Constraining depositional ages of Potomac Terrane formations by zircon U/Pb isotope analysis

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Abstract:

The Potomac terrane is a north trending group of metasedimentary formations, intruded by numerous igneous bodies. Lower depositional age constraints have been placed on these formation based primarily on $^{40}Ar/^{39}Ar$ cooling ages. Conversely, there has been little to no work conducted that attempts to place an upper age constraint on the deposition of these formations. In order to determine an upper age constraint for the Laurel Formation, as well as the Bear Island and Blockhouse Point domains of the Mather Gorge Formation, and in an attempt to determine a more accurate lower age constraint for the Bear Island domain, detrital zircons were radiometrically dated. Radiometric ages were determined based on data collected using a laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS) at the University of Arizona. The upper depositional age constraints determined by the radiometric zircon data of the Blockhouse Point domain and the Bear Island domain of the Mather Gorge formation and the Laurel Formation were 960 Ma, 540 Ma, and 520 Ma respectively. As for the Bear Island Granodiorite, a magmatic growth zone crystallization age of 440 Ma was concluded. Zircon analysis was made possible with the use of magnetic and density separation techniques intended to isolate zircons from the pulverized samples collected from the field.

Introduction:

The American eastern coast is the product of over a billion years of rifting and collisions that ultimately resulted in the Appalachian Mountains seen today. For some of the geologic units in the Appalachian Mountains with poor or no outcrop exposure and/or limited fossil incorporation, dating and measuring them is difficult. However the use of radiometric age determination can provide valuable data for creating a lower depositional constraint from crosscutting intrusive igneous bodies, as well as upper depositional constraints of the lithological units themselves. The age data from the various lithological units in the Appalachian mountain range are of importance in the reconstruction of the complex orogenic and tectonic history that forged the modern Appalachian Mountains.

The Mather Gorge and the Laurel formations are both formations in the Potomac terrane, a subdivision of the Piedmont Province. These two formations are composed of metasedimentary rocks, each with numerous intrusive igneous bodies. Much work has been done to date the igneous bodies and to determine muscovite or amphibole cooling ages from the once buried formations. All the aforementioned data provide a lower age constraint before which these sediments were deposited. Without an upper age constraint to bracket a time that deposition could have occurred, it is difficult to determine with any certainty whether or not the tectonic, lithological, and chronological relationships of these formations have been properly placed in Appalachian geologic history. Since a date of deposition is impossible to determine, a constraint on the maximum age of deposition can be useful.

By analyzing detrital zircons from sedimentary or metasedimentary rocks, it is possible to calculate an age for the crystallization of the parent rock(s) that contributed the aforementioned zircons through erosion and transport. Since deposition could not have occurred prior to the formation of the parent rock(s), zircon crystallization ages can provide an upper depositional age constraint. Zircons also have a high melting temperature which often allows them to resist melting, affording them the opportunity to then be incorporated into the intruding igneous body. As the intruding body cools and crystallization begins, zircon preferentially crystallizes on preexisting inherited zircons, as magmatic growth zones. Since a lithological unit must exist in order to be intruded, the magmatic growth zones around inherited zircons provide a lower depositional age constraint.

The chronologic and tectonothermal history of the Potomac terrane has been the subject of many previous studies. Kunk et al., (2005) analyzed cooling ages of muscovites and amphiboles. Aleinikoff et al. (2002) utilized both SHRIMP and TIMS to analyze zircons from many of the terrane's intrusive suites. These age data have been extensively measured and studied, and provide a useful cooling curve for the metamorphism of the lithological units of these formations. A cooling curve graph based on such measurements can be seen in Fig 1.

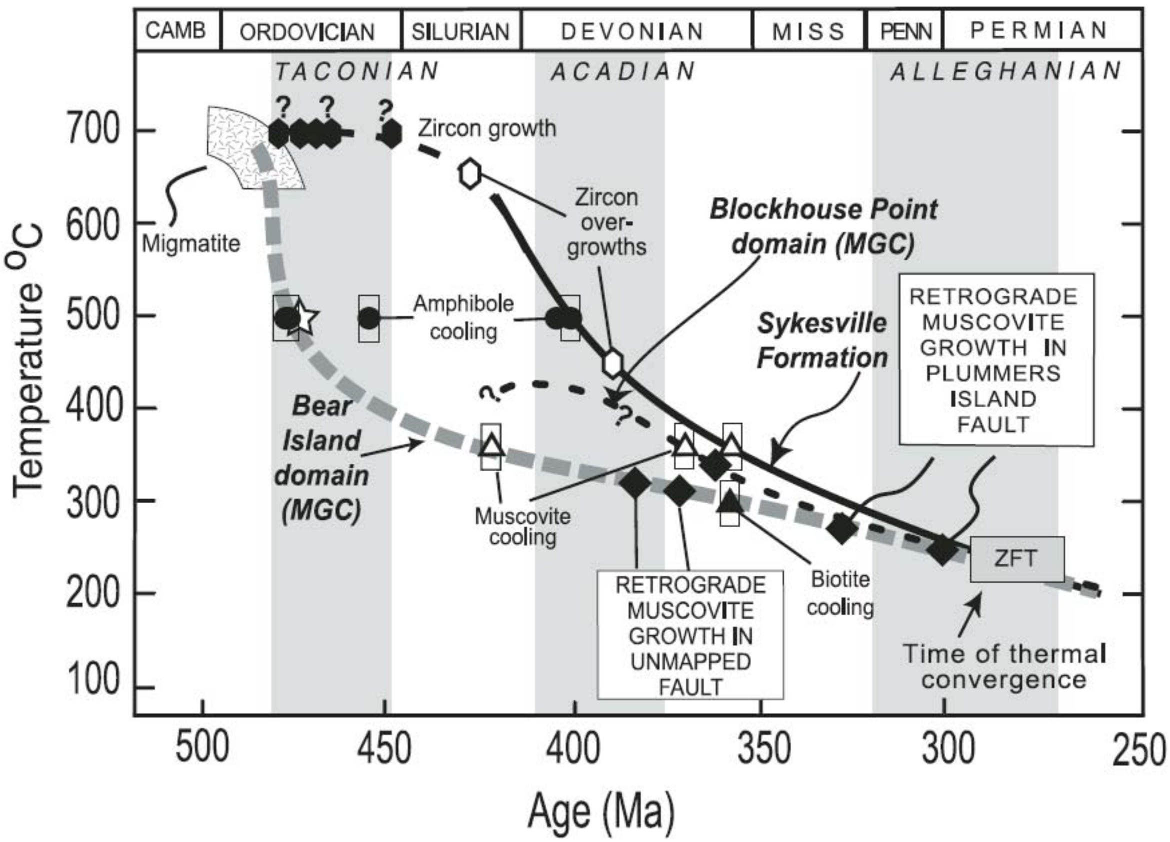


Figure 1. Kunk et al., 2005, cooling curve for Sykesville Formation, the Bear Island and Blockhouse Point domains

However this cooling curve only represents the later half of the thermal history of these rocks, but provides no insight to how long they could have been buried, or existed prior to burial. Furthermore since cooling ages can be reset by later thermal events, the ages previously measured are not absolute, and only illuminate the history of these rocks since they experienced their highest level of metamorphism. This is no indication of an upper depositional age constraint due to the possibility that the rocks of the Potomac terrane have undergone one or more separate episodes of burial for which any thermal remnant could have been overprinted by the youngest and most intense episode.

The work of Kunk et al., (2005) and Aleinikoff et al., (2002) as well as others, has not only provided age data to interpret the more recent tectonothermal history of these formations but also indicated possible field collection sites. Previous work by Southworth et al., 2006 has provided critical structural and lithological observations and maps that are vital in visualizing the terrane as it exists today while, at the same time providing lithological and mineralogical observations and interpretations eliminating the need for an individual to visit the related units not in question

Geologic setting:

The North American eastern coast is dominated by the long rolling hills of the Appalachian Mountains. The Appalachian Mountains are subdivided into several provinces called the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and the Coastal Plain from west to east. The Piedmont province ranges from Canada to as far south as Alabama. The Piedmont province in Maryland is further divided into three terranes called the Westminster, Potomac, and Baltimore terrane, and it is within the Potomac terrane that lies the focus of this project.

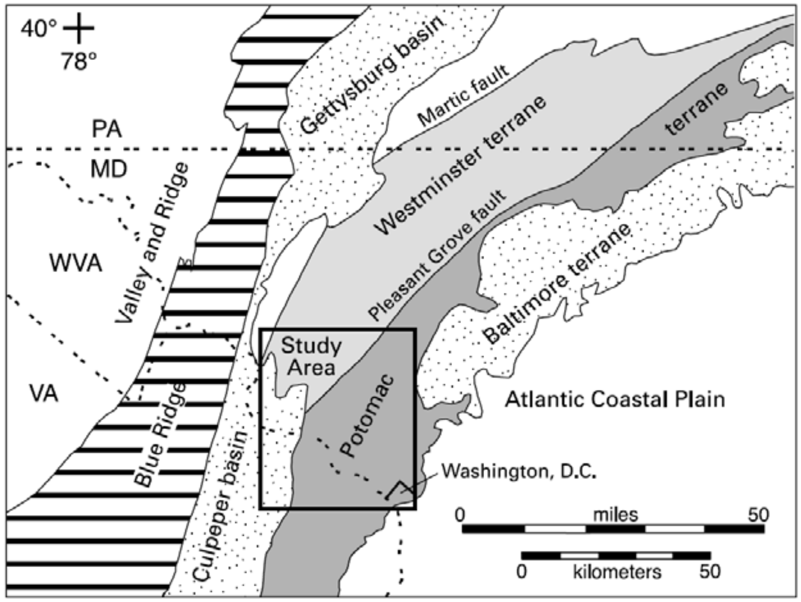


Figure 2. Kunk et al., 2004, geologic map Appalachian provinces.

The Appalachian mountains are the remnants of several orogenic events as Laurentia collided with a series of ocean island arcs. Prior to these events rifting tore apart Laurentia and Baltica resulting in the Iapetus ocean ca. 600 Ma. The next event that occurred was the Penobscottian Orogeny, occurring between 490 Ma 520 Ma. Kunk et al., (2005) interprets that it was during this orogeny that the to be Potomac terrane sediments were accreted onto Laurentia. According to Drake and Froelich, (1997) the Mather Gorge formation was deposited in the closing Iapetus as a sequence of turbidities. From 490 Ma – 450 Ma the second orogeny called the Taconic Orogeny was taking place coinciding with several intrusive bodies. Aleinikoff et al., (2002) dated the Georgetown Intrusive Suite to be ~472 Ma, coinciding with the Taconic Orogeny. The Acadian Orogeny was the third collisional even with eastern Laurentia and took place between 410 Ma and 390 Ma. As can be seen in Fig 1. the Acadian Orogeny had little affect on the metamorphism of the Potomac terrane relative to the Taconic Orogeny. However this is not the case for the whole Potomac terrane. Both the Stublefield Falls domain and the Blockhouse point Domain achieved peak metamorphism ~370 Ma during the Devonian (Kunk et al., 2005).

The north trending Potomac terrane overlies the Westminster terrane to the west along the Pleasant Grove fault, and is bound to the east by Cretaceous and Tertiary coastal plain deposits (Kunk et al., 2004). The westernmost Mather Gorge formation is divided into three domains: the Blockhouse Point domain, Bear Island domain, and the Stubblefield Falls domain, from west to east (Kunk et al., 2004). Kunk et al., (2004) subdivides the three domains of the Mather Gorge Formation based on lithology, chronology, structure and metamorphic observations. The Mather Gorge formation is bound on the west by the westward dipping Pleasant Grove fault and is separated from the Sykesville formation on the east by the Plummers

Island Fault. The Sykesville formation is a widely varied metasedimentary rock consisting of a quartzofeldspathic matrix with many round quartz, phyllonite, migmatite, metagraywacke, mafic and ultramafic rock inclusions (Southworth 2002). The rock creek shear zone divides the Sykesville formation to the west from the Laurel formation to the east (Kunk 2002). Southworth et al., (2002) describes the rocks of the Mather gorge formation as mostly quartz-rich schist containing minor mica, gneiss and metagraywacke, metagraywacke containing schist, migmatite and phyllonite. The Blockhouse Point domain is primarily a chlorite-sericite phyllonite ,placing it in the upper greenschist facies, while the Bear Island domain is characterized by garnet to sillimanite grade migmatic metagraywackes, placing it in the mid amphibolite facies (Southworth et al., 2006). The Laurel formation is observed by Kunk et al., (2005) as having been metamorphosed to the upper amphibolite facies. Southworth et al., (2002) describes the Laurel formation as consisting of quartz grains and fragments of meta-arenite as well as muscovite-biotite schist in a quartzofeldspathic matrix.

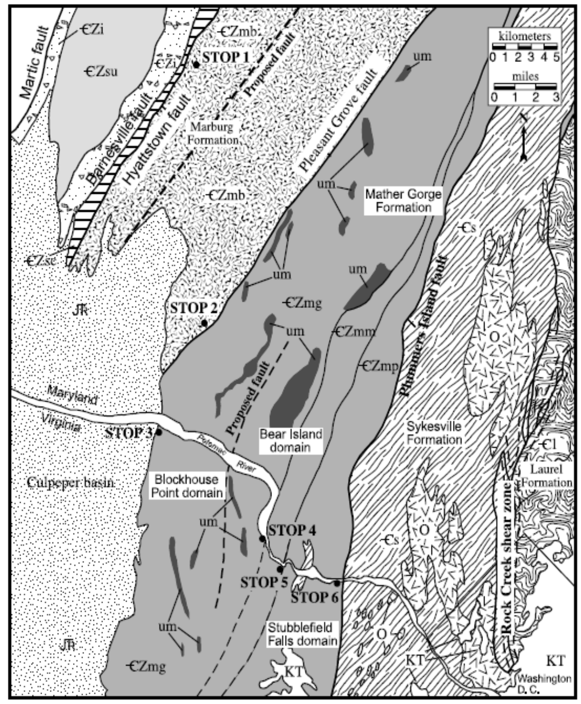


Figure 3. Kunk et al., 2004, geologic map Potomac terrane

Methodology

Field collection:

Prior to sample collection, each field site was studied, photographed, and all observations and measurements recorded. Measurements taken at each site include a GPS position as well as strike and dips of any foliations, bedding, joints and/or folds using a Brunton compass. A sample of the rock was collected using a hammer, chisel and sledgehammer. Discarding the outermost, and assumed more weathered pieces, a deeper sample was then removed, collected and sealed in a clean plastic bag which was prelabeled.

Pulverizing:

A large enough piece of the sample was preserved for a hand sample and for making a thin section later if needed. Each sample was then crushed in a preparation room after all surfaces were thoroughly cleaned, to protect against contamination. A mortar and pestle were cleaned and scrubbed to ensure the removal of any remaining grains from previous use. Two sieves, with mesh sizes of 2 mm and 0.25 mm were cleaned and all grains stuck in their mesh were plucked out. Samples were pulverized sufficiently as to pass through the 0.25 mm mesh sieve into a collection tray.

Panning:

Portions of the <0.25 mm grained sample were poured into a hand pan where water was used to separate the sand size grains from all the silt and clay sized grains, small enough to stay in suspension. Each sample portion, once thoroughly separated, was washed with ethanol onto trays made of aluminum foil and then dried under a heat lamp.

Frantz barrier field magnetic separator:

After the panned samples were dry, they were then passed through a Frantz barrier field magnetic separator The Frantz barrier field magnetic separator is a large electro-magnet, through which a chute passes that leads to two collection trays. All surfaces and components where cleaned thoroughly and dried prior to each use. Prior to placement in the separator, each sample was passed over with a hand magnet to remove any iron flake remnants from the mortar and magnetite grains from the sample that could potentially interfere with the effectiveness of the separation. Sample grains placed in a controllable flow dispenser then fall on the vibrating chute, and pass through the magnetic barrier separating the grains The magnetic field manipulates the magnetically susceptible grains to one collection tray while the grains that are not magnetically susceptible (at the particular set amperage) collect in a separate tray (fig 4.)/ Each sample was passed thought the Frantz no fewer than four times at increasing magnetic intervals of 0.5, 1.0, 1.5 and 2.0 amps (2.25 max) on average. Once completed, the remaining sample grains consist of non magnetic minerals such as quartz, feldspars, and the zircons of interest, as well as a few other miscellaneous minerals.

Fig. 4. magnetic grains left, non magnetic right.

Density separation:

Further separation of the samples was accomplished by taking advantage of zircons high density. Zircon, which has a density between 3.9 and 4.2, is denser than many non-magnetic minerals. A dense solution called methylene iodide (MEI), that has a density of 3.3 (less dense than zircon, but more dense than minerals like quartz and feldspar) was used to separate the zircons further. In 80 ml beakers, portions of the sample were poured into the methylene iodide where the less dense mineral grains like quartz and feldspar remain at the surface and the zircons and other dense grains sink to the bottom. Using liquid nitrogen, the bottom of the beaker was then frozen, trapping the sunken grains in frozen MEI, at which point the floating portions were poured and rinsed into a filter paper cone and funnel that drained into a 1000 ml flask. Acetone was used to wash out any remaining float grains that may have remained in the beaker. After the float was removed, the beaker with the frozen MEI was dipped in water to loosen the block; it too was then poured into a separate filter paper cone and funnel, draining into a 1000 ml flask. This pouring-freezing process was repeated as needed to isolate a sufficient amount of dense grains. Repeatedly rinsing both the float and sink samples with acetone dissolved any remaining MEI, allowing the samples to then be safely dried and stored to later be mounted

Picking and mounting:

Under a microscope, the zircon grains are identifiable and can be hand picked from the remaining grains and then placed on a piece of double sided tape, adhered to a ceramic tile to provide a smooth surface. For the detrital samples, the zircon separate was concentrated enough for the grains to be poured onto the tape surface using a metallic guide 1 cm in diameter. For the samples that were poured onto the tape, using a microscope the zircons were manually reoriented to optimize their orientation parallel to the eventual mount surface. Once the sample grains were placed on the tape, zircons whose ages were determined were placed on the tape to act as standards. The standards were placed on a clear strip of tape in the middle of the mounted unknown zircons, ensuring they could easily be differentiated from the unknown grains. Once this was done, a 1 in plastic ring was placed around the grains of each sample on the tape and then filled with epoxy. Before the epoxy hardened, using a dental pick any bubbles that might have been trapped near the zircons were picked and removed from the eventual mount surface. Once the epoxy was hardened it was then removed from the tape along with the zircons. Using very fine grained sand papers of 1000grit, 2500grit and 3000grit sequentially, each sample mount was carefully sanded to expose a cross section of each zircon. This exposed the cores and magmatic growth rims of the granodiorite zircons and the cores of the metasedimentary zircons.

Electron Microprobe

Once the mounts were completed, backscatter electron images (BE) and cathodoluminescent images (CL) were taken using a JXA-8900 electron microprobe at the University of Maryland's Microanalyzer laboratory. The BE and CL images were then arranged into composite images of each mount, later to serve as a map to help avoid inclusions and to provide direction to zircon rims or cores while operating the LA-ICP-MS. This is a crucial step since the mass spectrometers optics are incapable of providing such visual differentiation.

LA-ICP-MS

The use of zircons for radiometric dating is made possible by the zircons ability upon crystallization to incorporate uranium and thorium into its crystal structure which then continue to decay predictably. In order to determine an accurate radiometric age based on uranium and its decay to lead another element thorium must also be measured, and its relationship with uranium and lead understood. The decay of ^{232}Th and the two isotopes of uranium, ^{238}U and ^{235}U result in three different daughter isotopes of lead: ^{208}Pb, ^{206}Pb, ^{207}Pb respectively. ^{204}Pb is a stable lead isotope, not formed through radioactive decay, and must be measured and corrected for during data analysis. The measured ^{204}Pb is used as a bench mark value for the amount of the other three lead isotopes that were already present upon crystalization and were not a radiogenic produced in that zircon. These values are then subtracted from the measured lead values to arrive at the presumed value of the lead isotopes formed by radiotive decay. Once the measurments have been made and any data are corrected, the analyses can be plotted with ^{207}Pb/^{235}U on the x axis and ^{206}Pb/^{238}U on the Y axis, and is called a concordia plot.

In order to acquire the desired data, a LA-ICP-MS was used at the LaserChron Center at the University of Arizona. Once each mount was secure and fastened in the machine, the analyses of the unkown zircons procceded. Data collection managment was conduccted simultaneoulsy with zircon ablation spot choosing. The LA-ICP-MS uses a new Wave/Lambda Physik DUV 193 Excimer laser, with a wavelength of 193 nm. The laser has a repetition rate of 8 Hz and a fluence of ~4 J/cm$^{2.}$ When prompted the LA-ICP-MS would fire the laser beam, produced from a tungsten filament, towards the intended ablation spot. The beam width used for all the detrital samples was 35µ in diameter. As for the magmatic zircons, a beam width of 15µ was used to analyze the magmatic growth rims, and a beam width of 20µ was used to analyze the inhereted zircon cores. Once firing, the laser causes the point of contact to become super heated and enter a gaseous state (ablated). The ablated material is then transported toward the collection cups via a streem of flowing helium and argon gas. Variations in the atomic masses of the isotopes causes the differiant atoms to follow differant trajectories towards the collection cups of the mass spectrometer. The collection cups are arranged according to this trajectory (fig). Once at the collection cups, the four lead isotopes, thorium and uranium are measured as a voltage readings. During the entire procedure, the computer records two things, the first being the voltage values at the collection cups, for twelve seconds, in one second intervals. The second recording is called the blank. The blank's value is whatever voltages are measured by the collector cups when the beam is not firing, and no material is being ablated. The blank reading accounts for background within the machine, and is later subtracted from the raw values to determine the voltage values of the ablated material alone. For every sample, five standard zircons analyses were made, and again another five upon concluding. For the detrital samples, a standard analysis was conducted every 5 unknown analyses, and every 3 unknown analyses for the magmatic sample. This enables the data to be corrected for fluctuations within the machine that occur over the duration of the analyses. For each detrital sample, a total of 200 unknown zircons were analyzed, and a total of 43 unknown zircons for the magmatic sample.

Data reduction and calculation

Once collected, the raw data from the LA-ICP-MS was reduced and corrected using an excel macro provided by the University of Arizona for isotopic analysis. Upon uploading the raw data, the spreadsheet automatically accounts for and removes some error. The first 3 seconds of every analysis are disregarded by the macro to account for depth related fractionation. With the remaining 9 seconds of analysis a regression line is used to correct for depth dependent changes between $^{207}Pb/^{235}U$ and $^{206}Pb/^{238}U$. While collecting the raw data with the LA-ICP-MS a specific title was given to the analysis of each standard, this allows the spreadsheet to properly identify them upon uploading. The fluctuations among the standard population are then applied to normalize the unknown zircon values to correct for the fluctuation. The standard that was used was an SL-2 zircon, a zircon standard from Sri Lanka with an accepted standard age of 564 +/- 4 Ma, determined by ID-TIMS (Gehrels et al., 2008).

Manual observation was then necessary to further reduce the converted data to a more accurate population of analyses. Before the unknown zircons could be managed, each standard had to be inspected for abnormalities, and if necessary were discarded and replaced by a less abnormal standard, in an attempt to minimize calculation error within the unknowns. The first manual correction necessary for the unknown samples was to ensure that all the ^{204}Pb values were within acceptable parameters, ommiting all measurments with ^{204}Pb values too large (indicative of measurment error, contamintion or an abnormality in the grain). Then the $^{206}Pb/^{204}Pb$ ratios were inspected along with the U/Th ratios for abnormalities such as a low $^{206}Pb/^{204}Pb$ or very high U/Th (also indicators of measurment error, contamintion or aa abnormality in the grain). It is at this point all the standards and all the remaining uknowns were plotted on their respective concordia curves with error elipses providing a comprehensive visualization of the distribution of the zircon ages, and the uniformity of the measured standards. Using a feature of the spreadsheet, a zircon datatable was created which includes the final age calculations of the unkowns and their error along with a concordance value. Lastly from the ages and age errors from the datatable a probability distribution graph with a histogram was made for each of the samples. Using the concordia plots, the probablity distribution graph and histogram, and the datable togethor, a zircon population from each sample was able to be determined as an upper or lower age constraint.

Sample Descriptions

Southworth et al., (2002) describe the rocks of the Mather gorge formation as mostly quartz-rich schist containing minor mica, gneiss and metagraywacke, metagraywacke containing schist, migmatite and phyllonite. The Blockhouse Point domain is primarily a chlorite-sericite phyllonite ,placing it in the upper greenschist facies, while the Bear Island domain is characterized by garnet to sillimanite grade migmatic metagraywackes, placing it in the mid amphibolite facies (Southworth et al., 2006). The Laurel formation is observed by Kunk et al., (2005) as having been metamorphosed to the upper amphibolite facies. Southworth et al., (2002) describes the Laurel formation as consisting of quartz grains and fragments of meta-arenite as well as muscovite-biotite schist in a quartzofeldspathic matrix.

U/Pb Data

The zircon analyses of the Blockhouse Point domain of the Mather Gorge formation revealed a single bundle of zircon age distributions (fig 5). The age distribution of this domain is predominantly comprised of greenvilian age zircons. The age population ranged from 921 Ma +/- 35 Ma as the youngest to 1,673 Ma +/- 20 Ma. The distrubution graph is characterized by three pronounced peaks within these age ranges, with largest and most pronounced at the age of ~1.2 Ga. However based on the age populations, an uppper depositional age contsraint of the Blockhouse Point domain was interpreted to be 960 Ma. After the conclusion of the data reduction for the Blockhouse Point domain, the remainder of zircon analyses used tottaled 136 zircons. (table 2.1)

Figure 5
Blockhouse Point domain of the Mather Gorge formation

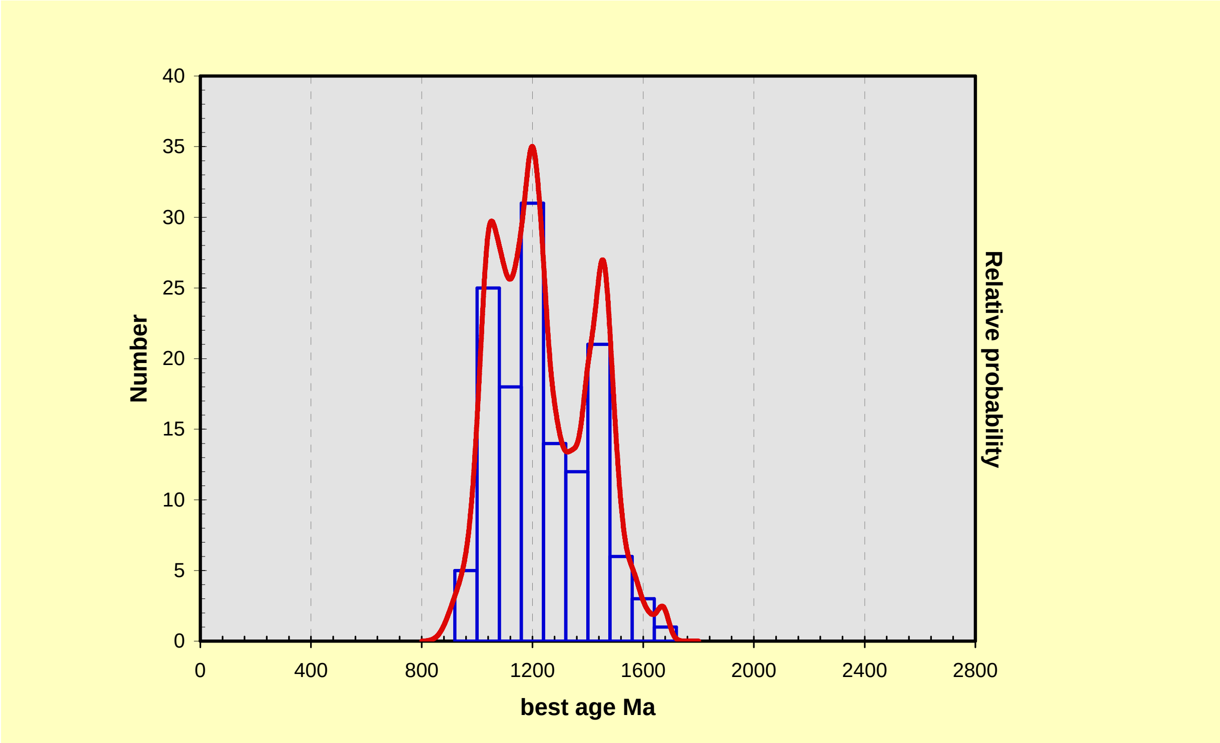
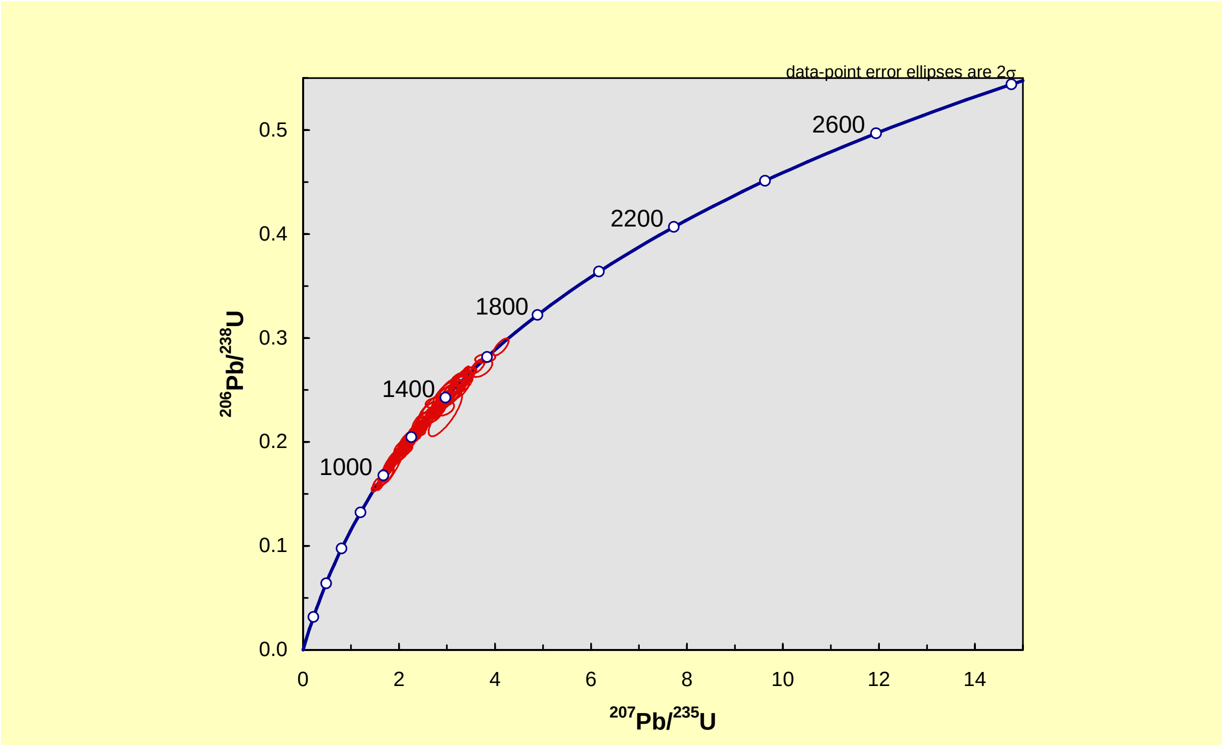
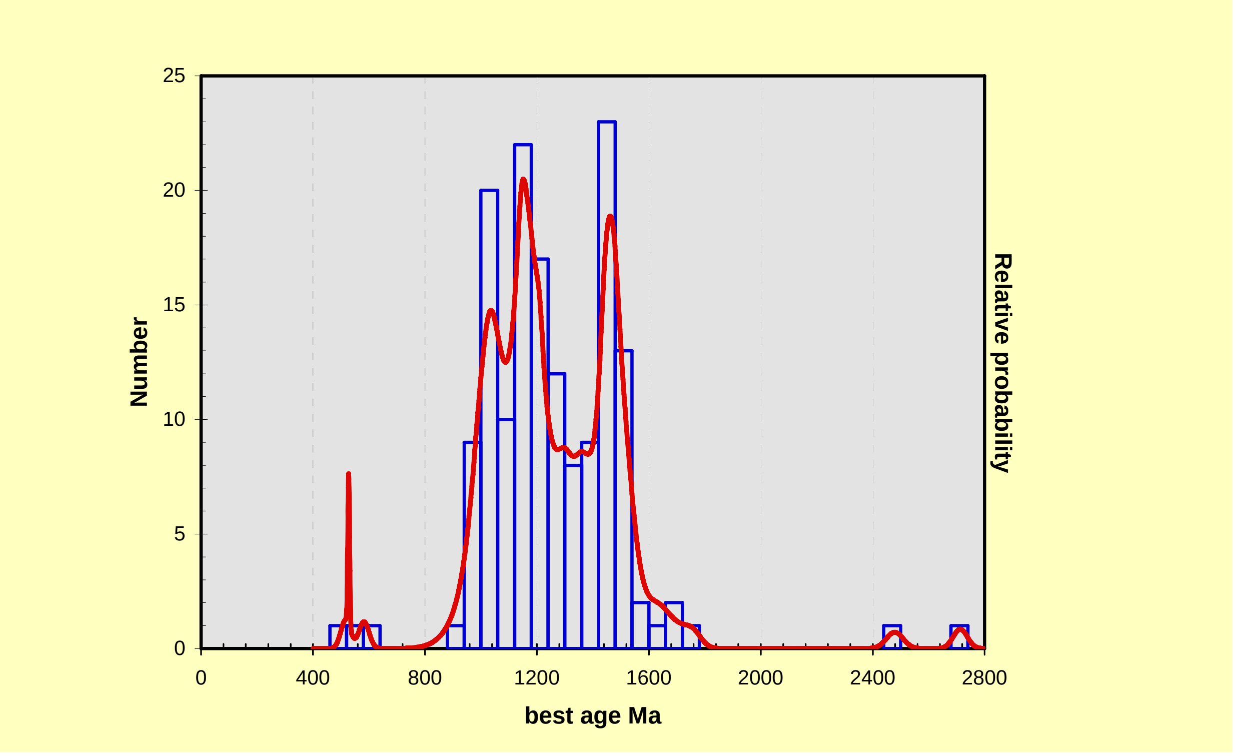


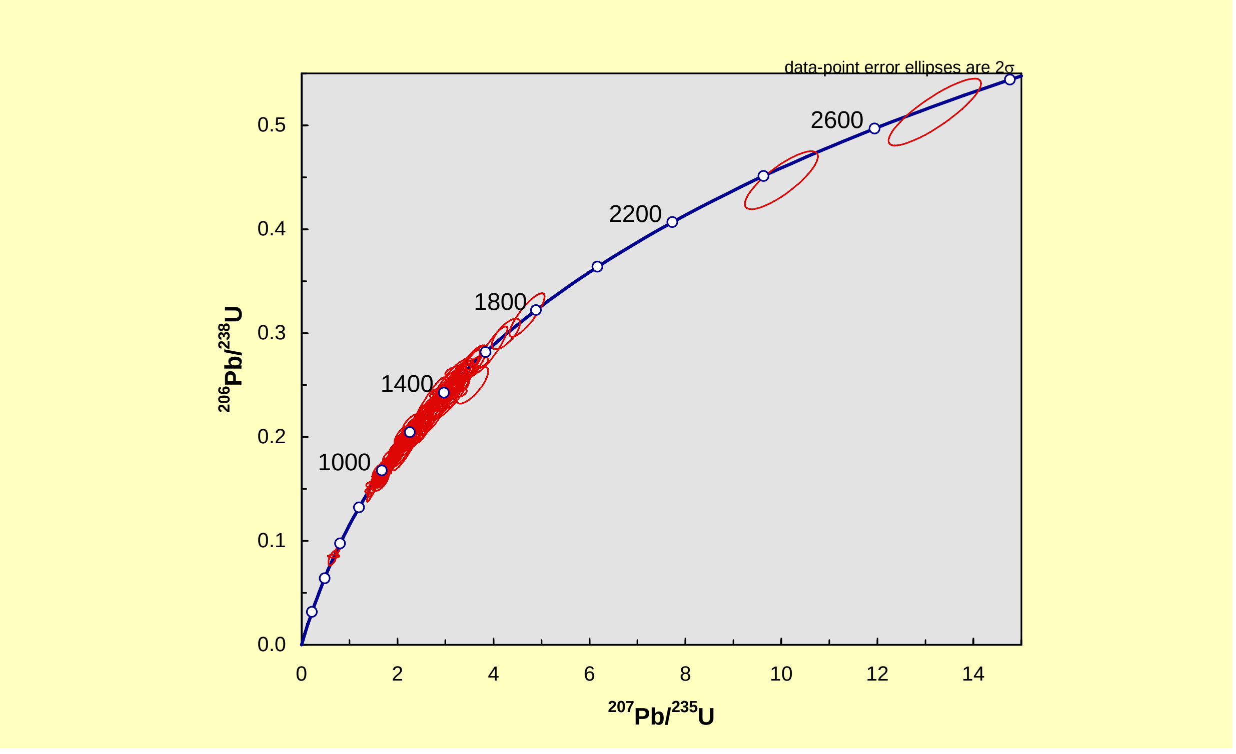
Figure 5. Continued



The zircon analyses of the Bear Island domain of the Mather Gorge Formation yielded a strickingly differant distribution of ages from its adjoining domain (fig 6). However despite the differances, there is still one pronounced similiarity in that the three-peaked zircon population is also present, and very symetrically similar. The distinction is made in the appearance of two outlying age populations, absent in the Blockhouse Point domain. The youngest age population is comprised of three differant zircons with closely matching radimetric ages. This young population also represents the upper age constraint with a interpreted age of 540 Ma. On the opposite side of the three peeked greenvilian population are two old zircons which yieleded ages of ~2,450 Ma and ~2,700 Ma. for this sample, 155 zircons analyses remained after data reduction. (table 2.2)

figure 6
Bear Island domain of the Mather Gorge formation





The zircon analyses of the Laurel Formation, similar to that of the Bear Island domain yielded an interpreted upper age constraint of 520 Ma. However the most striking similarity between the zircon analyses of the two samples is that their probability distribution graphs are nearly replicas of each other (fig 7.). The dominant three-peaked zircon population is still present with minor differances like the less pronounced youngest greenvillian peek at 1.0 Ga, as well as a slightly more protusive right peak at ~1.6 Ga. Despite these differances the similarity is still clearly evident. As experienced with the Bear Island analyses, two older outlying zircon ages were incorporated intot he final data. The ages of the older two grains were ~2,050 Ma and ~2,650 Ma, with the second very closely matching with the oldest Bear Island domain zircon of ~2,700 Ma. For this sample only 119 zircon analyses were accepted into the final calculation. (table 2.3)

Figure 7
Laurel formation

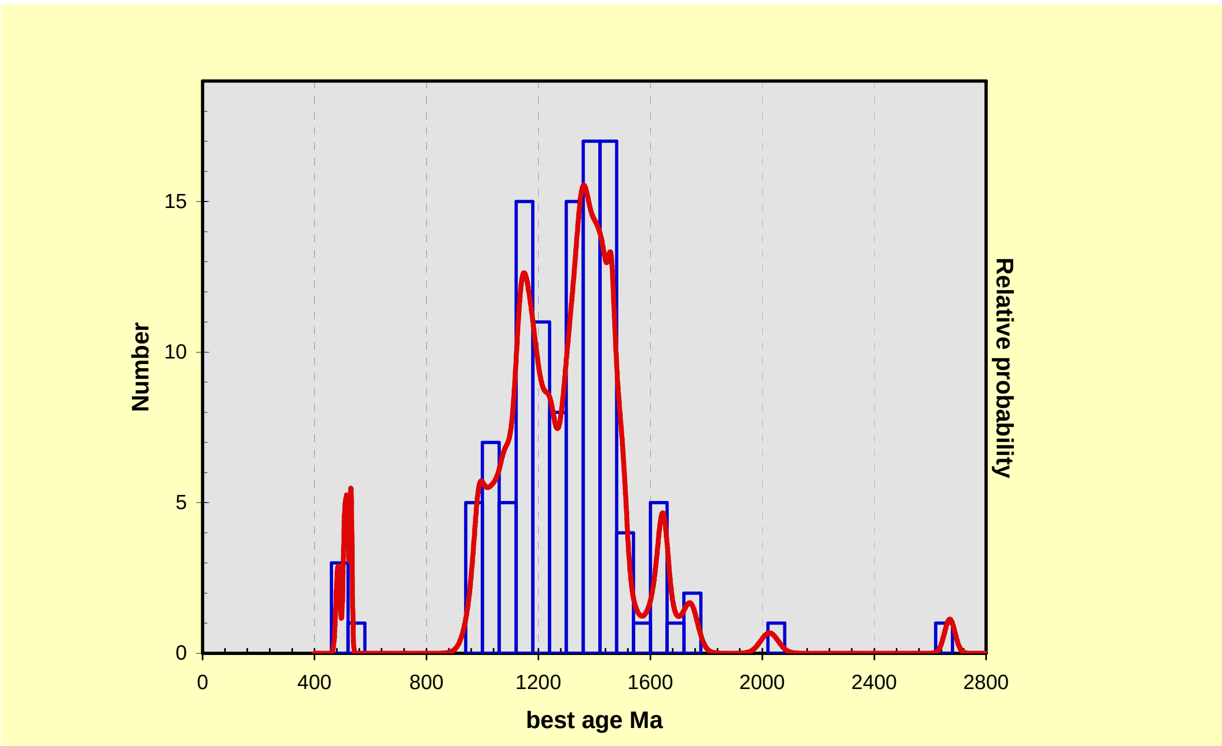
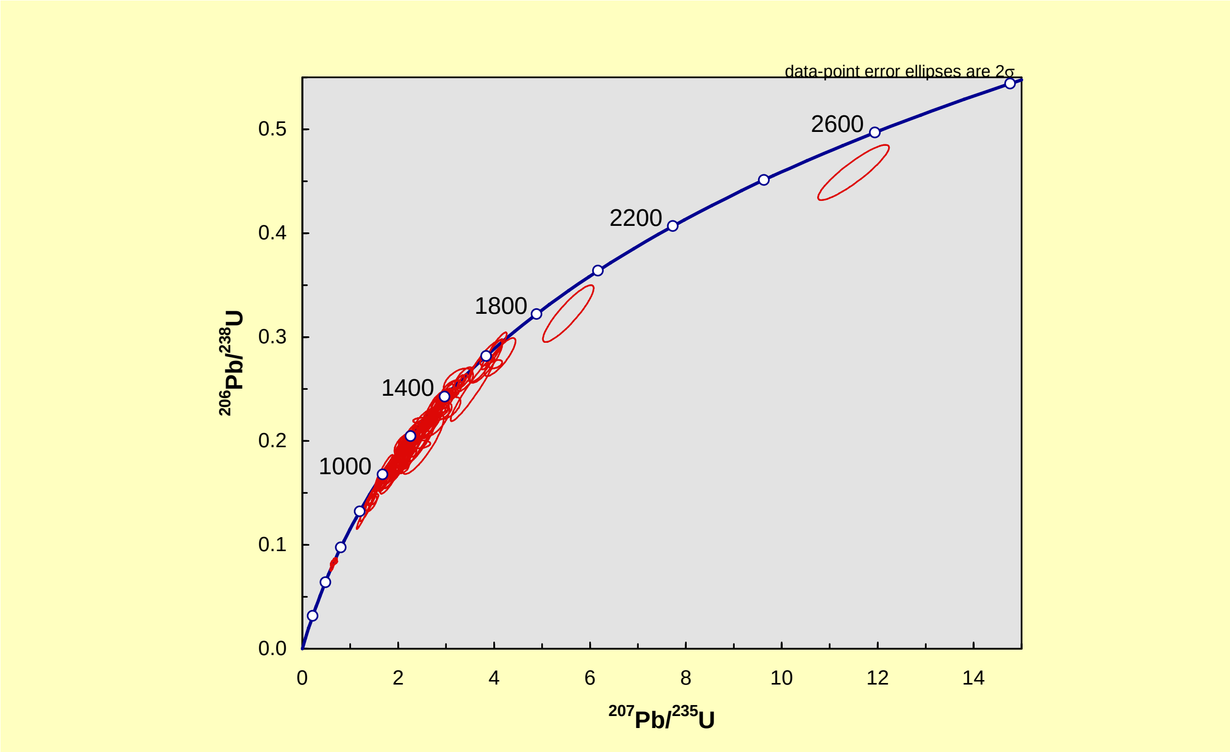
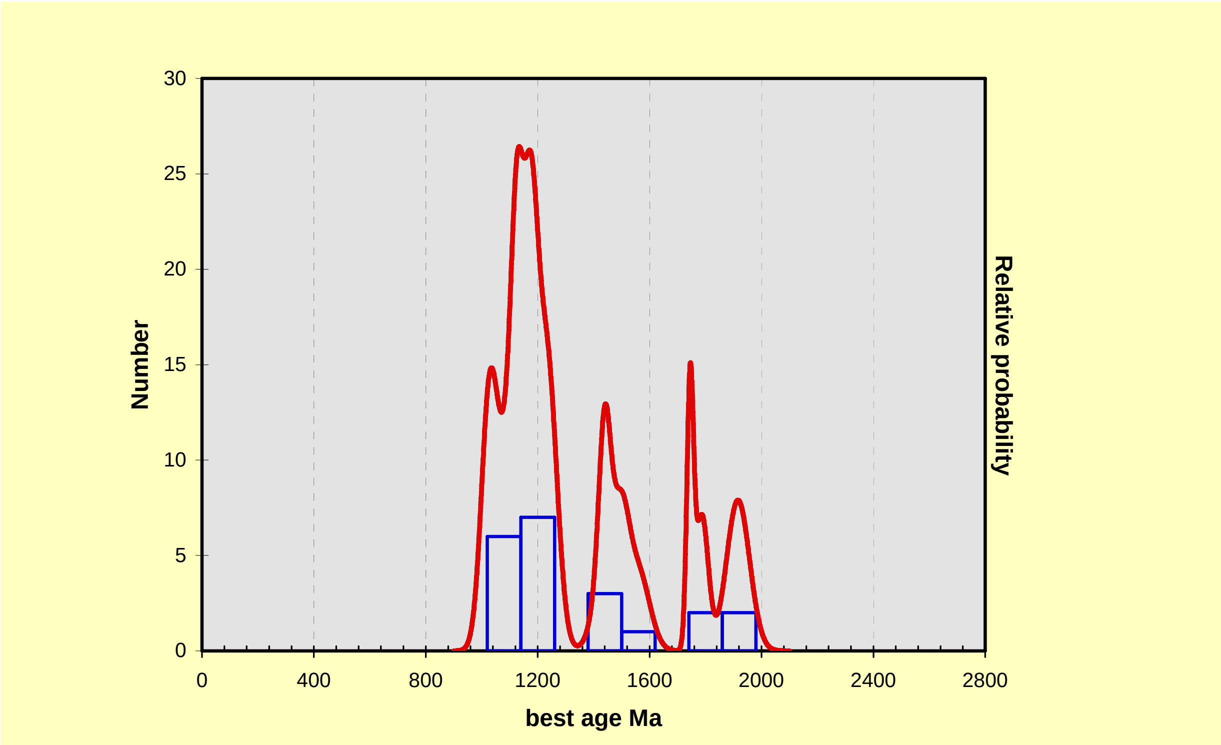


Figure 7. continued



As the only magmatic sample, the Bear Island Granodiorite analyses were much differant from the metasedimentary samples (fig 8, fig 9, fig 10). After data reduction only 20 analyses of the zircon cores remained and only 11 rim analyses were accepted, and of those 11 only 2 magmatic growth rim analyses of the BIG were used to interpret a lower age constraint for the Bear Island domain. The interpretated lower age constraint for the Bear Island domain is 440 Ma. The two analyses with which the constraint was determined were both concordant, and overlapped each other within error. The core analyses were conducted to provide data to demonstrate that the zircons extracted, and analyzed from the Granodiorite sample were in actuallity inherited zircons of the Bear Island domain, and not igneous zircons. Despite only 20 core measurments the three-peaked presence is still recognizable and confirms the successful extraction of inherated detrital zircons from the granodiorite. (table 2.4, 2.5)

Figure 8
Bear Island granodiorite intruding the Bear Island domain of the Mather Gorge formation
Zircon cores



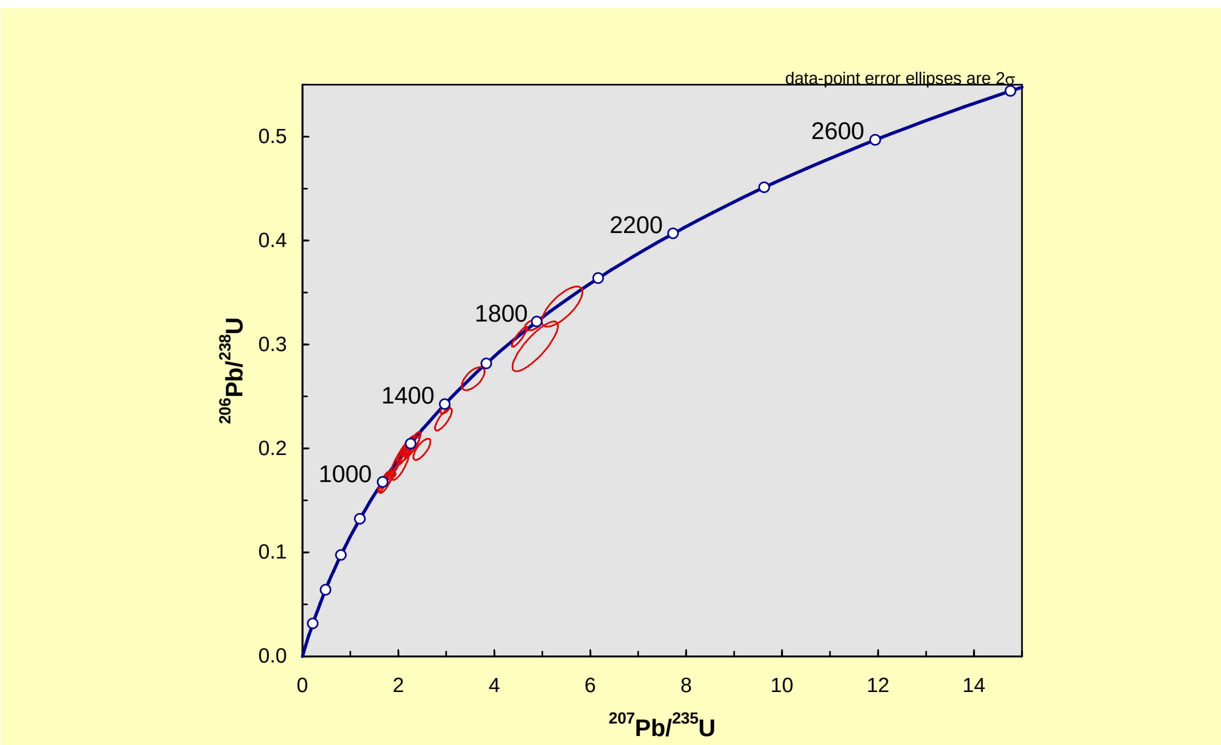
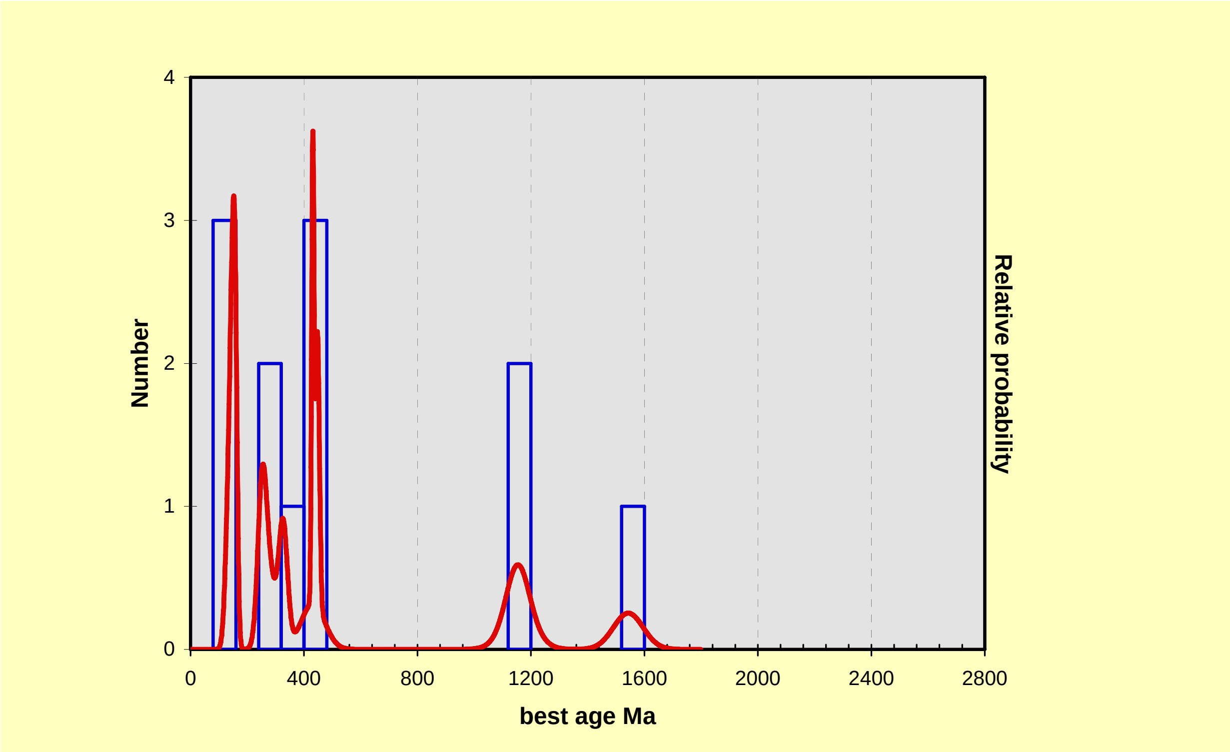


figure 9.
Bear Island granodiorite intruding the Bear Island domain of the Mather Gorge formation
Zircon rims



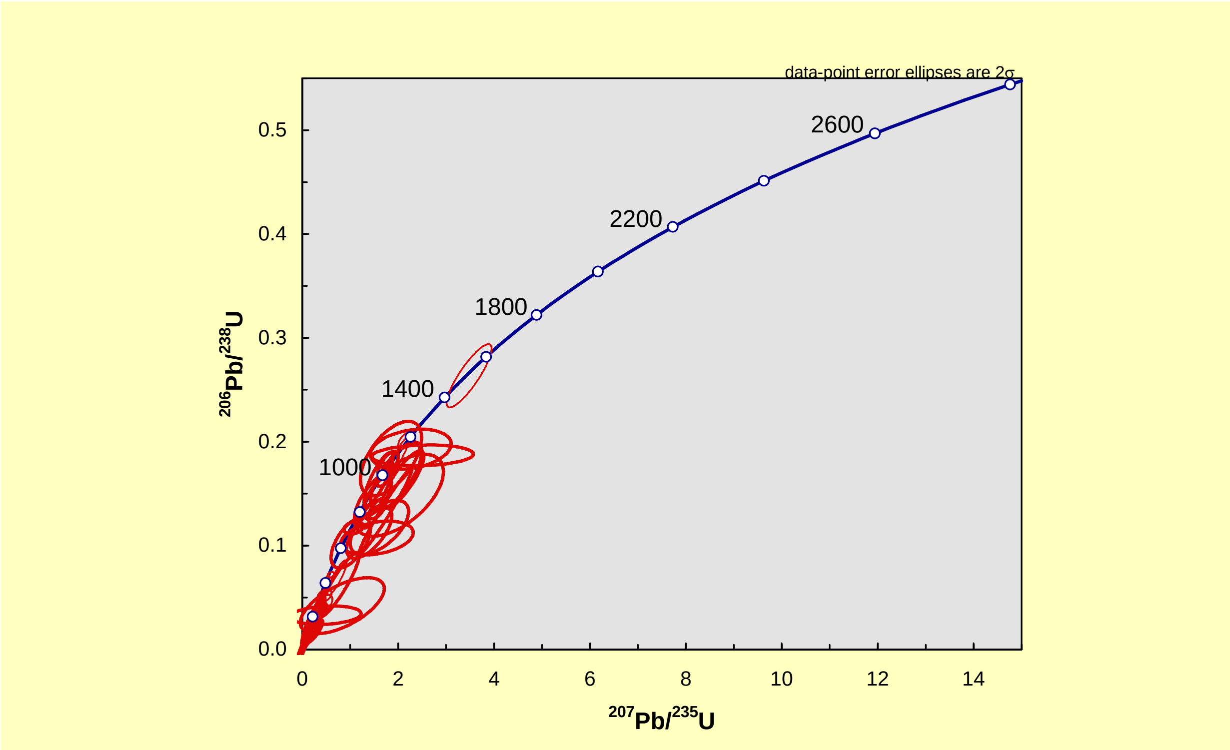
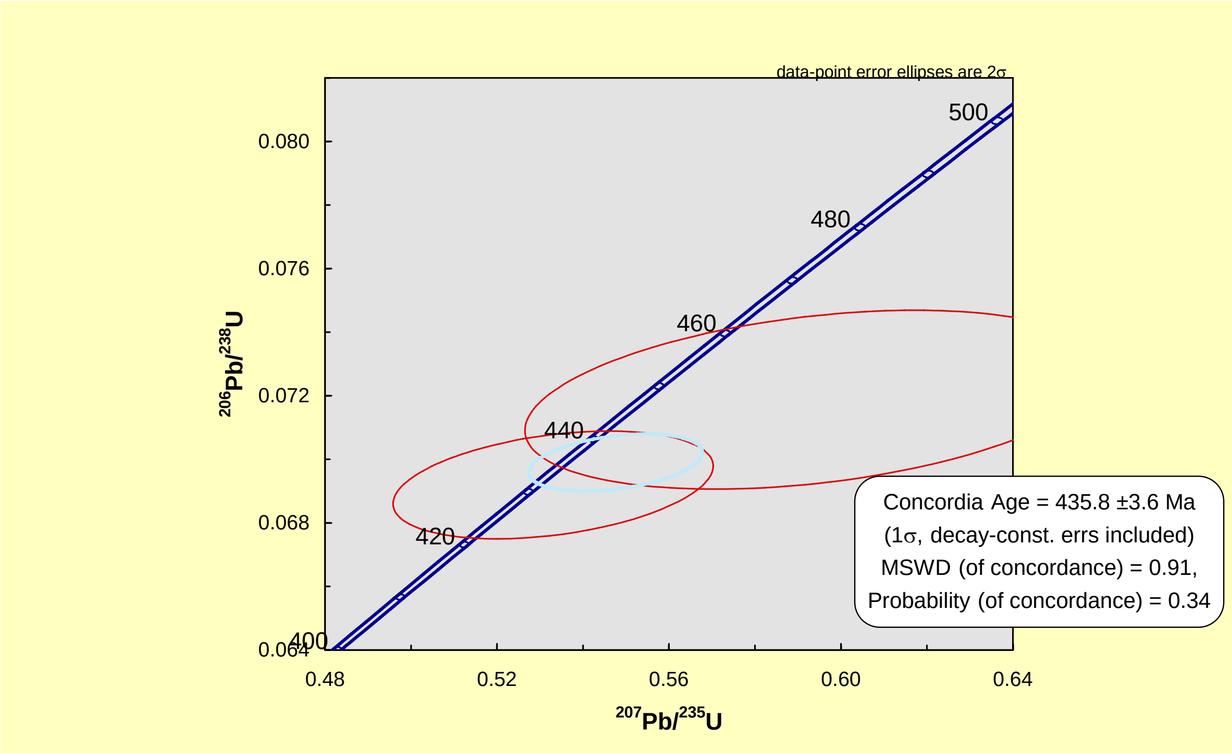


Figure 10
Bear Island Granodiorite (rim)
Lower depositional constraint ages



Implications and discussion.

The results of the Laurel Formation analyses and the Bear Island domain analyses both provided tight constraints of 520 Ma and 540 Ma respectively. However what makes the young ages important is that after data reduction, both samples retained at least three of the young results with the similar ages, which greatly increases the probability that the resulting ages are in fact a credible constraint age. The results from the Blockhouse Point domain did not yield a tight constraint, but nonetheless provided an upper depositional constraint age of 940 Ma.

In reviewing the probability distribution graphs from each of the samples, an interesting pattern becomes evident. Both the graph for the Laurel fm. and the graph of the Bear Island domain have a similar distribution of similarly aged peaks. The Blockhouse Point domain is not nearly as close in resemblance, but its three graph spikes at ~1050 Ma, ~1200 Ma, and ~1450 Ma do still appear to correlate.

There are implications to the findings of two closely correlating samples and a third different sample age distribution. The implications however mostly stem from the separation of the Laurel fm. and the Bear Island domain by the Sykesville Fm. and the proximity of the two Mather Gorge domains and their different probability distribution graphs. However on the other hand if the Sykesville did not yield a probability density graph similar to its eastern and western partners then it would imply that the modern surface separation of the Bear Island domain and the Laurel formation is not representative of their original relation to each other.

One of the other Implications of the Data resulting from the analyses is that the Blockhouse Point domain and the Bear Island domain are unified in the Mather Gorge Formation under false pretences, and that they are only related in modern geographic proximity. Further study of detrital zircons of the Marburg Formation, directly to the west of the domains could provide evidence into the proper placement of the Blockhouse Point domain if the Marburg Fm. probability density distribution graph matched that of the Blockhouse Point domain in the way that the Laurel Formation and the Bear Island domain do.

While analyzing the crystallization rims of the Bear Island Granodiorite, a number of inherited cores were analyzed to demonstrate that zircons from the Bear Island domain survived incorporation into the granodiorite, and that the zircons being analyzed contained inherited zircon core from the Bear Island domain. The confirmation that the cores of the Bear Island Granodiorite magmatic zircons are actually inherited Bear Island domain detrital zircons signifies that any magmatic growth zone age(s) of the BIG are indicative of a lower depositional age constraint for the Bear Island domain.

However there is the possibility that the zircons that yielded the young ages in the Bear Island domain and the Laurel formation were metamorphic and do not provide an upper age constraint for deposition. This possible explanation appears unlikely when considering that the Laurel fm and the Bear Island domain experienced slightly differently grades of metamorphism, and the discrepancies of muscovite cooling ages between the Blockhouse Point domain and the Bear Island domain, as well as the proposed fault dividing the two domains by authors such as Kunk et al., (2005). All things considered, the absence of the young zircon population in the Blockhouse Point domain analyses is more likely indicative of its individuality from the other two units than it is of the young population being metamorphic. Further supporting this is the presence and age similarity of the much older populations of outlying zircons that appear in both the Bear Island domain and Laurel form. The old outlying population indicates that the sediment source of both units may likely have been linked, or the same. This demonstrates that the two units would not have needed to experience closely timed metamorphic zircon growth in order to have matching age population distributions. The most compelling argument that the young populations zircon are not metamorphic is their concordance. Upon metamorphism diffusion resulting in lead loss can often result in a discordant age between the $^{207}Pb/^{235}U$ and $^{206}Pb/^{238}U$ ages (Lee et al., 1997). As is shown in the datatables and the concordia plots, only 2 of the 6 young grains that comprise the two young populations are slightly discordant. All things considered, there is a high likelyhood that the two young age populations are in actuallity upper depositonal age constraints and are not relicts of metamorphism.

Conclusion

In summation, Using the LA-ICP-MS at the University of Arizona’s LaserChron center to obtain U/Pb radiometric measurements of the detrital zircons of three metasedimentary units and one magmatic unit of the Potomac terrane resulted in success in determining three upper depositional age constraints and a lower depositional age constraint. The Laurel formation analyses and the Bear Island domain analyses both provided tight constraints of 520 Ma and 540 Ma respectively, the Blockhouse Point domain yielded a constraint of 940 Ma, and lastly the Magmatic crystallization rims of the Bear Island Granodiorite resulted in a lower age constraint for the Bear Island domain of 440 Ma. It is now possible to further the construction of the deposition and burial curve that precedes the developed cooling curve constructed by previous scientific studies, further progressing the ever-evolving geologic understanding of the Potomac terrane and the Appalachian Mountains.

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Table 1.1

Sample Name	orientations	Collection site coordinates	Rock
Blockhouse Point domain	Foliation 198˚, 10˚SE	39.05819˚N 77.33440˚W	Phyllonite
Bear Island domain	Foliation 190˚, 38˚SE	N38˚ 59. 203 W077˚ 14.876’	Metaquartzite
Laurel Formation	Foliation 194˚,84˚NW	39.02996˚N 77.00382˚W	Melange
Bear Island Granodiorite	Limb 1: 207˚, 84˚SW Limb 2: 222˚, 43˚NW	38.98306˚N 77.23048˚W	Granodiorite

Table 2.1 Blockhouse Point domain of the Mather Gorge formation

U (ppm)	206Pb 204Pb	207Pb* 235U*	± (%)	206Pb* 238U	± (%)	error corr.	206Pb* 238U*	± (Ma)	207Pb* 235U	± (Ma)	206Pb* 207Pb*	± (Ma)	Best age (Ma)	± (Ma)	Conc (%)
51	4810	1.4986	1.9	0.1558	0.9	0.48	933	8	930	12	921	35	921	35	101.3
112	10849	1.5436	2.3	0.1600	1.3	0.59	957	12	948	14	928	38	928	38	103.1
102	6080	1.5458	1.9	0.1573	0.7	0.36	942	6	949	12	965	37	965	37	97.6
152	14119	1.7042	1.9	0.1717	0.7	0.36	1022	7	1010	12	985	37	985	37	103.7
87	5221	1.7155	2.0	0.1718	0.5	0.24	1022	5	1014	13	998	40	998	40	102.4
212	16970	1.7463	1.4	0.1734	0.5	0.38	1031	5	1026	9	1015	26	1015	26	101.5
197	18887	1.6909	2.5	0.1676	1.7	0.68	999	16	1005	16	1018	37	1018	37	98.1
204	11249	1.7999	3.0	0.1776	2.1	0.70	1054	21	1045	20	1028	43	1028	43	102.5
83	7437	1.7791	2.1	0.1754	0.5	0.23	1042	5	1038	14	1029	42	1029	42	101.2
273	29968	1.6802	3.4	0.1657	2.9	0.86	988	27	1001	22	1030	36	1030	36	96.0
94	9331	1.7511	2.3	0.1724	0.9	0.41	1025	9	1028	15	1033	42	1033	42	99.3
1068	55293	1.7912	2.8	0.1763	2.3	0.82	1047	22	1042	18	1033	32	1033	32	101.4
767	9928	1.6699	2.6	0.1642	1.5	0.58	980	14	997	17	1035	43	1035	43	94.6
989	78663	1.7305	1.6	0.1700	0.8	0.46	1012	7	1020	11	1037	29	1037	29	97.6
192	24763	1.7746	1.7	0.1743	1.1	0.64	1036	11	1036	11	1037	27	1037	27	99.9
145	18844	1.7943	2.2	0.1759	1.1	0.51	1045	11	1043	14	1041	39	1041	39	100.4
572	14619	1.8014	2.0	0.1765	1.7	0.87	1048	16	1046	13	1042	19	1042	19	100.6
347	28486	1.7383	2.0	0.1703	1.7	0.84	1014	16	1023	13	1043	22	1043	22	97.2
281	35104	1.8094	2.0	0.1772	1.1	0.56	1051	11	1049	13	1044	34	1044	34	100.8
210	11209	1.8016	2.4	0.1763	1.3	0.54	1047	13	1046	16	1045	41	1045	41	100.2
246	19076	1.8450	2.3	0.1801	1.2	0.53	1068	12	1062	15	1049	40	1049	40	101.7
113	14104	1.8446	3.4	0.1801	2.6	0.75	1067	25	1062	22	1050	45	1050	45	101.7
607	11525	1.8136	2.6	0.1768	1.6	0.63	1050	16	1050	17	1052	40	1052	40	99.8
306	39749	1.8117	2.2	0.1766	1.1	0.47	1048	10	1050	15	1052	40	1052	40	99.6
279	17604	1.8869	1.9	0.1833	1.0	0.53	1085	10	1077	13	1059	32	1059	32	102.4
1245	10191	1.7621	2.0	0.1711	1.5	0.78	1018	15	1032	13	1060	25	1060	25	96.1
147	16539	1.8858	2.6	0.1830	1.6	0.61	1083	16	1076	17	1061	42	1061	42	102.1
209	21888	1.8716	2.5	0.1815	1.4	0.54	1075	14	1071	17	1063	42	1063	42	101.2
761	7011	1.7485	3.3	0.1686	2.3	0.70	1004	22	1027	22	1075	48	1075	48	93.4
677	63684	1.9160	1.1	0.1846	0.5	0.44	1092	5	1087	8	1076	21	1076	21	101.5
694	12211	1.8776	1.6	0.1802	1.2	0.74	1068	12	1073	11	1084	22	1084	22	98.5
566	23194	1.8821	1.7	0.1802	1.1	0.66	1068	11	1075	11	1088	25	1088	25	98.2
320	20772	1.9796	1.9	0.1895	0.9	0.46	1119	9	1109	13	1088	34	1088	34	102.8
175	18671	1.8995	2.0	0.1808	0.8	0.40	1071	8	1081	13	1100	36	1100	36	97.4
416	33146	1.9392	1.3	0.1845	0.7	0.53	1092	7	1095	8	1101	21	1101	21	99.1
183	8117	2.0029	2.8	0.1902	2.4	0.84	1122	24	1116	19	1105	30	1105	30	101.5
404	18676	1.9587	1.8	0.1852	1.3	0.75	1096	13	1101	12	1113	23	1113	23	98.4
63	6610	2.0226	1.8	0.1906	1.0	0.55	1125	10	1123	13	1120	31	1120	31	100.4
88	5741	2.0640	3.2	0.1940	1.6	0.49	1143	16	1137	22	1126	56	1126	56	101.5

894	26475	2.0420	2.2	0.1918	1.9	0.85	1131	20	1130	15	1127	23	1127	23	100.3
318	30718	2.0517	1.7	0.1926	0.5	0.30	1135	5	1133	11	1128	31	1128	31	100.6
515	12783	2.0341	2.5	0.1909	1.1	0.42	1126	11	1127	17	1128	45	1128	45	99.8
493	9269	1.9461	4.6	0.1808	4.4	0.94	1071	43	1097	31	1149	31	1149	31	93.3
92	12205	2.1287	2.8	0.1975	0.8	0.28	1162	9	1158	19	1151	54	1151	54	101.0
189	10183	2.1314	2.2	0.1976	1.6	0.70	1163	17	1159	15	1152	32	1152	32	100.9
468	25970	2.1468	1.2	0.1990	0.5	0.42	1170	6	1164	8	1153	22	1153	22	101.5
99	12233	2.1649	2.3	0.2001	1.2	0.51	1176	13	1170	16	1158	39	1158	39	101.5
567	10103	2.0925	3.1	0.1934	2.5	0.82	1140	26	1146	21	1159	35	1159	35	98.3
818	9229	2.1623	1.8	0.1997	0.9	0.49	1174	9	1169	12	1160	31	1160	31	101.1
269	34287	2.1882	1.6	0.2017	0.5	0.31	1184	5	1177	11	1164	30	1164	30	101.7
120	10662	2.2025	1.8	0.2030	0.9	0.48	1191	9	1182	13	1165	31	1165	31	102.3
81	8728	2.1016	3.5	0.1933	2.5	0.72	1139	26	1149	24	1168	48	1168	48	97.6
87	11577	2.0652	2.8	0.1900	0.7	0.26	1121	7	1137	19	1168	54	1168	54	96.0
141	6928	2.1716	2.4	0.1992	1.7	0.73	1171	19	1172	16	1174	32	1174	32	99.7
130	16593	2.1792	3.4	0.1999	1.8	0.54	1175	20	1174	23	1174	56	1174	56	100.0
734	11098	2.2268	3.0	0.2033	1.3	0.43	1193	14	1190	21	1183	54	1183	54	100.8
71	6786	2.2577	2.4	0.2060	0.8	0.35	1208	9	1199	17	1184	44	1184	44	102.0
404	22955	2.2380	1.7	0.2042	1.2	0.71	1198	13	1193	12	1185	24	1185	24	101.1
144	18540	2.1923	1.9	0.1999	0.5	0.27	1175	5	1179	13	1186	36	1186	36	99.0
301	7718	2.2694	2.6	0.2068	1.8	0.69	1212	20	1203	18	1187	37	1187	37	102.1
601	41482	2.1996	3.0	0.2003	1.7	0.58	1177	19	1181	21	1188	48	1188	48	99.1
92	4963	2.1260	3.0	0.1934	1.1	0.39	1140	12	1157	20	1190	54	1190	54	95.8
733	65587	2.2557	1.5	0.2049	1.2	0.79	1201	13	1199	10	1193	18	1193	18	100.7
81	6369	2.2400	2.2	0.2033	1.2	0.54	1193	13	1194	16	1195	37	1195	37	99.8
154	20523	2.1785	2.2	0.1973	0.9	0.42	1161	10	1174	15	1199	39	1199	39	96.9
123	8180	2.2592	1.7	0.2046	0.9	0.54	1200	10	1200	12	1199	28	1199	28	100.1
339	13906	2.2476	1.4	0.2031	1.0	0.70	1192	11	1196	10	1203	19	1203	19	99.0
431	21218	2.3108	2.7	0.2083	1.8	0.67	1220	20	1216	19	1208	40	1208	40	101.0
724	54060	2.2918	1.7	0.2064	0.9	0.52	1209	9	1210	12	1210	28	1210	28	99.9
794	51290	2.2681	2.0	0.2042	1.4	0.68	1198	15	1202	14	1210	29	1210	29	99.0
526	13303	2.2827	2.1	0.2052	1.8	0.84	1203	20	1207	15	1214	23	1214	23	99.2
205	5045	2.3260	2.0	0.2085	0.5	0.25	1221	6	1220	14	1219	37	1219	37	100.1
244	17089	2.2929	2.9	0.2051	2.7	0.93	1203	30	1210	21	1223	21	1223	21	98.3
176	36038	2.3005	2.9	0.2056	1.2	0.39	1205	13	1212	21	1225	53	1225	53	98.3
385	43323	2.3597	2.0	0.2105	0.9	0.44	1232	10	1230	15	1228	36	1228	36	100.3
57	5778	2.3643	2.0	0.2102	1.1	0.56	1230	13	1232	14	1235	33	1235	33	99.6
424	27207	2.3827	1.0	0.2117	0.5	0.48	1238	6	1237	7	1237	18	1237	18	100.1
55	9680	2.4618	3.2	0.2185	1.9	0.60	1274	22	1261	23	1239	50	1239	50	102.8
266	18857	2.3732	2.0	0.2105	0.5	0.26	1232	6	1235	14	1240	38	1240	38	99.3
155	17790	2.4298	2.0	0.2145	1.3	0.66	1253	15	1251	14	1249	29	1249	29	100.3
205	20991	2.5072	1.9	0.2209	0.5	0.26	1287	6	1274	14	1253	37	1253	37	102.7
47	7487	2.4728	2.8	0.2179	1.9	0.68	1271	22	1264	21	1253	41	1253	41	101.4
166	6848	2.3672	3.0	0.2085	0.6	0.20	1221	7	1233	22	1254	58	1254	58	97.4
273	6908	2.4517	1.9	0.2154	1.0	0.54	1257	12	1258	14	1259	32	1259	32	99.9
402	16632	2.4200	3.0	0.2124	1.5	0.51	1241	17	1249	21	1261	50	1261	50	98.5

304	14647	2.5770	4.3	0.2246	3.5	0.82	1306	42	1294	32	1274	48	1274	48	102.5
270	30054	2.4012	2.3	0.2086	1.7	0.76	1221	19	1243	16	1281	29	1281	29	95.4
129	14533	2.4729	1.8	0.2139	1.2	0.69	1249	14	1264	13	1289	25	1289	25	96.9
95	9001	2.5625	2.1	0.2194	0.9	0.40	1279	10	1290	16	1309	38	1309	38	97.7
207	11567	2.6013	2.0	0.2222	1.2	0.59	1294	14	1301	14	1313	30	1313	30	98.5
53	5790	2.6725	3.9	0.2280	2.0	0.51	1324	24	1321	29	1316	66	1316	66	100.7
700	62889	2.6927	1.9	0.2296	0.8	0.42	1333	10	1326	14	1317	34	1317	34	101.2
141	7720	2.7929	3.5	0.2378	0.9	0.26	1375	11	1354	26	1320	65	1320	65	104.2
211	43467	2.7246	3.6	0.2306	1.5	0.40	1338	18	1335	27	1331	64	1331	64	100.5
166	21517	2.7911	1.7	0.2349	1.3	0.77	1360	16	1353	13	1342	22	1342	22	101.3
392	12268	2.7377	1.8	0.2302	0.8	0.46	1336	10	1339	13	1343	31	1343	31	99.4
76	9675	2.7735	2.5	0.2306	1.5	0.58	1338	18	1348	19	1365	40	1365	40	98.0
178	6200	2.7220	2.3	0.2253	1.1	0.50	1310	14	1334	17	1375	38	1375	38	95.3
224	40538	2.8478	2.8	0.2349	1.8	0.64	1360	22	1368	21	1381	41	1381	41	98.5
198	27998	2.8592	1.9	0.2358	0.9	0.49	1365	11	1371	14	1381	31	1381	31	98.8
114	12334	2.9544	3.7	0.2433	2.4	0.66	1404	31	1396	28	1384	53	1384	53	101.4
106	15378	2.8390	2.3	0.2332	1.8	0.79	1351	22	1366	17	1389	28	1389	28	97.3
644	15892	2.7981	2.1	0.2294	1.3	0.60	1331	15	1355	16	1393	33	1393	33	95.6
338	17794	2.9575	1.2	0.2418	0.7	0.63	1396	9	1397	9	1398	18	1398	18	99.9
581	20640	2.9512	2.3	0.2413	1.4	0.59	1393	17	1395	17	1398	35	1398	35	99.7
149	15594	2.9940	1.4	0.2438	0.7	0.52	1406	9	1406	11	1406	23	1406	23	100.0
280	6278	3.0109	3.4	0.2441	1.9	0.56	1408	24	1410	26	1414	54	1414	54	99.6
305	32131	2.9321	1.3	0.2372	0.7	0.52	1372	9	1390	10	1418	22	1418	22	96.7
877	10482	2.9768	1.9	0.2392	1.4	0.76	1383	18	1402	14	1431	23	1431	23	96.6
87	14504	3.0734	2.0	0.2458	1.4	0.68	1417	17	1426	16	1440	28	1440	28	98.4
109	13118	3.0680	2.3	0.2448	2.0	0.86	1412	25	1425	17	1444	22	1444	22	97.7
200	6536	3.0915	3.1	0.2463	2.0	0.64	1419	25	1431	24	1448	46	1448	46	98.0
176	26341	3.1479	2.9	0.2506	2.7	0.92	1442	35	1444	23	1448	22	1448	22	99.5
370	24417	3.1128	1.6	0.2478	0.9	0.58	1427	12	1436	12	1449	25	1449	25	98.5
67	9721	3.1565	3.9	0.2511	1.9	0.49	1444	25	1447	30	1450	65	1450	65	99.5
238	18663	3.2739	1.9	0.2595	0.9	0.45	1487	12	1475	15	1457	33	1457	33	102.1
91	13729	3.1970	1.8	0.2530	1.0	0.53	1454	12	1456	14	1460	29	1460	29	99.6
68	9779	3.2544	2.6	0.2575	2.4	0.92	1477	32	1470	20	1460	19	1460	19	101.2
351	25331	3.2219	2.4	0.2541	1.5	0.62	1459	19	1462	18	1467	35	1467	35	99.5
225	23391	3.2657	1.7	0.2572	1.1	0.61	1476	14	1473	13	1469	26	1469	26	100.5
107	7811	3.2459	2.4	0.2554	1.6	0.64	1466	21	1468	19	1471	35	1471	35	99.7
219	27410	3.2231	1.6	0.2536	0.9	0.55	1457	11	1463	12	1471	25	1471	25	99.0
281	47746	3.2692	2.6	0.2572	2.0	0.76	1475	26	1474	20	1472	32	1472	32	100.2
167	18888	3.3102	2.7	0.2603	1.1	0.39	1492	14	1483	21	1472	48	1472	48	101.3
176	20415	3.2048	2.2	0.2520	0.6	0.26	1449	7	1458	17	1473	39	1473	39	98.4
111	19798	3.2939	2.7	0.2582	1.8	0.65	1480	23	1480	21	1478	39	1478	39	100.1
77	7152	2.9734	2.4	0.2318	1.1	0.47	1344	14	1401	18	1489	40	1489	40	90.3
178	15873	3.2970	3.0	0.2566	1.7	0.55	1472	22	1480	23	1492	47	1492	47	98.7
279	26855	3.3902	2.0	0.2636	0.7	0.33	1508	9	1502	16	1494	36	1494	36	100.9
200	16055	3.3777	2.4	0.2625	1.4	0.58	1503	19	1499	19	1494	37	1494	37	100.6
142	12760	3.4554	1.9	0.2670	0.8	0.40	1526	10	1517	15	1505	32	1505	32	101.4

306	5649	2.9662	4.8	0.2268	3.9	0.80	1318	46	1399	36	1525	54	1525	54	86.4
331	18477	3.6458	1.6	0.2729	1.0	0.65	1555	14	1560	13	1565	23	1565	23	99.4
106	15817	3.7952	2.3	0.2804	0.6	0.27	1594	9	1592	18	1589	41	1589	41	100.3
304	14622	3.7219	2.4	0.2709	1.3	0.52	1545	17	1576	19	1617	39	1617	39	95.5
354	16497	4.1252	1.6	0.2914	1.1	0.72	1649	16	1659	13	1673	20	1673	20	98.5

Table 2.2 Bear Island domain of the Mather Gorge formation

U (ppm)	206Pb 204Pb	207Pb* 235U*	± (%)	206Pb* 238U	± (%)	error corr.	206Pb* 238U*	± (Ma)	207Pb* 235U	± (Ma)	206Pb* 207Pb*	± (Ma)	Best age (Ma)	± (Ma)	Conc (%)
193	12154	1.9053	3.2	0.1791	2.1	0.64	1062	20	1083	21	1126	49	517	17	94.3
108	5830	0.6690	7.3	0.0853	0.6	0.09	528	3	520	30	488	160	528	3	108.2
242	23628	3.1244	2.6	0.2399	1.9	0.72	1386	23	1439	20	1518	34	582	18	91.3
104	8763	1.4312	3.0	0.1484	0.7	0.23	892	6	902	18	927	59	927	59	96.2
82	7980	1.5020	4.1	0.1542	0.9	0.21	925	8	931	25	947	83	947	83	97.6
197	6141	1.8012	1.5	0.1750	0.5	0.34	1039	5	1046	10	1060	28	953	46	98.1
98	9730	1.6446	4.2	0.1663	2.1	0.51	992	20	987	26	978	73	978	73	101.4
351	37049	3.2677	2.1	0.2568	1.9	0.89	1474	25	1473	16	1473	18	981	37	100.0
73	7168	1.6533	2.2	0.1667	0.9	0.40	994	8	991	14	984	42	984	42	101.0
675	10722	1.4784	3.3	0.1487	3.0	0.93	894	25	922	20	989	25	989	25	90.4
174	17183	2.6264	3.1	0.2255	2.9	0.94	1311	35	1308	23	1304	21	996	38	100.6
100	18193	1.5598	2.6	0.1562	1.1	0.40	935	9	954	16	998	49	998	49	93.7
127	12969	2.3975	3.1	0.2122	2.1	0.69	1241	24	1242	22	1244	44	1000	22	99.7
148	16048	1.6231	3.8	0.1620	0.5	0.13	968	4	979	24	1004	77	1004	77	96.4
205	24878	1.7086	2.4	0.1698	1.4	0.56	1011	13	1012	16	1013	41	1013	41	99.8
108	6135	1.6630	4.0	0.1650	3.0	0.74	984	27	995	25	1017	54	1017	54	96.8
90	5549	3.0870	2.7	0.2473	1.7	0.63	1425	21	1429	20	1437	40	1021	46	99.2
300	16999	4.6986	3.2	0.3173	2.7	0.85	1777	42	1767	27	1756	31	1022	28	101.2
175	15445	1.6500	3.8	0.1633	1.2	0.30	975	10	990	24	1022	74	1022	74	95.4
95	9973	2.8725	3.0	0.2382	2.5	0.85	1378	31	1375	23	1370	31	1027	24	100.5
409	49533	1.7492	1.1	0.1725	0.5	0.47	1026	5	1027	7	1028	19	1028	19	99.8
100	8221	2.0460	4.2	0.1926	3.6	0.84	1136	37	1131	29	1122	45	1031	44	101.2
107	12295	1.6842	4.6	0.1657	0.5	0.11	988	5	1003	29	1034	92	1034	92	95.6
198	17915	1.6434	2.6	0.1616	0.8	0.31	966	7	987	16	1035	50	1035	50	93.3
197	19660	1.6637	2.2	0.1635	0.5	0.23	976	5	995	14	1036	43	1036	43	94.3
118	10993	1.7767	3.0	0.1742	1.0	0.32	1035	9	1037	20	1040	58	1040	58	99.6
182	24135	1.6129	2.7	0.1579	1.2	0.44	945	10	975	17	1044	48	1044	48	90.5
132	21013	1.6289	3.6	0.1594	2.2	0.62	953	20	981	23	1044	57	1044	57	91.3
393	48363	1.8215	1.9	0.1779	1.4	0.76	1055	14	1053	12	1049	25	1049	25	100.6
128	9348	2.0442	2.5	0.1917	1.8	0.74	1131	19	1130	17	1130	34	1050	52	100.1
217	24353	1.7572	1.4	0.1713	0.7	0.51	1019	7	1030	9	1053	25	1053	25	96.8
216	14402	2.1989	3.3	0.1993	3.1	0.93	1172	33	1181	23	1197	24	1059	31	97.8
221	17949	3.2055	1.8	0.2521	1.5	0.83	1449	19	1458	14	1472	19	1060	28	98.4
78	10658	1.7840	2.9	0.1726	0.5	0.18	1026	5	1040	19	1068	57	1068	57	96.1
109	10540	1.6385	4.5	0.1580	2.6	0.57	946	23	985	28	1074	75	1074	75	88.1
94	10768	1.8415	2.7	0.1774	1.2	0.43	1053	11	1060	18	1076	48	1076	48	97.9
102	7955	1.6806	3.8	0.1614	2.4	0.63	964	21	1001	24	1083	59	1083	59	89.1
186	26940	1.8368	2.6	0.1760	0.5	0.20	1045	5	1059	17	1087	50	1087	50	96.2
78	5933	1.8491	3.0	0.1772	2.2	0.73	1052	21	1063	20	1087	41	1087	41	96.8
77	8763	1.8996	4.4	0.1806	1.7	0.39	1070	17	1081	29	1103	80	1103	80	97.0

373	58123	1.9862	3.3	0.1881	1.6	0.50	1111	17	1111	22	1111	57	1111	57	100.0
115	8845	2.1156	2.2	0.1898	0.7	0.34	1120	8	1154	15	1217	40	1116	36	92.0
146	12140	2.1464	2.2	0.1956	1.8	0.84	1152	19	1164	15	1187	24	1117	29	97.1
184	6036	1.6525	3.1	0.1613	1.8	0.56	964	16	990	20	1050	52	1122	45	91.8
565	22764	2.7889	5.2	0.2226	5.0	0.98	1295	59	1353	39	1444	21	1124	40	89.7
297	31773	3.9479	3.6	0.2841	3.2	0.90	1612	46	1624	29	1639	29	1126	49	98.4
361	24935	1.9815	3.9	0.1850	3.4	0.87	1094	34	1109	27	1138	39	1130	34	96.1
452	25501	2.1030	3.9	0.1934	3.7	0.94	1140	38	1150	27	1169	27	1131	50	97.5
118	9197	3.0876	2.3	0.2455	0.8	0.37	1415	11	1430	17	1451	40	1135	30	97.5
807	61973	1.9412	3.2	0.1815	2.4	0.77	1075	24	1095	21	1135	40	1135	40	94.7
149	16898	2.1262	2.7	0.1988	0.8	0.28	1169	8	1157	19	1136	52	1136	52	102.9
154	11159	1.6191	2.8	0.1635	2.1	0.75	976	19	978	17	981	37	1138	39	99.5
92	9010	2.1520	4.0	0.2007	2.2	0.54	1179	23	1166	28	1141	68	1141	68	103.4
410	32888	1.9706	2.9	0.1837	2.0	0.69	1087	20	1106	19	1142	41	1142	41	95.2
281	33755	1.9894	0.8	0.1852	0.5	0.63	1095	5	1112	6	1145	13	1145	13	95.6
44	5653	1.9194	1.6	0.1786	0.9	0.53	1059	8	1088	11	1146	27	1146	27	92.4
252	23680	3.1390	2.6	0.2491	1.7	0.68	1434	22	1442	20	1455	36	1147	25	98.5
225	30115	2.0630	1.4	0.1917	0.9	0.62	1131	9	1137	9	1148	22	1148	22	98.5
439	56255	2.0414	3.1	0.1890	1.8	0.59	1116	18	1129	21	1156	49	1156	49	96.5
213	16465	1.9001	2.5	0.1759	2.2	0.86	1044	21	1081	17	1156	25	1156	25	90.3
185	21800	2.0404	1.9	0.1888	1.4	0.75	1115	15	1129	13	1157	25	1157	25	96.4
317	29195	2.0274	1.6	0.1876	1.2	0.74	1108	12	1125	11	1157	21	1157	21	95.8
306	38728	2.1114	2.2	0.1946	1.9	0.82	1146	19	1153	15	1164	25	1164	25	98.5
177	13691	2.5994	6.4	0.2251	5.9	0.92	1309	69	1300	47	1287	50	1169	27	101.7
381	20267	3.2065	3.3	0.2503	1.2	0.35	1440	15	1459	26	1486	59	1172	50	96.9
233	25778	2.0535	2.8	0.1877	1.0	0.36	1109	10	1133	19	1181	51	1181	51	93.9
178	17710	1.6396	2.1	0.1640	1.8	0.86	979	17	986	13	1000	22	1181	17	97.9
142	30198	13.1949	3.0	0.5127	2.6	0.86	2668	56	2694	28	2713	25	1187	24	98.4
202	32853	2.1093	2.2	0.1921	0.8	0.38	1133	9	1152	15	1188	40	1188	40	95.3
223	26500	2.1077	1.6	0.1918	0.6	0.39	1131	7	1151	11	1190	29	1190	29	95.0
46	8218	2.0267	4.0	0.1842	3.7	0.92	1090	37	1125	27	1192	31	1192	31	91.5
220	35648	2.3316	4.1	0.2114	2.2	0.53	1236	24	1222	29	1197	68	1197	68	103.3
352	36900	2.1295	1.4	0.1980	0.5	0.37	1164	5	1158	9	1147	25	1197	24	101.5
46	1275	0.6483	5.6	0.0834	3.5	0.62	517	17	507	22	466	97	1198	30	110.7
136	10668	1.6382	2.0	0.1642	0.7	0.34	980	6	985	12	996	38	1209	12	98.4
676	64175	2.2504	2.1	0.2020	1.7	0.80	1186	18	1197	15	1217	24	1217	24	97.5
104	9112	2.5130	3.3	0.2148	2.0	0.60	1254	23	1276	24	1312	52	1217	40	95.6
173	5864	3.3067	1.9	0.2583	1.1	0.55	1481	14	1483	15	1485	31	1220	53	99.7
153	5736	3.0876	3.4	0.2451	1.8	0.55	1413	23	1430	26	1454	53	1221	60	97.2
108	11129	3.1204	4.3	0.2490	2.7	0.64	1433	35	1438	33	1444	62	1225	21	99.2
122	10828	2.0792	3.2	0.1856	0.7	0.21	1097	7	1142	22	1228	62	1228	62	89.4
170	16508	2.2200	2.9	0.1978	1.4	0.47	1164	15	1187	20	1231	50	1231	50	94.5
260	13796	1.6408	2.0	0.1624	1.5	0.75	970	14	986	13	1022	28	1244	44	95.0
59	8880	2.2738	4.8	0.2001	0.7	0.16	1176	8	1204	34	1255	92	1255	92	93.7
88	8173	2.2223	3.9	0.1955	0.8	0.21	1151	9	1188	27	1256	74	1256	74	91.6
135	12394	1.7408	2.1	0.1719	1.8	0.83	1022	17	1024	14	1027	24	1268	52	99.6

388	27563	2.1095	2.1	0.1928	1.9	0.92	1136	20	1152	14	1181	17	1271	26	96.2
296	34238	2.3439	4.2	0.2045	1.1	0.25	1199	12	1226	30	1272	79	1272	79	94.3
43	7258	2.9607	4.5	0.2396	3.8	0.85	1385	48	1398	34	1417	45	1273	51	97.7
121	16435	2.3026	3.2	0.2002	1.1	0.34	1176	12	1213	22	1279	58	1279	58	91.9
360	72848	2.5856	2.4	0.2243	1.1	0.46	1305	13	1297	18	1283	42	1283	42	101.7
1017	18769	1.7813	4.4	0.1675	3.9	0.89	998	36	1039	29	1124	40	1287	50	88.8
282	19518	2.4195	2.9	0.2093	0.5	0.17	1225	6	1248	21	1289	56	1289	56	95.0
233	35463	2.4319	5.5	0.2092	4.2	0.76	1224	47	1252	40	1300	69	1300	69	94.2
280	30328	3.5173	3.2	0.2683	2.8	0.89	1532	39	1531	25	1529	28	1304	21	100.2
402	39760	2.4573	3.7	0.2106	1.4	0.37	1232	15	1260	27	1307	67	1307	67	94.3
175	22466	3.4340	3.4	0.2642	3.0	0.90	1511	41	1512	27	1513	29	1312	52	99.9
331	13494	2.1562	4.9	0.1980	4.1	0.85	1165	44	1167	34	1172	50	1314	61	99.4
263	34473	2.3480	2.8	0.2001	2.1	0.74	1176	22	1227	20	1318	37	1318	37	89.2
168	21568	2.6159	1.9	0.2207	0.5	0.27	1285	6	1305	14	1337	35	1337	35	96.1
147	20963	2.7049	2.3	0.2269	1.8	0.77	1318	21	1330	17	1349	29	1349	29	97.7
712	20123	0.7811	3.9	0.0945	3.3	0.84	582	18	586	17	602	46	1358	23	96.6
330	16725	2.3298	1.7	0.2082	1.3	0.78	1219	15	1221	12	1225	21	1370	31	99.5
326	55443	2.8464	3.1	0.2355	2.1	0.67	1363	25	1368	23	1375	44	1375	44	99.2
319	29508	2.3938	3.8	0.2090	3.6	0.94	1223	40	1241	28	1271	26	1378	65	96.3
101	12858	2.7887	1.5	0.2288	0.5	0.34	1328	6	1353	11	1391	27	1391	27	95.5
440	47863	2.7364	3.7	0.2237	2.9	0.80	1302	35	1338	27	1398	42	1398	42	93.1
320	50128	2.6943	4.2	0.2191	3.1	0.74	1277	36	1327	31	1408	54	1408	54	90.7
290	28355	3.0016	3.9	0.2435	0.7	0.18	1405	9	1408	30	1413	74	1413	74	99.5
54	10365	2.9725	4.0	0.2409	0.9	0.23	1392	12	1401	31	1414	75	1414	75	98.4
303	12202	2.0071	2.7	0.1894	2.2	0.83	1118	23	1118	18	1117	29	1417	45	100.1
61	5708	3.1754	2.6	0.2446	1.6	0.62	1411	20	1451	20	1511	38	1437	40	93.4
666	89938	3.0084	1.6	0.2408	0.7	0.46	1391	9	1410	12	1439	27	1439	27	96.7
148	20440	3.0673	2.0	0.2453	1.0	0.49	1414	12	1425	15	1440	33	1440	33	98.2
283	32508	3.0571	1.0	0.2441	0.7	0.67	1408	9	1422	8	1443	14	1443	14	97.6
121	10421	3.5423	3.6	0.2695	2.8	0.79	1538	39	1537	28	1535	41	1444	21	100.2
168	15708	2.4531	3.3	0.2140	2.1	0.62	1250	23	1258	24	1273	51	1444	62	98.2
224	32225	2.9903	1.1	0.2383	0.5	0.46	1378	6	1405	8	1446	19	1446	19	95.3
123	4897	2.0330	3.2	0.1905	2.0	0.62	1124	21	1127	22	1131	50	1449	34	99.4
91	5395	2.6198	3.6	0.2237	1.8	0.50	1301	21	1306	27	1314	61	1451	40	99.1
156	24749	3.1256	3.7	0.2456	3.2	0.85	1416	40	1439	29	1474	37	1454	53	96.0
179	22491	3.1468	3.0	0.2505	2.4	0.80	1441	30	1444	23	1449	34	1455	36	99.5
188	6077	1.7903	2.4	0.1764	0.9	0.37	1047	9	1042	15	1031	44	1457	26	101.6
367	18950	2.2377	6.4	0.1956	5.8	0.91	1152	61	1193	45	1268	52	1463	72	90.8
406	26058	2.8998	2.6	0.2289	1.7	0.64	1329	20	1382	20	1465	38	1465	38	90.7
248	12479	3.3741	2.6	0.2614	1.8	0.70	1497	24	1498	20	1500	35	1468	39	99.8
350	47143	2.9625	3.4	0.2333	1.4	0.40	1352	17	1398	26	1469	59	1469	59	92.0
116	22893	3.3298	4.1	0.2621	1.1	0.26	1501	14	1488	32	1470	75	1470	75	102.1
152	15028	2.7632	4.2	0.2282	2.5	0.59	1325	29	1346	31	1378	65	1471	20	96.2
107	9786	3.1620	3.3	0.2507	3.0	0.90	1442	38	1448	25	1457	26	1472	19	99.0
415	32373	2.9635	2.1	0.2330	1.5	0.71	1350	18	1398	16	1472	28	1472	28	91.7
231	25716	3.2875	3.1	0.2591	2.3	0.74	1485	30	1478	24	1468	39	1473	18	101.2

140	4999	1.5591	5.0	0.1596	4.4	0.89	955	39	954	31	953	46	1474	37	100.2
253	11889	1.9715	3.6	0.1844	3.3	0.91	1091	33	1106	24	1135	30	1475	33	96.1
929	113798	3.1282	2.0	0.2449	1.5	0.73	1412	19	1440	15	1481	26	1481	26	95.4
335	9494	2.1516	5.4	0.1949	5.2	0.96	1148	54	1166	37	1198	30	1485	31	95.8
43	5095	3.1930	3.7	0.2494	1.4	0.36	1435	17	1455	29	1485	66	1485	66	96.6
253	27028	2.6624	3.3	0.2222	3.1	0.93	1294	37	1318	25	1358	23	1486	59	95.3
210	23598	3.2375	2.2	0.2514	0.9	0.39	1446	11	1466	17	1496	39	1496	39	96.6
739	56831	2.1787	1.9	0.1963	1.8	0.95	1156	19	1174	13	1209	12	1500	35	95.6
68	10251	9.9987	3.1	0.4471	2.6	0.82	2382	51	2435	29	2479	30	1511	38	96.1
136	12927	3.1042	2.1	0.2442	1.8	0.87	1408	23	1434	16	1471	20	1513	29	95.7
116	17573	3.3944	1.9	0.2607	0.7	0.36	1494	9	1503	15	1517	33	1517	33	98.5
61	9575	3.4473	2.8	0.2647	0.9	0.32	1514	12	1515	22	1517	51	1517	51	99.8
975	26278	1.8404	3.1	0.1738	2.5	0.81	1033	24	1060	20	1116	36	1518	34	92.6
126	14484	3.1370	2.1	0.2463	1.1	0.55	1419	15	1442	16	1475	33	1529	28	96.2
296	14731	1.6784	2.6	0.1661	1.4	0.51	991	12	1000	17	1021	46	1535	41	97.0
47	6480	3.2754	2.1	0.2427	0.8	0.37	1401	10	1475	16	1584	36	1584	36	88.4
205	26305	3.6998	2.1	0.2720	0.9	0.41	1551	12	1571	17	1598	36	1598	36	97.0
82	8058	3.1194	6.2	0.2465	4.9	0.79	1421	62	1437	47	1463	72	1639	29	97.1
643	66620	3.5578	3.8	0.2499	2.9	0.76	1438	37	1540	30	1684	46	1684	46	85.4
126	36743	4.2605	2.8	0.2992	2.0	0.71	1687	30	1686	23	1684	37	1684	37	100.2
1088	41558	1.8345	4.0	0.1782	3.7	0.92	1057	36	1058	26	1059	31	1756	31	99.8
585	22452	2.1495	5.3	0.1925	4.3	0.81	1135	45	1165	37	1221	60	2479	30	92.9
386	7848	2.0396	3.7	0.1827	2.5	0.68	1082	25	1129	25	1220	53	2713	25	88.7

Table 2.3 Laurel formation

U	206Pb	207Pb*	±	206Pb*	±	error	206Pb*	±	207Pb*	±	206Pb*	±	Best age	±	Conc
(ppm)	204Pb	235U*	(%)	238U	(%)	corr.	238U*	(Ma)	235U	(Ma)	207Pb*	(Ma)	(Ma)	(Ma)	(%)
289	6770	0.6168	2.2	0.0780	1.6	0.70	484	7	488	9	505	35	484	7	95.8
122	4168	0.6365	2.9	0.0818	1.1	0.36	507	5	500	11	468	60	507	5	108.3
174	3349	0.6679	3.6	0.0835	1.0	0.27	517	5	519	15	530	77	517	5	97.6
446	6823	0.6845	2.3	0.0857	0.8	0.34	530	4	530	9	526	47	530	4	100.8
492	15995	1.3381	6.2	0.1351	6.1	0.98	817	47	862	36	981	27	981	27	83.3
750	10796	1.4254	2.1	0.1437	1.2	0.54	865	9	900	13	985	37	985	37	87.9
254	18506	1.5998	1.2	0.1612	0.9	0.79	963	8	970	7	986	15	986	15	97.7
381	11255	1.3967	5.6	0.1406	5.3	0.94	848	42	888	33	987	39	987	39	85.9
120	6214	1.6363	2.6	0.1641	2.0	0.75	979	18	984	17	995	35	995	35	98.4
710	15320	1.4418	2.0	0.1436	1.6	0.82	865	13	906	12	1009	23	1009	23	85.8
112	8617	1.6978	4.8	0.1686	4.4	0.90	1004	40	1008	31	1015	42	1015	42	98.9
638	32370	1.6690	3.0	0.1645	2.6	0.86	982	23	997	19	1030	31	1030	31	95.3
260	21550	1.7443	1.5	0.1718	1.1	0.70	1022	10	1025	10	1032	22	1032	22	99.0
518	28309	1.7616	3.0	0.1717	2.8	0.95	1021	27	1031	19	1053	19	1053	19	97.0
346	6707	1.6856	2.1	0.1641	1.6	0.73	980	14	1003	14	1055	30	1055	30	92.9
664	12808	1.4377	3.2	0.1396	2.2	0.67	843	17	905	19	1060	49	1060	49	79.5
371	23143	1.9072	1.0	0.1837	0.6	0.57	1087	6	1084	7	1077	17	1077	17	100.9
387	37999	1.8768	1.5	0.1801	1.1	0.74	1067	11	1073	10	1084	20	1084	20	98.4
189	5461	1.5154	1.9	0.1440	1.4	0.73	867	11	937	11	1104	26	1104	26	78.5
264	24398	1.7777	4.5	0.1686	3.7	0.82	1004	34	1037	29	1108	52	1108	52	90.7
399	23758	1.7771	3.8	0.1684	3.5	0.93	1003	32	1037	24	1109	28	1109	28	90.5
297	12892	1.8673	1.7	0.1756	1.2	0.71	1043	12	1070	11	1124	24	1124	24	92.8
65	6285	2.0466	1.9	0.1923	0.8	0.44	1134	9	1131	13	1126	34	1126	34	100.7
152	6441	2.0932	3.4	0.1964	2.1	0.61	1156	22	1147	23	1129	53	1129	53	102.4
443	22018	1.7604	3.8	0.1648	3.4	0.89	983	31	1031	25	1134	35	1134	35	86.7
113	11763	2.0940	2.0	0.1960	1.6	0.80	1154	17	1147	14	1134	24	1134	24	101.8
309	15865	2.0004	1.7	0.1869	1.5	0.86	1105	15	1116	12	1137	17	1137	17	97.2
469	23359	1.9351	3.9	0.1808	3.8	0.97	1071	37	1093	26	1138	18	1138	18	94.1
124	8942	2.1467	2.7	0.1997	1.7	0.64	1174	19	1164	19	1146	41	1146	41	102.4
67	6005	2.0613	2.0	0.1916	1.4	0.69	1130	14	1136	13	1148	28	1148	28	98.5
517	35703	2.0964	2.6	0.1935	2.3	0.89	1140	24	1148	18	1162	24	1162	24	98.2
78	9973	2.0742	1.5	0.1913	1.0	0.68	1129	11	1140	10	1163	22	1163	22	97.1
95	11986	2.1686	2.9	0.1998	0.9	0.32	1174	10	1171	20	1165	55	1165	55	100.7
858	36818	1.9624	3.5	0.1807	3.3	0.95	1071	33	1103	24	1166	21	1166	21	91.8
411	18445	1.9373	1.8	0.1776	0.7	0.39	1054	7	1094	12	1175	33	1175	33	89.7
214	21718	2.1913	2.5	0.2007	1.9	0.77	1179	20	1178	17	1177	31	1177	31	100.2
551	29389	2.1143	2.2	0.1926	1.0	0.45	1135	10	1153	15	1188	39	1188	39	95.6
86	11773	2.2808	2.1	0.2075	1.4	0.68	1216	16	1206	15	1190	30	1190	30	102.2
133	8277	1.8364	2.6	0.1669	2.0	0.77	995	18	1059	17	1192	33	1192	33	83.5
169	7672	1.9163	4.2	0.1734	3.1	0.74	1031	29	1087	28	1201	55	1201	55	85.9

109	10631	2.2472	2.6	0.2032	0.7	0.28	1193	8	1196	18	1202	49	1202	49	99.3
97	13358	2.2262	1.9	0.2013	0.5	0.27	1182	5	1189	13	1202	35	1202	35	98.4
391	11242	1.8361	4.9	0.1660	4.1	0.85	990	38	1058	32	1202	51	1202	51	82.3
116	12156	2.2339	4.2	0.2009	3.3	0.80	1180	36	1192	29	1212	49	1212	49	97.4
539	22903	2.2266	1.6	0.2002	0.8	0.48	1176	8	1189	11	1213	28	1213	28	97.0
399	10315	1.8584	3.6	0.1668	3.0	0.85	994	28	1066	24	1217	37	1217	37	81.7
177	9568	2.0932	2.0	0.1867	0.9	0.43	1103	9	1147	14	1229	35	1229	35	89.8
623	40170	2.3378	2.0	0.2070	1.8	0.91	1213	20	1224	14	1243	16	1243	16	97.6
161	10332	2.2759	2.2	0.2013	1.6	0.74	1182	18	1205	15	1245	29	1245	29	94.9
82	9685	2.4893	2.9	0.2197	0.5	0.17	1280	6	1269	21	1250	56	1250	56	102.5
102	4627	2.1391	4.5	0.1877	3.7	0.82	1109	38	1162	31	1261	50	1261	50	88.0
155	8397	2.1301	4.8	0.1856	4.0	0.84	1098	40	1159	33	1275	50	1275	50	86.1
259	23195	2.4422	1.8	0.2122	0.9	0.49	1241	10	1255	13	1280	30	1280	30	96.9
299	18393	2.2951	2.2	0.1980	1.5	0.69	1165	16	1211	15	1294	31	1294	31	90.0
195	9602	2.0984	4.8	0.1809	4.4	0.92	1072	43	1148	33	1296	36	1296	36	82.7
290	12971	2.2519	4.6	0.1936	4.5	0.97	1141	47	1197	32	1301	20	1301	20	87.7
202	12683	2.3549	2.5	0.2020	1.7	0.67	1186	18	1229	18	1305	36	1305	36	90.9
145	10713	2.0925	3.5	0.1794	2.6	0.75	1064	26	1146	24	1306	45	1306	45	81.4
116	9564	2.5799	2.6	0.2198	2.2	0.86	1281	26	1295	19	1319	26	1319	26	97.1
168	13960	2.6623	1.5	0.2255	0.9	0.58	1311	10	1318	11	1330	23	1330	23	98.6
129	16692	2.7444	2.9	0.2324	2.5	0.86	1347	31	1341	22	1330	29	1330	29	101.3
219	10221	2.3195	5.8	0.1962	5.5	0.96	1155	59	1218	41	1332	33	1332	33	86.7
239	8467	2.3796	1.7	0.2008	0.8	0.48	1180	9	1237	12	1337	28	1337	28	88.2
376	17325	2.5709	4.3	0.2165	2.7	0.63	1263	31	1292	32	1341	65	1341	65	94.2
78	5863	2.5639	2.0	0.2159	0.9	0.44	1260	10	1290	15	1341	35	1341	35	93.9
115	10421	2.5273	4.0	0.2126	1.9	0.48	1242	21	1280	29	1343	67	1343	67	92.5
128	8456	2.8065	2.2	0.2353	1.8	0.85	1362	22	1357	16	1350	22	1350	22	100.9
423	17220	2.4049	4.4	0.2016	4.1	0.93	1184	44	1244	31	1350	32	1350	32	87.7
185	12172	2.5852	3.5	0.2159	3.3	0.94	1260	38	1296	26	1357	23	1357	23	92.9
660	28161	2.5018	1.9	0.2089	1.6	0.87	1223	18	1273	14	1357	18	1357	18	90.1
240	8297	2.0844	2.7	0.1738	1.2	0.45	1033	12	1144	18	1361	46	1361	46	75.9
196	11802	2.6791	2.2	0.2230	1.9	0.86	1298	22	1323	16	1364	22	1364	22	95.2
409	14575	2.1357	2.2	0.1773	1.1	0.50	1052	10	1160	15	1369	36	1369	36	76.8
262	8662	2.2154	3.1	0.1837	2.3	0.74	1087	23	1186	21	1371	39	1371	39	79.3
305	29098	2.7055	2.5	0.2243	0.5	0.20	1304	6	1330	19	1372	48	1372	48	95.1
448	14316	2.6425	2.5	0.2184	1.8	0.72	1273	21	1313	19	1377	34	1377	34	92.5
120	11986	2.9191	2.3	0.2410	0.8	0.32	1392	10	1387	18	1379	43	1379	43	100.9
102	13117	2.9172	1.9	0.2407	1.6	0.80	1391	19	1386	15	1380	22	1380	22	100.8
122	16434	2.8483	1.6	0.2342	1.0	0.66	1356	13	1368	12	1387	23	1387	23	97.8
153	16774	2.9500	2.0	0.2425	0.9	0.43	1400	11	1395	15	1387	34	1387	34	100.9
183	13730	2.8779	2.7	0.2351	0.9	0.35	1361	11	1376	20	1399	48	1399	48	97.3
445	21800	2.6559	1.4	0.2169	0.8	0.57	1265	10	1316	11	1400	23	1400	23	90.4
196	13935	2.4845	4.6	0.2027	3.7	0.81	1190	40	1268	33	1402	52	1402	52	84.9
108	13661	2.9030	3.4	0.2366	3.1	0.91	1369	39	1383	26	1404	28	1404	28	97.5
400	14512	2.6759	3.5	0.2176	2.7	0.75	1269	31	1322	26	1408	45	1408	45	90.2
570	19779	2.5274	6.3	0.2055	6.0	0.96	1205	66	1280	46	1408	33	1408	33	85.6

197	18858	2.8610	3.4	0.2322	3.3	0.95	1346	40	1372	26	1412	20	1412	20	95.4
257	10020	2.4477	3.7	0.1967	0.8	0.21	1157	8	1257	27	1431	69	1431	69	80.9
298	18481	2.6269	2.1	0.2108	1.6	0.79	1233	18	1308	15	1433	24	1433	24	86.0
135	18220	3.1340	1.8	0.2511	1.1	0.60	1444	14	1441	14	1437	28	1437	28	100.5
227	22534	3.1072	2.9	0.2486	1.6	0.57	1431	21	1434	22	1439	45	1439	45	99.5
207	6312	2.8747	2.3	0.2299	0.5	0.22	1334	6	1375	17	1440	43	1440	43	92.6
561	14945	2.4417	3.4	0.1952	3.0	0.89	1150	32	1255	25	1441	30	1441	30	79.8
134	10074	2.8691	2.7	0.2294	1.3	0.49	1331	16	1374	20	1441	45	1441	45	92.4
257	30216	3.0547	1.2	0.2439	0.8	0.62	1407	10	1421	10	1443	19	1443	19	97.5
526	24355	2.8670	1.7	0.2289	0.7	0.43	1329	9	1373	13	1443	29	1443	29	92.0
99	10764	3.0888	1.7	0.2461	0.5	0.30	1419	6	1430	13	1447	30	1447	30	98.0
219	10904	3.0506	1.8	0.2426	0.6	0.33	1400	8	1420	14	1451	32	1451	32	96.5
195	7787	2.8789	3.4	0.2284	1.6	0.48	1326	19	1376	25	1456	57	1456	57	91.1
503	52488	3.0462	1.0	0.2410	0.8	0.86	1392	10	1419	7	1461	10	1461	10	95.3
170	20625	3.2577	3.8	0.2576	1.9	0.50	1478	25	1471	30	1461	63	1461	63	101.1
388	29594	3.1144	1.9	0.2455	0.7	0.38	1415	9	1436	15	1467	34	1467	34	96.4
344	27290	2.7909	4.1	0.2194	2.8	0.69	1279	33	1353	30	1473	56	1473	56	86.8
183	20841	3.2680	1.5	0.2564	1.1	0.77	1471	15	1473	11	1477	18	1477	18	99.7
111	10472	3.0458	1.4	0.2382	1.1	0.81	1377	14	1419	11	1482	16	1482	16	92.9
122	19703	2.5176	7.0	0.1969	6.0	0.85	1158	63	1277	51	1483	69	1483	69	78.1
370	50582	3.3616	2.2	0.2606	1.6	0.72	1493	21	1495	17	1499	29	1499	29	99.6
177	14947	3.3342	1.3	0.2576	1.1	0.86	1477	15	1489	10	1506	13	1506	13	98.1
117	6759	3.0627	3.2	0.2316	1.9	0.58	1343	23	1423	24	1546	49	1546	49	86.9
206	33466	3.7097	2.7	0.2705	2.1	0.77	1543	28	1573	21	1614	32	1614	32	95.6
155	11774	3.8430	1.4	0.2771	0.7	0.46	1577	9	1602	11	1635	23	1635	23	96.5
111	11321	3.8322	3.6	0.2762	3.0	0.84	1572	42	1600	29	1636	37	1636	37	96.1
213	32042	4.0692	2.0	0.2919	1.8	0.89	1651	25	1648	16	1644	16	1644	16	100.4
405	37528	3.9608	2.3	0.2833	2.1	0.91	1608	30	1626	19	1650	18	1650	18	97.5
670	25733	3.5529	5.3	0.2496	5.0	0.95	1436	65	1539	42	1683	30	1683	30	85.4
438	25782	4.1254	3.2	0.2807	2.7	0.83	1595	38	1659	26	1742	32	1742	32	91.6
359	32256	4.0307	1.4	0.2739	0.6	0.43	1560	8	1640	11	1744	23	1744	23	89.5
274	26133	5.5479	3.9	0.3225	3.5	0.89	1802	55	1908	34	2025	31	2025	31	89.0
137	10946	11.4947	2.6	0.4584	2.4	0.90	2432	48	2564	25	2670	19	2670	19	91.1

Table 2.4
Bear Island granodiorite (core)

U	206Pb	207Pb*	±	206Pb*	±	error	206Pb*	±	207Pb*	±	206Pb*	±	Best age	±	Conc
(ppm)	204Pb	235U*	(%)	238U	(%)	corr.	238U*	(Ma)	235U	(Ma)	207Pb*	(Ma)	(Ma)	(Ma)	(%)
210	27951	1.6964	2.8	0.1677	2.4	0.86	1000	22	1007	18	1024	28	1024	28	97.7
365	20502	1.7027	2.1	0.1678	1.4	0.70	1000	13	1010	13	1030	30	1030	30	97.1
180	14041	1.7187	3.0	0.1661	2.2	0.74	991	20	1016	19	1069	41	1069	41	92.6
152	12980	1.8306	2.4	0.1742	0.8	0.34	1035	8	1057	16	1100	46	1100	46	94.1
192	20791	1.9827	3.2	0.1876	2.9	0.92	1108	30	1110	21	1112	25	1112	25	99.7
671	8316	1.8277	2.1	0.1716	1.8	0.88	1021	17	1055	14	1127	19	1127	19	90.6
319	40793	2.1783	2.2	0.2008	1.7	0.78	1179	18	1174	15	1164	27	1164	27	101.3
453	18262	2.1466	3.2	0.1976	2.8	0.87	1163	30	1164	22	1167	32	1167	32	99.7
127	10471	2.1445	2.9	0.1969	2.1	0.70	1159	22	1163	20	1172	41	1172	41	98.9
852	63404	2.2116	2.3	0.2023	2.0	0.85	1188	21	1185	16	1179	24	1179	24	100.7
216	7161	2.0441	3.4	0.1824	2.8	0.84	1080	28	1130	23	1229	36	1229	36	87.9
165	19087	2.3064	2.3	0.2054	1.3	0.56	1204	14	1214	16	1232	37	1232	37	97.7
687	30813	2.2999	2.9	0.2037	2.4	0.84	1195	26	1212	20	1243	31	1243	31	96.2
177	28728	2.9747	1.3	0.2379	0.7	0.57	1376	9	1401	10	1440	21	1440	21	95.5
1020	14189	2.4912	2.9	0.1992	2.1	0.72	1171	22	1269	21	1441	38	1441	38	81.3
481	7709	2.9411	2.4	0.2279	1.9	0.78	1324	23	1393	18	1500	29	1500	29	88.3
288	56898	3.5606	2.7	0.2672	1.7	0.62	1526	23	1541	22	1560	40	1560	40	97.8
355	31139	4.5268	1.4	0.3074	1.3	0.89	1728	19	1736	12	1745	12	1745	12	99.0
191	24799	4.8025	1.4	0.3188	0.7	0.47	1784	10	1785	12	1787	23	1787	23	99.8
324	41984	5.4134	3.2	0.3365	2.3	0.73	1870	38	1887	27	1906	39	1906	39	98.1
829	126900	4.8536	4.0	0.2982	3.3	0.82	1682	49	1794	34	1927	40	1927	40	87.3

Table 2.5
Bear Island granodiorite (rims)

U (ppm)	206Pb 204Pb	207Pb* 235U*	± (%)	206Pb* 238U	± (%)	error corr.	206Pb* 238U*	± (Ma)	207Pb* 235U	± (Ma)	206Pb* 207Pb*	± (Ma)	Best age (Ma)	± (Ma)	Conc (%)
863	249	0.2126	19.0	0.0213	8.7	0.46	136	12	196	34	997	344	136	12	13.6
526	338	0.2608	18.9	0.0232	5.8	0.31	148	8	235	40	1231	356	148	8	12.0
632	134	0.2725	10.2	0.0248	4.8	0.47	158	7	245	22	1191	179	158	7	13.3
300	436	0.3792	14.7	0.0399	6.0	0.41	252	15	326	41	899	279	252	15	28.0
252	784	0.4550	15.5	0.0434	8.6	0.55	274	23	381	49	1097	260	274	23	24.9
160	614	0.4614	13.1	0.0519	4.9	0.37	326	15	385	42	756	257	326	15	43.2
4008	4070	0.4888	4.8	0.0584	4.0	0.83	366	14	404	16	628	57	366	14	58.2
3839	6594	0.5225	6.4	0.0646	4.7	0.73	403	18	427	22	555	95	403	18	72.6
269	1334	0.7250	11.3	0.0692	9.9	0.88	431	41	554	48	1095	110	431	41	39.4
1001	27723	2.0029	4.6	0.1857	4.2	0.91	1098	42	1116	31	1153	38	1153	38	95.2
290	8081	2.1744	3.2	0.2011	1.6	0.50	1181	18	1173	23	1158	56	1158	56	102.0
497	90643	3.4659	5.5	0.2625	4.7	0.86	1503	63	1519	43	1543	52	1543	52	97.4

I pledge on my honor that I have not given or received any unauthorized assistance on this assignment.