Extreme Thermal Gradient and Carbon Loss in Contact Metamorphic Rocks: A Field-Based Study of the Tudor Gabbro Contact Aureole, Grenville Orogeny, Canada

Kanwa Sengupta [1,2] & Emily M Stewart [1,2]

1. Earth Ocean and Atmospheric Sciences, Florida State University, Tallahasse, FL, 32306
2. National High Magnetic Field Laboratory, Tallahassee, FL, 32310

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Contact: ksengupta@fsu.edu

Introduction:

The Tudor Gabbro is an ovoid gabbroic intrusion in a thick section of marbles lying within the Elzevir Terrane. The Tudor gabbro is dated at >1279 Ma (Silver & Lumbers, 1966) and predates at least one metamorphic event (Ottawan Orogeny) of Grenville orogenesis. Previous investigations by Allen (1976) and Dunn & Valley (1996) indicate the presence of a number of mineral reaction lines (isograds) in the contact aureole of the Tudor gabbro. All previous investigations point towards an anomalous fluid history and a complex polymetamorphic record.

Here we present an example of extreme heat and mass transfer in the contact aureole of Tudor Gabbro. The samples presented here are from a roadcut along Ontario Highway 62 between the towns of Madoc and Gilmour. The aureole rocks are from a roadcut >150 m in length located ~ 300m from the gabbro outcrop. The Contact aureole is marked by the prograde appearance of amphibole, titanite, and ultimately pyroxene, towards the gabbro accompanied by the disappearance of carbonates and, subsequently, amphibole and titanite in the highest-grade rocks. These mineral reactions indicate an unusually steep thermal gradient and loss of carbon from the protolith sediments. Further petrographic analysis of the gabbro reveals a regional metamorphic overprint and evidence of fluid flow through metamorphic recrystallisation and retrograde mineral reactions, respectively.

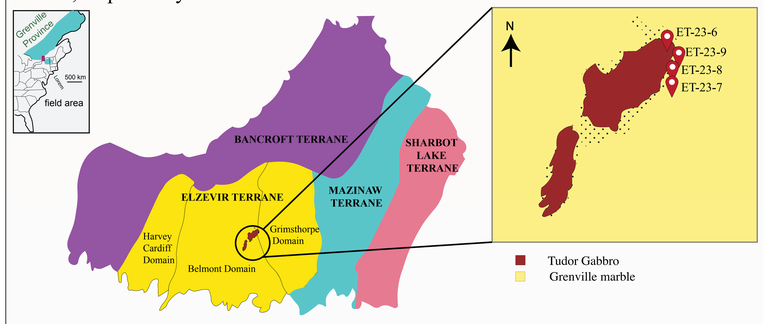
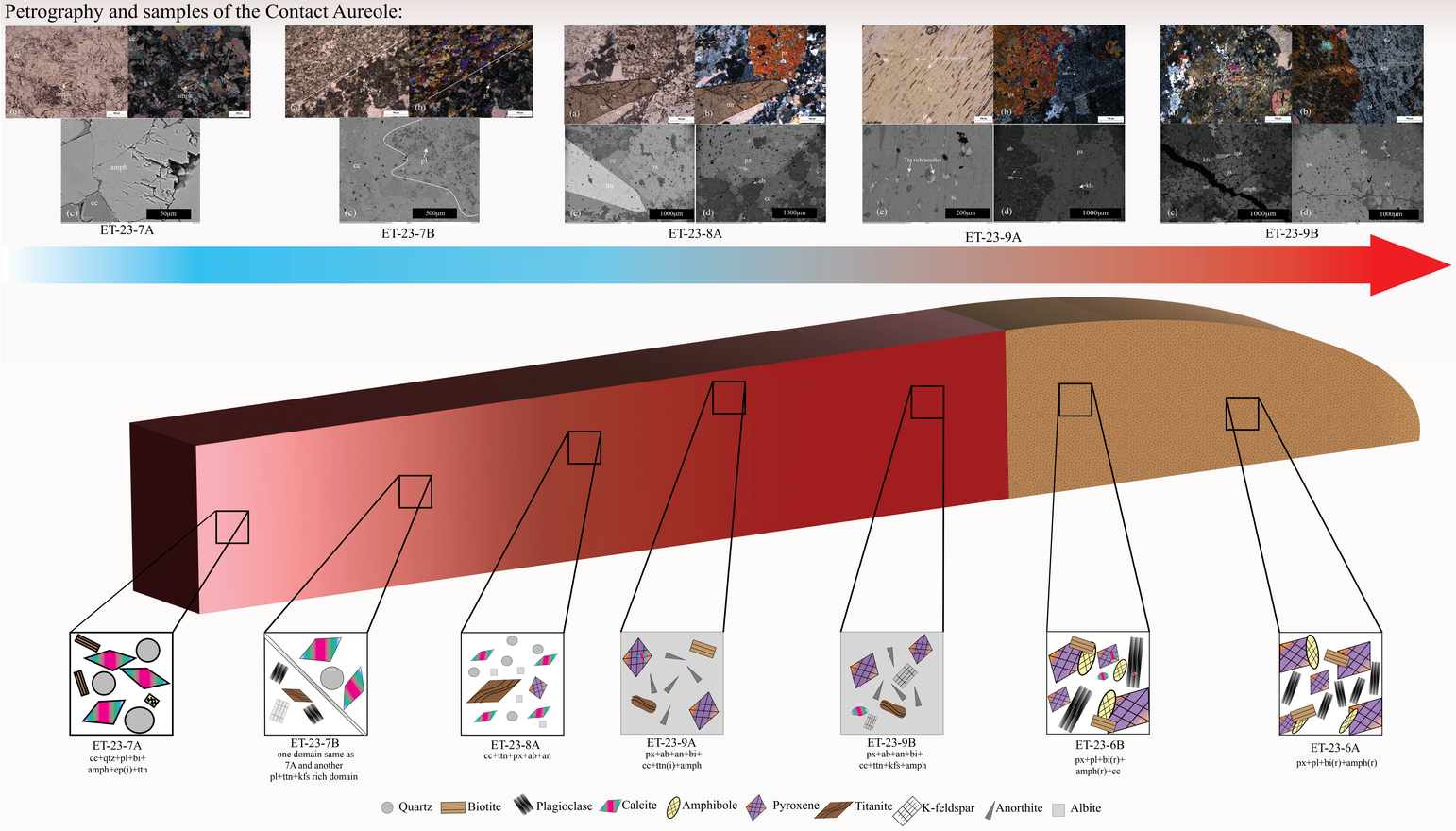


Fig : Map of Central Metasedimentary Belt with its domains (after Easton, 2000) and location of Tudor gabbro, contact aureole and our samples

Petrography and samples of the Contact Aureole:



Petrography: Tudor Gabbro

Petrographically the Tudor gabbro is a typical meta- gabbro with an assemblage of plagioclase + pyroxene ± opaque minerals. The grains show evidence of metamorphism in the form of recrystallisation. The evidence of fluid induced metamorphism is evident from mineral reactions forming amphibole, biotite and chlorite along the rims of the pyroxene grains. Some of these retrograde products are present as pseudomorphs. Samples near the outer part of gabbroic intrusion show the presence of carbonate inclusions. Their textural relationship to the pyroxenes suggests that the carbonates were assimilated into the magma during emplacement and not as a result of post crystallization alteration.

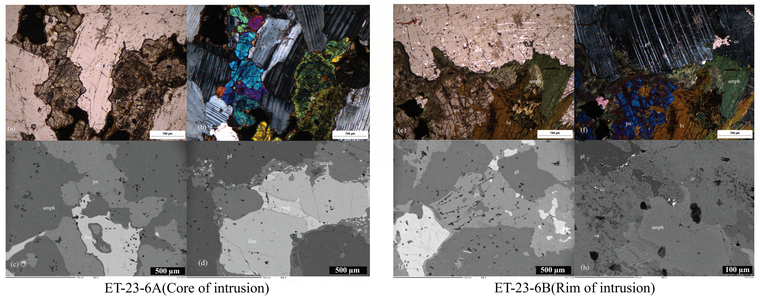


Fig : (a-d) Transmitted light images (PPL, XPL) and BSE images of ET-23-6A, from the inner part of Tudor gabbro. Dominant mineral assemblage includes cpx (Mg# ~ 0.63-0.65) + pl (X_{An} = 0.46 - 0.49) and retrogressed amph and bi. (e-h) Transmitted light images (PPL, XPL) and BSE images of ET-23-6B, from the outer part of Tudor gabbro. Dominant mineral assemblage includes cpx (Mg# ~ 0.54-0.65) + pl (X_{An} = 0.30 - 0.50) + cc and retrogressed amph and bi. Cc appear as inclusions pointing to assimilation during emplacement of the gabbroic body rather than product of retrograde alteration

Stable isotope geochemistry and Transport Function

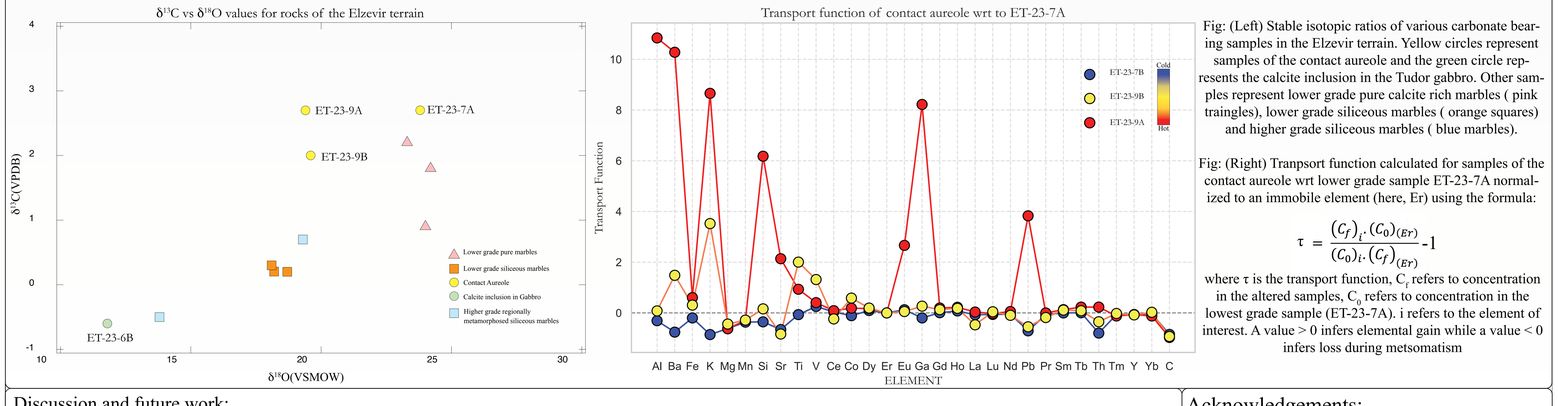


Fig: (Left) Stable isotopic ratios of various carbonate bearing samples in the Elzevir terrain. Yellow circles represent samples of the contact aureole and the green circle represents the calcite inclusion in the Tudor gabbro. Other samples represent lower grade pure calcite rich marbles (pink traingles), lower grade siliceous marbles (orange squares) and higher grade siliceous marbles (blue marbles).

Fig: (Right) Tranpsort function calculated for samples of the contact aureole wrt lower grade sample ET-23-7A normalized to an immobile element (here, Er) using the formula:

$$\tau = \frac{(C_f)_i \cdot (C_0)_{(Er)}}{(C_0)_i \cdot (C_f)_{(Er)}} - 1$$

where τ is the transport function, C_f refers to concentration in the altered samples, C_0 refers to concentration in the lowest grade sample (ET-23-7A). i refers to the element of interest. A value > 0 infers elemental gain while a value < 0 infers loss during metsomatism

Discussion and future work:

- As seen from mineral assemblages, the marbles surrounding the Tudor gabbro were metamorphosed due to the intrusion.
- Petrography and geochemical analyses point towards a large scale mass transfer between the intrusion and the host rock possibly mediated by large scale fluid flow.
- The large variation in istopic signature can be thought to be due to combination of variation of depositional signature, extent of decarbonation and effect of fluids.
- Previous studies (Sengupta and Stewart, AGU, 23) show only ~ 27% decarbonation during regional metamorphism of marbles. Similar temperature in the contact aureole, results in more efficient decarbonation (~90%) and might have a significant impact to orogen scale degassing flux.

Acknowledgements:

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