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

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Summary In order to emphasize the tectonic behaviour of stabilized continental crust during later tectonic activity, we investigated the composite metamorphic basement of the Terre Adélie Craton (TAC). Two domains are recognized: (1) a Neoarchean basement, made of a deep granulitic crust to the East, and an amphibolitic crust to the West, and (2) two Paleoproterozoic basins overlying the Neoarchean amphibolitic crust and extending further West. New geochronological data from the TAC reveal a tectonic evolution with two major events. Monazites ages from the Neoarchean granulitic crust illustrate a main tectono-metamorphic event around 2.45Ga. Localized resetting of monazites geochronometer occurred around 1.7Ga within small fluid bearing shear zones. New $^{40}Ar/^{39}Ar$ ages from amphibole, and micas from both Neoarchean basement and Paleoproterozoic basins illustrate their differential evolution during a major 1.69Ga event. Finally, 1.55-1.5Ga ages are only recognized close to the Mertz Shear Zone along the Eastern craton boundary.

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Introduction

Structures in high-grade Precambrian terrains remain complex to understand as they often result in a polyphased tectonic history due to superposition of orogenc events in a same area. Field investigations and new geochronology analyses performed on metamorphic rocks from Terre Adélie and George Vth Land sampled during the GEOLETA program allow constraining the tectonic evolution of this Precambrian continental province. The Terre Adélie province is built up by two major domains (Monnier et al., 1996) of Archean and Paleoproterozoic ages. These domains have been interpreted as two accreted terrains delimited by a major tectonic boundary (Monnier et al., 1996: Pelletier et al., 1999). The main tectono-metamorphic event structuring the Paleoproterozoic domain, which may account for the craton stabilization, has been dated at about 1.69 Ga (Peucat et al., 1999; Pelletier et al., 2002). In contrast, the Archean basement which formed at *ca.* 2.8-2.7 Ga (Nd model ages) suffered a polyphased evolution with a late and major event at *ca.* 2.5 - 2.4 Ga (Ménot et al., 1999, 2005; Peucat et al., 1999). Ages at *ca.* 1.7 Ga are considered either as a local thermal resetting related to shear zones (Oliver and Fanning, 2002; SHRIMP U-Pb zircon) or as a regional and pervasive event (Di Vincenzo et al., 2007; $^{40}Ar/^{39}Ar$ laserprobe biotite dating). Consequently, the tectonic and metamorphic history of the Neoarchean domain appears to be complex. Thus, its Paleoproterozoic evolution needs to be re-appraised in order to estimate the spatial extension of tectonic reworking in an already cooled Archean continental domain.

We propose here a reassessment of the geodynamic evolution in the light of new geochronological data, assuming a double method approach, comprising Th-U-Pb dating of monazite (for high temperature processes dating or fluid induced recrystallization) and $^{40}Ar/^{39}Ar$ dating of amphibole (closure temperature at *ca.* 500˚C), biotite (closure temperature around 300˚C), and muscovite (closure temperature around 350˚C).

Geological setting

The Terre Adélie and George Vth Land rock basement is built up by two main domains (Monnier et al., 1996) (see Ménot et al. (2007) for further details and maps): (1) a Neoarchean to Siderian age (2.7 to 2.42 Ga), below referred as the Neoarchaean domain, to the East and (2) a Statherian (1.7 Ga) domain below referred as the Paleoproterozoic domain. These domains have been interpreted as two accreted terrains delimited by a major tectonic boundary (Monnier et al., 1996: Ménot et al., 1999). They are considered as a single geological province cratonized during

Paleoproterozoic times: the Terre Adélie Craton (TAC) (Peucat et al., 1999). The TAC is a part of the Mawson block of Fanning et al. (2003). The composite TAC extends along the Antarctic coast between 135°E (?) and 144,5°E and represents the easternmost area of the East Antarctic Shield (Fig. 1). The eastern boundary is marked by the prominent Mertz Shear Zone (SZ) (144.3°E) (Talarico and Kleinschmidt, 2003; Di Vincenzo et al., 2007), which separates the Archean and Proterozoic basement of the TAC from the Ross-Delamerian granitoids and metasediments from the Cape Webb area (Fanning et al., 2002; Di Vincenzo et al., 2007).

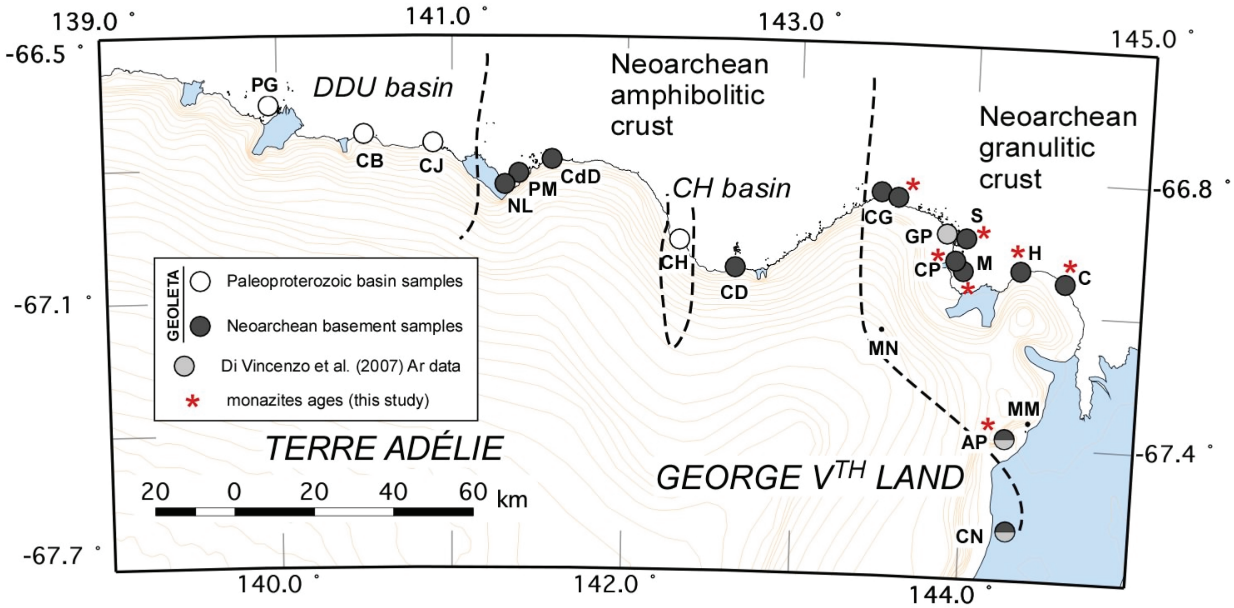

Figure 1. General map of the Terre Adélie Craton coast (including Terre Adélie and George Vth Land) indicating samples locations for Ar/Ar and monazites dating. *From West to East, PG: Pointe Géologie, CB: Cap Bienvenüe, CJ: Cap Jules, NL: Nunatak Lacroix, PM: Port Martin, CdD: Cap de la Découverte, CH: Cape Hunter, CD: Cape Denison, MN: Madigan Nunatak, CG: Cape Grey, GP: Garnet Point, S: Stillwell Island, CP: Cape Pigeon, M: Moyes Archipelago, H: Hodgemann Archipelago, C: Close Island, MM: Murchinson Mount, AP: Aurora Peak, CN: Correll Nunatak.* – Dashed lines correspond to crustal domains boundaries (see text for further explanation).

Observations and results

The Neoarchaean basement

The Neoarchean basement corresponds to the easternmost domain, extending from the Zélée SZ (141°E) to the Mertz SZ (145°E). It is made of felsic to mafic orthogneisses and intrusive granodiorites together with subordinate metasediments including carbonates. At regional scale, two successive metamorphic foliations may be defined, respectively marked by granulite or amphibolite facies parageneses. The granulitic foliation when preserved from transposition is relatively flat, gently deeping to the South. The amphibolite foliation is steeper and associated with large isoclinal folds (Ménot et al, 2005). Further horizontal boudinaged mafic rods and calc-silicate layers, parallel to the mineral stretching lineation, indicate horizontal flow in the crust (Duclaux et al., 2007). These later fabrics are compatible with the dome shape structure of the granulitic crust in the Neoarchean domain.

The Neoarchean granulitic crust tectonic evolution has first been constrained by in situ monazites analyses. Ages have been modelled according to the method of Montel et al. (1996). Bulk data display two peaks at *ca.* 2500 Ma and 1780 Ma. These two population ages are neither statistically valid nor representative of accurate tectonic events ages as they regroup some inheritance and mixing ages due to Pb loss. Nevertheless, these new data indicate a tectonic history featured by two distinct stages: (1) Neoarchean and (2) Paleoproterozoic. A closer look at some selected samples, as those from C Island, selected for their evidenced field relationships allow precising the robustness of the different ages. A fluid bearing mylonitic shear zone dated at *ca.* 1696 Ma cross-cut an istotropic hectometric tonalitic body dated at *ca.* 2433 Ma that includes foliated granulitic mafic xenoliths dated at *ca.* 2629 Ma. Some other monazites display clear Pb loss, suggesting intermediate ages between 2.5 and 1.7 Ga, but without geologic significance. Then, $^{40}Ar/^{39}Ar$ data from amphibole display staircase shape spectra with ages ranging from *ca.* 1540 to >1900 Ma close to the Mertz Shear Zone. In the same area, biotite ages range between ca. 1510 and 1610 Ma. Further west, amphibole ages range between *ca.* 1750 and 1920 Ma and biotite ages are at *ca.*1700 Ma. The Neoarchean amphibolitic crust tectonic evolution is constrained by new $^{40}Ar/^{39}Ar$ data from amphibole and biotite. Previous zircon ages in between *ca.* 2.6 and 2.44 Ga had been discussed by Ménot et al. (1999), Peucat et al. (1999) and Fanning et al. (2002). Amphibole ages are very homogeneous at *ca.* 1720 Ma toward the amphibolitic crust and close to the Zélée SZ to the west. Three disturbed amphibole spectra exhibit ages ranging from 1900 Ma to 2350 Ma indicating only partial resetting of the amphibole chronometer. Biotite plateau ages are homogeneous and range between 1680 and 1700 Ma, underlining a positive age gradient from east to west.

The Paleoproterozoic basins

Two basins are considered in the Paleoproterozoic domain: (1) the Cape Hunter phyllites overlying the Neoarchean amphibolitic crust, and (2) the western Dumont D'Urville (DDU) basin. The Cape Hunter phyllites correspond to squeezed metapelites and is considered as a Paleoproterozoic autochtonous sedimentary basin that recrystallized in greenschist conditions at *ca.* 1.7 Ga (Oliver and Fanning, 1997). The western Dumont D'Urville basin extends west of the Zélée SZ (141°E). It corresponds to a highly strained and metamorphosed Paleoproterozoic basin with a W-E deformation gradient with domes and flat foliations to the west, to predominant transpressive vertical shear zones to the east (Pelletier et al., 2002). Metamorphic conditions were significantly higher and it consists in metapelitic migmatitic gneisses with subordinate metagraywackes, silicic metavolcanics and mafic intrusives. Oldest crustal precursors are 2.2-2.4 Ga old (T_{DM}) with inherited zircons up to 2.8 Ga. A short time period, from 1.72 to 1.69 Ga, brackets the time between deposition, HT-LP metamorphism, anatexis and coeval intrusion of mafic magmas (Peucat et al, 1999).

In Cape Hunter phyllites, a single $^{40}Ar/^{39}Ar$ muscovite age yields a slightly "U" shaped disturbed spectrum, with an average age at ca. 1585 Ma with parts of the spectra remaining older. So, this might be regarded as a maximum age since "U" shaped spectra are generally interpreted as reflecting the presence of excess or inherited ^{40}Ar. In the three areas from the DDU basin, Capes Jules (the easternmost area) samples exhibit plateau ages in all analysed amphibole and biotite samples. Biotite ages are comprised within the range of 1643 Ma and 1663 Ma. Amphibole ages range between 1678 and 1691 Ma. Cap Bienvenüe (the central area) biotite samples have plateau and mini-plateau ages of 1651 Ma and 1606 Ma respectively. Pointe Géologie (the westernmost area) samples exhibit a biotite plateau age of 1567 Ma and a muscovite mini-plateau age of 1577 Ma. Thus, amphibole and mica ages show a W-E gradient with increasing ages toward the basin rim. Within the basin, in the Pointe Géologie area, exhumation rate is low at 0.1 $mm.yr^{-1}$ and increases eastward, up to 0.2 $mm.yr^{-1}$, in the Cap Jules area.

Mesoproterozoic processes

Latest geochronological record seems to be of limited spatial extension. The eastern boundary of the TAC, along the Mertz SZ, records recrystallization between 1550 and 1500 Ma associated with fluid circulation. This time bracket is also recorded in the DDU basin and in moraines blocks dated by Peucat et al. (1997). Nevertheless, no tectonic reactivation has been recognized in these later areas.

Discussion and conclusion

The combination of structural and geochronological studies allow us to propose a detailed geological scenario for the TAC, from the Neoarchean to the Mesoproterozoic:

(1) During the Archean: following a period of juvenile crust formation prior to 2.6 Ga, the Neoarchean domain underwent a major tectono-metamorphic event at ca. 2.44 Ga. Retrogression from granulite to amphibolite occurred within a short time period before 2.44 Ga. Diapiric rise of the Lower crust is evidenced by dome-structures cored by granulites, juxtaposed with Upper crust amphibolites during this major orogenic episode (Ménot et al., 2005; Duclaux et al., 2007).

(2) During the Paleoproterozoic period: basins probably opened in a transcurrent regime within an already exhumed Archean basement. This phase was shortly followed by convergence and basin domain closure at ca. 1.7 Ga. Within the already cooled Archean crust, deformation at the ductile/brittle transition is localized within meter-scale anastomozed shear zones. The Mertz SZ is active during this period. While in the DDU basin, the HT deformation is more penetrative at hectometre-scale. Despite contrasted exhumation rates within the basin, exhumation rates remain low (0.1 to 0.2 $mm.yr^{-1}$) reflecting massive horizontal flow of the Paleoproterozoic crust, in agreement with fabrics described by Pelletier et al. (2002).

(3) During the Mesoproterozoic period: A large magmatic event affects the Mawson Continent. In our study, this event is only recorded at the eastern margin of the craton and marked by fluid induced recrystallization of biotite.

These detailed chronological, metamorphic and tectonic data allow precising the view generally admitted for the cratonic evolution in the Archean to Proterozoic times. In general models, cratons growth is explained in terms of progressive accretion of tectonic blocks of smaller dimensions, with little internal deformation within the Craton itself. In contrast, the data presented here strongly support the idea that much of the deformation is accommodated by internal transcurrent deformation, with significant extension and compression within the Craton. Further, most of the peripheral growth is featured by recycling of the products of erosion of the Craton itself. No tectonic collage such as suture zone or accretionary collage has been evidenced.

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