Pressure-temperature & temporal constraints on regional metamorphism near Big Thompson Canyon, CO (USA)

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Studied area

What?
Paleoproterozoic supracrustal rocks

Where?
Big Thompson Canyon (Front Range, North CO)
Geological map  
(Cole & Braddock, 2009)

Mineral zones from biotite- to migmatite-zone (unique in Front Range).

Surrounded by three shear zones.
Problematic & approach

• **Why and when?** Complex tectonometamorphic history spanning from ~1.8 to 1.4 Ga…
  • Single (main) metamorphic cycle at ~1.7-1.65 Ga (Yavapai) with minor effect from 1.4 Ga event?
  • …or multiple events at 1.7, 1.6 an 1.4 Ga (Yavapai, Mazatzal and “Berthoud” orogenies)?
  • Tectonic origin of the event(s)? (*not discussed here…*)

Preliminary study (this talk):
• Detailed petrographic analysis
• Multi-equilibrium thermobarometry & PT-pseudosections
• Electron microprobe U-Th-Pb dating of monazite & xenotime
Evidence for multiple events?

Monazite ages at both 1.65 Ga & 1.4 Ga

Shah & Bell (2012)

Multi-stage Grt growth (Ca-map, FOV 1 mm). Multiple generations of other index minerals (St, And, Sil, Crd).

Mahan et al. (2013)

Fresh staurolite and St pseudomorph. Resetting of Ar-Ar ages at 1.4 Ga (partial for Hbl, complete for mica)

Shaw et al. (1999)
Geological map
(Cole & Braddock, 2009)
Three zones investigated:
- And/St-zone,
- And → Sil,
- Migmatite.

3) Estes Park
Staurolite grade samples

• Rare fresh staurolite, mostly pseudomorphed.
• Two Grt-bearing metapelite samples: M08-16 (St pseudomorph) and M13-11 (fresh and pseudomorphed St)
• Ms, Bt, Pl, Qtz, Grt, ±St, ±Chl (±And in Al-rich sample)
Staurolite grade samples

Bobcat ridge (M08-16)

- Prograde zoning
- Ca-poor overgrowths
- No late re-equilibration

⭐ M08-16 Multi-equilibrium PT (TWQ): ~0.3 Gpa, 540 °C

⭐ M13-11: slightly higher pressure (~0.43 GPa, 570 °C)
First monazite U-Th-Pb

- First results in St-bearing sample (M13-11) obtained on Cameca SX-100 “Ultrachron” (University of Massachusetts, Amherst)
- Mnz included in St = 1.67 Ga (max. age for 2\textsuperscript{nd} St-growth)

Work by C. Condit and RESESS student D. Rattanasith
Transition And ➔ Sil

- Grt-bearing metapelite, transition And (M09-24) ➔ Sil (M09-22)
- Bt, Ms, Pl, Qtz, Grt, Sil (or And)
- PT results uncertain (Grt resorption), ~0.4 GPa, 550-600 °C?
Transition And → Sil
Migmatite grade sample

- Possible 2-stage melting: 1\textsuperscript{st} melt near Glen Haven (Ms dehydration), 2\textsuperscript{nd} melt near Estes Park (Bt dehydration)?
- Assemblage @ Estes Park: Pl, Kfs, Qtz, Grt, Sil, Crd, ±Bt (± spinel*)

1\textsuperscript{st} evidence of melting (~Glen Haven)

\begin{align*}
    Ms + Pl & \pm H_2O \rightarrow Sil + Kfs + melt \pm Bt
\end{align*}

2\textsuperscript{nd} melting (~Estes Park)

\begin{align*}
    Bt + Sil + Qtz & \rightarrow Grt + Kfs + Crd + melt
\end{align*}

400 μm

* Zn and Cr-rich: \((Fe_{0.64}Zn_{0.26}Mg_{0.10})(Al_{1.90}Cr_{0.03}Fe_{0.07})O_4\)
Homogeneous composition
Inclusion rich

Highest grade migmatite

Multiequilibrium PT (TWQ):
~0.5 Gpa, 670 °C

1.42 Ga
1.7 Ga

Bt+Sil+Qtz ±Pl
Grt+Crd+Kfs+melt

Ca Kα

Mn Kα

Mnz-Xnt Gaussian age distribution

Mnz core (rare)

Pseudosection suggest similar conditions (work in progress...)
Summary PT-work & age

- Multiple events confirmed by Mnz & Xnt.
- All PT-work so far suggests low pressure around 0.3-0.5 GPa, from ~520 to 700°C.

**Low grade samples:**
- Main metamorphism @ 1.70-1.65 Ga.
- 2\textsuperscript{nd} St generation younger than 1.67 Ga
- Minor evidence for 1.4 Ga (Grt resorption).

**Highest grade migmatite:**
- Relic monazite ~1.67 Ga (Yavapai orogeny).
- Most Mnz & Xnt @ 1.45-1.40 Ga
  \(\Rightarrow\) Bt dehydration (2\textsuperscript{nd} melting?).
Future work

- Additional PT-work in metapelite and amphibolite, especially intermediate grade samples (Sil zone to 1st melting).
- Whole rock data for pseudosections (PT) & provenance analysis.
- Link Mnz & Xnt growth with metamorphic reactions.
- Complete dating with in situ zircon U-Th-Pb ages and Nd- and Hf-isotopes (origin of intrusions).
- Detailed structural geology and study of shear zones...

Combination of the above data should help deciphering these tectonometamorphic events in terms of origin and PTt.
Organizers: Paul Carpenter, John Armstrong, John Foumelle, Raynald Gauvin, Dan Kremer, Heather Lowers, Julien Allaz, Kat Crispin, and Nicholas Ritchie

- User group meetings
- Tutorial on electron-probe microanalysis (EPMA)
- Quantitative microanalysis and mapping using WDS and EDS
- Correction algorithms
- FE-EPMA and FE-SEM microanalysis
- Quality control for microanalysis
- Standard reference materials
- Practical EPMA for the novice
- Problem solving and experts discussion
- Laboratory demonstrations of microanalysis