Inside the Granite Harbour Intrusives of northern Victoria Land: Timing and origin of the intrusive sequence

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Summary Cambro-Ordovician Granite Harbour Intrusives define, in northern Victoria Land, a complex intrusive sequence composed of metaluminous and peraluminous granitoids, and minor ultramafic and mafic rocks, with variable K-enrichment and magmatic arc affinity. The main intrusive units cropping out in the Wilson Terrane between the Prince Albert Mountains and the Mountaineer Range have been dated by means of in-situ U-Pb LA-ICPMS analyses of zircons. The obtained results constrain the timing of emplacement of major crustal-derived anatectic melts in this area between 521 and 481 Ma, a time interval of 40 Ma. The mantle-derived mafic-ultramafic rocks, associated to the main high-K granitoids in the Deep Freeze Range-Northern Foothills, cover a time interval between 521 and 487 Ma. The long-lasting intrusive mafic and felsic magmatism caused the slow cooling of the basement responsible, together with local deformation and fluid circulation, of the common young reset ages observed in some of the studied intrusions.

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Introduction

Late Proterozoic - Early Paleozoic times were characterized by a widespread igneous activity occurred in response to convergence along the Cambro-Ordovician margin of Gondwana. In northern Victoria Land - Antarctica a large amount of felsic to mafic plutonic rocks known as Granite Harbour Intrusives (GHI - Gunn and Warren, 1962) were emplaced during the Cambro-Ordovician Ross Orogeny. They show variable geochemical characters, suggesting the involvement of distinct source rocks in the melting processes.

In this study we report new in-situ zircon U-Pb ages for the main intrusive suites cropping out in the Wilson Terrane between the Prince Albert Mountains and the Mountaineer Range, with the aim to more precisely constrain their time of emplacement.

Geological setting

During Late Proterozoic-Early Palaeozoic times, the convergence between the Antarctic sector of Gondwana and the palaeo-Pacific oceanic lithosphere generated the Ross-Delamerian Orogen at the border of the East Antarctic Craton and in southeastern Australia (Dalziel, 1992; Borg and DePaolo, 1994; Stump, 1995; Goodge et al., 2004 and references therein). The subduction along the active continental margin of the East Antarctic Craton, produced a widespread plutonism represented by the Granite Harbour Intrusives. In northern Victoria land this intrusive sequence, characterized by both I-type metaluminous and S-type peraluminous felsic melts, with variable K-enrichment and magmatic arc affinity and intruded into low- to high-grade metamorphic rocks, covers a long time span between 540 and 480 Ma (Armienti et al., 1990; Tonarini and Rocchi; 1994; Bomparola et al., 2007; Giacomini et al., 2007). In southern Victoria Land this magmatism is preceded by older, often gneissic, plutons, locally showing alkaline character (e.g. The Koettliz Glacier Alkaline Province interpreted as having formed between 551 and 530 Ma by Cooper et al., 1997 and Read et al., 2002).

Mapping and analytical work on plutonic bodies of the Wilson Terrane has outlined the occurrence of spatial isotopic and geochemical variations (Armienti et al., 1990; Borg et al., 1987; Ghezzo et al., 1987; Borg and DePaolo, 1994; Rocchi et al., 1998) which define distinct suites of granitoids and a variety of dyke swarms. Borg et al. (1987) and Vetter and Tessensohn (1987) identified a compositional zonation in the GHI with I-type granites occurring mainly in the northeastern region and S-type granitoids occurring in the soutwestern part of the Wilson Terrane. Such polarity was attributed by the authors to the involvement of increasing amounts of older crustal material in the production of granitoids close to the Wilson-Craton boundary. However, Ghezzo et al. (1987) successively showed that the compositional variability of the GHI has a more complex pattern, involving also calc-alkaline plutons and higk-K rocks in the southwestern sector of the region. Rocchi et al. (1998) interpreted the geographical variation of geochemical and isotopic compositions of granitoids as related to orogen-parallel displacement and rotation of crustal blocks along the active Gondwana margin affected by oblique subduction. According to the authors, these movements took place along a major discontinuity in the Tinker-Campbell Glacier belt giving rise to two distinct adjoining portions characterized by different geochemical characters, although belonging to the same crustal province: an oceanward portion where granites are generated by extensive interaction of mantle-derived magmas with high-level crustal melts, a continentward portion where intrusives were generated by interaction between mantle-derived melts and a mafic granulite lower crust.

The intrusive suites

Felsic and mafic intrusives in the area between the Prince Albert Mountains and the Mountaineer Range belong to at least three distinct suites (Borg et al., 1987; Ghezzo et al., 1987; Armienti et al., 1990; Rocchi et al., 1998; Rocchi et al., 2004); mafic rocks are generally not genetically related to the associated felsic members (Armienti et al., 1990; Rocchi et al., 2004) and show often mingling and mixing evidence of interaction with the granitoids (Di Vincenzo and Rocchi, 1999).

The calc-alkaline granitoids

The calc-alcaline granitoids are widely exposed in the whole Wilson Terrane, from the western Eisenhower Range to the eastern Mountaineer Range at the Wilson-Bowers boundary. They include metaluminous subalkaline rocks ranging in composition from tonalites to syenogranites. The larger intrusive bodies are mostly made up of monzogranites, granodiorites and tonalites, grey or whitish in colour, characterized by medium- to coarse-grained, sometimes porphyritic structure and by massive to foliated fabric. Microgranular mafic enclaves are common.

An attempt to date the metaluminous calc-alkaline granitoids has been carried out by Tonarini and Rocchi (1994): a Rb-Sr pseudo-isochron age of 610 Ma has been obtained for the granitoids cropping out at Mt. Jiracek in the Mountaineer Range. Recent in-situ zircon U-Pb ages constrain the emplacement age of one monzogranite from Mt. Keinath and one quartz diorite and one tonalite from the Corner Tonalite unit in the Deep Freeze Range at 481 and between 508 and 497 Ma respectively (Bomparola et al., 2007).

The high-K granitoids

The high-K granitoids include a variety of rocks mainly composed of monzo- and syenogranites, with variable K_2O enrichment and different petrographic and geochemical features. They are localized west of the Campbell Glacier. North of the Browning Pass they crop out in the Deep Freeze Range (the "Howard Peaks Pluton" of Bomparola et al., 2007); south of Browning Pass they make part of the Terra Nova Intrusive Complex along the eastern shore of the Terra Nova Bay (e.g. the "Abbott felsic unit" of Rocchi et al., 2004). Other outcrops of high-K granitoids crop out in the Prince Albert Mountains (e.g. at Teall Nunatak), and include the Irizar Granite intrusive bodies.

U-Pb zircon ages obtained from four samples of granodiorites and monzogranites from the Howard Peaks Pluton constrain the emplacement age of the high-K granitoids of the Deep Freeze Range to between 506 and 493 Ma (Bomparola et al., 2007). Moreover, a Rb-Sr whole-rock isochron (Armienti et al., 1990) and a conventional multigrain zircon U-Pb age (Rocchi et al., 2004) provide the emplacement age for the Mt. Abbott granites in the range 508±5 - 495±4 Ma.

The peraluminous granitoids

The peraluminous granitoids are widely exposed along an intermediate belt between the Campbell and Aviator Glaciers. They are characterized by a wide range of peraluminous rocks cropping out as dykes and large plutons. Two main groups of peraluminous granitoids can be recognized on the basis of petrographic and field relationships (Biagini et al. 1991): synkinematic (SKG) and postkinematic granites (PKG). SKG, mainly exposed in the Deep Freeze Range, are fine-grained leuco-monzogranitic dykes and sills, with a common solid-state foliation parallel to the regional metamorphic trend. PKG form large and massive plutons along a NW-trending belt between the Tinker-Aviator Glaciers zone and the Lichen Hills. The dominant PKG type have been defined TTG (Tinker Type Granites) from Biagini et al. (1991). They range in composition from granodioritic to monzogranitic and are characterized by the presence of metasedimentary inclusions.

Rb-Sr whole-rock isochron ages of 484±17 and 481±10 Ma obtained respectively on SKG and PKG by Tonarini and Rocchi (1994), suggested that the two groups of granites are coeval.

The mafic intrusives

The mafic intrusives are generally associated to both calc-alkaline and high-K granitoids. They constitute a heterogeneous group of rocks with variable composition, from minor ultramafites to dominant gabbros and quartz-diorites, characterized by variable and frequently strong K_2O enrichment, typical of a shoshonitic suite. They are mainly localized along a linear belt from the Deep Freeze Range to the Northern Foothills and the Prince Albert Mountains north of the David Glacier.

In-situ U-Pb LA-ICPMS zircon ages of 489 Ma have been obtained for one micro-monzodiorite from the Boomerang Glacier in the Deep Freeze Range (Bomparola et al., 2007) and for one gabbro-diorite from the Teall Nunatak, in the Prince Albert Mountains (Giacomini et al., 2007). An older age of 521 Ma has been obtained for one ol-bearing ultramafic cumulate cropping out at Teall Nunatak (Giacomini et al., 2007) and interpreted as dating the early pulses of subduction related mantle melts in North Victoria Land, which predate, according to the authors, the diffuse igneous activity dominated by intermediate to felsic products.

Geochronological results

New in-situ U-Pb LA-ICPMS zircon data have been obtained for three samples belonging to the calc-alkaline suite: one monzogranite from Mt. Jiracek in the Southern Cross Mountains and two granodiorites from Mt. Brabec and Mt. Monteagle in the Mountaineer Range. The inferred emplacement ages are respectively about 521, 491 and 489 Ma. The new data, together with the literature ages of 481 Ma for the post-tectonic Mt. Keinath monzogranite and 508-497 Ma for one quartz diorite and one tonalite of the Corner Tonalite unit in the Deep Freeze Range, constrain the emplacement of the high-K calc-alkaline felsic units between 521 and 481 Ma.

Four samples, representative of distinct felsic units of the high-K intrusions, have been selected for in-situ U-Pb analyses. They are one monzogranite and one quartz-monzonite from Mt. Baxter and Teall Nunatak in the Prince Albert Mountains, and one syenogranite from Mt. Abbott, in the Terra Nova Intrusive Complex of the Northern Foothills. The obtained emplacement ages are respectively 513 Ma for both the Mt. Baxter monzogranite and the Teall Nunatak quartz-monzonite and 499 Ma for the Mt. Abbott syenogranite, which together with the 506-493 Ma ages obtained from Bomparola et al. (2007) for four samples of the Howard Peaks Pluton, in the Deep Freeze Range, constrain the emplacement of the high-K granitoids between 513 and 493 Ma.

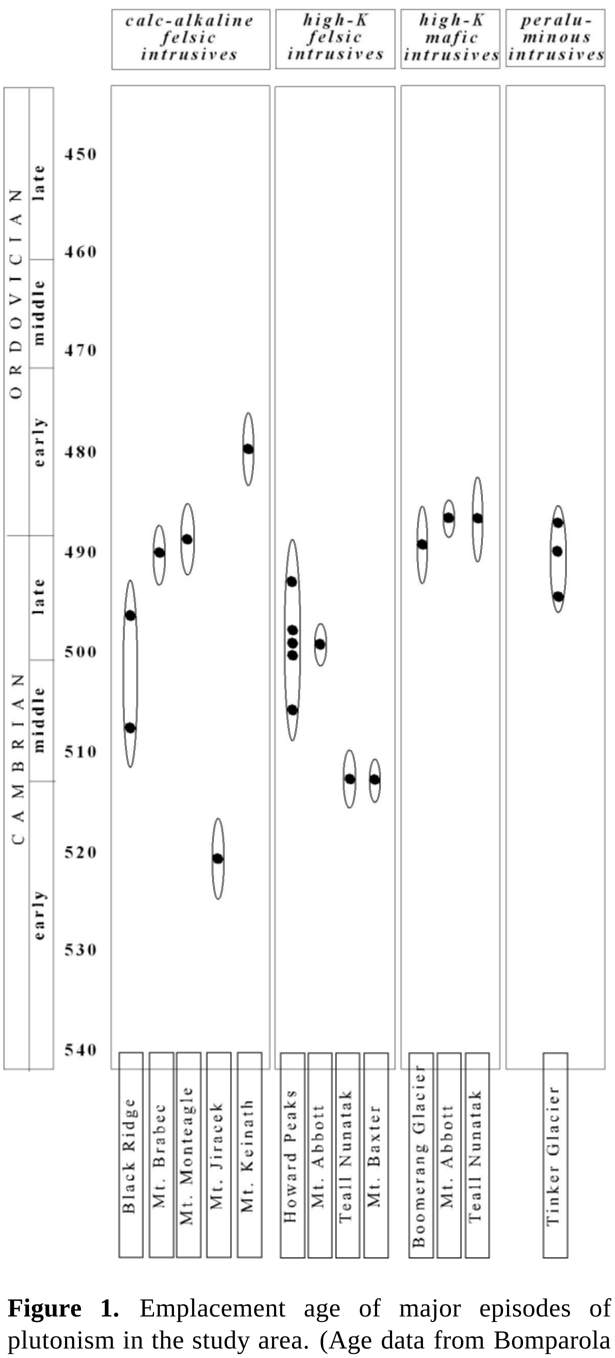

Figure 1. Emplacement age of major episodes of plutonism in the study area. (Age data from Bomparola et al., 2007 and Bomparola, unpublished data).

Three samples of the peraluminous Tinker Type Granites give emplacement ages between about 494 and 487 Ma.

The analyzed mafic intrusives includes one quartz-monzodiorite from Mt. Abbott in the Terra Nova Intrusive Complex and one gabbrodiorite from Teall Nunatak in the Prince Albert Mountains. They show the same emplacement age of 487 Ma, post-dating the associated felsic magmatism in the same areas. Considering also the literature ages of 489 Ma for the Boomerang Glacier micro-monzodiorite (Bomparola et al., 2007) and 489 and 521 Ma for one gabbrodiorite and one ol-bearing ultramafic cumulate of Teall Nunatak (Giacomini et al., 2007), the mafic magmatism seems to covers a time interval of more than 30 Ma, between 521 and 487 Ma.

Inherited components are common in most of the studied peraluminous and metaluminous granitoids, but rare or absent in the more mafic rocks (tonalites, diorites and gabbros). They show a wide spectrum of concordant ages between 530 and more than 2 Ga, with major peaks around 530-540 Ma, 600 and 700 Ma.

Many of the studied samples are characterized by a large number of young concordant ages, spanning from the emplacement ages to about 435 Ma, related to resetting processes which affected the U-Pb system of zircons.

Discussion and conclusions

The data presented above, even if not exhaustive, indicate that the calc-alkaline felsic intrusives, distributed along the southern transect of the Wilson Terrane, emplaced between 521 and 481 Ma. The high-K felsic intrusives were preferentially localized west of the Campbell Glacier. Their emplacement age covers a more restricted time interval, between 513 and 493 Ma. The peraluminous granitoids, mainly localized along an intermediate narrow belt of the Wilson Terrane, between the Campbell and the Aviator Glaciers, were emplaced between 494 and 487 Ma ago. The high-K mafic intrusives, cropping out from the Deep freeze Range to the Northern Foothills and Prince Albert Mountains, were emplaced between 521 and 487 Ma.

The regional distribution highlighted by the geochemical data is, therefore, not fully reflected in the U-Pb isotope data, calc-alkaline and high-K rocks showing emplacement ages in the same time interval, implying a more complex tectono-metamorphic evolution of the active continental margin.

The first documented subduction-related crustal melts production occurred around 521 Ma ago. This event requires that subduction and production of mantle-derived melts, responsible of the heating and melting of the crust, was already operating. The recent finding of cumulate mafic-ultramafic rocks 521 Ma old seems to confirm the underplating of basaltic melts at that time in the region.

The occurrence of gneissic granitoids and minor mafic orthogneisses at Inexpressible Island (the "Inexpressible Orthogneiss" of Skinner, 1983, dated at about 530 Ma by conventional U-Pb zircon method by Tonarini and Rocchi, 1994), clearly intruded by the widespread GHI, suggests an even older production of mafic and felsic melts in this region.

The common occurrence, in the studied granitoids, of inherited components between 530-540 and 600 Ma, often showing magmatic zoning and both crustal and mantle affinity (Lu-Hf unpublished data), seems to confirm the occurrence of unexposed and/or still unknown older igneous rocks.

The widespread mafic calc-alkaline to mainly shoshonitic magmatism west of the Campbell Glacier, along with the coeval presence in the same area of high-K granitoids, suggest a peculiar thermo-tectonic regime in this area, probably involving crustal thinning and/or delamination in an intra-arc environment far from the subduction margin.

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