time span brackets sediment deposition at about 1.72 Ga (age of the youngest inherited volcanic zircons) to HT-LP metamorphism, anatexis and coeval intrusion of mafic magmas dated at 1.69 Ga (Peucat et al., 1999; Pelletier et al., 2002).

More to the East, the Cape Hunter metapelites occur as a small outcrop squeezed within the Neoarchean basement. Based on rock types, ages of deposition and of metamorphism, the Cape Hunter basin is quite comparable with the larger Dumont d'Urville basin, but metamorphic conditions where significantly lower. The Cape Hunter metapelites recrystallized under greenschist facies conditions at *ca.* 1.7 Ga (Oliver and Fanning, 1997).

West from Pointe Géologie, rare outcrops allow the recognition of a 1.6 Ga magmatic event recorded by calc-alkaline granites and microgranites from Rocher Janet. Based on petrography, geochemistry and age of crystallization, these granites are very similar to the felsic blocks found in the moraines along the Terre Adélie coast and to the Gawler Range Volcanics of South Australia (Peucat et al., 2002).

More to the West, outcrops of Rocher X and Rocher Matthieu (Inset, Fig.1) are still badly known; they display biotite-hornblende migmatitic gneisses associated with mafic and intermediate intercalations as amphibolites and metatonalites. They are cross cut by numerous pegmatitic

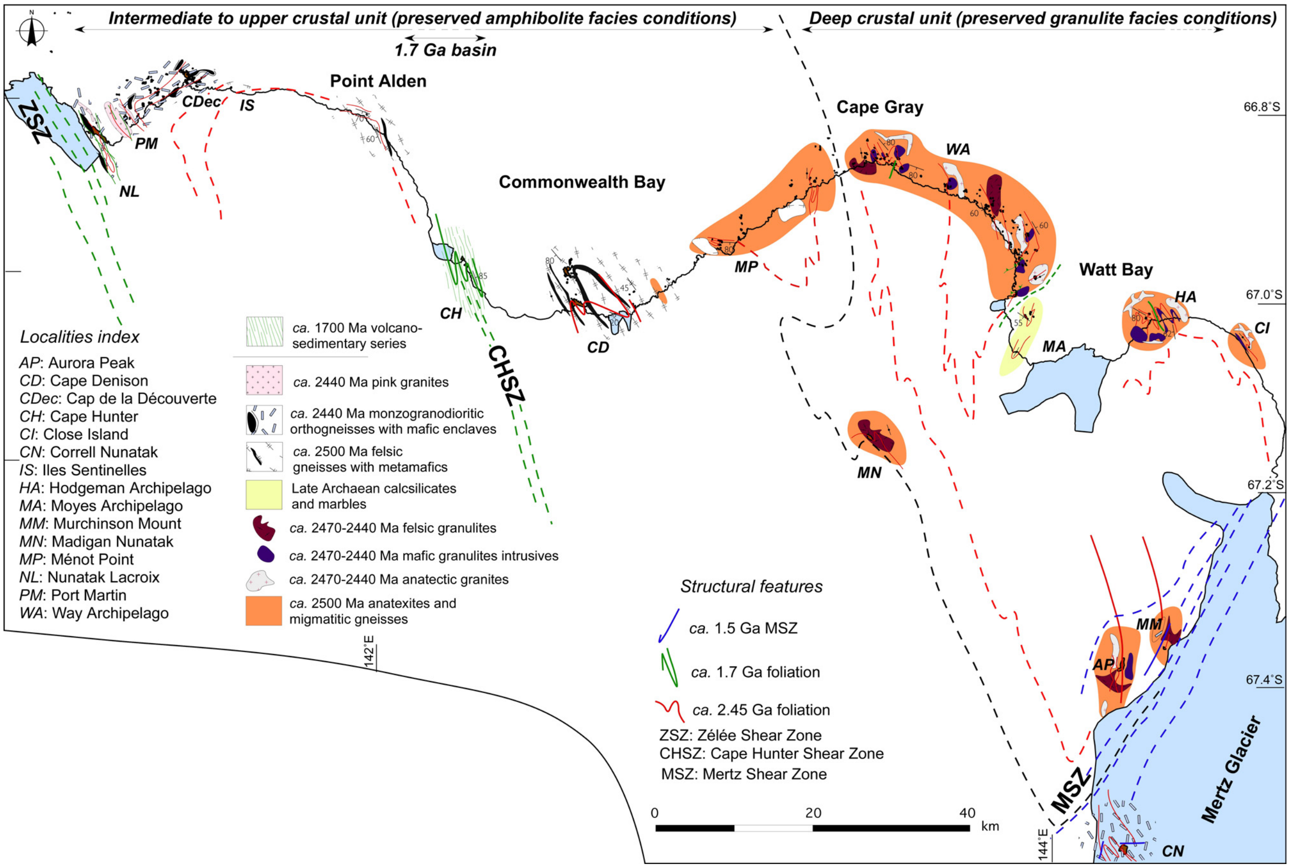

Figure 2. Geological sketch map of the Neoarchean domain and the overlying Cape Hunter Paleoproterozoic basin, east of the TAC.

dikes. The metamorphic evolution may be compared to that of the migmatitic series of Pointe Géologie, but ages need to be more accurately determined.

Late tectonic activity

The latest tectono-thermal event seems to be of limited spatial extent, concentrated on the Mertz shear zone (MSZ) (Talarico and Kleinschmidt, 2003) where synkinematic recystallizations have been dated between 1550 and 1500 Ma (Di Vincenzo et al., 2007). The MSZ separates the Neoarchean basement from the Early Palaeozoic unit of Cape Webb and Penguin (Fanning et al., 2002; Di Vincenzo et al., 2007) and therefore it represents the eastern boundary of the TAC and of the East Antartica Shield (Fig.1).

Finally, the opening of the Southern Ocean drove the rifting and the latter separation of the Terre Adélie and the Gawler cratons during Mesozoic times.

Discussion and conclusion

As clearly shown by the different maps presented here, the TAC may be considered as a composite basement built up through two major orogenic events at *c.a.* 2.5 and 1.7 Ga and devoid of any later significant reworking. Then it differs from most of others areas of the East Antarctic shield that display strong tectonic and/or metamorphic reworking related to Mesoproterozoic and Neoproterozoic-Cambrian orogens. Therefore, the TAC represents a meaningful place to constrain continental crust's genesis and recycling processes and to precisely define the evolution of the geodynamic processes during the Archaean to Paleoproterozoic transition.

In that context, detailed investigations are carried on to better understand the behaviour of the "young", Neoarchean and Paleoproterozoic, continental lithosphere during orogenesis. Through numerical experiments and field constraints, Duclaux et al. (2007a) demonstrated the role of gravity in the structural evolution of a hot Neoarchean continental crust. The related 2.45 Ga L>S fabric recognized in the TAC reflects a massive orogen-parallel flow that was acquired during the progressive waning of the tectonic force at the end of convergence. With regard to the 1.7 Ga event, Gapais et al. (2007) and Duclaux et al. (2007b) described the contrasted evolution between the cooled and stabilized Neoarchean basement and the warmer, radiogenic-rich, intracontinental Paleoproterozoic basin of Dumont d'Urville.

The exposure of Paleoproterozoic basins developed upon a Neoarchean basement gives a good opportunity to investigate crustal recycling and juvenile, mantle derived,

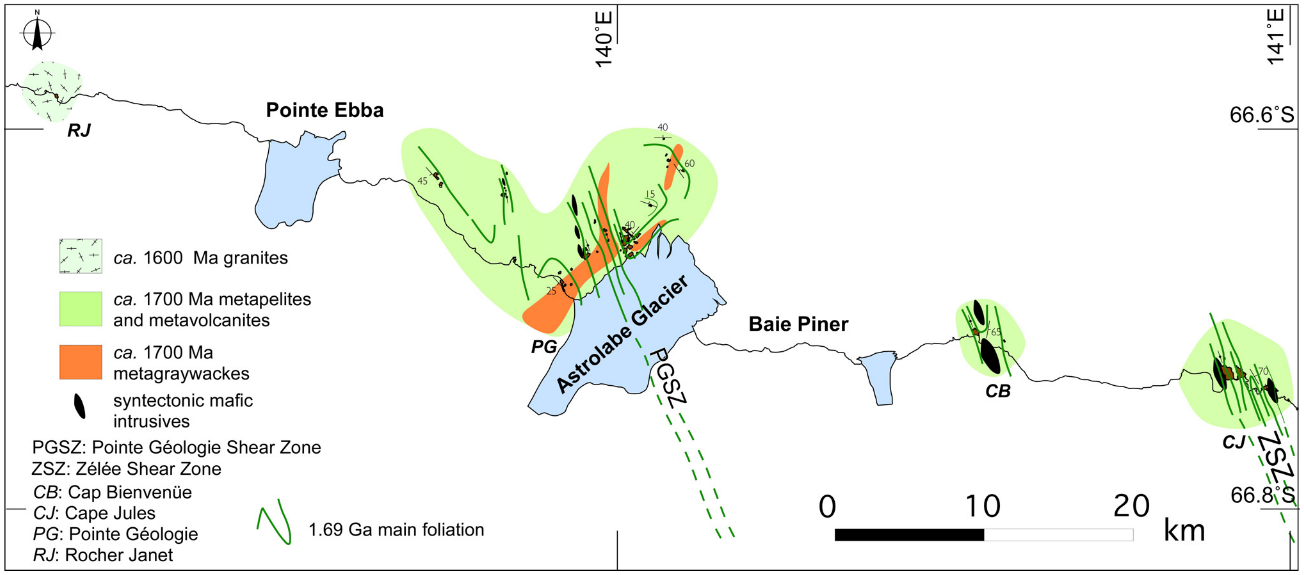

Figure 3. Geological sketch map of the Paleoproterozoic Dumont D'Urville basin.

accretion processes and their relative contribution during the 2.8 – 1.6 time span. Preliminary results based on Sm-Nd and trace element geochemistry have been proposed (Peucat et al., 1999b) and further elucidation will be forthcoming (Duclaux, PhD in progress).

The high quality of outcrops and rocks permits a detailed study of relationships between metamorphic reactions and partial melting. Migmatitic gneisses from DDU area display very different degrees of melting at peak metamorphism and varied retrograde mineral assemblages. Such features are assumed to be associated with space and time heterogeneities in the distribution of fluids within the Paleoproterozoic ductile crust (Pelletier et al, 2005).

Furthermore, according to Fanning et al. (2002,2003), the TAC represents also a key region linking the East Antarctic Shield and the Gawler Craton in Southern Australia. This link was examined in details and is supported by lithological, structural and age similarites. It supports the Mawson continent hypothesis (Fanning et al., 2003), i.e. a remnant of the Rodinia Supercontinent that was later amalgamated to the East Antarctic continent (Fitzsimons, 2003 and ref. therein). A better understanding of the geological evolution of the TAC and of adjacent areas (Eastern George V Land) would improve models for Rodinia and East Gondwana reconstructions.

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References

Aubert de la Rüe, E. and P. Tchernia, (1951), Sur quelques roches de Terre Adélie, C.R.Acad.Sci., Paris, 232, 995-996.

Bellair, P., (1961a), Sur les formations anciennes de l'archipel de Pointe Géologie (Terre Adélie), C.R.Acad.Sci., Paris, 252, 3087-3089

Bellair, P., (1961b), Pétrographie du socle cristallin de Terre Adélie, C.R. Acad. Sci., Paris, 252, 3296-3298.

Bellair, P., and L. Delbos, (1962), Age absolu de la dernière granitisation en Terre Adélie. C.R.Acad.Sci., Paris, 254, 1465-1466.

Di Vincenzo, G., F. Talarico and G. Kleinschmidt, (2007), An ^{40}Ar-^{39}Ar investigation of the Mertz Glacier area (George V Land, Antarctica): implications for the Ross Orogen- East Antarctic Craton relationship and Gondwana reconstruction, Precambrian Res., 152, 93-118.

Duclaux, G., P. Rey, S. Guillot and R.P. Ménot, (2007a), Orogen-parallel flow during continental convergence: Numerical experiments and Archaean field examples, Geology, 35, 8, 715-718..

Duclaux, G., Y. Rolland, G. Ruffet, R.P. Ménot, S. Guillot, J.J. Peucat and J. Bascou, (2007b), Superposition of Neoarchean and Paleoproterozoic tectonics in the Terre Adélie Craton (East Antarctica): evidence from Th-U-Pb ages on monazite and Ar-Ar ages, 10th ISAES, Santa Barbara, Extended Abstract Volume.

Fanning, C.M., Ménot, R.P., Peucat, J.J. and A. Pelletier, (2002) A closer examination of the direct links between southern Australia and Terre Adélie and George V Land. In "Preiss V.P. (Ed.), Geosciences 2002, Expanding Horizons. Abstracts of the 16th Australian Geological Conference, vol.67, Adelaïde, p.224.

Fanning, C.M., J.J. Peucat and R.P. Ménot, (2003), Whither the Mawson continent? 9th ISAES, Potsdam, Abstract.

Fitzsimons, I.C.W. (2003), Proterozoic basement provinces of southern and southwestern Australia and their correlation with Antarctica,. In Yoshida M., Windley B.F. and Dasgupta S. (Eds), Proterozoic East Gondwana: Supercontinent Assembly and Breakup, Geological Society, London, Special Publications, 206, 93-130.

Gapais, D., Pelletier, A., Ménot, R.P., and Peucat, J-J., (2007), Paleoproterozoic tectonics in the Terre Adélie Craton (East Antarctica), Precam. Res., in press.

Heurtebize, G., (1952a), Sur les environs de Port Martin (Terre Adélie), C.R.Acad.Sci., Paris, 234, 1780-1782.

Heurtebize, G., (1952b), Sur les formations géologiques de Terre Adélie, C.R.Acad.Sci., Paris, 234, 2209-2211.

Ménot, R.P., A. Pêcher, Y. Rolland, J.J. Peucat, A. Pelletier, G..Duclaux and S. Guillot, (2005), Structural setting of the Neoarchean terrains in the Commonwealth Bay Area (143–145°E), Terre Adélie Craton, East Antarctica, Gondwana Res., 8, 1–9

Monnier, O., R.P. Ménot, J.J. Peucat, M. Fanning and A. Giret (1995), Actualisation des données géologiques sur Terre Adélie (Antarctique

Est) : mise en évidence d'un collage tectonique au Paléoprotérozoïque, C.R.Acad.Sci., Paris, 322, IIa, 55-62.

Oliver, R.L. and C.M. Fanning, (1997). Australia and Antarctica: Precise correlations of Palaeoproterozoic terrains. In Ricci C.A. (Ed.) The Antarctic Region : geological evolution and processes. Sienna, Terra Antartica Publication. 163-172.

Oliver, R.L.and C.M. Fanning, (2002), Proterozoic geology east and southeast of Commonwealth Bay, George V land, Antarctica, and its relationship to that of adjacent Gondwana terranes, in Gamble J.A., Skinner D.N.B and Henry S. (Eds), Antarctic at the close of a millennium, The Royal Soc. of N.Z. Bull., 35, 51-58.

Pelletier, A., D. Gapais, R.P. Ménot and J.J. Peucat, (2002), Tectonique transpressive en Terre Adélie au Paléoprotérozoïque (Est Antarctique), C.R. Geoscience, 334, 505-511.

Pelletier, A., M. Guiraud and R.P. Ménot, (2005), From partial melting to retrogression in the Pointe Géologie migmatitic complex: a history of heterogeneous distribution of fluids, Lithos, 81, 153-166.

Peucat, J.J., R.P. Ménot, O. Monnier and C.M. Fanning, (1999a), The Terre Adélie basement in the East Antarctica Shield: geological and isotopic evidence for a major 1.7 Ga thermal event; comparison with the Gawler Craton in South Australia, Precam. Res., 94, 205–224.

Peucat, J.J., Ménot, R.P., Fanning, C.M., Pelletier, A. and Pecora, L., (1999b), Geochronological evidence for a Late-Archean basement in the Terre Adélie Craton, 8th ISAES, Wellington, NZ, p.242.

Peucat J.J., R. Capdevila, C.M. Fanning, R.P. Ménot, L. Pécora and L. Testut, (2002), 1.60 Ga felsic volcanic blocks in the moraines of the Terre Adélie Craton, Antarctica: comparisons with the Gawler Range Volcanics, South Australia, Australian. J. E.S. 49, 831–845.

Stillwell, F.L., (1918), The metamorphic rocks of Adélie Land, AAE 1911-1914, Sci. Rep., Ser.A, v.3, 1-230.

Stüwe, K.and R.L. Oliver, (1989), Geological history of Adélie Land and King George V Land, Antarctica: evidence for a polycyclic metamorphic evolution, Precam. Res., 43, 317-334.

Talarico, F. and G. Kleinschmidt, (2003), Structural and Metamorphic Evolution of the Mertz Shear Zone (East Antarctica Craton, George V Land): Implications for Australia/Antarctica Correlations and East Antarctic Craton/Ross Orogen Relationships, Terra Antartica, 10, 229-248.

Tilley, C.E. (1923), The metamorphic limestones of Commonwealth Bay, Adélie Land, AAE 1911-1914, Sci. Rep., Ser.A, v.3, 231-244.