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Detrital garnet geochronology: Application in tributaries of the French Broad River, southern Appalachian Mountains, USA

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SUPPLEMENTARY GEOLOGIC BACKGROUND

Previously Published Detrital Geochronology: Tributaries and French Broad Main Trunk

Pb-Th detrital monazite ages by secondary ion mass spectrometry (SIMS) and U-Pb detrital zircon ages by SIMS and by laser ablation- inductively coupled plasma- mass spectrometry (LA-ICP-MS) for the tributary streams were previously published by Hietpas et al. (2010). Published zircon and monazite ages included one sigma age errors that incorporate analytical error along with propagation of errors from uncertainty in decay constant, standard analysis, and standard age.

Published tributary detrital U-Pb zircon and detrital Th-Pb monazite ages preserve different portions of the regional tectonometamorphic record (Hietpas et al., 2010; Moecher et al., 2011). U-Pb igneous crystallization ages from detrital zircon cores in all three tributaries record only the Grenville Orogeny, likely due to sampling within a restricted basin, efficient recycling of abundant Grenville province zircon due to zircon's chemical resistance, and failure of later events to attain the conditions necessary for new zircon nucleation (Morton and Hallsworth, 1999; Rubatto et al., 2001). Younger metamorphic rims for detrital zircon grains in the tributaries record Ordovician ages associated with Taconic metamorphism or Silurian ages younger than the classic Taconic age range (Moecher et al., 2011; Hietpas et al., 2010). Previous studies did not attribute specific tectonic significance to the limited Silurian rim ages (Moecher et al., 2011; Hietpas et al., 2010). Pb-Th detrital monazite core crystallization ages have a strong age peak at ca. 460 Ma (Hietpas et al., 2010), in agreement with U-Pb zircon crystallization ages from leucosome at Winding Stair Gap, NC, interpreted to constrain the timing of the Taconic metamorphic peak (458.1 ± 1 Ma, MSWD=0.095; Moecher et al., 2004). Additional limited U-Th-Pb ages for metamorphic rims on two monazite grains from the tributaries give ages of 395 ± 6 Ma and 427 ± 6 Ma that agree with younger detrital zircon rim ages, while the third gives a rim age of 479 ± 5 Ma in agreement with the oldest monazite core ages (Moecher et al., 2011). No clear Neoacadian or Alleghenian signal was previously reported from modern detritus captured within the studied tributaries (Hietpas et al., 2010; Moecher et al., 2011).

The detrital U-Pb apatite and U-Pb rutile metamorphic crystallization ages from main trunk alluvium record all four major orogenic events, although the youngest events (Neoacadian and Alleghenian) are the dominant age signals recorded by apatite and rutile (O'Sullivan et al., 2016). The detrital U-Pb zircon record is dominated by core igneous crystallization ages from the Grenville Orogeny and metamorphic rim ages from the Taconic Orogeny, with little evidence for the youngest Neoacadian and Alleghanian events (Hietpas et al., 2010; Moecher et al., 2011). Th-Pb monazite detrital ages also record all four major orogenies through metamorphic crystallization but with a dominant Taconic age population. Scattered Silurian and Devonian ages between the Taconic and Neoacadian events can be found in the detrital monazite, zircon rim, apatite, and rutile records (Hietpas et al., 2010; Moecher et al., 2011; O’Sullivan et al., 2016).

SUPPLEMENTARY METHODOLOGY

Garnet Chemistry: SEM Surface Analysis

SEM grain surface analyses provide major element chemistry for identification of garnet sub-populations and determination of garnet compositional range prior to dating individual grains. Although surface measurements are biased toward the rim composition and may be systematically offset from measurements obtained on polished grain centers for chemically zoned garnet grains, use of surface analyses are preferred to avoid sample loss from polishing for grain center analyses. Values for end-member chemistry and associated errors are available in Table S1. Two different ternary diagrams in Figure S1 plot the major element chemistry from surface analyses based on the four predominant cation components of garnet (Fe, Mn, Mg, and Ca).

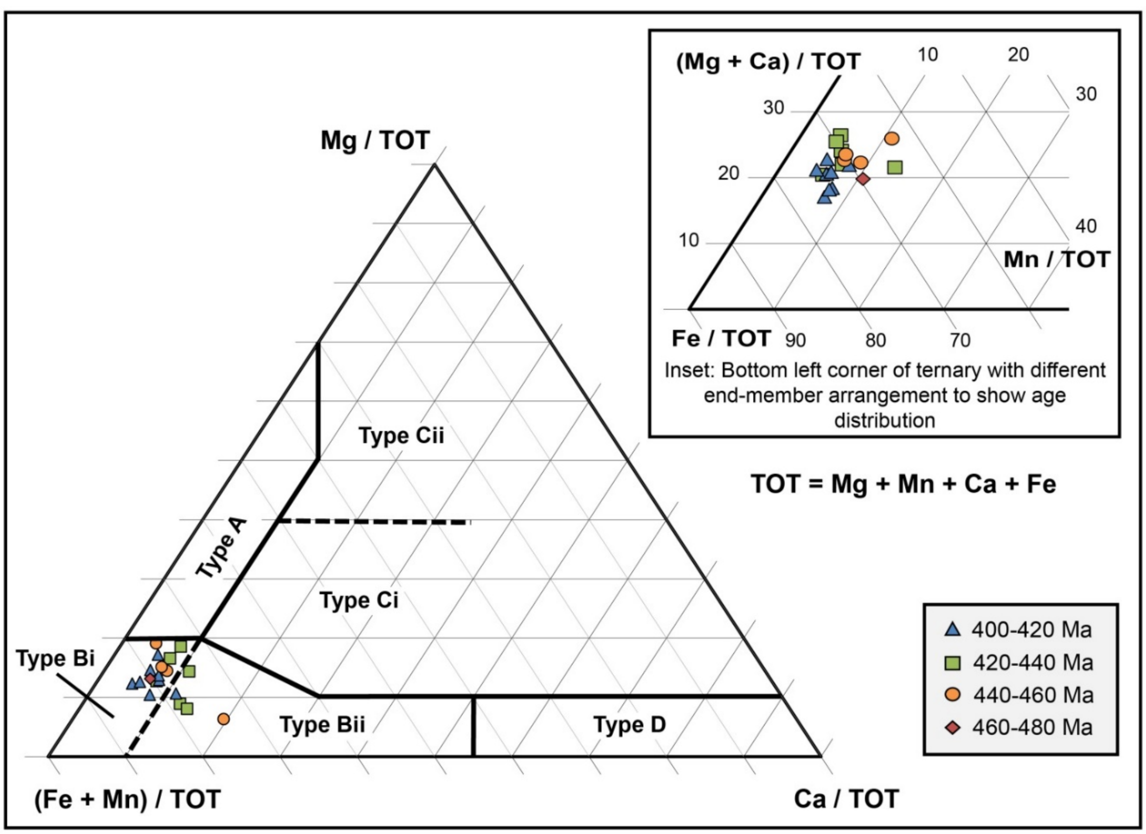
Table S1. Surface major element chemistry by tabletop SEM for dated garnet grains

Garnet major-element chemistry measured on uncoated, unpolished grain surfaces using a tabletop SEM. The value given for the end-member represents the average of all analyses on a single grain, while the error is one standard deviation of all averaged values. Full SEM data is available by request from the corresponding author.

	Grain avg. Pyrope (Mg)	Mg 1SD	Grain avg. Almandine (Fe)	Fe 1SD	Grain avg. Spessartine (Mn)	Mn 1SD	Grain avg. Grossular (Ca)	Ca 1SD
T1 grain04	12.31	3.85	75.47	2.93	7.48	1.77	4.74	0.65
T2 grain12	6.33	2.39	63.13	1.50	10.97	1.20	19.57	1.23
T3 grain13	12.93	4.14	72.80	3.60	6.36	1.21	7.91	1.75
T4 grain08	19.12	3.24	69.76	3.74	6.71	1.09	4.41	0.85
T5 grain03	15.11	2.64	68.61	2.42	9.13	1.54	7.15	1.20
T6 grain09	10.40	2.04	73.92	3.87	7.69	0.04	7.99	1.79
T8 grain01	13.12	2.15	69.55	0.85	10.65	2.44	6.67	1.14
T9 grain02	14.46	2.95	70.34	3.60	7.01	1.90	8.19	2.36
T10 grain05	14.59	0.40	73.50	0.87	5.95	1.17	5.95	0.10
T11 grain06	16.54	2.28	70.00	0.80	5.94	1.03	7.52	2.49
T13 grain11	10.65	4.17	70.17	3.20	7.94	2.75	11.25	0.71
T15 grain16	12.71	1.13	74.00	1.05	5.59	0.60	7.69	1.02
T16 grain30	17.17	6.62	72.28	5.98	4.92	1.99	5.64	1.90
T17 grain33	18.55	1.70	68.88	0.00	4.67	1.02	7.90	2.72
T18 grain36	14.36	2.23	69.88	8.14	4.67	0.48	11.09	5.43
T20 grain24	12.61	2.03	74.38	1.89	7.43	0.96	5.59	0.76
T22 grain39	8.91	3.09	64.94	2.55	13.50	2.75	12.64	3.34
T26 grain35	13.69	2.61	74.34	2.52	4.49	1.28	7.48	2.77
T29 grain45	8.05	2.01	70.88	0.22	7.10	0.50	13.97	1.70

Figure S1. Ternary plots of garnet major element chemistry

Ternary plots of detrital garnet major element chemistry with discrimination fields in the main panel after Mange and Morton (2007). Type Bi: Granitoids; Type Bii: Amphibolite-grade metasediments. Although the garnet grains fall in both Bi and Bii, Krippner et al. (2014) established that the Mange and Morton (2007) discrimination diagram is limited in its ability to discriminate these two fields. Garnet falling across both regions is "likely derived from metasedimentary rocks up to amphibolite facies rather than from metaigneous rocks" (Krippner et al., 2014). The SEM chemical end-member data in Table S1 supports interpretation of garnet with a metasedimentary origin (amphibolite facies) and some within grain variation, as almandine + spessartine content is routinely less than 97% (Krippner et al, 2014). Inset shows a different ternary arrangement with the grains separated into four series based on resulting age from garnet geochronology. Note the possible correlation of age and Fe content in the inset.



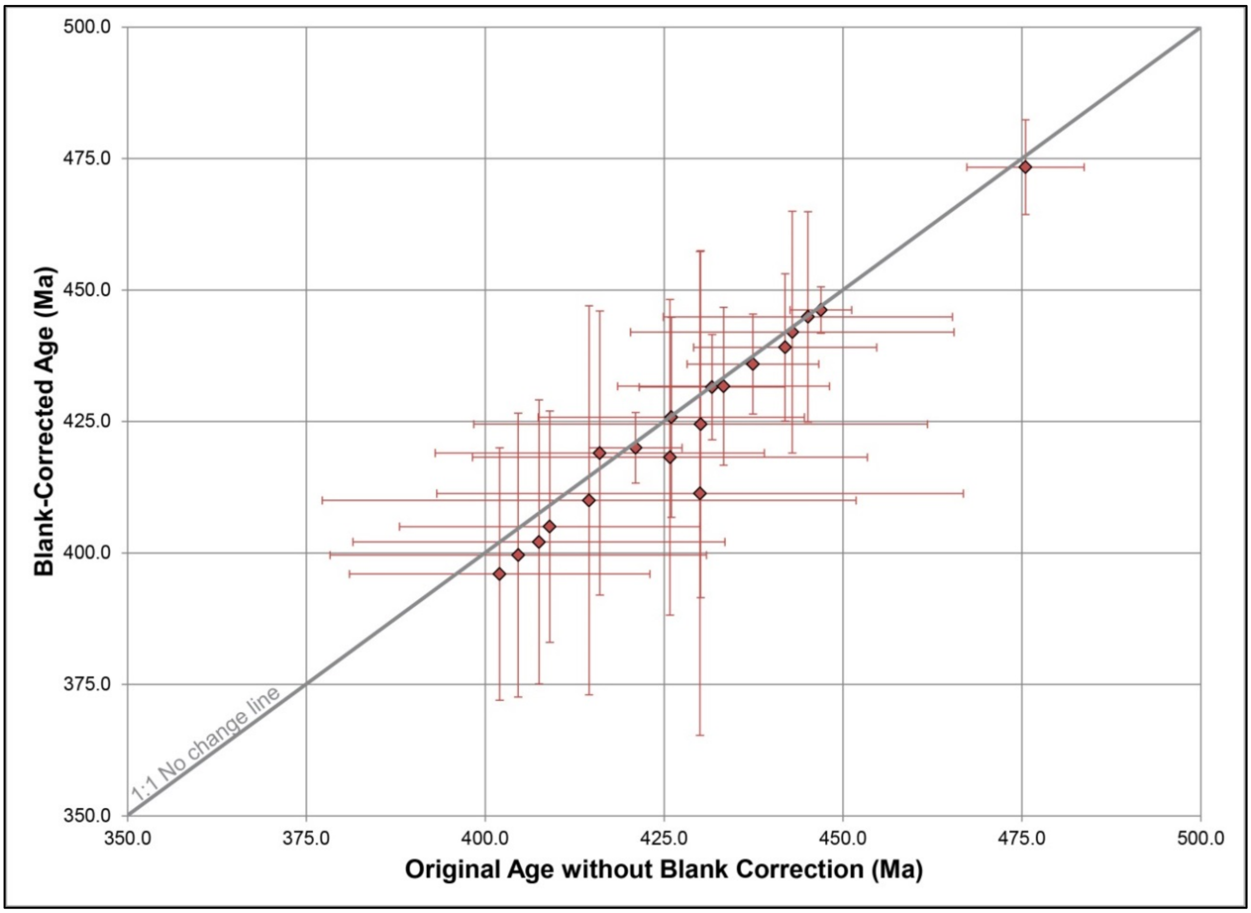
Blank Correction and Systematic Uncertainty

Repeat analyses of three-column analytical blanks for the study duration resulted in a measured blank magnitude of 4.3 ± 0.6 pg (weighted average, n=22). The blank magnitude and weighted average isotope ratios calculated from repeat blank measurements ($^{147}Sm/^{144}Nd$ = 0.045 ± 0.017, $^{143}Nd/^{144}Nd$ = 0.5125 ± 0.0012) were used to apply a rigorous blank correction to the ages by using Monte Carlo simulation to subtract the effect of the blank from the isotope ratios before averaging the results and calculating a correlation coefficient representing the correlation in the $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ errors. Calculated isotope ratios and correlation coefficients were then used in Isoplot to calculate blank-corrected ages (Ludwig, 2003). Figure S2 plots original age versus blank-corrected age, demonstrating that despite the extremely small sample sizes, blank correction never changed the age outside of calculated 2σ age error and therefore has no impact on the tectonic story.

Each blank-corrected age was then further corrected to include the propagation of uncertainty in the Sm decay constant, resulting in the final garnet ages presented in Figure 2. Decay constant uncertainty is included along with analytical errors, uncertainty on standard analyses, and uncertainty on standard age for the previously published monazite and zircon data (Hietpas et al., 2010). Incorporation of uncertainty from the respective decay constants facilitates appropriate comparison of detrital garnet, monazite, and zircon ages dated using different decay systems.

Figure S2. Impact of blank-correction on age

Assessment of the impact of blank-correction on the nineteen accepted ages by comparison of uncorrected and corrected ages, with associated 2σ age errors. Note that the magnitude of the calculated age error generally increases slightly after the blank-correction is applied. The age most impacted by blank-correction is also the least precise. The blank-correction introduced minimal change in the absolute age calculated, pulling ages slightly younger but still well within error.



SUPPLEMENTARY RESULTS

Detrital Garnet Ages

Detailed grain size, isotope ratios, and calculated ages for the detrital garnet ages undertaken in this study are presented without blank-correction (Table S2) and with blank-correction (Table S3). A final summary table of all detrital garnet ages for this study, along with failed attempts and the reason for failure, is provided as Table S4.

Table S2: Isotope ratios, grain size, and non-corrected ages for CT-147 detrital garnet

Isotope ratios and original ages calculated without blank-correction along with grain size estimates. The grain size estimates are based on starting grain weight (mg) and the maximum cross-sectional area of the grain calculated from BSE images. The grains with the darkest grey backgrounds were discarded due to low precision ages or analytical problems. Age errors are 2σ.

Table 2.3: Isotope Ratios, Grain Size, and Non-Corrected Ages for CT-147 Detrital Garnet

	147Sm/144Nd	2 sigma err	143Nd/144Nd	2 sigma err	Initial grain weight (mg)	Cross-section max. (mm^2)	ORIGINAL AGE
garnet T1	3.454604	0.003009	0.521588	0.000189	0.88	0.85	437.4 +/- 9.2 Ma
leach T1 AL2	0.293084	0.000539	0.512528	0.000030			
garnet T2	2.844762	0.002307	0.520143	0.000214	0.98	0.70	445.1 +/- 20.2 Ma
leach T2 AL2	0.873040	0.003459	0.514370	0.000152			
garnet T3	3.410635	0.002417	0.521426	0.000157	2.40	1.15	431.7 +/- 10.2 Ma
leach T3	0.634500	0.005867	0.513563	0.000097			
garnet T4	2.359129	0.004741	0.518790	0.000062	1.90	1.13	446.9 +/- 4.3 Ma
leach T4 AL2	0.153465	0.000046	0.512203	0.000006			
garnet T5	0.196574	0.000033	0.512295	0.000011	1.59	1.15	442.9 +/- 22.6 Ma
leach T5	0.115169	0.000006	0.512059	0.000005			
garnet T6	1.258271	0.001244	0.515294	0.000110	0.90	0.71	433.3 +/- 14.8 Ma
leach T6	0.123907	0.000361	0.512072	0.000009			
garnet T7	3.081143	0.003545	0.520887	0.000135	0.81	0.69	596 +/- 88 Ma
leach T7	2.417928	0.003417	0.518295	0.000365			
garnet T8	1.431119	0.000647	0.516227	0.000068	0.55	0.59	475.5 +/- 8.2 Ma
leach T8	0.169151	0.000057	0.512196	0.000013			
garnet T9	1.431428	0.002854	0.515986	0.000080	0.85	0.66	441.9 +/- 12.8 Ma
leach T9	0.471686	0.000243	0.513158	0.000017			
garnet T10	1.159475	0.000402	0.514832	0.000042	0.58	0.49	421.0 +/- 6.5 Ma
leach T10 AL2	0.110139	0.000092	0.512009	0.000013			
garnet T11	1.169703	0.000431	0.515193	0.000033	0.66	0.53	416 +/- 23 Ma
leach T11	0.531036	0.000603	0.513376	0.000097			
garnet and leach T12	Sm failed to run				0.54	0.53	No age calculated
garnet T13	0.606406	0.000488	0.513422	0.000043	0.37	0.46	426.0 +/- 18.6 Ma
leach T13	0.149008	0.000371	0.512140	0.000036			
garnet T14	0.298374	0.000237	0.512637	0.000016	0.42	0.36	622 +/- 130 Ma
leach T14	0.954452	0.005009	0.515366	0.000564			

garnet T15	3.522253	0.014754	0.521083	0.000557	0.63	0.55	404.6 +/- 26.3 Ma
leach T15	0.279137	0.000374	0.512392	0.000083			
garnet T16	1.660236	0.008357	0.516462	0.000345	0.44	0.50	430.0 +/- 36.8 Ma
leach T16	0.268871	0.000216	0.512400	0.000039			
garnet T17	2.398253	0.004674	0.518220	0.000389	0.75	0.57	407.5 +/- 26.0 Ma
leach T17	0.145810	0.000080	0.512127	0.000015			
garnet T18	3.231762	0.004855	0.520559	0.000406	0.76	0.54	409 +/- 21 Ma
leach T18	0.338512	0.000544	0.512640	0.000049			
garnet and leach T19	Grain lost during clean lab chemistry				0.64	0.62	No age calculated
garnet T20	2.650500	0.006237	0.519343	0.000528	0.51	0.59	430.1 +/- 31.7 Ma
leach T20	0.154292	0.000136	0.512172	0.000029			
garnet T21	1.666358	0.012387	0.516833	0.001083	0.86	0.51	479 +/- 120 Ma
leach T21	0.265597	0.000375	0.512473	0.000032			
garnet T22	3.072970	0.007801	0.520227	0.000613	0.89	0.82	414.5 +/- 37.3 Ma
leach T22	0.568721	0.001006	0.513396	0.000048			
garnet and leach T23	No spread in Sm/Nd of points				1.06	0.88	No age calculated
garnet and leach T24	Grain lost during clean lab chemistry				0.51	0.64	No age calculated
garnet T25	0.210530	0.002083	0.512426	0.000047	0.75	0.63	600 +/- 73 Ma
leach T25	0.088878	0.000061	0.512035	0.000008			
garnet T26	2.230180	0.009263	0.518007	0.000390	0.62	0.48	425.8 +/- 27.6 Ma
leach T26 AL2	0.111635	0.000163	0.511985	0.000007			
garnet and leach T27	Grain lost during clean lab chemistry				0.86	0.56	No age calculated
garnet T28	1.686596	0.011482	0.515816	0.001087	0.38	0.42	612 +/- 380 Ma
leach T28	2.172145	0.006269	0.517660	0.000420			
garnet T29	2.334538	0.009143	0.517962	0.000322	0.66	0.52	402 +/- 21 Ma
leach T29	0.097050	0.000108	0.512000	0.000019			
garnet and leach T30	Sm failed to run				0.74	0.47	No age calculated
garnet T31	2.586358	0.082150	0.519102	0.000522	0.60	0.48	535 +/- 130 Ma
leach T31	1.553543	0.002849	0.516479	0.000330			

Table S3: Isotope ratios and blank-corrected ages for CT-147 detrital garnet analyses

Isotope ratios and ages calculated using the blank-correction protocol along with Nd TIMS load size. The values (isotope ratios, magnitude, and associated errors) for the blank used in the blank-correction are provided in the final row of the table. The grains with the darkest grey backgrounds were discarded due to low precision ages or analytical problems. Age errors are 2σ but do not include the propagation of uncertainty in the decay constant, which is available in Table S4.

Table 2.5: Isotope Ratios and Blank Corrected Ages for CT-147 Detrital Garnet Analyses

	147Sm/144Nd	2 sigma err	143Nd/144Nd	2 sigma err	Correlation coefficient	Nd load size (pg)	CORRECTED AGE
garnet T1	3.632194011	0.025305	0.522058363	0.000218	0.28721	87.8	435.9 +/- 9.5 Ma
leach T1 AL2	0.294217134	0.000534	0.512528541	0.000031	-0.01001	940.5	
garnet T2	2.962642114	0.017046	0.520462635	0.000234	0.18967	107.3	444.9 +/- 20 Ma
leach T2 AL2	0.893901358	0.005369	0.514435067	0.000163	0.03743	127.0	
garnet T3	3.497741503	0.012492	0.521655817	0.000168	0.18347	171.3	431.5 +/- 10 Ma
leach T3	0.641704662	0.005978	0.513583997	0.000101	0.00759	220.4	
garnet T4	2.446626668	0.007294	0.518904177	0.000068	0.18636	241.9	446.2 +/- 4.4 Ma
leach T4 AL2	0.153595988	0.000049	0.512202996	0.000006	0.01252	6622.6	
garnet T5	0.196729074	0.000039	0.512294809	0.000012	-0.00389	5644.8	442.0 +/- 23 Ma
leach T5	0.115266121	0.000026	0.512058962	0.000005	-0.01567	52918.7	
garnet T6	1.281698714	0.003385	0.515345087	0.000114	0.05680	238.5	431.7 +/- 15 Ma
leach T6	0.124024524	0.000364	0.512071646	0.000009	0.00874	5199.5	
garnet T7	3.192505572	0.015797	0.521185607	0.000150	0.28606	124.9	635 +/- 110 Ma
leach T7	2.606329307	0.027591	0.518747278	0.000408	0.17120	59.5	
garnet T8	1.514092463	0.006126	0.516338233	0.000081	0.19127	148.7	473.4 +/- 9.0 Ma
leach T8	0.177733815	0.000100	0.512194686	0.000014	-0.00590	1304.4	
garnet T9	1.521935689	0.007881	0.516108719	0.000095	0.17368	126.1	439.1 +/- 14 Ma
leach T9	0.497220589	0.000475	0.513161919	0.000019	0.03046	697.4	
garnet T10	1.144761854	0.001544	0.514854938	0.000044	0.05881	444.7	420.0 +/- 6.7 Ma
leach T10 AL2	0.110196636	0.000093	0.512008951	0.000013	-0.02244	6099.5	
garnet T11	1.228544287	0.002464	0.515233208	0.000039	0.14722	292.3	419 +/- 27 Ma
leach T11	0.564466877	0.003170	0.51341243	0.000113	0.04247	106.9	
garnet and leach T12	Sm failed to run - no calculated age						
garnet T13	0.61918556	0.000963	0.513431366	0.000044	0.02697	427.7	425.8 +/- 19 Ma
leach T13	0.154918682	0.000435	0.512136745	0.000038	0.00377	471.2	
garnet T14	0.298521895	0.000290	0.512637895	0.000017	0.00664	1028.7	588 +/- 130 Ma
leach T14	1.167765872	0.033918	0.515989677	0.000749	0.14689	24.1	

garnet T15	4.212938856	0.108401	0.522657579	0.000744	0.34699	27.8	399.6 +/- 27 Ma
leach T15	0.290219172	0.000594	0.512391344	0.000084	-0.01395	363.2	
garnet T16	2.283392861	0.105512	0.517811901	0.000662	0.37223	17.0	411.3 +/- 46 Ma
leach T16	0.273866618	0.000326	0.51239951	0.000039	0.01177	641.5	
garnet T17	2.784556697	0.054932	0.519056947	0.000493	0.28068	33.8	402.1 +/- 27 Ma
leach T17	0.152268046	0.000100	0.512125883	0.000016	0.01143	1839.3	
garnet T18	3.734414871	0.068307	0.521639081	0.000518	0.32567	36.4	405 +/- 22 Ma
leach T18	0.346271405	0.000883	0.512642118	0.000053	0.00470	281.1	
garnet and leach T19	Grain lost during clean lab chemistry - no calculated age						
garnet T20	3.155517121	0.072467	0.520496159	0.000677	0.26990	29.9	424.5 +/- 33 Ma
leach T20	0.161163457	0.000173	0.512171009	0.000029	-0.00675	1042.7	
garnet T21	1.808919631	0.025525	0.517230502	0.001184	0.03220	51.6	473 +/- 120 Ma
leach T21	0.274232034	0.000518	0.512472671	0.000035	-0.00655	434.0	
garnet T22	3.643658221	0.089655	0.521619635	0.000788	0.28848	28.2	410.0 +/- 37 Ma
leach T22	0.586321415	0.001585	0.513410175	0.000052	0.02792	272.1	
garnet and leach T23	No spread in Sm/Nd of points - no calculated age						
garnet and leach T24	Grain lost during clean lab chemistry - no calculated age						
garnet T25	0.209538854	0.002108	0.512425263	0.000050	-0.00116	316.3	586 +/- 76 Ma
leach T25	0.107857406	0.000075	0.512035059	0.000008	-0.02648	14381.3	
garnet T26	2.661018854	0.062952	0.518959939	0.000526	0.28302	29.1	418.2 +/- 30 Ma
leach T26 AL2	0.114595425	0.000170	0.511985105	0.000007	0.01238	5981.9	
garnet and leach T27	Grain lost during clean lab chemistry - no calculated age						
garnet T28	2.634968912	0.185385	0.517549711	0.001770	0.18660	12.6	negative age
leach T28	2.458595915	0.038452	0.518255829	0.000495	0.17317	41.5	
garnet T29	2.709710686	0.054727	0.518770663	0.000432	0.28888	33.4	396.0 +/- 24 Ma
leach T29	0.098706232	0.000110	0.511997204	0.000018	-0.01595	5648.2	
garnet and leach T30	Sm failed to run - no calculated age						
garnet T31	2.6308493	0.094160	0.519909479	0.000613	0.08783	39.7	521 +/- 120 Ma
leach T31	1.706596631	0.016069	0.516751836	0.000362	0.09778	67.9	
blank (wtd avg, n=22)	0.045	0.017	0.5125	0.0012		4.31 +/- 0.59	

Table S4: Blank-corrected garnet age summary

Nineteen accepted, blank-corrected detrital garnet ages including error propagation of uncertainty in the Sm decay constant. Also included are the reasons for sample loss or rejection.

Sample:	Age (Ma)	+/- (Ma, 2σ)
T1:	436	12
T2:	445	22
T3:	432	13
T4:	446	9
T5:	442	24
T6:	432	17
T7:	Leach small and <1.0 spread in Sm/Nd 635 +/- 110 Ma	
T8:	473	13
T9:	439	16
T10:	420	10
T11:	419	28
T12:	Sm failed to run - no age	
T13:	426	21
T14:	Leach small and <1.0 spread in Sm/Nd 588 +/- 130 Ma	
T15:	400	28
T16:	411	47
T17:	402	28
T18:	405	23
T19:	Grain lost in chemistry - no age	
T20:	425	34
T21:	Garnet Nd ran poorly - 473 +/- 120 Ma	
T22:	410	38
T23:	No spread in Sm/Nd data - no age	
T24:	Grain lost in chemistry - no age	
T25:	Garnet small and <1.0 spread in Sm/Nd 586 +/- 77 Ma	
T26:	418	31
T27:	Grain lost in chemistry - no age	
T28:	Both garnet and leach small negative age	
T29:	396	25
T30:	Sm failed to run - no age	
T31:	Both garnet and leach small - 521 +/- 120 Ma	

Statistical Comparison of Garnet, Monazite, and Zircon Ages

Table S5: Variable Bandwidths for LA-KDE Calculations

Values for the optimized variable bandwidths calculated for use in a locally adaptive kernel density estimation plot for tributary Sm-Nd garnet, U-Pb zircon rim, and Th-Pb monazite ages using DZstats (Saylor and Sundell, 2016).

Age (Ma)	Sm-Nd Garnet	Th-Pb Monazite	U-Pb Zircon Rims
340	8.987873718	4.993216905	16.59319968
341	8.436322894	4.993216905	16.00438624
342	8.709685621	4.993216905	16.00438624
343	8.538346841	4.993216905	15.50212434
344	8.538346841	4.993216905	15.06863679
345	8.18230451	4.993216905	15.06863679
346	8.18230451	4.993216905	14.69070293
347	7.883455529	4.993216905	14.69070293
348	7.984699353	4.993216905	13.83192286
349	8.00997744	4.993216905	13.97909904
350	8.087252349	4.993216905	13.73083448
351	8.016361762	4.993216905	13.73083448
352	8.083905517	4.993216905	13.50694715
353	7.895362167	4.993216905	13.50694715
354	8.018453243	4.993216905	12.64624343
355	7.839870281	4.993216905	12.64624343
356	8.262992414	4.993216905	12.93027293
357	8.622206122	4.993216905	12.93027293
358	9.086637037	4.993216905	12.24987855
359	8.851354066	4.993216905	12.24987855
360	8.870079777	4.993216905	12.24987855
361	8.650892256	4.993216905	12.24987855
362	8.77740736	4.993216905	11.69907119
363	8.678302759	4.993216905	11.90837885
364	9.018543946	4.993216905	11.80790724
365	8.904896242	4.993216905	11.80790724
366	8.999419512	4.993216905	11.43628434
367	8.892179361	4.993216905	11.27506061
368	9.229353345	4.993216905	10.93700668
369	9.192444909	4.993216905	10.80027951
370	9.313382262	4.993216905	10.64414766
371	9.407168835	4.993216905	10.95453925

372	9.772534959	4.993216905	10.74735568
373	9.986766068	4.993216905	10.69887982
374	10.07901089	4.993216905	10.54212127
375	10.30208725	4.993216905	10.7003865
376	10.69372152	4.993216905	10.50253042
377	11.30224381	4.993216905	10.66198514
378	11.7860827	4.993216905	10.87648763
379	12.57758167	4.993216905	11.34759099
380	13.1937172	4.993216905	11.11515725
381	13.26499126	4.993216905	11.50923937
382	13.93646043	4.993216905	11.50923937
383	14.6795332	4.993216905	11.60185955
384	15.50630808	4.993216905	11.29477604
385	15.54441015	4.993216905	11.77879986
386	16.45361595	4.993216905	11.58710341
387	17.47578978	4.993216905	11.68469264
388	17.47681872	4.993216905	11.76309768
389	17.47780579	4.993216905	12.25513192
390	17.47875347	4.993216905	12.17034395
391	17.47966408	4.993216905	12.37584121
392	17.48053977	4.993216905	12.70155356
393	17.48138249	4.993216905	13.26179637
394	17.48219407	4.993216905	13.56230052
395	17.48297622	4.993216905	13.56230052
396	17.63311579	4.993216905	13.87673889
397	17.63117917	4.993216905	14.43033731
398	17.62931091	4.993216905	14.82897286
399	17.62931091	4.993216905	14.89385656
400	17.46705385	4.993216905	15.85267341
401	17.46807266	4.993216905	16.56547459
402	17.46905645	4.993216905	16.61157911
403	17.470007	4.993216905	17.38129365
404	17.47092595	4.993216905	18.22580501
405	17.47181488	4.993216905	18.24846336
406	17.47267521	4.993216905	18.27039391
407	17.47350831	4.993216905	18.29163118
408	17.47431545	4.993216905	18.31220752
409	17.47509783	4.993216905	18.33215331
410	17.47585657	4.993216905	18.3514971
411	17.47659272	4.993216905	18.37026575
412	17.47730728	4.993216905	18.38848452
413	17.47800118	4.993216905	18.40617723
414	17.47867531	4.993216905	18.71385318

415	17.47867531	4.993216905	19.54737399
416	17.47800118	4.993216905	19.466487
417	17.48191574	4.993216905	18.93036716
418	17.43630829	4.993216905	18.94306377
419	17.54711643	4.993216905	18.95529736
420	17.51192531	4.993216905	18.9670928
421	17.50619263	4.993216905	18.97847321
422	17.4747734	4.993216905	18.98946012
423	17.37547318	4.993216905	18.98946012
424	17.37322253	4.993216905	19.00007358
425	17.37090325	4.993216905	19.01033233
426	17.37090325	4.993216905	18.99325084
427	17.37184709	4.993216905	19.00310972
428	17.37405208	4.993216905	19.01266032
429	17.37405208	4.993216905	19.01266032
430	17.40025372	4.993216905	19.02191688
431	17.37090325	4.993216905	19.03089277
432	17.33979771	4.993216905	19.01470659
433	17.24310447	4.993216905	19.02338157
434	17.24310447	4.993216905	19.02338157
435	17.23876701	4.993216905	19.02338157
436	17.23429414	4.993216905	19.02338157
437	17.22967942	4.993216905	19.03960057
438	17.22491599	4.993216905	19.01948182
439	17.21999654	4.993216905	19.00709279
440	17.21491329	4.993216905	19.03583419
441	17.20965791	4.993216905	18.95828439
442	17.20422151	4.993216905	18.85922406
443	17.19859457	4.993216905	18.76759056
444	17.1927669	4.993216905	18.76759056
445	17.18672756	4.993216905	18.7764167
446	17.10653163	4.993216905	18.79955621
447	17.37637043	4.993216905	18.79955621
448	17.73493926	4.993216905	18.7764167
449	17.78249062	4.993216905	18.70895346
450	17.82629732	4.993216905	18.66402121
451	17.82958986	4.993216905	18.66402121
452	17.83295524	4.993216905	18.66402121
453	17.8363959	4.993216905	18.68459841
454	17.83991439	4.993216905	18.60331414
455	17.84351338	4.993216905	18.60331414
456	17.84719567	4.993216905	18.60331414
457	17.85096418	4.993216905	18.58680151

458	17.85482198	4.993216905	18.56974033
459	17.85877228	4.993216905	18.57188698
460	17.86281844	4.993216905	18.55363231
461	17.866964	4.993216905	18.5347267
462	17.87121267	4.993216905	18.31555815
463	17.87556834	4.993216905	18.29271003
464	17.88003511	4.993216905	18.26904339
465	17.88461728	4.993216905	18.24451344
466	17.88931938	4.993216905	18.21907208
467	17.89414618	4.993216905	18.19266755
468	17.89910272	4.993216905	18.16524408
469	17.90419428	4.993216905	18.13674155
470	17.90942647	4.993216905	18.10709499
471	17.9148052	4.993216905	16.93061687
472	17.9203367	4.993216905	16.14995426
473	17.92602758	4.993216905	15.57419419
474	17.93188483	4.993216905	15.52001503
475	17.93791585	4.993216905	15.46436288
476	18.02510114	4.993216905	15.40717683
477	18.03289295	4.993216905	15.34839259
478	18.04093157	4.993216905	15.28794222
479	18.04922891	4.993216905	15.22575384
480	18.05779766	4.993216905	15.16175143
481	18.11230357	4.993216905	14.5407604
482	18.17086924	4.993216905	14.46879123
483	18.22126248	4.993216905	14.39475075
484	18.27371916	4.993216905	13.81273035
485	18.54407311	4.993216905	13.27594636
486	18.96113828	4.993216905	13.19069794
487	18.96113828	4.993216905	12.81477671
488	19.40928572	4.993216905	12.33325339
489	19.45110556	4.993216905	12.23860798
490	19.49482415	4.993216905	12.23860798
491	19.49482415	4.993216905	11.9634044
492	19.49482415	4.993216905	11.47388291
493	19.75600505	4.993216905	11.29122672
494	20.2258715	4.993216905	11.12001069
495	20.63373138	4.993216905	10.93871028
496	21.14734374	4.993216905	10.69987557
497	21.14734374	4.993216905	10.6316018
498	21.14734374	4.993216905	10.64405248
499	21.14734374	4.993216905	10.5105328
500	21.44048283	4.993216905	10.3729781

501	21.90091731	4.993216905	10.69669973
502	22.35912325	4.993216905	10.51090791
503	22.35912325	4.993216905	10.29241161
504	22.35912325	4.993216905	10.17423562
505	22.35912325	4.993216905	10.45523609
506	22.35912325	4.993216905	10.45523609
507	22.64408694	4.993216905	10.30409431
508	22.95436723	4.993216905	10.10580663
509	23.2934947	4.993216905	10.43565643
510	23.66568841	4.993216905	10.15043764

Figure S3: Cumulative Distribution Functions (CDFs)

Cumulative Distribution Functions calculated along with the Probability Distribution Plot (top plot) and the locally adaptive Kernel Density Estimation (bottom plot) by DZstats (Saylor and Sundell, 2016). The CDFs are utilized for two-sample comparison of age distributions using a Kolmogorov-Smirnov Test (Supplementary Table S6).

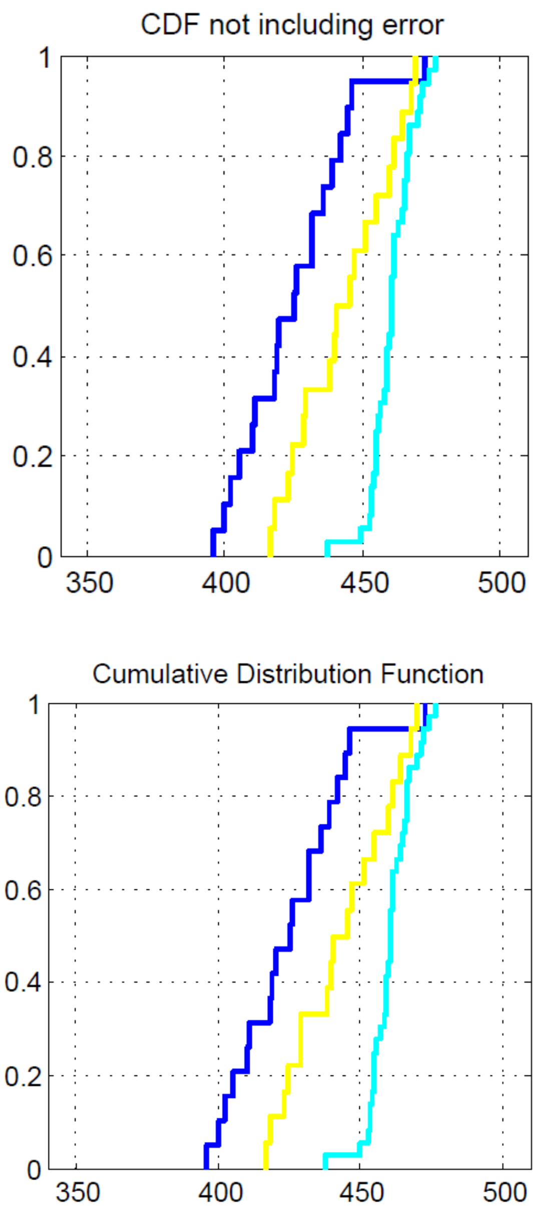


Table S6: Values from Statistical Comparison of Garnet, Monazite, and Zircon Ages

Results from statistical comparison of PDP plots (Figure 3) through cross-correlation, likeness, and similarity testing and CDF plots (Supplementary Figure S3) using a Kolmogorov-Smirnov test. These tests were run using the program DZstats to compare the age distributions of the Sm-Nd garnet, U-Pb zircon rim, and Th-Pb monazite ages from the tributaries (Saylor and Sundell, 2016). A two-sample, non-parametric Kolmogorov-Smirnov test comparing the cumulative distribution functions for the Sm-Nd garnet and the Pb-Th monazite ages, results in a p-value of 2.32×10^{-10} (see below). A p-value <0.05 correlates to a 95% confidence level that the garnet and monazite age distributions are not drawn from the same parent age distribution (Saylor and Sundell, 2016). Small sample sizes (n<50) limit the reliability of some alternative statistical means of population comparison but are still useful in confirming conclusions from visual inspection of the PDP. Cross-correlation, likeness, and similarity tests on the PDP support the fundamental conclusion that the monazite and garnet age distributions are not drawn from the same parent age distribution.

Statistical Comparison using the PDP and CDF for all Paleozoic Sm-Nd garnet, U-Pb zircon rim, and Th-Pb monazite tributary ages			
1. garnet, 2. monazite, 3. zircon rims			
Cross-correlation (R-Squared crossplot)	1	2	3
1	1	0.0039	0.4822
2	0.0039	1	0.3744
3	0.4822	0.3744	1
Likeness	1	2	3
1	1	0.2578	0.6846
2	0.2578	1	0.5516
3	0.6846	0.5516	1
Similarity	1	2	3
1	0.9999	0.546	0.901
2	0.546	1	0.8267
3	0.901	0.8267	0.9996

Kolmogorov-Smirnov Test			
k-statistic (not including uncertainty)	1	2	3
1	0	0.9196	0.4035
2	0.9196	0	0.6111
3	0.4035	0.6111	0
p-value (not including uncertainty)	1	2	3
1	1	2.32E-10	0.0718
2	2.32E-10	1	1.15E-04
3	0.0718	1.15E-04	1

SUPPLEMENTARY DISCUSSION

Age Calculation Sensitivity Checks

Results of sensitivity testing support accuracy (within quoted uncertainty) of the garnet age distribution. Since this is the first full-scale application of detrital garnet geochronology we also consider the accuracy of the method using two age calculation sensitivity checks:

1. The sensitivity of the blank correction protocol was tested using two different sets of blank parameters, one measured and the other idealized from a synthesis of values published in the literature. The difference in the resulting absolute ages were <5 Ma for all samples and well within the reported 2σ age error.
2. The impact of using inclusions as a proxy for the source whole-rock was also considered, as inclusions are unlikely perfectly representative of the whole-rock chemistry. To test sensitivity to the variable inclusion population we replaced leached inclusion analyses with four different whole-rock Sm-Nd value from along-strike ATFMS schist samples measured by Goldberg and Dallmeyer (1997). These whole rock compositions are the best available representation of the likely Sm-Nd composition of a pelitic parent source rock, although they are geographically sourced from a different part of the ATFMS. Direct analysis of Sm-Nd whole rock composition for an Ashe Gneiss and Ashe Schist sample from within the tributary basin would be preferable, but that material was not available during sample analysis. All but two of the garnet grains have ages using all four whole rock values that remain within the 2σ age error of the original results, and the overall age distribution pattern remains unchanged, with ages from the Devonian to Ordovician. The two grains that showed variation in the absolute age beyond the stated age error were the only two analyses with Sm/Nd ratios below 1.0, indicating that the garnet may not have been fully cleansed.

The high Sm-Nd garnet analyses act as the primary control over the slope of the isochron and resulting age, limiting the impact of variation in the inclusions on age accuracy. Detrital garnet age analyses with an Sm/Nd ratio exceeding 1.0 should be insulated from variation imposed by variable inclusion populations.

Table S7: Age Variation from Age Sensitivity Testing using Whole Rock Analyses

	Final Detrital Garnet Age	Age w/ Ashe Schist WR #15	Age w/ Ashe Schist WR #21	Age w/ Ashe Schist WR #24	Age w/ Ashe Schist WR #29
garnet T1	436 +/- 12	432 +/- 10	433 +/- 10	437 +/- 10	432 +/- 10
garnet T2	445 +/- 22	448 +/- 13	450 +/- 13	454 +/- 13	447 +/- 13
garnet T3	432 +/- 13	431 +/- 8	432 +/- 8	436 +/- 8	431 +/- 8
garnet T4	446 +/- 9	445 +/- 5	447 +/- 5	452 +/- 5	444 +/- 5
garnet T5	442 +/- 24	334 +/- 24	399 +/- 28	565 +/- 26	340 +/- 23
garnet T6	432 +/- 17	423 +/- 15	427 +/- 15	438 +/- 15	423 +/- 15
garnet T8	473 +/- 17	461 +/- 9	465 +/- 9	474 +/- 9	461 +/- 9
garnet T9	439 +/- 16	433 +/- 10	437 +/- 10	446 +/- 10	433 +/- 10
garnet T10	420 +/- 10	406 +/- 7	411 +/- 7	424 +/- 7	406 +/- 7
garnet T11	419 +/- 28	428 +/- 5	432 +/- 5	444 +/- 5	427 +/- 5
garnet T13	426 +/- 21	399 +/- 13	409 +/- 14	434 +/- 13	399 +/- 13
garnet T15	400 +/ 28	393 +/- 29	394 +/- 29	397 +/- 29	393 +/- 29
garnet T16	411 +/- 47	401 +/- 49	404 +/- 50	409 +/- 50	401 +/- 49
garnet T17	402 +/- 28	397 +/- 29	399 +/- 29	404 +/- 29	397 +/- 29
garnet T18	405 +/- 23	402 +/- 23	403 +/- 23	407 +/- 23	402 +/- 23
garnet T20	425 +/- 34	421 +/- 35	423 +/- 35	427 +/- 35	421 +/- 35
garnet T22	410 +/- 38	411 +/- 35	413 +/- 35	416 +/- 35	411 +/- 35
garnet T26	418 +/- 31	410 +/- 32	413 +/- 33	418 +/- 33	410 +/- 32
garnet T29	396 +- 25	392 +/- 26	394 +/- 26	399 +/- 26	392 +/- 26

Potential Sampling Bias in Previously Published Data

We also consider potential variability in age populations resulting from sampling bias. Monazite is fairly stable during sedimentary diagenesis, but its stability during sedimentary transport is not well quantified (Morton and Hallsworth, 1999). Silurian monazite growth or resetting may have occurred regionally but was missed in the tributary record due to rim abrasion or loss of smaller, later nucleating monazite grains (Moecher et al., 2011). Garnet's moderate to high stability during transport and diagenesis (Morton and Hallsworth, 1999) and much larger original grain size as a rock-forming mineral (often orders of magnitude larger than the accessory mineral detrital grain fragments sampled) reduces potential for sampling bias from loss of small secondary grains.

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