DETRITAL ZIRCON AGES FOR THE CAMBRIAN MONKTON AND DANBY FORMATIONS, CHAMPLAIN VALLEY, VERMONT

MAGUIRE, Henry, MEHRTENS, Charlotte, CHIARENZELLI, Jeffrey, WEBB, Laura. Department of Geology, University of Vermont, Burlington, Vermont 05401, USA

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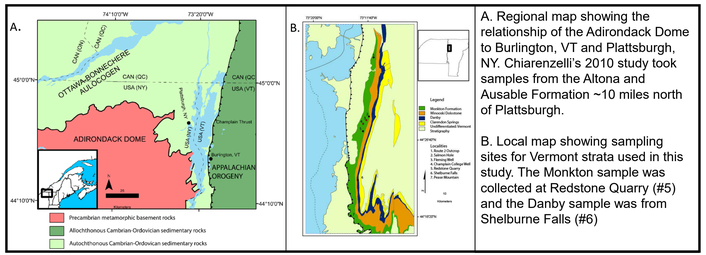
Abstract

The Monkton and Danby Formations of the Cambrian shelf stratigraphic sequence in Western Vermont (VT) are comprised of arkose to sub-arkose sandstones and dolomite. Biostratigraphic relationships of the Monkton Formation to the Potsdam Group in New York (NY) by previous workers suggest they would be at least partially correlative. Detrital zircon studies have been completed on the Potsdam Group by others to identify to help constrain the age and provenance of this stratigraphy. This study was done to complete the first detrital zircon study of Cambrian stratigraphy in the Champlain Valley of Vermont (VT) to better constrain the provenance of this stratigraphy and to better correlate it with the Cambrian strata of NY.

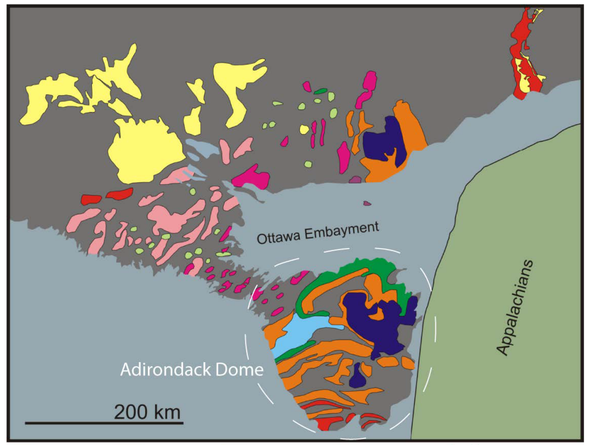
Samples were collected at Redstone Quarry in Burlington, VT and Shelburne Falls in Shelburne, VT for the Monkton and Danby, respectfully. Samples were analyzed by laser ablation–inductively coupled plasma mass spectrometry (LA-ICPMS) at University of Arizona Laserchron Center. Backscattered Electron (BSE) imaging for both samples was done to identify zircons for analysis within the mounts. LA-ICPMS analysis of 279 spots for the Monkton and 298 for the Danby was completed. Cathodoluminescence (CL) imaging of the two mounts was completed at Middlebury College to identify the locations of the spots within the zircon and the two populations morphologies.

Zircon population distribution shows two dominate age peaks between 1.05-1.09 Ga and 1.15-1.18 Ga for the Monkton and Danby, suggesting either a continuity of provenance source through the Cambrian or the cycling of the Monkton's sand. The 1.05-1.09 Ga age range corresponds to the Ottawan Orogeny while the 1.15-1.18 Ga range to the Shawinigan Orogeny and AMCG plutonism. Dominant age peaks in the VT samples between 1.15-1.18 Ga are similar to the 1.16 Ga age peak seen in the Altona and Ausable Formations of *the* Potsdam Group of NY. A local (VT) Grenville source for the zircons is rejected based on paleogeographic reconstruction of the lapetian shelf margin. The complex age distributions described by others in the younger members of the Potsdam Group are not statistically significant in the Vermont stratigraphy.



A. Regional map showing the relationship of the Adirondack Dome to Burlington, VT and Plattsburgh, NY. Chiarenzelli's 2010 study took samples from the Altona and Ausable Formation ~10 miles north of Plattsburgh.

B. Local map showing sampling sites for Vermont strata used in this study. The Monkton sample was collected at Redstone Quarry (#5) and the Danby sample was from Shelburne Falls (#6)



-Figure from Lowe (2016) identifying potential source rocks of Grenville age in Northern NY, Ontario and Quebec. Paleocurrent data from the Vermont stratigraphy preclude Grenville aged rocks in Vermont as a source for the Monkton and Danby Formation sand. Accessory mineral assemblages in the Monkton (Goldberg and Mehrtens, 1998) suggest that the sediment was predominantly sourced from the Adirondack Dome (encircled in white, above).

Methods

-Samples were collected for the Monkton Formation at Redstone Quarry and for the Danby Formation at Shelburne Falls, VT

-The samples were crushed and pulverized using a jaw crusher and plate grinder

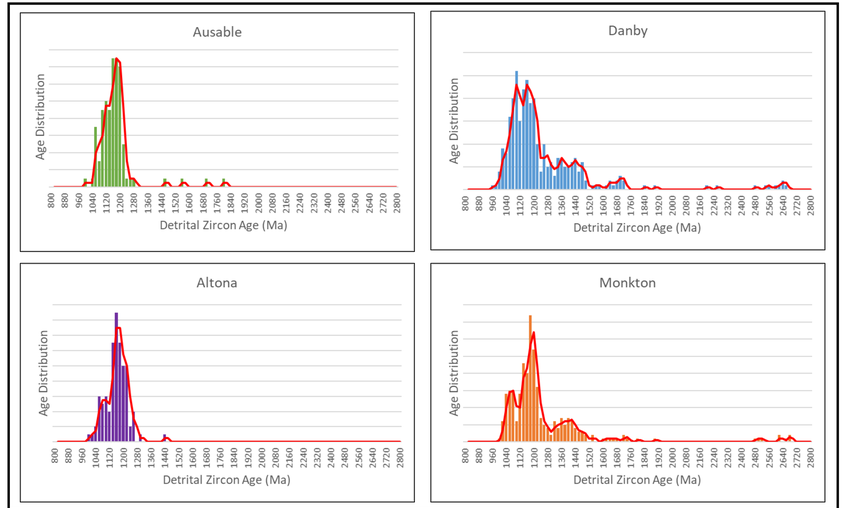
-Gravity separation was completed using a Gemini table

- Magnetic separation was completing first by using a hand magnet then by Frantz Isodynamic Magnetic Separator

-Samples were sent to the University of Arizona Laserchron Center for heavy liquid separation and mounting before being analyzed via Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-IC-PMS)

-LA-IC-PMS analysis to generated detrital zircon U-Th-Pb age data was completed on 279 spots for the Monkton and 298 for the Danby

- Cathodoluminescence (CL) imaging of zircon populations to determine sampling sites within zircons was completed at Middlebury College



Zircon age distributions of the Monkton and Danby Formations from this study and the Altona and Ausable Formations (from Chiarenzelli et al. (2010). The Y axis represents increasing probability in zircon age distributions. Major modes >20% were identified using Gehrels (2010) AGE PICK Excel add-on calculating peak ages for the detrital zircon populations. Zircon population for the Monkton and Danby share two major peak between 1.05-1.09 Ga and ~1.16 Ga. The Altona and Potsdam have a single peak age ~1.16 Ga.

Background

-The Cambrian clastic and carbonate stratigraphy of western Vermont was deposited on a thermally subsiding tectonically stable shelf following the rifting events of the lapetus margin (Rodgers, 1968).

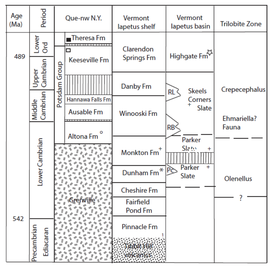
-The age of the Monkton is *Olenellus* zone (late Lower Cambrian) (Palmer and James, 1980) while that of the Danby is less well constrained but is thought to be Upper Cambrian in age (Cady,1945).

-The Altona Formation of the Potsdam Group in northern NY also contains an *Olenellid*-zone assemblage (Landing, et al. 2009), making the Altona and Monkton at least partially coeval.

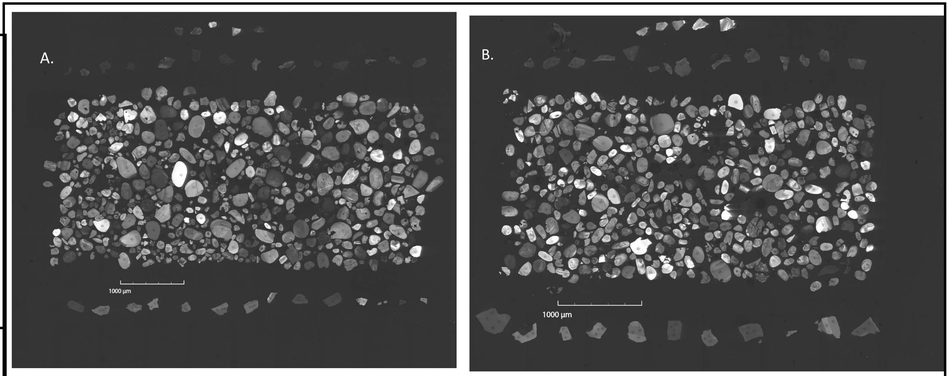
-Geochronologic studies of zircons retrieved from sandstones of the Altona Formation and the overlying Ausable Formation (Potsdam Group) by Chiarenzelli et al. (2010) yielded a dominate unimodal age distribution between 1300-1000 Ma for the zircons, which indicates a Grenville-aged source for the sand.

-Detrital studies of the Altona Formation and younger Potsdam strata in northern New York and adjacent Quebec and Ontario by Lowe (2016) and Montario and Garver (2009) show more age complex population age distributions for zircons, with multiple major and minor modes. These studies sampled sandstones retrieved from more northern and western locations when compared to Chiarenzelli's study of the Altona.

-The transition from a simple age distribution in older Potsdam Group sandstones to a more complex distribution in younger Potsdam strata was interpreted by Lowe (2016) to reflect a change in provenance.



-Stratigraphic relationship between the N.Y and Vermont sedimentary sequences. The Olenellid-zone assemblage overlap shows the Altona and Monkton at least partially coeval. Brink, 2015



- Cathodoluminescence (CL) imaging of zircon populations for the Monkton (A.) and Danby (B.) samples. These images were used to help determine the locations of (LA-IC-PMS) analysis on rims or cores. The majority of the identifiable samples were determined to be analyzed in the core of the zircon.

Conclusions

-The Monkton and Danby Formation share nearly identical age modes, two possible provenance interpretations have been identified for the Vermont stratigraphy: (1) The Danby is comprised of re-worked sands from the Monkton or (2) provenance sources have remained constant through deposition of the Cambrian strata in Vermont

-The Danby and the Monkton Formations both have minor peaks of pre-Grenville age, however the majority of their grains ages are similar to the Altona and Ausable Formation's 1300-1000 Ma Grenville aged source

- Provenance interpretations for the zircons recovered from the Vermont stratigraphy suggest an Adirondack Grenville aged source, an interpretation that agrees with that for the Altona and Ausable Formations in northeastern New York (Brink,2014).

References

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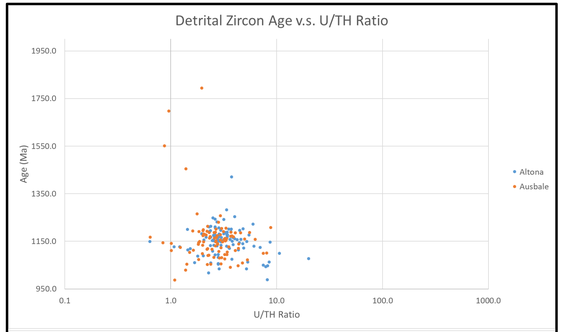
Additional Material



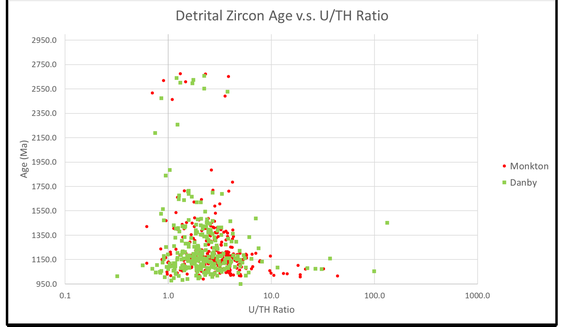


Figure. U–Pb isotopic data from zircon collected using laser-ablation ICPMS, plots of U/Th versus Age. The y axis represents the age of the detrital zircon in millions of years and the x axis shows the U/Th ratio. These plots help us to identify the igneous petrogenesis. Higher U/TH values, greater than 10, are usually associated with metamorphic zircon rather than igneous (Williams, 2001 [Australian Journal of Earth Sciences, v. 48, p. 557-580], Rubatto et al., 2001 [Contributions to Mineralogy and Petrology, v. 140, p. 458-468], Rubatto, 2002 [Chemical Geology, v. 184, p. 123-138]). It can be seen in the graph that the Monkton and Danby both have samples that would fall into this range of metamorphic zircon U/TH values. The majority of these metamorphic zircon ages span the range of 1-1.15 Ma associated with the Ottawan and Shawinigan Orogenies. The Altona also has two samples falling into this U/TH metamorphic range and 1-1.15 Ma age.

	Similarity			
Altona	**Altona**			
Ausable	0.936	**Ausable**		
Monkton	0.874	0.885	**Monkton**	
Danby	0.857	0.868	0.936	**Danby**

Results from Arizona Laserchron Center's OVERLAP-SIMILARITY PROGRAM 2010 from using detrital zircon age data of the Monkton, Danby, Altona and Ausable. Like an R value the closer the value is to 1 the more similar the populations are. All populations show a high similarity value with the other member of their respective stratigraphy, however it should be noted that similarity values were also high when comparing the Vermont and New York stratigraphy.

Altona DZ AGES					
MIN AGE	MAX AGE	# GRAINS	PEAK AGE	# GRAINS	%
910	1394	95	1157	79.00658	83.16482
Ausable DZ AGES					
MIN AGE	MAX AGE	# GRAINS	PEAK AGE	# GRAINS	%
914	1331	92	1168	77.00177	83.69757
Montkon DZ AGES					
MIN AGE	MAX AGE	# GRAINS	PEAK AGE	# GRAINS	%
952	1759	269	1048	59.00498	21.93494
2477	2495	1	1172	122.0019	45.35388
2623	2679	3	1393	29.00065	10.78091
			1632	4.008954	1.490318
			1714	3.017966	1.12192
			2489	3.006659	1.117717
			2658	4.003096	1.48814
Danby DZ AGES					
MIN AGE	MAX AGE	# GRAINS	PEAK AGE	# GRAINS	%
927	1738	286	1090	102.0032	35.66544
2522	2526	0	1151	103.003	36.01505
2557	2582	0	1351	31.00193	10.83984
2592	2656	4	1424	23.00174	8.042567
			1686	8.004145	2.798652
			2622	5.009132	1.751445

Results from Gehrels (2010a) AGE PICK Excel add-on calculating peak ages for the detrital zircon populations. Zircon population for the Monkton and Danby shows major peak age modes (>20%) of 1.05-1.09 Ga. The Altona and Potsdam have a single major peak age mode ~1.16 Ga.

Notes

-Analytical methods for Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-IC-PMS) was done according to procedures outlined in Gehrels et al. (2010)

-Analysis comparing grain size and age was completed, however no relationships between the two variables determined.

-U-Th-Pb raw data can be found in the appendix of Maguire (2018).

References for Additional Material

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