# DETRITAL ZIRCON GEOCHRONOLOGY ACROSS THE CHOPAWAMSIC FAULT, WESTERN PIEDMONT OF VIRGINIA, AND ITS BEARING ON EARLY PALEOZOIC TECTONIC DEVELOPMENT IN THE SOUTHERN APPALACHIANS

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## Abstract

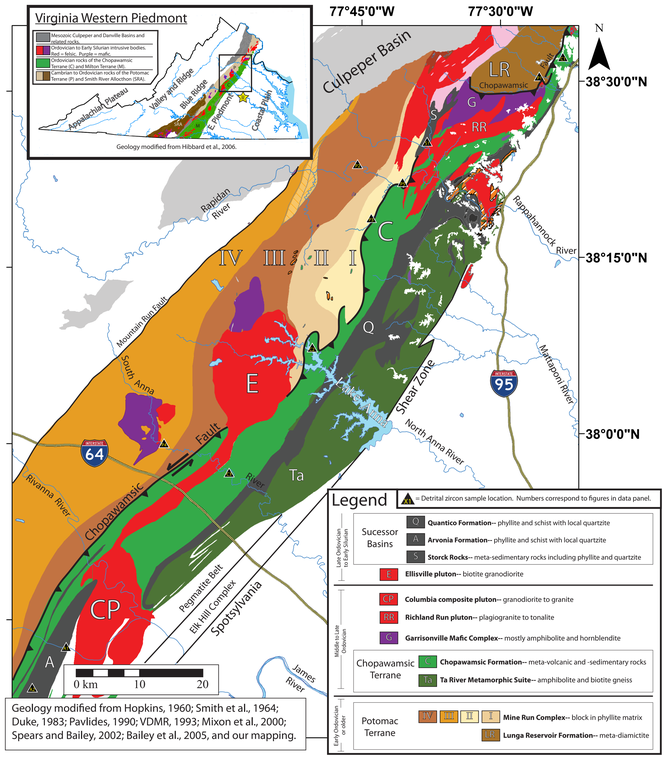
The Late Ordovician-Early Silurian Chopawamsic fault bisects early Paleozoic rocks of the western Piedmont of Virginia into a probable Laurentian accretionary complex, the Potomac terrane (Pt), to the west and an lapetan arc of unknown crustal affinity, the Chopawamsic terrane (Ct), to the east. We have analyzed more than 1000 individual detrital zircon grains from 11 samples of metasedimentary rocks from these terranes as well as two previously mapped successor basins using laser ablation ICP-MS, U-Pb geochronology. Our results reinforce the importance of the Chopawamsic fault and lend insight into the tectonic landscape prior to and after the accretion of the Ct to Laurentia.

Samples from the pre-Ordovician Pt display various peak modes from 1.00 – 1.25 Ga; almost all analyses in these samples span from c. 500 Ma to c. 1.6 Ga. These results support a Laurentian provenance for the Pt.

Metasedimentary samples from the Middle to Late Ordovician Ct are dominated by detrital zircons between 450 – 470 Ma; these ages likely represent recycled debris from adjacent volcanic rocks in the Ct. However, one sample from the Ct displays a sub-population of Proterozoic zircons ranging from 600 Ma to 1.2 Ga; this set provides the only indication of any basement input to these samples. Zircons from 600 – 800 Ma may reflect the influence of a peri-Gondwanan crustal basement to the Ct.

Samples from the Arvonia successor basin, which unconformably overlies the Ct, display dissimilar detrital inputs. A sample from the Bremo quartzite exhibits peak modes at c. 460 Ma and 1.01 Ga, while a sample from the Buffards Formation consists mostly of Middle Silurian, c. 425 Ma, detrital zircons. The age disparities between these two samples may reflect a transition in sediment provenance from underlying older terranes (potential input from both Ct and Pt) to the introduction of contemporaneous magmatism to the Arvonia depositional system. A sample from a smaller unit of metasedimentary rocks (Storck area) previously interpreted to be related to the Arvonia basin displays a wide distribution of detrital ages ranging from 500 Ma to 2.25 Ga, with principal modes at c. 525 Ma, 605 Ma, 945 Ma and 1.14 Ga; it is uncertain how or if this sample may be related to the Arvonia basin, but the distribution of detrital ages is consistent with input from a Gondwanan source.

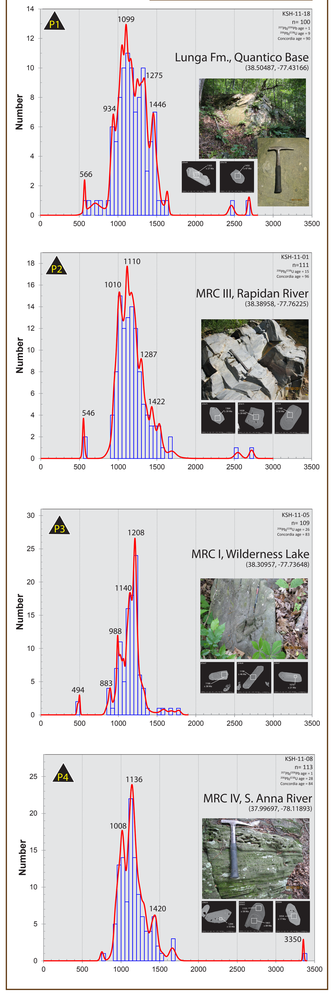
## Study Area



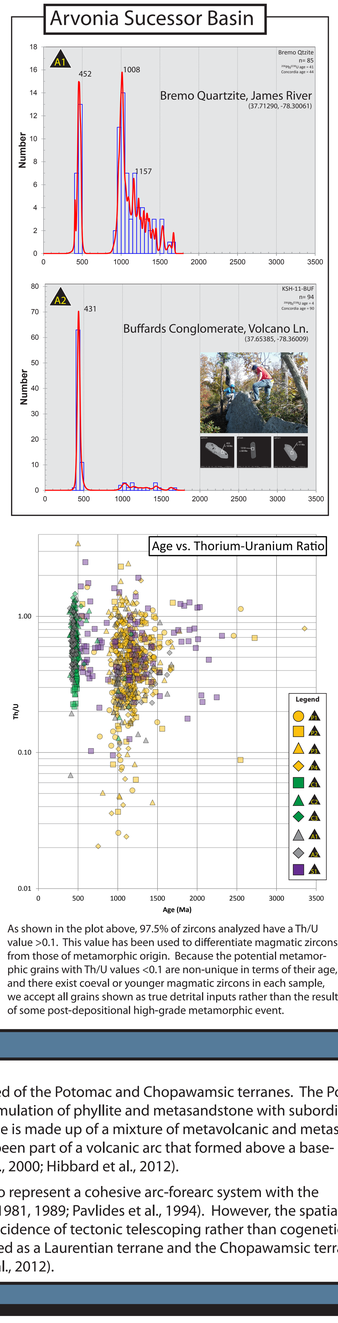

Geology modified from Hopkins, 1960; Smith et al., 1964; Duke, 1983; Pavlides, 1990; VDMR, 1993; Mixon et al., 2000; Spears and Bailey, 2002; Bailey et al., 2005, and our mapping.

## Data

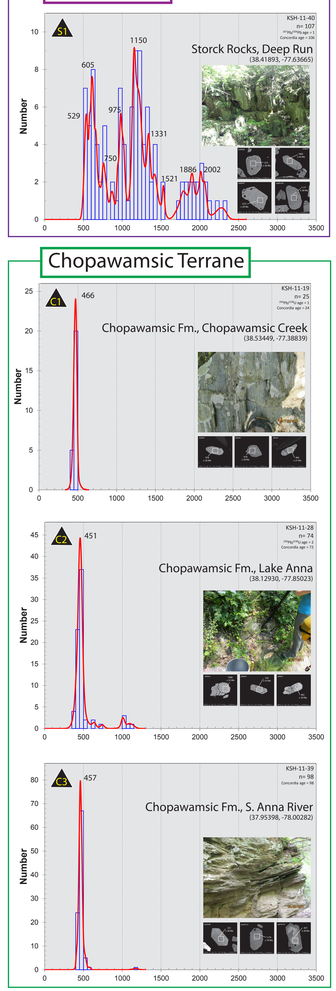
### Potomac Terrane




### Arvonia Sucessor Basin




### Storck Rocks




### Chopawamsic Terrane

### Age vs. Thorium-Uranium Ratio




As shown in the plot above, 97.5% of zircons analyzed have a Th/U value >0.1. This value has been used to differentiate magmatic zircons from those of metamorphic origin. Because the potential metamorphic grains with Th/U values <0.1 are non-unique in terms of their age, and there exist coeval or younger magmatic zircons in each sample, we accept all grains shown as true detrital inputs rather than the result of some post-depositional high-grade metamorphic event.

## Regional Overview

The western Piedmont of Virginia is chiefly comprised of the Potomac and Chopawamsic terranes. The Potomac terrane consists of a mainly metaclastic accumulation of phyllite and metasandstone with subordinate mafic to felsic blocks. The Chopawamsic terrane is made up of a mixture of metavolcanic and metasedimentary rocks that have been interpreted to have been part of a volcanic arc that formed above a basement of continental crust (Pavlides, 1981; Coler et al., 2000; Hibbard et al., 2012).

These terranes have traditionally been interpreted to represent a cohesive arc-forearc system with the Chopawamsic fault between the two (e.g. Pavlides, 1981, 1989; Pavlides et al., 1994). However, the spatial proximity of the two terranes may actually be a coincidence of tectonic telescoping rather than cogenetic formation, as the Potomac terrane has been identified as a Laurentian terrane and the Chopawamsic terrane could represent a peri-Gondwanan arc (Hibbard et al., 2012).

## Methods

After collection, samples were sealed until each was processed. Sample crushing, disc-milling, Wilfley table separation, magnetic separation, and methylene-iodide separation were carried out at the Department of Geological Sciences at the Univ. of North Carolina at Chapel Hill. Heavy mineral fractions were transported to the MicroAnalysis Facility at Memorial Univ. in St. John's, Newfoundland where they were mounted in epoxy and polished; zircons were subsequently identified and imaged with a MLA-SEM and then analyzed using Laser-Ablation, Inductively Coupled Plasma Mass Spectrometry. All analyses were performed with a 10 μm beam that scanned over a 40x40 μm area on each grain. Laboratory standards--Plešovice standard, 337.13 ± 0.37 Ma (Sláma et al., 2008); 91500 standard, 1065 Ma (Wiedenbeck et al., 1995)--were analyzed frequently as our grains of unknown age were analyzed. All ages and error ranges are reported at the 2σ confidence level. In most cases, the ages reported are concordia ages, however, if the concordia age for any given grain younger than 1.5 Ga is <50% probable, the $^{206}Pb/^{238}U$ age is reported, but only if it is between 85-110% concordant with the $^{207}Pb/^{206}Pb$ age. For zircons older than 1.5 Ga, when concordia ages were <50% probable, the $^{207}Pb/^{206}Pb$ age was reported because sufficient $^{207}Pb$ is present for an accurate age determination. Histograms and cumulative probability plots were prepared with the Isoplot software package (Ludwig, 2012).

## Discussion

**Potomac Terrane--** These samples are dominated by c. 1.0 - 1.2 Ga detrital zircons. This range in ages is consistent with the standing interpretation that the Potomac terrane is derived from Laurentian crust created in the Grenville orogeny. The lack of any Ordovician input indicates that the metaclastic system recorded in the Potomac terrane probably wasn't coeval with the Chopawamsic arc. The presence of Ediacaran to Cambrian detrital grains in some samples may represent the depositional age of the Potomac metaclastics.

**Chopawamsic Terrane--** Detrital zircons within the Chopawamsic Formation are strongly unimodal with peak values at 466, 457, and 451 Ma. These ages likely record syn-depositional recycling of Chopawamsic volcanic rocks, which have been dated elsewhere at 453 Ma (Horton et al., 2010) and 471 Ma (Coler et al., 2000). The geographic distribution of specific detrital zircon ages within the Chopawamsic Formation indicate long-lived volcanic activity associated with the Chopwamsic arc, rather than potential distinct phases of volcanism. It seems that the age of volcanism recorded in the Chopawamsic Formation is a reflection of stratigraphic, rather than geographic, position within the arc. Although only one sample shows significant inherited component, it is important because it reaffirms the interpretation that there is some Mesoproterozoic basement to the Chopawamsic arc (Pavlides, 1981; Coler et al., 2000).

**Storck Rocks--** This sample shows the most variability amongst the dataset. The peak mode at 529 Ma could suggest Gondwanan input for these rocks. This interpretation is reinforced by the presence of zircons ranging from 1520-1550 Ma--a crystallization age that is absent in the Laurentian realm. The other ages represented are mostly ambiguous in terms of cratonic affinity. It seems that this sample has no relation to either Potomac or Chopawamsic terranes or the Arvonia successor basin and may represent a small fragment of metasedimentary rocks that was derived from a peri-Gondwanan terrane or source area that is no longer exposed.

**Arvonia Successor Basin--** The data from two samples of the Arvonia basin are heterogeneous. The Bremo Quartzite sample shows nearly equal amounts of input from Late Ordovician as well as late Mesoproterozoic sources. Due to the stratigraphic and geologic position of the Arvnoia basin, we interpret these ages to represent recycling from BOTH Chopawamsic and Potomac terranes. The Buffards Formation sample includes mostly Early Silurian zircons with a muted Mesoproterozoic population. The prevalence of a younger set of zircons in the Buffards sample could be indicative of a higher stratigraphic position in the Arvonia basin.

**Tectonic Implications--** Clearly, metasedimentary rocks in the Chopawamsic and Potomac terranes were tapping different sources at the time of their respective depositions. While the data do not unequivocally identify a source craton for the Chopawamsic arc, they do signify that some type of Mesoproterozoic basement existed with the arc. Furthermore, these results reinforce the importance of the Chopawamsic fault as a major boundary in the western Piedmont of Virginia. The lack of Ordovician detritus, derived from the Chopawamsic terrane, in the Potomac terrane challenges the idea that the Chopawamsic and Potomac terranes formed as part of a single convergent margin system. Data from the Arvonia sucessor basin may indicate that it received detrital input from both the Chopawamsic and Potomac terranes, which means it would have been deposited only after the accretion of the Chopawamsic terrane to Laurentia.

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