Origins of the Moretown Formation, Vermont: a detrital zircon study

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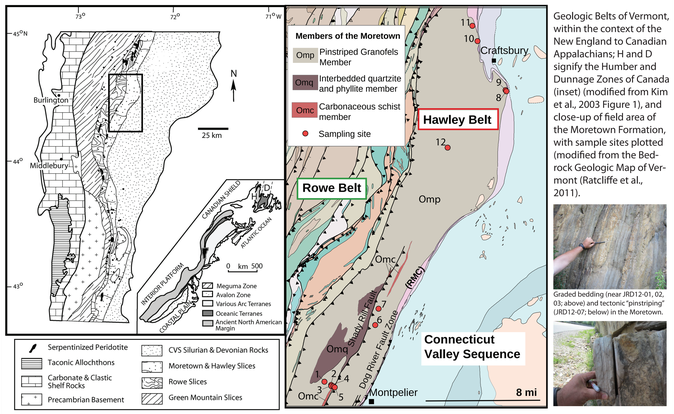
Abstract

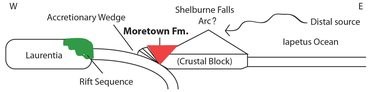
The tectonic history of the Vermont Appalachians can be refined with the aid of geochronological data. The Moretown Formation of Vermont has been interpreted as sediments deposited in the fore-arc basin of the Cambrian-Ordovician Shelburne Falls arc. This study uses detrital zircons to provide new information on the provenance of the Moretown sediments. Zircons have been separated from ten samples taken from the Moretown Formation of northern Vermont. U-Pb ages were determined on 75 to 100 zircons per sample using the LA-ICP-MS at Rensselaer Polytechnic Institute. Age distributions represent a signature of the range of ages of zircons from sources that contributed to the sediment. The age signatures of the Moretown, and some rift-related sediments of Vermont, are compared to age signatures of potential source regions to determine the sedimentary provenance. The Late Proterozoic, rift-related Hazens Notch Formation shows, as expected, a dominant Laurentian (Grenville) signature. Ages from Moretown samples have a strong peak at 600 Ma, suggesting a peri-Gondwanan source component, likely mixed with a Laurentian Grenville component. This result indicates more provenance sources than the exclusively Laurentian signature postulated by previous work on the Moretown in southern Vermont and northern Massachusetts. Such a distinction could indicate that the Moretown is not the same along strike and that there is variation in local sources of zircons, or that tectonic models that explain the origin of the Moretown sediments need to be revised to incorporate the peri-Gondwanan signature.

Introduction



Geologic Belts of Vermont, within the context of the New England to Canadian Appalachians; H and D signify the Humber and Dunnage Zones of Canada (inset) (modified from Kim et al., 2003 Figure 1), and close-up of field area of the Moretown Formation, with sample sites plotted (modified from the Bedrock Geologic Map of Vermont (Ratcliffe et al., 2011).

Graded bedding (near JRD12-01, 02, 03; above) and tectonic "pinstriping" (JRD12-07; below) in the Moretown.

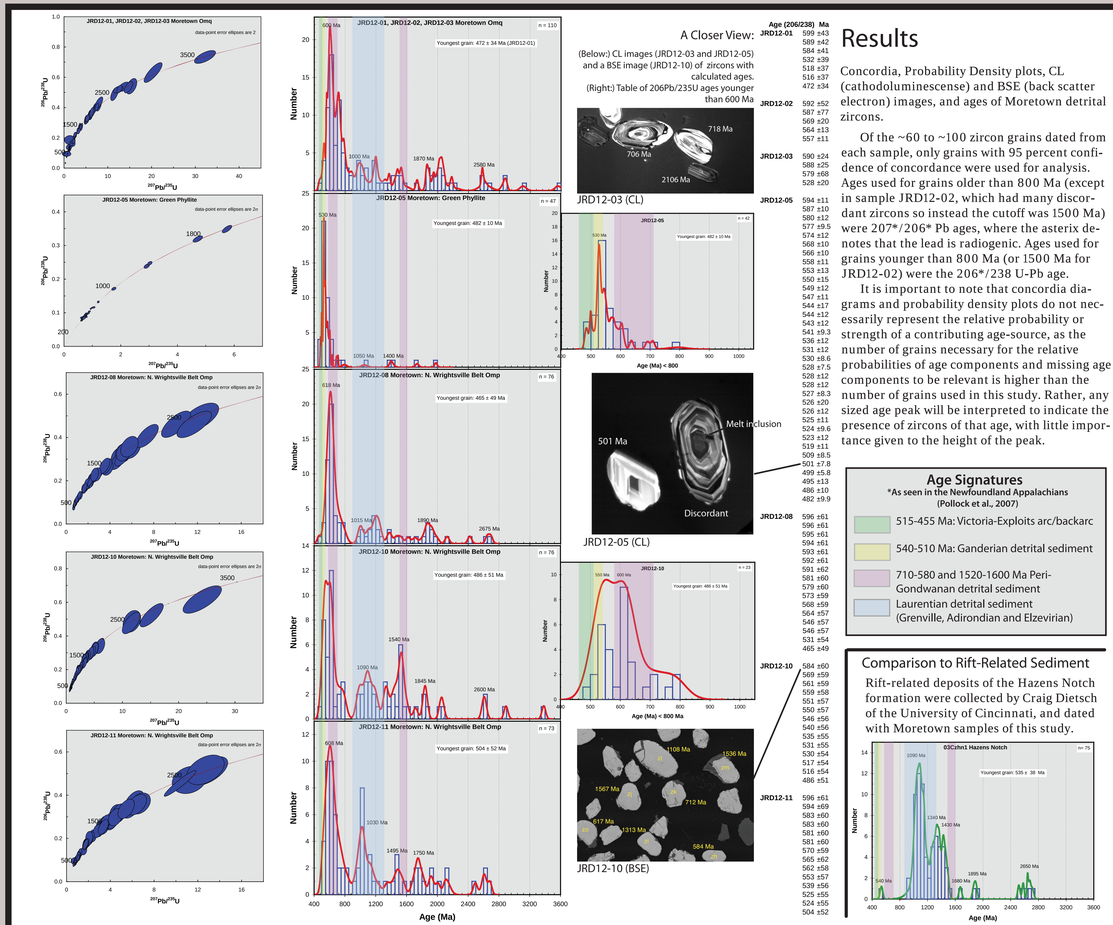


Hypothesized sources of zircons contributing to the Moretown Formation: The tectonic history of the Laurentian Margin and its offshore island arcs provide ages of zircons that represent potential sources of detritus, and thus age components of Moretown samples. Possible west-derived sources are as follows, from oldest to youngest: cratonic material from the North American interior with a range of ages, depending upon the source region within the continent; Laurentian basement, of ~1000 Ma Grenville age; Neoproterozoic ~750-550 Ma rift-sequence material from the Laurentian margin; and potentially material eroded from the accretionary wedge, of a range of ages. Possible east-derived sources are, from oldest to youngest: a crustal block component of the Shelburne Falls or Bronson Hill island arcs, possibly Laurentian, Avalonian or peri-Gondwanan; igneous material directly from the island arc, either Shelburne Falls age (~500-460 Ma) or possibly Bronson Hill age (~470-435 Ma); or some distal eastern terrane.

Goals and Objectives

Although the Moretown Formation has been described as forearc sediment of the Ordovician Shelburne Falls Arc, initial detrital zircon studies did not indicate an age component that eroded from the adjacent volcanic material (Aleinikoff and Karabinos, 1990; Karabinos and Gromet, 1993). More detrital ages would confirm or reject this missing signature. Furthermore, the exact source of sediment should be determined. The age signature of the Moretown detrital zircons must be compared to ages of source rocks as well as age signatures of possible source regions and other detrital rocks in order to determine the source.

The source of the Moretown, along with a maximum depositional age potentially constrained by the youngest detrital zircon, can provide further information about the series of collisional events that formend the northern Appalachian Mountains. Furthermore, the along-strike variability of Cambrian-Ordovician Rocks in the Appalachians, especially the transitional northern Vermont portion between Quebec and southern New England, may be explained through a deeper understanding of rocks in the Moretown Formation.



A Closer View:

(Below:) CL images (JRD12-03 and JRD12-05) and a BSE image (JRD12-10) of zircons with calculated ages.

(Right:) Table of 206Pb/235U ages younger than 600 Ma

JRD12-03 (CL)

JRD12-05 (CL)

JRD12-10 (BSE)

	Age (206/238) Ma
JRD12-01	599 ±43
	589 ±42
	584 ±41
	532 ±39
	518 ±37
	516 ±37
	472 ±34
JRD12-02	592 ±52
	587 ±77
	569 ±20
	564 ±13
	557 ±11
JRD12-03	590 ±24
	588 ±25
	579 ±68
	528 ±20
JRD12-05	594 ±11
	587 ±10
	580 ±12
	577 ±9.5
	574 ±12
	568 ±10
	566 ±10
	558 ±11
	553 ±13
	550 ±15
	549 ±12
	547 ±11
	544 ±17
	544 ±12
	543 ±12
	541 ±9.3
	536 ±12
	531 ±12
	530 ±8.6
	528 ±7.5
	528 ±12
	528 ±12
	527 ±8.3
	526 ±20
	526 ±12
	525 ±11
	524 ±9.6
	523 ±12
	519 ±11
	509 ±8.5
	501 ±7.8
	499 ±5.8
	495 ±13
	486 ±10
	482 ±9.9
JRD12-08	596 ±61
	596 ±61
	595 ±61
	594 ±61
	593 ±61
	592 ±61
	591 ±62
	581 ±60
	579 ±60
	573 ±59
	568 ±59
	564 ±57
	546 ±57
	546 ±57
	531 ±54
	465 ±49
JRD12-10	584 ±60
	569 ±59
	561 ±59
	559 ±58
	551 ±57
	550 ±57
	546 ±56
	540 ±56
	535 ±55
	530 ±54
	517 ±54
	516 ±54
	486 ±51
JRD12-11	596 ±61
	594 ±69
	583 ±60
	583 ±60
	581 ±60
	581 ±60
	570 ±59
	565 ±62
	562 ±58
	553 ±57
	539 ±56
	525 ±55
	524 ±55
	504 ±52

Results

Concordia, Probability Density plots, CL (cathodoluminescense) and BSE (back scatter electron) images, and ages of Moretown detrital zircons.

Of the ~60 to ~100 zircon grains dated from each sample, only grains with 95 percent confidence of concordance were used for analysis. Ages used for grains older than 800 Ma (except in sample JRD12-02, which had many discordant zircons so instead the cutoff was 1500 Ma) were 207*/206* Pb ages, where the asterix denotes that the lead is radiogenic. Ages used for grains younger than 800 Ma (or 1500 Ma for JRD12-02) were the 206*/238 U-Pb age.

It is important to note that concordia diagrams and probability density plots do not necessarily represent the relative probability or strength of a contributing age-source, as the number of grains necessary for the relative probabilities of age components and missing age components to be relevant is higher than the number of grains used in this study. Rather, any sized age peak will be interpreted to indicate the presence of zircons of that age, with little importance given to the height of the peak.

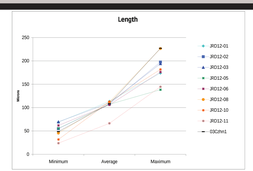
Age Signatures

*As seen in the Newfoundland Appalachians (Pollock et al., 2007)

- 515-455 Ma: Victoria-Exploits arc/backarc
- 540-510 Ma: Ganderian detrital sediment
- 710-580 and 1520-1600 Ma Peri-Gondwanan detrital sediment
- Laurentian detrital sediment (Grenville, Adirondian and Elzevirian)

Comparison to Rift-Related Sediment

Rift-related deposits of the Hazens Notch formation were collected by Craig Dietsch of the University of Cincinnati, and dated with Moretown samples of this study.

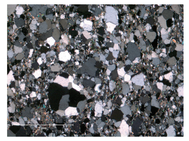


Zircon Grain Size and Morphology

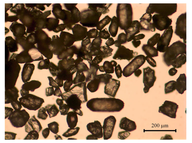
The length and width of zircons from each sample were measured under transmitted and reflected light. The fewest large zircons were found in samples JRD12-05, the green phyllite, and sample JRD12-11, pinstriped greywacke, which also had the smallest zircons. Sample JRD12-05 also had more rounded zircons, with generally low length to width ratios.

The ages of zircons in sample JRD12-05 have the highest proportion of ages less than 600 Ma, with a strong peak at 530 Ma. This finer-grained sample is formed by less mature sediment than most other Moretown samples, suggesting a period of rapid uplift.

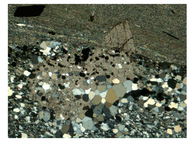
JRD12-02 thin section (cross polarized)



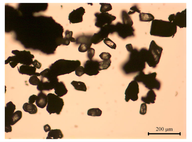
JRD12-02 zircons (transmitted light)



JRD12-05 thin section (cross polarized)



JRD12-05 zircons (transmitted light)

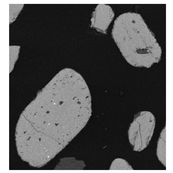


Discussion

Removing discordant grains from the final histograms for each sample reduced the number of viable measurements, affecting the reliability of the data in reporting all potential zircon populations. For example, it is 95% certain that no fraction f < 0.07 of the total population was missed if 60 grains were dated, or that no fraction f < 0.05 of the total population was missed if 95 grains were dated (Vermeesch, 2004).

Certain source of sediment may not be rich in zircon, such as mafic or carbonate rocks, or may have zircons that were too small to be collected and analyzed.

During analysis, multiple zones of a single zircon may be sampled, and thus the age would represent an average of closure temperature events in the crystal system. That is why it is important to take the ages as signatures of sources.

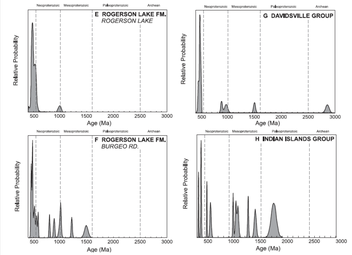


Possible reasons for discordance:

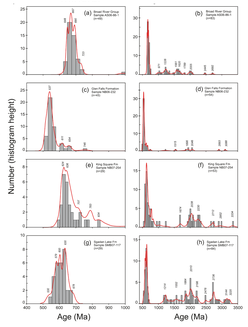
- Metamict grains
- Lead loss (at ~800°C or greater)
- Inclusions:
  - Melt
  - Mineral

Conclusion

- The Moretown signature is mainly peri-Gondwanan, possibly with a mixture of some Laurentian sediment.
- Ages close to ~500 – 460 Ma, of Shelburne Falls Arc age, are present, but may also be present in other peri-Gondwanan detrital sediment (particularly Ganderian).
- The depositional basin of the Moretown was near the suture zone of Laurentia and peri-Gondwana, possibly deposited during the closure of the Iapetus Ocean.



Left: Moretown detrital sediment is similar to peri-Gondwanan detrital sediment in Newfoundland (Pollock et al., 2007: modified from Fig. 6).



Above: detrital sediment is similar to peri-Gondwanan (Avalonian) detrital sediment in New Brunswick and Cape Breton Island (from Barr et al. 2012, Fig. 3).

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