Tectonics at the Bowers - Robertson Bay Terrane boundary, northern Victoria Land (Antarctica)

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Summary In northern Victoria Land, the boundary between the Bowers and Robertson Bay terranes is characterized by the Millen Schist (MS), a high strain belt, comprising two superposed elements. The upper element is made up of mafic metavolcanites that have a strong affinity to the Glasgow Volcanics. The underlying element comprises phyllitic schist and minor greywacke that bears a strong resemblance to those of the Robertson Bay arenaceous sequence. The two elements of the MS are in contact along a thrust surface where detailed structural analysis has revealed a consistent top to NE sense of shear. The southwestern boundary between Millen Schist and Bowers Terrane is known as the Leap Year Fault, but the fieldwork indicates that this boundary has transitional features and that the Leap Year Fault cut a pre-existing tectonic structure.

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Introduction

This work deals with the tectonics at the boundary between the Bowers Terrane and the Robertson Bay Terrane, in northern Victoria Land (NVL), Antarctica. Here we supply new data and constraints on this topic, derived from a detailed structural analysis on regional scale structures exposed in the Millen Range.

The goal of this paper is to achieve a better understanding of the structural records at the Bowers - Robertson Bay boundary, to build up its tectonic evolution and frame it in the evolution and kinematics of northern Victoria Land.

Geological framework

NVL represents the Pacific edge of the Transantarctic Mountains and its architecture was mainly produced by a long-lasting and complex orogenic evolution, i.e. the Neoproterozoic to early Paleozoic Ross Orogeny.

In NVL, the Ross Orogeny is characterized by the accretion of three terranes: Wilson (WT), Bowers (BT) and Robertson Bay Terrane (RBT). Recent contributions (Ferraccioli et al., 2002; Federico et al., 2006) suggest that these terranes did not develop an independent tectonic evolution and hence they do not match the definition of terrane by Coney et al. (1980). Nevertheless the term terrane is of common usage and it will maintained in this paper.

The BT comprises the Sledgers, the Mariner and the Leap Year Group. The Sledger Group consists of low-grade meta-volcanic rocks (Glasgow Volcanics) and intercalated proximal volcanoclastic sequence of Middle Cambrian age (Molar Formation).

The RBT is made up of a thick flysch-type sequence of Cambrian - Early Ordovician low-grade metasedimentary rocks. After the Early Paleozoic Ross Orogeny, all the three terranes were intruded by the Admiralty Intrusives, a calc-alkaline association of Devonian - Carboniferous age (Borg 1984).

WT and BT are in contact by the Lanterman Fault (Capponi et al., 1999), a tectonic lineament decorated by eclogite (Capponi et al., 1997; Di Vincenzo et al., 1997) that testify the subduction - driven nature of the docking mechanism.

The boundary between BT and RBT is characterized by the occurrence of the Millen Schist (MS), which are built by the superposition of two tectonic elements. The upper element is made up of mafic metavolcanics in which relics of effusive textures and pillow structures are frequently preserved, with minor clastic-volcanoclastic metasediments. The metamorphic assemblage of metabasite retain chlorite, albite, zoisite, actinolite, +/- stilpnomelane, calcite and sphene, suggesting a re-equilibration in the low greenschist facies. These metavolcanites strongly recall the Glasgow Volcanics; the volcanoclastic rocks resemble the metasandstone of the Molar Formation. The underlying element comprises phyllitic schist and minor metagreywacke; the metamorphic assemblages indicate the chlorite zone of the greenschist facies (Findlay, 1986). On the whole, these lithologies recall those of the RBT arenaceous sequence.

Compared to BT and RBT, the MS shows a more complex structural pattern, with two sets of folds, accompanied by two well developed foliations. Older structures (F_1) are recumbent isoclinal folds with a sub-horizontal pervasive axial plane schistosity (S_1), underlined by the main metamorphic crystallization. Age of metamorphism and F_1 deformation is constrained around 500 Ma by Ar/Ar dating (Wright & Dallmeyer, 1991) i.e. the Ross orogenic cycle. Younger folds (F_2) are open in shape and the related foliation (S_2) is parallel to the axial plane. S_2 is sub-vertical, trends NW-SE and has the feature of an asymmetric, well developed crenulation cleavage deforming the older foliation. As a result, the mesoscopic aspect of the MS is often characterized by 1-2 cm spaced microlithons. The superposition of the younger folds on the older ones generates an interference pattern of type 3 (Ramsay, 1967), recognizable also at a microscopic scale. S_2 foliation is a crenulation along which the S_1-related minerals are re-oriented and no relevant blastesis occurs.

On the whole the MS can be regarded as the high-strain equivalent of the adjoining terranes (Capponi et al., 1994). Finite strain determinations quantitatively demonstrate the higher degree of deformation with respect to BT and RBT and that the prevailing deformation was achieved by apparent flattening (Capponi et al. 2003).

The two elements of the MS are in contact by a main thrust fault, that can be followed for kilometers and is exceptionally exposed in the mountain walls in the area of Mt Aorangi - Crosscut Pk and hereafter it will be named Crosscut-Aorangi thrust (CAT). At SW the thrust fault appears to be locally truncated by the Leap Year Fault and to the NE by an unnamed NW-SE fault (Capponi et al., 2003).

Field data

All accessible outcrops between Turret Pk and Mt Hancox were visited during the XIX and XXI Italian Antarctic Expeditions. Fieldwork was made mainly at Crosscut Pk, Mt Aorangi, Mt McDonald, Mt Burton and Mt Hancox. Observations were made also along SW-NE transects, i.e. Mt McCarthy - Mt Burton and spotheight 2900 - Mt Hancox (Fig. 1). Structural analysis was focused on the tectonic structures between the upper and the lower element of the MS and on the steep faults bounding the MS belt.

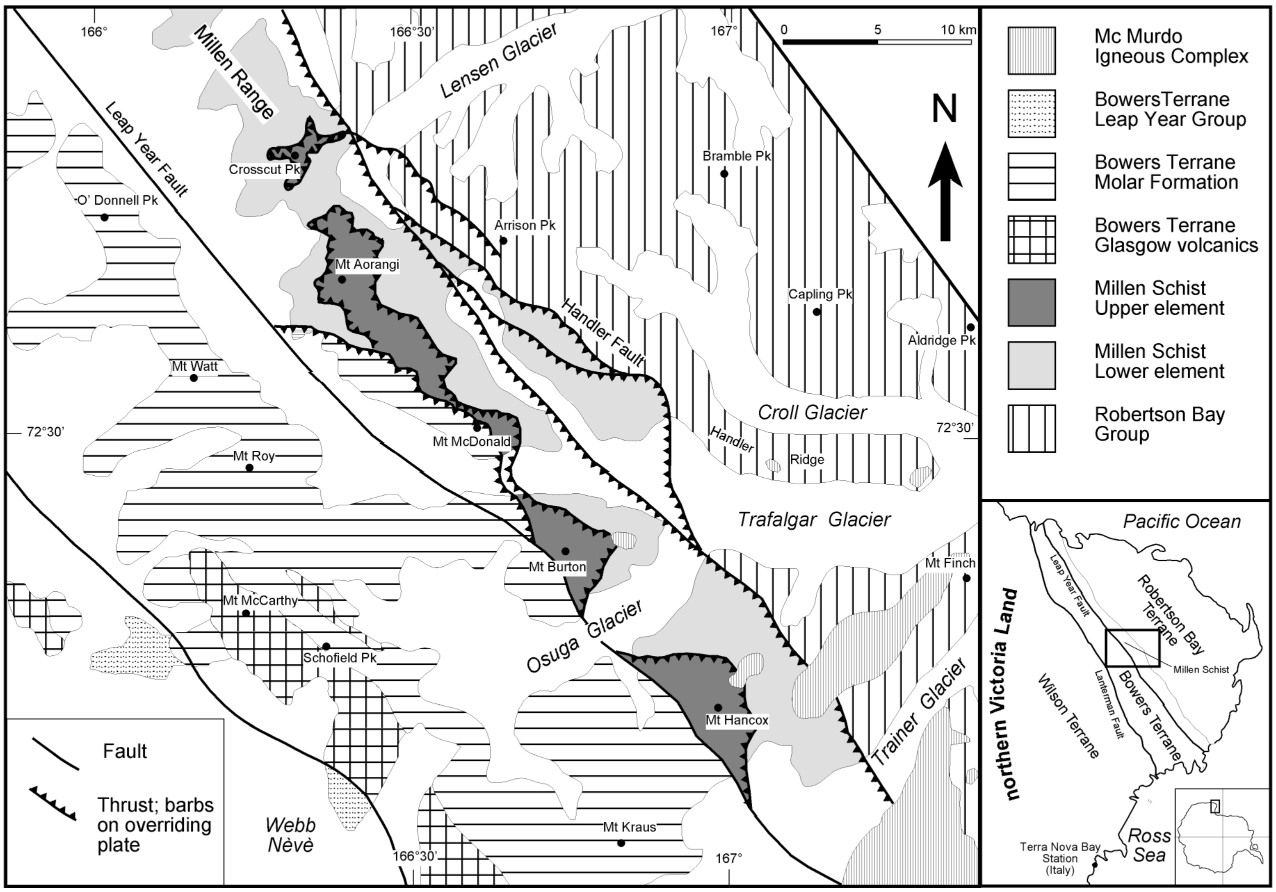

Figure 1. Study area and its location in northern Victoria Land.

The contact between the two elements of the MS (CAT) is a shear zone characterized by a duplex system. The CAT comprises a main thrust plane and several splay surfaces, bounding 10 to 100 m-scale horses. Normal and antiformal duplexes occur in the schists, whereas imbricate fan and normal duplexes characterize the metabasites at the top. At the outcrop scale shear planes are lined by mylonites, tectonites and diffuse veining. The CAT clearly cuts older structures of the schists in the footwall, e.g. sub-isoclinal folds, that can be ascribed to the F_1 deformation of the MS. In most places CAT dips towards SW; the only site in the Millen Range where CAT dips towards NE is Crosscut Pk. Here the antiformal stack of CAT is amplified by a superposed km-scale fold, already described in Bradshaw et al. (1985) and Findlay (1986). The interference of a folding phase with CAT is evident at the outcrop scale, but is visible also at Mt Hancox where m-scale folds affect CAT.

As concerns the kinematics, the sense of imbrication of the horses suggests a top to NE sense of shear. At several outcrops we obtained data from mesoscopic kinematic indicators of different types. We checked the drag of pre-existing foliations, overlapping fibers and mineral steps on slickensides, sigma-type structures and the asymmetry of shear folds. The above structures indicate a prevalent top to NE thrusting, consistent throughout the whole area.

In most geological sketch maps the Millen Schist is represented as an elongated belt bounded by two steeply dipping faults. The southwestern fault is usually referred to as the Leap Year Fault (LYF); we will refer to the northeastern fault as the Handler Fault (HF). Though both the LYF and the HF are not frequently exposed, a number of structural observations were made in the outcrops close to the associated fault zones. The LYF and HF are both characterized by the occurrence of widespread vein networks. Veins are mainly composed of quartz, carbonate and sulphide; rocks close to the veinwalls are often transformed into reddish-brown recrystallized lithologies. In places along the fault zones, the occurrence of hydraulic breccia and jagsaw-puzzle textured veins testify to tectonic events accompanied by hydrofracturing. On the whole, the above features testify to an important syn-tectonic fluids circulation and a significant rock-fluid interaction.

In the outcrops close to the HF, kinematic indicators as S-C tectonites, drag of pre-existing foliations and overlapping fibers, point to a reverse / strike-slip movement, with left-hand sense of shear.

In the outcrops of the LYF, kinematics of the structures are more ambiguous and complicated: here structures with left-hand reverse / strike-slips coexist with top to E and top to W reverse shear zones.

At some sites along the HF, tectonized dacitic to ryodacitic volcanites occur; though a precise attribution is not sure, they resemble the Carboniferous Gallipoli Volcanics. In these volcanics the S-C structures indicate left-hand reverse / strike-slip movements. The LYF and HF have the characteristics of two late tectonic steeply dipping faults superposed on preexisting high strain zones.

Along SW - NE transects, it is possible to point out a transitional character of the boundary between BT and MS. From the lithological point of view, moving from SW to NE and from the BT (Molar Formation) to the MS, the lithologic convergence is very strong. From the deformational point of view, a progressive increase in strain intensity occurs approaching the HF. This is shown by tightening of the F_1 folds shape, by the progressive change in attitude of F_1 folds axial surfaces and by the appearance of a nearly vertical crenulating foliation (S_2). So the boundary between BT and MS appears to be somewhat gradational in origin and later overprinted by the LYF. In places, e.g. Mt Burton and Mt Hancox, the LYF also truncates the thrust system of CAT and hence overprints a pre-existing tectonic situation.

The boundary between MS and RBT appears to be more abrupt both from the lithologic and the deformation point of view; e.g. NE of the HF Glasgow-like volcanic rocks no more occur.

Discussion

As the CAT truncates limbs of F_1 sub-isoclinal folds, this limits the timing of the CAT, that is post-F_1 deformation. Thrust faulting can be considered also as the last step of the progressive F_1 evolution. In this way, the timing of the CAT is syn- to post-F_1, that is constrained around 500 Ma by Ar/Ar dating (Wright & Dallmeyer, 1991).

The matching of the structural features between the F_2 folds in the schists of the Millen Schists Belt and the folds that deform CAT thrust system, suggest that the folding of the CAT is due to F_2 deformation. This refines the time constraint of the CAT, that is syn- to post-F_1 and pre-F_2.

F_1 folding and thrusting of the BT over the RBT can be regarded as the main tectonic phase of the Ross Orogeny, related to the terranes amalgamation. The origin of the MS, i.e. a higher strain belt, between the BT and RBT could be driven by the occurrence of the faulted area of transition between the Molar basin and the deeper RBT basin, as suggested by Capponi et al. (2003), in a scenario of tectonic inversion. Actually F_2 deformation is still un-constrained in age, but it can be obviously linked to the main phase of convergence during Ross Orogeny.

The geometric arrangement of horses, the kinematic indicators and the vergence of shear folds consistently indicate that CAT accomplished an overthrusting towards NE; the same is supported by other authors, as Gibson & Wright (1985), Bradshaw (1985), Wright & Brodie (1987) and Bradshaw (1989). The top to E-NE overthrusting is also consistent with a derivation of the upper element from the BT and a derivation of the lower element from RBT. Moreover this kinematics fits with the early tectonic evolution described for the boundary between WT and BT (Capponi et al., 1999), though achivied at deeper structural levels.

On the other hand, Findlay (1986, 1987) supported an E over W thrusting event, superposed by a later overthrusting to the E. During our detailed structural analyses in the thrust system zone and on related shear planes, we did not detect any indicators for an E over W thrusting phase. As far as we could observe, at this stage there is no factual evidence of a E over W thrusting.

The transitional character of the boundary between BT and MS and the overprinting relationship of the LYF over the CAT indicate that the Leap Year Fault can be considered a late tectonic structure overprinting a pre-existing tectonic arrangement.

This is less evident for HF, but the tectonized volcanites involved in the fault motion provide time constraints. If the volcanites are actually related to the Gallipoli Volcanics (as the field appearance suggests), this constrains the activity (or the re-activation) of the HF to post Carboniferous time.

The left-hand oblique-slip motion detected along HF (and partly LYF), matches the features of post-Ross evolution described by Capponi et al. (1999) along the Lanterman Fault.

On the whole, we can reconstruct a tectonic evolution as follows:

Ross Orogeny main tectonic phase, driven by terranes convergence. In the MS belt the higher intensity of deformation is accomplished by F_1 tighter and recumbent folds and by thrust systems development of thrust (i.e. CAT); the above structures are later deformed by F_2 folds.

LYF and HF activity, associated to a relevant syn-tectonic fluid circulation and rock-fluid interaction. Assuming that the volcanites involved in the fault zone pertain to the Gallipoli Volcanics, activity of HF is constrained to post Carboniferous time. LYF is un-constrained in time, but anyway it overprints the CAT, i.e. structures of the main Ross tectonic phase. A reworking of pre-existing lineaments cannot be excluded.

Conclusions

- The boundary zone between BT and MS, though cut by the LYF, is transitional, with a strain gradient and an increasing lithologic convergence.
- CAT shows consistent top to NE sense of shear, matching the early evolution detected along the Lanterman Fault.
- LYF and HF cut and overprint the tectonic structure achievied during the main Ross tectonic phase.
- Kinematics of the HF (and partly of the LYF) easily fits a post-Ross regional framework of left-hand oblique-slip tectonics.

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