**Appendix 2**

**Results from individual detrital zircon samples**

When possible, some grains were targeted for multiple analyses. This tactic was used to detect any possible age differences between rim and core domains of selected grains. Only two grains yielded statistically different ages between rim and core areas. One of these grains was in sample KSH-11-05 and had a core age of 1336 ± 36 Ma with a rim age of 1226 ± 68 Ma (analyses jl24b66 and jl24b68 in Table 2.1). The other grain was in sample KSH-11-08 and had a core age of 1663 ± 89 Ma with a rim age of 1155 ± 58 Ma (analyses jl25b32 and jl25b35 in Table 2.1; see also Fig. 3C insert). In this case, each age was treated as a separate analysis and was included in the histogram plot for its respective sample. When a rim and core yielded the same age, the more precise analysis was chosen to be included in the histogram plot for the sample. Morphological characteristics and internal zoning patterns (where present) can be seen in SEM images of analyzed grains presented in the North Carolina State University dissertation by Hughes (2014).

**Potomac Terrane**

***Sample KSH-11-01, Mine Run Complex Unit III***

Sample KSH-11-01 (38.38958N, 77.76225W; Fig. 3A) is from Unit III of the Mine Run Complex (Pavlides 1989). This quartzite was taken from an outcrop on the Rapidan River where graded bedding can be seen and, along with a parallel foliation, is openly folded (~90° interlimb angle). The rock contains mostly fine- to medium-grained quartz grains along with fine-grained muscovite that defines the foliation; accessory minerals include biotite, magnetite, and zircon.

Of the 111 acceptable analyses performed for this sample, 96 are reported as concordia age and 15 are reported as 206Pb/238U age (Table 2.1). Most zircon grains are Mesoproterozoic (Fig. 4A); peak modes occur as two pulses in the Stenian at 1.01 Ga and 1.11 Ga. The two oldest zircon grains crystallized in the Neoarchean at ca. 2.55 Ga and ca. 2.72 Ga. Twelve of the 14 zircon grains younger than the Mesoproterozoic are all 900+ Ma; however, most of these have 2σ errors that overlap with the Mesoproterozoic. The maximum age of deposition for this sample is constrained by the two youngest zircon grains which have concordia ages (2σ) of 551 ± 19 Ma and 554 ± 34 Ma.

***Sample KSH-11-05, Mine Run Complex Unit I***

Sample KSH-11-05 (38.30957N, 77.73648W; Fig. 3B) is from Unit I of the Mine Run Complex (Pavlides 1989). It was taken from a unit reference outcrop (outcrop P-77-34 in Pavlides 1989) along Wilderness Run just downstream of the Wilderness Run Lake dam. It is a poorly sorted metagreywacke composed of sub-angular to sub-rounded polycrystalline quartz grains and lesser feldspar grains. In a few places, this matrix contains larger clasts of identical composition. This outcrop is the same as Stop 1 described in a Wilderness area field guide (Terblanche and Nance 2012) and Stop 1-6 in another field trip guide (Hughes et al. 2014).

From 108 acceptable analyses, 82 are reported as concordia ages and 26 are reported 206Pb/238U ages (Table 2.1). Most zircon in this sample is Mesoproterozoic (Fig. 4B); the peak mode occurs at 1.21 Ga and the histogram pattern is asymmetrically skewed toward younger, Neoproterozoic ages. There are only five zircon grains that are 1.40 Ga or older and the oldest zircon was dated at c. 1.78 Ga. The youngest zircon has a crystallization age (2σ) of 499 ± 15 Ma ( concordancy at 99% and concordancy at 94%). This single Late Cambrian zircon provides a maximum possible age of deposition for this sample and is the youngest detrital zircon analyzed from the Mine Run Complex.

***Sample KSH-11-08, Mine Run Complex Unit IV***

Sample KSH-11-08 (37.99697N, 78.11893W; Fig. 3C) was taken from an outcrop of Unit IV of the Mine Run Complex (Rossman 1991; Hughes 2011) along the South Anna River. This rock is a feldspathic quartzite composed mostly of fine- to medium-grained polycrystalline quartz grains and fine-grained feldspar grains. Elongate quartz grains define a weak foliation that is enhanced by fine-grained muscovite. The sampled rock occurs as a small quartzite lens within fine-grained muscovite-rich phyllite. Faint graded bedding is present and in the coarsest beds, physical weathering has produced a pot-marked texture along the outcrop surface.

There are 113 acceptable analyses for this sample; these are reported as 84 concordia ages, 28 206Pb/238U ages, and one 207Pb/206Pb age (Table 2.1). Most of these ages are Mesoproterozoic (Fig. 4C); peak modes occur in two pulses at 1.01 Ga and 1.14 Ga. Of four zircon grains older than Mesoproterozoic, three have Paleoproterozoic ages of ca. 1.665 Ga and one has a Paleoarchean age of 3.35 ± 0.02 Ga, the oldest zircon analyzed in this study. The youngest zircon in the sample is a lone Neoproterozoic, 753 ± 41 Ma grain that has a Th/U ratio of 0.020, which possibly reflects a metamorphic origin (e.g. Williams and Claesson 1987; Williams et al. 1996; Rubatto 2002; Hoskin and Schaltegger 2003). The youngest grain with a Th/U ratio >0.1 is a c. 910 Ma grain. Although collected proximal to the contact with the intrusive Ordovician–Silurian Green Springs complex, no grains have ages that would correlate to contact metamorphic zircon growth at any time in the Paleozoic.

***Sample P310-04, Mine Run Complex Unit I***

Sample P310-04 (38.35749N, 77.68502W; Fig. 3D) is from Unit I of the Mine Run Complex (Pavlides 1989). It was taken from an outcrop near Eley’s Ford on the Rapidan River. This location is proximal to a previously mapped ‘exotic volcanic block’ in the Mine Run Complex (Pavlides 1989; Mixon et al. 2000) and was sampled to evaluate the hypothesis that such blocks were derived from the Middle Ordovician Chopawamsic arc. Although most of the rock present in outcrop is phyllite and metasiltstone, the area sampled was a lens of medium-grained metagreywacke composed mostly of quartz, feldspar, and muscovite. In places, quartz pebbles are distinctly blue. Graded bedding is evident in a few places and indicates stratigraphic younging to the SE. This outcrop is the same as Stop 4 that is described in a Wilderness area field guide (Terblanche and Nance 2012) and Stop 1-7 in a subsequent field guide (Hughes et al. 2014).  
 From this sample, 53 analyses are statistically acceptable (Table 2.1) with a total of 15 concordia ages and 38 206Pb/238U ages considered. Peak modes occur at 1.04 Ga and 1.15 Ga and there is no zircon from any source older than Mesoproterozoic (Fig. 4D). The youngest zircon has a poorly constrained 206Pb/238U age of 905 Ma with an uncertainty (2σ) of ±70 Ma. No zircon grains were found to be similar in age to the Middle Ordovician Chopawamsic arc and detailed mapping (Terblanche, 2013) performed between collecting and analyzing this sample revealed that the nearby ‘exotic volcanic block’ is actually part of the Chopawamsic Formation.

***Sample KSH-11-18, Lunga Reservoir Formation***

Sample KSH-11-18 (38.50487N, 77.43166W; (Fig. 3E) was taken from a small abandoned quarry site along Beaver Dam Run on Marine Corps Base Quantico. This location is one of the reference locations used to define the Lunga Reservoir Formation (P-72-6 of Pavlides 1989). The rock is a poorly sorted metagreywacke that includes mostly fine- to medium-grained quartz, feldspar, and muscovite as well as pebbles of mafic schist and polycrystalline quartz. This location is also Stop 2 and Stop 2-2 in field trip guides (Pavlides 1976; Hughes et al. 2014).

One hundred analyses are acceptable for this sample (Table 2.1). Of those, 90 are concordia ages and 10 are 206Pb/238U ages. Most ages are Mesoproterozoic and peak modes are at 1.10 Ga and 1.28 Ga (Fig. 4E). Considerable detritus is also present from sources with crystallization ages of ca. 935 Ma and ca. 1.45 Ga. There are only three zircon grains older than Mesoproterozoic and the oldest has a poorly constrained Neoarchean age of ca. 2.55 Ga. The youngest zircon present has a concordia age (2σ) of 569 ± 21 Ma.

***Sample KSH-11-16, Lunga Reservoir Formation***

Sample KSH-11-16 (38.48978N, 77.46853W) is from the Lunga Reservoir Formation metadiamictite and was sampled from near Aquia Creek at a reference location for the formation (P-71-63 of Pavlides 1989). The rock was called a “biotite-chlorite-muscovite-plagioclase-quartz granofels (schist-chip feldspathic metagreywacke)” by Pavlides (1989).

One hundred and twenty-two analyses are acceptable for this sample. Of those, 22 are concordia ages, 95 are 206Pb/238U ages, and five are 207Pb/206Pb ages (Table 2.1). Most ages in this sample are Mesoproterozoic with peak modes at 1.02–1.12 Ga, 1.31 Ga, and 1.43 Ga (Fig. 4F). The two youngest zircon grains in this sample have crystallization ages (2σ) of 500 ± 18 and 527 ± 11 Ma. These are the youngest zircon grains analyzed from the Lunga Reservoir Formation and are within error of the youngest zircon analyzed in the Mine Run Complex (ca. 499 Ma, sample KSH-11-05).

**Chopawamsic Terrane**

***Sample KSH-11-19, Chopawamsic Formation***

Sample KSH-11-19 (38.53449N, 77.38839W; Fig. 3G) was taken from the type section (Southwick et al. 1971) of the Chopawamsic Formation along Chopawamsic Creek on Marine Corps Base Quantico. It is a medium-grained micaceous quartzite in a zone ~250 metres downstream from the Breckenridge Reservoir dam that has been documented to display the best preserved sedimentary features (Southwick et al. 1971) in the type section. Our sample contains mostly subangular to subrounded quartz pebbles with additional biotite, muscovite, and feldspar; pyrite is also ubiquitous.

The total acceptable analyses from this sample include 24 concordia ages and one 206Pb/238U age (Table 2.1). The total number of zircon grains reported here is much lower than the desired amount (~90+) due to the paucity of zircon in the rock. Nonetheless, the analyses are reported due to the location of the sample along the type section for the Chopawamsic Formation. All 25 analyses plot as part of one population with a Middle Ordovician age of ca. 470 Ma (Fig. 4G). Due to the temporal coincidence of all ages within analytical uncertainty (2σ), we do not consider the youngest or oldest grains to be statistically distinct from 470 Ma.

***Sample KSH-11-28, Chopawamsic Formation***

Sample KSH-11-28 (38.12930N, 77.85023W; Fig. 3H) was taken from the Chopawamsic Formation along the north shore of Lake Anna. The sandy matrix of this sample is made up of sub-equal amounts of fine-grained quartz + feldspar + biotite. Interspersed medium-grained pebbles of feldspar and quartz have a well rounded appearance in hand sample and thin section. Garnet is also present in moderate amounts.

Sixty-eight analyses are acceptable for this sample, including 66 concordia ages and two 206Pb/238U ages (Table 2.1). Most ages are Late Cambrian to Ordovician with the main peak mode occurring at ca. 457 Ma (Fig. 4H). This age also serves as the youngest population present in the sample. Zircon with poorly constrained Early–Middle Cambrian and Neoproterozoic ages is also present. The oldest zircon grains are a set of five Mesoproterozoic grains with a group of three clustered around ca. 1.01 Ga and the oldest grain dated at c. 1.14 Ga.

***Sample KSH-11-39, Chopawamsic Formation***

Sample KSH-11-39 (37.95398N, 78.00282W; Fig. 3I) was taken from the Chopawamsic Formation along the South Anna River (Hughes 2011). This rock is a metasandstone with plentiful medium-grained rounded quartz and feldspar grains in a fine-grained quartz + feldspar + biotite matrix. 1–5 mm thick layers of biotite-rich zones are also common.

For this sample, all 97 acceptable ages are concordia ages (Table 2.1). Almost all zircon grains are Ordovician with a main peak mode at c. 458 Ma (Fig. 4I). The sample also includes eight grains that span the Cambrian period in addition to one c. 575 Ma Neoproterozoic grain and one c. 1.17 Ga Mesoproterozoic grain.

***Sample KSH-12-70, Chopawamsic Formation***

Sample KSH-12-70 (38.48899N, 77.41918W; Fig. 3J) was taken from the Chopawamsic Formation along an unnamed southern tributary to Smith Reservoir (Aquia Creek). This rock is a recrystallized quartzite with mostly fine- to medium-grained quartz as well as considerable pyrite.

Thirty-eight analyses are acceptable for this sample. Three analyses are reported as 206Pb/238U ages and the remainder are concordia ages (Table 2.1). All but one analysis cluster for a peak age of ca. 476 Ma (Fig. 4J). A single older zircon has a Mesoproterozoic age of ca. 1.09 Ga.

**Arvonia Successor Basin**

***Sample BREMO, Bremo Quartzite Member, Arvonia Formation***

Sample BREMO (37.71290N, 78.30061W; Fig. 3K) was taken from the Bremo quartzite Member of the Arvonia Formation at Bremo Bluff along the north shore of the James River. The rock is a medium-grained quartzite that locally displays cross-bedding structures which indicate stratigraphic younging towards the west.

Eighty-four acceptable analyses are reported for this sample. Of these, 44 are concordia ages and 40 are 206Pb/238U ages (Table 2.1). The data are strongly bimodal with ~75% of grains being latest Paleoproterozoic to earliest Neoproterozoic. The bulk of this group is Mesoproterozoic and displays a peak mode at ca. 1.01 Ga (Fig. 4K). The oldest zircon analyzed has an age of ca. 1.68 Ga. The remainder of the zircon analyzed crystallized in the Ordovician or Silurian; this group has a peak mode at ca. 452 Ma. The extreme bimodality of the sample is prominent with no zircon between the ages of ca. 488 and ca. 924 Ma. The youngest zircon analyzed yields an age of 407 ± 10 Ma but is not reported as detrital zircon due to an anomalously low Th/U ratio of 0.068; this value suggests the Early Devonian age may be more representative of zircon growth during metamorphism (e.g. Williams and Claesson 1987; Williams et al. 1996; Rubatto 2002; Hoskin and Schaltegger 2003). The youngest zircon of interpreted igneous origin has a concordia age (2σ) of 415 ± 34 Ma – an age that is very close, within error, to the peak mode of the Ordovician–Silurian population.

***Sample KSH-11-BUF, Buffards Formation, Arvonia Basin***

Sample KSH-11-BUF (37.65385N, 78.36009W; Fig. 3L) was taken from the Buffards Formation (Brown 1969) along Volcano Ln., south of the town of Arvonia. Although there is a spectacular metaconglomerate zone in this outcrop, we sampled an area with a more consistent micaceous pebbly metagreywacke matrix and fewer large volcanic clasts. This strategy was employed in order to avoid a skewed representation of zircon ages which a collection of large volcanic clasts could create. Well rounded pebbles in the micaceous metagreywacke are most commonly a mix of ~1 cm diameter sized “blue” and clear quartz. This site is also Stop 5 of an Owens (2010) field trip guide and stop 2-6 of a Bailey and Owens (2012) field trip guide.

For this sample, 90 of 94 acceptable analyses are concordia ages; the remaining four are 206Pb/238U ages (Table 2.1). Over 75% of the grains reported are Ordovician or younger. The remainder of the grains (n = 19) are Mesoproterozoic (within 2σ uncertainties). The oldest two zircon grains present have an age of ca. 1.63 Ga. The peak mode of the sample is Early Silurian at ca. 430 Ma (Fig. 4L). No grains have ages that are statistically younger than this mode; therefore it is also interpreted to be the age of youngest zircon delivered to the sample.

**Storck Area**

***Sample KSH-11-40, Storck micaceous quartzite***

Sample KSH-11-40 (38.41893N, 77.63665W; Fig. 3M) was taken from a sequence of metasedimentary rocks previously interpreted to be equivalent to the Arvonia and Quantico formations (Pavlides 1990; Mixon et al. 2000). We informally refer to this mature, well sorted, very fine-grained muscovite quartzite unit and associated phyllite as the “Storck rocks.” Muscovite folia are tightly spaced (~1–2 mm) and pervasive throughout the rock. This outcrop is the same as Stop 5 in a Storck area field trip guide (Terblanche and Nance 2012).

One-hundred and six concordia ages are reported with one 207Pb/206Pb age for a total of 107 acceptable analyses (Table 2.1). Among all samples analyzed in this study, KSH-11-40 displays the most variability in detrital ages. Almost all grains are Proterozoic with only five younger, Cambrian, zircon grains present; the youngest of these has a concordia age (2σ) of 504 ± 36 Ma. Peak modes occur at 533 Ma, 607 Ma, 978 Ma, 1.15 Ga, and 1.33 Ga (Fig. 4M). There is considerable input from populations that span all of these modes with few gaps in analytical error apparent. The largest gap present is at the Mesoproterozoic–Paleoproterozoic boundary between grains dated at ca. 1.53 – ca. 1.71 Ga. The Paleoproterozoic population includes 18 of the grains analyzed and the oldest zircon of this set crystallized at ca. 2.31 Ga.

Table 2.1: For an excel spreadsheet of the data below, please contact Stephen Hughes ([kstephenhughes@gmail.com](mailto:kstephenhughes@gmail.com). Underlined values indicate possibly unacceptable values.

Sample P-310-4:



Sample P-310-4 continued:



Sample P-310-4 continued:



Sample KSH-11-01:



Sample KSH-11-01 continued:



Sample KSH-11-01 continued:



Sample KSH-11-01 continued:



Sample KSH-11-05:



Sample KSH-11-05 continued:



Sample KSH-11-05 continued:



Sample KSH-11-05 continued:



Sample KSH-11-08:



Sample KSH-11-08 continued:



Sample KSH-11-08 continued:



Sample KSH-11-08 continued:



Sample KSH-11-16:



Sample KSH-11-16 continued:

Sample KSH-11-16 continued:



Sample KSH-11-16 continued:



Sample KSH-11-16 continued:



Sample KSH-11-18:



Sample KSH-11-18 continued:



Sample KSH-11-18 continued:



Sample KSH-11-18 continued:



Sample KSH-11-19:



Sample KSH-11-28:



Sample KSH-11-28 continued:



Sample KSH-11-28 continued:



Sample KSH-11-39:



Sample KSH-11-39 continued:



Sample KSH-11-39 continued:



Sample KSH-11-39 continued:



Sample KSH-11-40:



Sample KSH-11-40 continued:



Sample KSH-11-40 continued:



Sample KSH-11-40 con tinued:



Sample KSH-11-BUF:



Sample KSH-11-BUF continued:



Sample KSH-11-BUF continued:



Sample KSH-11-BUF con tinued:



Sample KSH-12-70:



Sample KSH-12-70 continued:



Sample KSH-12-70 continued:



Sample BREMO:



Sample BREMO continued:



Sample BREMO continued:



|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (a) Concordancy value is equal to (206Pb/238U age / 207Pb/206Pb age)\*100. Unacceptable values italicized and underlined. | | | | | | | | | | | | | | | | | | | | | | |  |  |
| (b) Concordia age determined using Isoplot function (Ludwig, 2012) | | | | | | | | | | | | |  |  |  |  |  |  |  |  |  |  |  |  |
| (c) Probability of concordance statistic determined using Isoplot function. Unacceptable values italicized and underlined. | | | | | | | | | | | | | | | | | | | | | | |  |  |
| (d) Th/U ratio determined simultaneously with in-situ laser ablation. Potentially metamorphic values italicized and underlined. | | | | | | | | | | | | | | | | | | | | | | | |  |
| (e) Age used in histogram plots. Criteria for selecting concordia, 206Pb/238U, or 207Pb/206Pb age outlined in methods section of text. | | | | | | | | | | | | | | | | | | | | | | | |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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