Ross aged ductile shearing in the granitic rocks of the Wilson Terrane, Deep Freeze Range area, north Victoria Land (Antarctica)

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Summary The Deep Freeze Range of north Victoria Land, Antarctica, consists of high-grade metamorphic and igneous rocks belonging to the Wilson Terrane, primarily structured during the Cambrian-Ordovician Ross-Delamerian Orogeny. In this contribution we present a systematic study of the spatial distribution and of the kinematic and petrological characteristics of the major ductile shear zones that cross-cut the granitoid rocks of the Deep Freeze Range. The shear zones range in grade from greenschist to amphibolite facies and record compressional (?) transport directed towards the NE. Field relationships constrain the shearing event to the waning stage of the Ross-Delamerian Orogeny, due to the overprinting relationships with the emplacement of texturally-late leucocratic dykes in the region. We use these results to define the significance of these shear zones in the framework of the Ross orogenic cycle and to constrain the tectonic history of the region.

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Introduction

The Neoproterozoic-Early Paleozoic Wilson Terrane rocks exposed in northern Victoria Land, Antarctica (inset in Fig. 1), are extensively cross-cut by ductile shear zones, of variable thickness and distinct kinematics and metamorphic record (Wilson Mobile Belt in Roland et al., 2004 and references therein). These shear zone were active during the polyphase metamorphic evolution of the Cambrian-Ordovician Ross-Dalamerian Orogeny that is a part of the orogenic belt that constituted the Early Paleozoic, active paleo-Pacific margin of eastern Gondwana. The remnants of this formerly continuous belt are, now exposed in south-eastern Australia and northern Victoria Land, Antarctica, recording similar tectonic histories (Flöttman, 1993).

Up to now a systematic study of the spatial distribution and of the geometric, kinematic, petrological and temporal characteristics of the major ductile shear zones affecting the Wilson Terrane on north Victoria Land is lacking. Definition of the metamorphic recrystallization processes and the shear sense distribution within such ductile shear zones could thus provide fundamental constraints to the *P-T-t*-deformation history of the rock sequences involved in the Ross-Delamerian orogenic cycle.

We present the preliminary results of an integrated study that examines a set of ductile shear zones that cut the Granite Harbour intrusive rocks of the Wilson Terrane exposed in the Deep Freeze Range, north Victoria Land, Antarctica (Fig.1). Field studies are combined with textural, petrological and geochronological investigations to estimate the metamorphic conditions and the timing of shearing. We use these results to define the significance of these shear zones in the framework of the Ross orogenic cycle and to constrain the tectonic history of the region.

Regional Geological Setting and the local geology

The Early Paleozoic tectonic evolution of the Pacific margin of Gondwana has been classically interpreted as the collision of separate terranes along a convergent plate boundary during the Cambrian-Ordovician Delamerian/Ross Orogeny. In north Victoria Land, three major northwest-trending belts of accreted crustal domains, Neoproterozoic to Early Paleozoic in age, are generally recognised to constitute the Ross-Delamerian orogen. These different crustal domains are known in the literature as constituting three major terranes; from west to east: the Wilson, the Bowers and the Robertson Bay terranes (GANOVEX Team, 1987, and references therein) (inset in Fig. 1). There is increasing consensus in considering the terrane model of north Victoria Land as a fossil arc-trench system linked to a westward-directed subduction system at the paleo-Pacific active margin of Gondwana (e.g. Ricci et al., 1997; Federico et al., 2006).

The Deep Freeze Range of north Victoria Land is located within the Wilson Terrane and its structure and metamorphic style is dominated by the Ross–Delamerian orogenic cycle. This encompasses polyphase deformation during regional amphibolite-to-granulite grade metamorphism and the emplacement of Cambrian-Ordovician, syn-to-post-tectonic granitoid bodies of the Granite Harbour Intrusives (GHI) in a time span ranging from c. 510 to 480 Ma (Bomparola et al., 2006). The Ross aged structures consists of polyphase NW-SE steeply dipping overturned folds, reverse and strike-slip shear zones developed under low-to-high grade regional metamorphism (Carmignani et al., 1988; Palmeri et al., 1991; Musumeci and Pertusati, 2000).

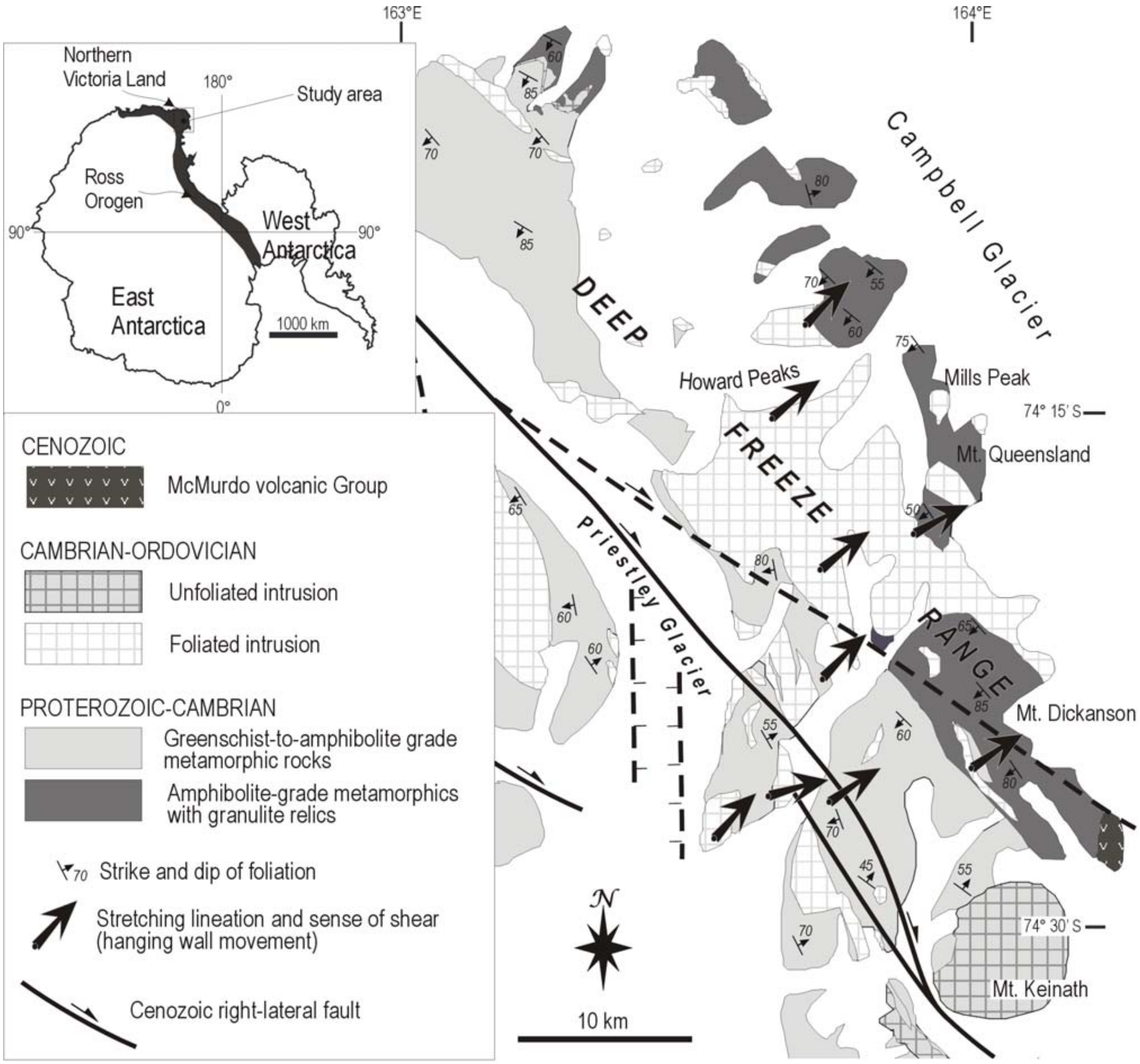

Figure 1. Structural sketch map of the Deep Freeze Range area (modified and re-adapted from Carmignani et al., 1988). The black arrows indicate localisation of the studied ductile shear zones and the associated sense of shear (hanging wall movement).

Shear zones characteristics

Field data

A set of ductile shear zones cutting the GHI of the Deep Freeze Range has been recognised in the field. They form a series of subparallel, NW-SE trending belts of high shear strain which collectively define a regional shear zone in excess of 30 km. Shear zone thickness ranges from few decimetres to more than 100 metres (Black Ridge area in Figure 1). These shear zones are typically shallow dipping to the SW, with steep-plunging mineral lineations and systematically overprint both the magmatic foliation and a NW-SE striking steeply-dipping solid-state planar fabric (Howard Peak area in Figure 1) (Fig. 2a). The gradual change from host granitic rocks to shear zone is invariably associated to intensely foliated rocks and marked by intense grain size reduction with the progressive transition from protomylonites to ultramylonites. General NE-SW trending stretching lineations are provided by the alignment of elongated minerals such as quartz, biotite and plagioclase+sillimanite+phengite composite associations. The kinematic indicators are abundant within the mylonitic rocks and invariably indicate top-to-the-NE sense of shear (Figs. 2a, b). The structural relationships indicate that the shear zones are overprinted by the intrusion of sub-horizontal leucocratic sills and dikes that can be ascribed to the Ross aged Granite Harbour Intrusive suite (Fig. 2a).

Textural data

At the thin section scale, the shear deformation overprints the previous magmatic fabric. Previous magmatic minerals are constituted by K-feldspar, Ca- rich plagioclase and garnet. They constitute porphyroclasts wrapped and/or augened by the mylonitic fabric, characterised by distinctive porphyroblasts of phengite, biotite, Na-rich plagioclase+ sillimanite within a matrix of recrystallised quartz (Fig. 2b). Euhedral garnet crystals up to 1 millimetre in diameter form porphyroblasts within the shear zone assemblage. Biotite and phengite are also present as mica fish wrapped by the quartz-biotite shear fabric, indicating that crystal growth occurred during progressive increments of shearing. Pristine magmatic garnets, with dimensions up to one centimetre, show a general rounded shape showing evidence of chemical resorption and several sets of biotite+plagioclase+quartz filled micro-fractures. K-feldspar appears only as large-size porphyroclasts with irregular shapes and wrapped by the external mylonitic foliation; myrmekite structures commonly occur at the boundary of feldspars. Accessory minerals consists of zircon, monazite, allanite and rutile. Monazite and allanite typically are aligned along the mylonitic foliation.

In summary, the samples display a combination of igneous and metamorphic microtextures. Evolution of mineralogical assemblage and texture includes (i) resorption and fracturing of feldspar and garnet porphyroclasts, with development of myrmekite and biotite coronas, (ii) development of a fine-grained mylonite matrix with the syn-tectonics growth of porphyroblasts of biotite, Na-rich plagioclase, phengite and sillimanite.

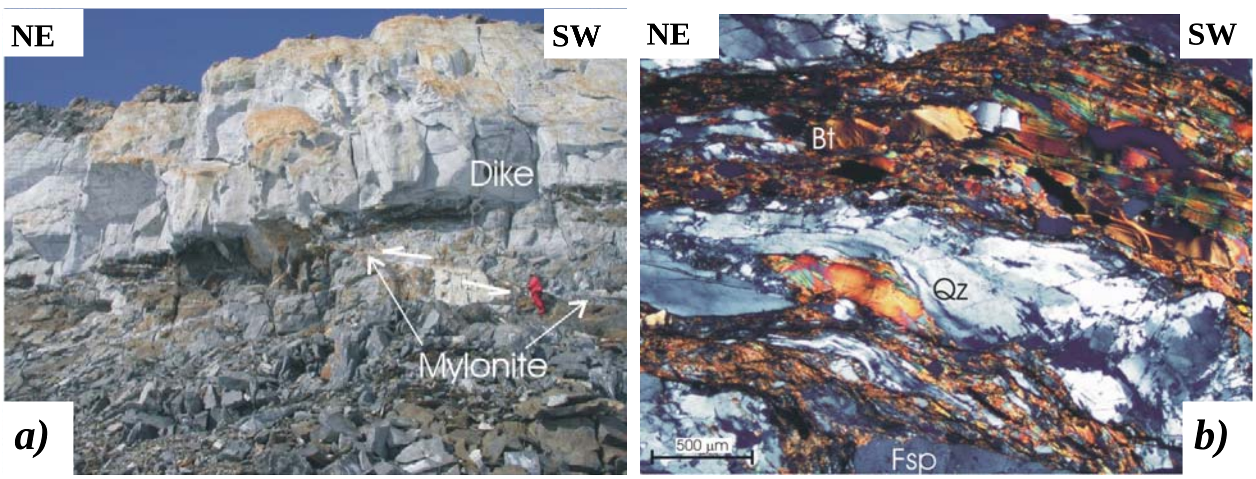

Figure 2. Field example of a top-to-the-NE ductile shear zone that cross cuts the granitoid rocks of the Wilson Terrane in the Deep Freeze Range. The foliation attitude within the shear zone indicate top-to-the-NE shearing. The shear zone is cut by a leucocratic dike (Mt. Queensland area in Figure 1). (b) Thin section showing typical mylonitic fabric comprising lensoid bands of granular feldspar (Fsp) and highly elongate quartz lenses (Qz) enclosed by matrix biotite (Bt). Shear sense sinistral (Black Ridge area in Figure 1).

Conditions of shearing

Metamorphic conditions during shearing were estimated using internally consistent thermobarometry through the software THERMOCALCv.3.25 (Holland and Powell, 1998) with the composition-activity formulations for minerals provided by the AX2000 program, in the form of the July 2006 update. Calculations were performed in the average *P-T* mode and the results are presented as a 95% confidence ellipse. The reaction textures reconstructed at the thin section scale were used to choose the appropriate equilibrium assemblage to utilise for thermobarometric calculations. The compositional zoning of garnet document that the porphyroclastic igneous garnet cores are unzoned, whereas a general rimward decrease in XFe and XMg concomitant with an increase in XMn were systematically observed. This is interpreted to correspond to diffusional re-equilibration at the metamorphic conditions of the shearing event. The garnet porphyroblasts in the mylonite matrix are instead almost unzoned and show a similar composition to that of the porphyroclastic garnet rims. The assemblage used in these calculations is thus phengite, biotite, sillimanite, garnet (rim), plagioclase, quartz. The garnet-biotite Fe-Mg exchange thermometry of Kaneko & Miyano (2004) applied to the garnet-biotite pairs found in the mylonite matrix was also used to provide additional constraints to the temperature of shearing.

Eight samples from five different shear zones were analysed and yielded *P-T* conditions of 600-750°C and 0.5-07 GPa (variations within single samples). These *P-T* estimates constrain shear zone formation in the granites to have occurred at metamorphic conditions typical of the amphibolite facies.

Some inferences

This study documents that the granitoid rocks of the Wilson Terrane record a major episode of ductile shearing that was directed towards the NE and was accompanied by sillimanite-grade metamorphism. Magmatically zoned zircons from the granitic rocks of the Howard Peaks area (Fig. 1) yielded U–Pb in situ ages of 510–490 Ma, whereas zircons from texturally-late leucogranitic dikes yielded ages of c. 480 (Bomparola et al., 2006), suggesting that the shear zones formed prior to 480 Ma and after the crystallisation of the main granitic body at c. 510 Ma. These shear zones were thus likely active during the waning stage of the Ross–Delamerian Orogeny. While this tectonometamorphic event is likely to have been of widespread regional extent, it has so far been identified only within the Deep Freeze Range and it is unclear how it extends into the adjacent Wilson Terrane rocks of north Victoria Land. As such, it implies: (i) a diachronous development of the Ross aged structures and (ii) the possible presence of a structural break within the rocks of the Wilson Terrane. In particular, it should be noted that the Deep Freeze Range area, due to the occurrence of anomalous young K-Ar and Rb-Sr ages (c. 460 Ma), has been claimed as a distinct crustal sector within the Wilson Terrane realm of north Victoria Land. This argues for a prolonged history of deformation and tectonism in the region and the potential importance of these shear zones in understanding the tectonic history of the Wilson Terrane rocks during the polyphase, Early Paleozoic orogenic construction at the paleo-Pacific margin of Gondwana.

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