Summer 2020

Detrital Zircon Petrochronology for Sedimentary Provenance Analysis: Source to Sink of the Mississippi/Missouri River Drainage Basin

Sage Denali Muttel
Missouri State University, Muttel991@live.missouristate.edu

DETRITAL ZIRCON PETROCHRONOLOGY FOR SEDIMENTARY PROVENANCE ANALYSIS: SOURCE TO SINK OF THE MISSISSIPPI/MISSOURI RIVER DRAINAGE BASIN

A Master's Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Geography and Geology

By

Sage Denali Muttel

August 2020

PETROCHRONOLOGY FOR DETRITAL ZIRCON PROVENANCE ANAYLSIS:

SOURCE TO SINK OF THE MISSISSIPPI/MISSOURI DRAINAGE BASIN

Geography, Geology, & Planning

Missouri State University, August 2020

Master of Science

Sage Denali Muttel

ABSTRACT

Detrital petrochronology can provide a detailed look into sedimentary provenance through integrated mineral radioisotopic ages with corresponding mineral chemistry. By combining U-Pb ages and Th/U values of detrital zircon from 13 samples collected from Quaternary sand deposits in the Upper Missouri, Yellowstone, Bighorn, Platte, Kansas, Arkansas, Mississippi, Red and Brazos Rivers, an interpretation of detailed signatures that record evidence of the evolution of the Mississippi/Missouri River drainage and the tectonic events that shaped it were observed. Low Th/U values in zircon correlate temporally to convergent magmatism, whereas, higher and more variable Th/U zircon are coeval with known extensional tectonism. Using these data, this study was able to resolve the evolution of drainage patterns from the Cretaceous to the Cenozoic. Grains found within the N. Rocky Mountains and Northern Plains samples as well as the Central Plains samples exhibited Cordilleran ages (<280 Ma) and Th/U values <0.75 and were found to be derived from Cordilleran magmatism that were transported into the drainage basin prior to the formation of the Continental Divide. We also observed northwest trends in sediment transport that occurred well into the Cretaceous (Blum and Pecha, 2014) and northeast trends from the Rio Grande Rift Valley into central river samples (Platte, Kansas, Arkansas, Missouri, and Mississippi Rivers) which was restricting sediment transport to the southern Red and Brazos Rivers. Mean weighted ages of the youngest, coherent Cordilleran populations in the Upper Missouri and Central Plains drainages suggest that the current Continental Divide developed synchronously in the northern and central Rocky Mountains ~67 Ma during the Laramide orogeny. Therefore, tectonic development of headwater regions is recorded in modern river sediment, and tectonic provenance studies to investigate ancient orogenic systems is not limited to coeval sedimentary strata.

KEYWORDS: zircon, provenance, North America, Th/U, petrochronology, detrital, Missouri River, basin

DETRITAL ZIRCON PETROCHRONOLOGY FOR SEDIMENTARYPROVENANCE ANALYSIS: SOURCE TO SINK OF THE MISSISSIPPI/MISSOURI RIVER DRAINAGE BASIN

By

Sage Denali Muttel

A Master's Thesis
Submitted to the Graduate College
Of Missouri State University
In Partial Fulfillment of the Requirements
For the Degree of Master of Science in Geography and Geology

August 2020

Approved:

Matthew McKay, Ph.D., Thesis Committee Chair

Melida Gutierrez, Ph.D., Committee Member

Charles Rovey, Ph.D., Committee Member

Kenneth Johnson, Ph.D., University of Houston-Downtown, Committee Member

Julie Masterson, Ph.D., Dean of the Graduate College

ACKNOWLEDGEMENTS

I would like to thank first and foremost my mother, father, and Grammy for their love and support throughout my entire life. Without them, I never would have made it to where I am today. Thank you Mom for never giving up on me even when I was a pain. Thank you Dad for showing me that hard work always pays off and that family will always be there. Thank you Grammy for the art, the love, the talks in your kitchen, the random concoctions you'd create when I lived with you, the long talks on the phone, and most of all thank you for being my safety net. Without you Grammy I don't think I'd get very far. I would also like to thank the following persons for their individual support: Derek Spurgeon for your continuous love throughout grad school and then some; Dr. Matthew McKay for always pushing me to do better and spur me to win everything; Dr. Kenneth Johnson for recommending MSU as my graduate school; Brooke Benz for tea time, D&D sessions, and endless support even when I didn't deserve it; Pudge and Rainier for being the cutest doggos of all time who knew exactly what I needed to cheer up; all the friends I've made along the way (you know who you are); and lastly I'd like to mention my brothers – Cooper and Sawyer. I hope you both succeed in anything you do and I want to remind you to never give up on your dreams!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Provenance and zircon

Provenance analysis is a useful tool which often utilizes U-Pb age dating of zircon in order to reconstruct sediment transport patterns, better understand tectonic histories, and interpret spatial and temporal trends. Zircon is a common accessory mineral found in igneous, metamorphic, and clastic sedimentary rocks. Zircon is highly resistant to weathering and intense changes in heat and pressure which allows for distinct chemical signatures of the zircon to be left intact (Finch and Hanchar, 2003). Chemical signatures are often linked to U-Pb age or trace elements with U-Pb representing age of crystallization. U-Pb ages in zircon alone provide accurate and precise age analysis; however, U-Pb signatures become harder to distinguish from one another especially when multiple sources with similar ages are present. With the possibility of coeval-age zircon populations, determining provenance may require more than U-Pb ages alone. Zircon geochemical data coupled with U-Pb ages may, however, allow for the enhanced ability to interpret the provenance of clastic detritus. This study aims to examine the relationship between age and the geochemistry of zircon with emphasis on Th and U concentrations in zircon, and the relationship between Th/U in detrital zircon and tectonic settings within the sedimentary source regions.

Previous applications of zircon petrochronology

Zircon geochronology is often paired with rare earth elemental analysis to investigate the petrogenetic history of igneous and metamorphic rocks. Concepts that have been demonstrated in crystalline rocks, however, have not been widely applied to the sedimentary record (i.e.

detrital petrochronology) due to the complexity of mixed-source detrital systems. Early investigations concluded that zircon chemical signatures from various tectonic settings were too similar to allow for an adequate provenance identification (Hoskin and Ireland, 2000). The initial attempt to link sandstones with known sources failed to identify definitive chemical signatures and suggested significant overlap between geologic settings, which made provenance identification difficult (Hoskin and Ireland, 2000). With the development of rapid analytical capabilities, more recent studies have demonstrated applicable petrochronologic signatures related to crustal origin (Grimes et al., 2007), magmatic composition, temperature, oxygen fugacity, melt source (Grimes et al., 2015, Kirkland et al., 2015), and tectonic environment (McKay et al., 2018); therefore the utility of detrital zircon petrochronology should be reassessed.

Zircon rare-earth element compositions have been demonstrated to distinguish between oceanic and continental crust using U/Yb, Hf, and Y content (Grimes et al., 2007). Zircon from mid-ocean ridge basalts yield U/Yb as low as 0.18, while zircon from continental granitoids average around 1.07. Zircon from kimberlites have U/Yb values that average 2.1 (Grimes et al., 2007). U and Th concentrations are highest in continental sources, intermediate for Iceland and Hawaii, and lowest for mid-ocean ridge and kimberlite source rocks (Grimes et al., 2015). Zircon from mid-ocean ridge and Iceland have heavy rare earth elements and Y values comparable to continental sources, and Iceland and Hawaii were found to have light and middle rare earth elements when compared similar to the mid-ocean ridge zircon (Grimes et al., 2015). Median Sc values were highest in continental zircon while lower in oceanic settings (Grimes et al., 2015).

The relationship between Th/U in zircon and melt compositions and conditions can be applied to infer tectonic environment, because different tectonics environments (1) produce

various rock types and (2) experience different temperatures during rock formation. (McKay et al., 2018) In the western United States, Th/U in zircon can be directly correlated to the evolution of tectonic environments. In Mesozoic to Cenozoic-age zircon, the average Th/U in zircon of the population increased during the extension/opening of the Gulf of Mexico and Atlantic Ocean. During Cretaceous Cordillera arc magmatism, the average Th/U in zircon decreased. During the extensional formation of Basin and Range magmatism in the western U.S., the average Th/U in zircon again increased (McKay et al., 2018), suggesting a direct relationship between zircon Th/U in zircon and tectonic stress regime. Western U.S. data suggest that magmatism during times of increased shortening during convergent margin activity results in the formation of low Th/U zircon, whereas extensional magmatism produces zircon with variable Th/U, including higher Th/U values >1.0, which may also be observed in late Paleozoic rocks from fragments of southern Gondwana (McKay et al., 2018)

GEOLOGIC BACKGROUND

Geologic provinces of North America

North America was formed through the accretion and suturing of multiple microcontinents over the past 2.8 Ga (Figure 1; Fildani et al., 2016). The Archean represents a time of early continental construction with limited understanding of chemically significant trends especially in zircon. Construction of North America began through the formation of plutons of the Superior province around 2.5 Ga in northern Wyoming and north of the Great Lakes (Lidiak, 1971; Grenn et al., 1985). The Superior craton is exposed in Canada and the northern Great Lakes and extends into the subsurface of North and South Dakota (Lidiak, 1971; Green et al., 1985). West of the Superior province, the Wyoming province was most likely created from the collision of island arcs and subsequently faulted and sheared during collision (Green et al., 1985). The Wyoming/Superior provinces contain granitic gneiss, mafic schist, and granite (Lidiak, 1971).

The Penokean orogen is exposed in the northernmost part of the United States and is 2000-1800 Ma (Fildani et al., 2016). The rocks of the Penokean orogeny are dominated by volcanic and gneissic rocks that formed when an ocean began to close and island arcs began to collide with the Superior orogen around 1880 Ma (Schulz and Cannon, 2007). The Trans-Hudson orogen is exposed primarily in Canada, also occurs from 2000-1800 Ma, and is a result of ocean basin closure and terrane accretion (Corrigan et al., 2009).

The western United States is underlain by the Yavapai and Mazatzal provinces, which partially overlap in age. The Yavapai and Mazatzal provinces formed from island arc collisions with Laurentia. The Yavapai province formed 1800-1700 Ma and is exposed in Arizona,

Colorado, and Utah (Bickford and Hill, 2007). The rocks associated with the Yavapai orogeny are mostly volcanic and metavolcanic rocks (Bickford and Hill, 2007). The Mazatzal orogeny (1700-1600 Ma) formed from a series of island arcs and basins that formed offshore and collided with the Yavapai orogenic belt around 1654 Ma (Amato et al., 2008). The Mazatzal orogeny occurred southeast of the Yavapai orogen with rocks exposed in Arizona, Colorado, New Mexico, and Kansas (Bickford and Hill, 2007). Igneous rocks which that primarily arc-related dominate the Mazatzal orogeny (Amato et al., 2008).

The Granite Rhyolite province formed between 1500-1300 Ma during extensional magmatism and is composed of granite and rhyolitic rocks (Slagstad et al., 2009).

The Grenville province (1200-900 Ma) is a ~500 km wide orogenic belt starting at the coast of Labrador and extending through the southeastern U.S. to Northern Mexico and consists of medium to high grade metamorphic rocks (Rainbird et al., 1992). Grenville-age continental crust underlies significant portions of eastern North America**,** and Grenville-age zircon have been transported across North America through continental-scale drainages coupled with episodes of mass wasting (Rainbird et al., 1992).

The Appalachian orogen formed 750-280 Ma and extends from Northern Mexico along the East Coast of the United States. The formation was due to the collision of Gondwana to Laurentia ~300 Ma (Hopper et al., 2017). Arc magmatism was common in this orogen and during the collision with Laurentia, the rocks also underwent metamorphism. Rifting processes were also active in the form of ocean separation (Pollock et al., 2011).

The western Cordillera was constructed through a series of magmatic events in the western U.S. and Canada over the last 280 Ma by a series of island arcs colliding with Laurentia. This collision involved a period of subduction that produced volcanic/magmatic activity and

regional shearing (Dickinson, 2004). The Cordillera extends from the Gulf of Alaska to the mouth of the Gulf of California which is roughly 5000 km in length (Dickinson, 2004). During the last 280 Ma, the Western Cordillera was not the only source of terrane accretion and tectonic activity. Subducting plates colliding with Laurentia caused the Sevier orogeny which lasted from 119 Ma (Heller and Paola, 1989) to 50 Ma (DeCelles and Mitra, 1995; Bird, 1998). Extending from Western Montana to Southern California, the Sevier orogeny is a series of thrust faults caused by thin skinned deformation (DeCelles and Mitra, 1995). Farther inland and East of the Sevier fold and thrust belt, the Laramide uplift occurred 80-55 Ma which was the main tectonic process that formed the Rocky Mountains (English and Johnston, 2004). Most of the Laramide uplift is exposed in Utah, Arizona, Colorado, New Mexico, and Wyoming (Fildani et al., 2016). With the uplift of the Rocky Mountains, the Laramide orogeny can also be associated with the formation and uplift of the Continental Divide. Farther North in Idaho, emplacement of the Idaho Batholith was coeval with the Laramide orogeny around 110-40 Ma (Foster and Fanning, 1997), which produced various igneous suites in the area. High-grade metamorphism also occurred near the Idaho Batholith due to its proximity to the Salmon River suture zone which supplied ample heat and pressure to the preexisting rocks (Foster and Fanning, 1997).

Study Area

Missouri River drainage basin. All samples were collected from the Missouri River drainage basin, which encompasses the Missouri, Mississippi, Yellowstone, Platte, Kansas, Arkansas, Ohio, Tennessee, and Red rivers (see Figure 2). The uppermost portion of the Missouri River is in Three Forks, Montana, where three tributaries meet, and ends in the Gulf of Mexico in the form of the Mississippi River. The Missouri River drains approximately one-sixth

of the drainage for the United States (Missouri and Nebraska, 1998) largely due to the amount of tributaries feeding it. After Three Forks, Montana, the Upper Missouri meets the Yellowstone, Platte, and Kansas rivers before joining the Mississippi River in St. Louis, Missouri. Upstream of the Missouri/Mississippi confluence, sediment was routed from the northwestern United States. After the Missouri/Mississippi confluence, the Mississippi River is joined by the Ohio, Tennessee, Arkansas, and Red rivers which drain sediment from the eastern, middle, and southern United States.

Sediment found within the Missouri River drainage basin all come from North American provinces. Each province is exposed in certain areas of the United States and the rivers of the Missouri River drainage basin all act as transportation mechanisms for those provinces (see Figure 1). The Wyoming, Superior, Trans-Hudson, and Penokean provinces are likely draining into the Upper Missouri, Yellowstone, Platte, and Mississippi Rivers. Yavapai and Mazatzal sediment is most likely draining into the Platte, Kansas, Missouri, and Arkansas Rivers. Granite Rhyolite province aged grains are likely being transported via the Mississippi, Ohio, Tennessee, Arkansas, and Red Rivers. Grenville sediment has access to the Ohio, Tennessee, and Brazos Rivers. Appalachian sediment is primarily located in the southern United States therefore restricting transport to the Arkansas, Red, Brazos, and Southern Mississippi Rivers. Western Cordilleran aged grains represent a province outside the Missouri River drainage basin, and west of the present continental divide, would require critical reevaluation if those grains are found within the system.

Geologic history of the Missouri River drainage basin. Though the modern drainage pattern is well known, it has a geologic past that has influenced both drainage and sediment routing. Galloway et al., 2011 conducted a study that interpreted the Cenozoic history of the

drainage basin. In the Early Paleocene, two drainage basins existed in North America with the divide cutting through the modern central states (Kansas, Missouri, and Colorado). The Northern basin had a majority of sediment being routed from the slowly uplifting Front Range into a series of basins existing in modern day Colorado, Utah, Wyoming, and the Dakotas (Galloway et al., 2011). Sediment flux was largely located to the northern basin while the coastal plain, which existed over the modern southeastern states such as Texas, Louisiana, Alabama, and Florida, was deprived of sediment (Galloway et al., 2011). At the start of the Late Paleocene, the coastal plain had moved southward while the drainage divide moved northward. Northern movement of the divide as well as uplift in the West, increased the amount of sediment being routed to the Gulf coast (Sewall and Sloan, 2006). Concurrently, the Colorado River system as well as the Mississippi River system were developing due to the large amount of deltaic deposition (Galloway et al., 2011).

During the Early Eocene, the drainage divide remained seemingly unchanged while the west underwent more tectonic events closely associated with the Laramide uplift. The coast continued to move South and the Brazos River as well as the Rio Grande River developed due to their deltaic depositions. Also during the Early Eocene, the gulf received sizeable amounts of sediment (Galloway et al., 2011). During the Middle Eocene, the Laramide uplift was fully activated which allowed for the modern Continental Divide to take shape and cut off the West from the Missouri River drainage basin. The Laramide uplift triggered numerous small basins to form in the West and in turn provided less sediment being routed to the coast (Davis et al., 2009) which is evident in modern Mississippi with a transgressive sequence beginning to occur. The Late Eocene provided ample sediment for the gulf with the introduction of thermal activity providing crustal uplift of previously buried mountain belts. (Galloway et al., 2011). During this

process both the Arkansas and Platte Rivers developed, and volcanic activity supplied large amounts of ash which were aerially transported across the northeast (Galloway et al., 2011).

During the Oligocene, the Gulf of Mexico received a large amount of sediment which made the Oligocene the "longest and volumetrically most important" (Galloway et al., 2011, p.955) time for the Gulf of Mexico. Sediment deposition lasted more than 10 Ma which allowed for the accumulation of more than 50,000 km^3 of sediment in the Gulf of Mexico alone (Loucks et al., 1986). Volcanic activity was also present in the form of calderas stretching from Southern Mexico to Northern New Mexico supplying large amounts of volcanic material (Chapin et al., 2004). The Early Miocene represented a time of low sediment input due to the relative inactivity of recently active calderas that had previously provided source for the Gulf of Mexico.

The Middle Miocene experiences an arid climate and the uplift of the Appalachians. Uplift provided ample sediment load for the Gulf of Mexico while the West was supplying little to no sediment and the Rio Grande Rift was lacking fluvial deposition due to the arid climate at the time (Boettcher and Milliken, 1994). The Late Miocene provided limited sediment influx due to the decreased uplift of the Appalachians as well as the continued arid climate which reduced the amount of energy produced by rivers (Galloway et al., 2011).

The Pliocene allowed for sediment to be re-introduced to the Gulf of Mexico by ways of Western uplift and a more moisture-driven climate system. Seasonal floods as well as sediment runoff increased the sediment influx to the Gulf of Mexico. By the Pliocene, the Red River formed and transported sediment from a newly uplifted West which seemingly "tilted" the High Plains and allowed for a higher sediment load (McMillan et al., 2002). The Pleistocene represents a time that allowed the formation of ice sheets and glacial tills. The introduction of ice altered the drainage patterns of North America in a way that mimics the modern day drainage

pattern. The large amount of ice present during this time had drastic effects on erosion and sediment loads experience in this basin (Galloway et al., 2011). At the end of the Pleistocene, modern rivers (Platte, Arkansas, Red, Kansas, Yellowstone, Missouri, Mississippi, Ohio, Tennessee) were heavily involved with sediment transport and the Gulf of Mexico source-to-sink system was well in place (Dethier, 2001).

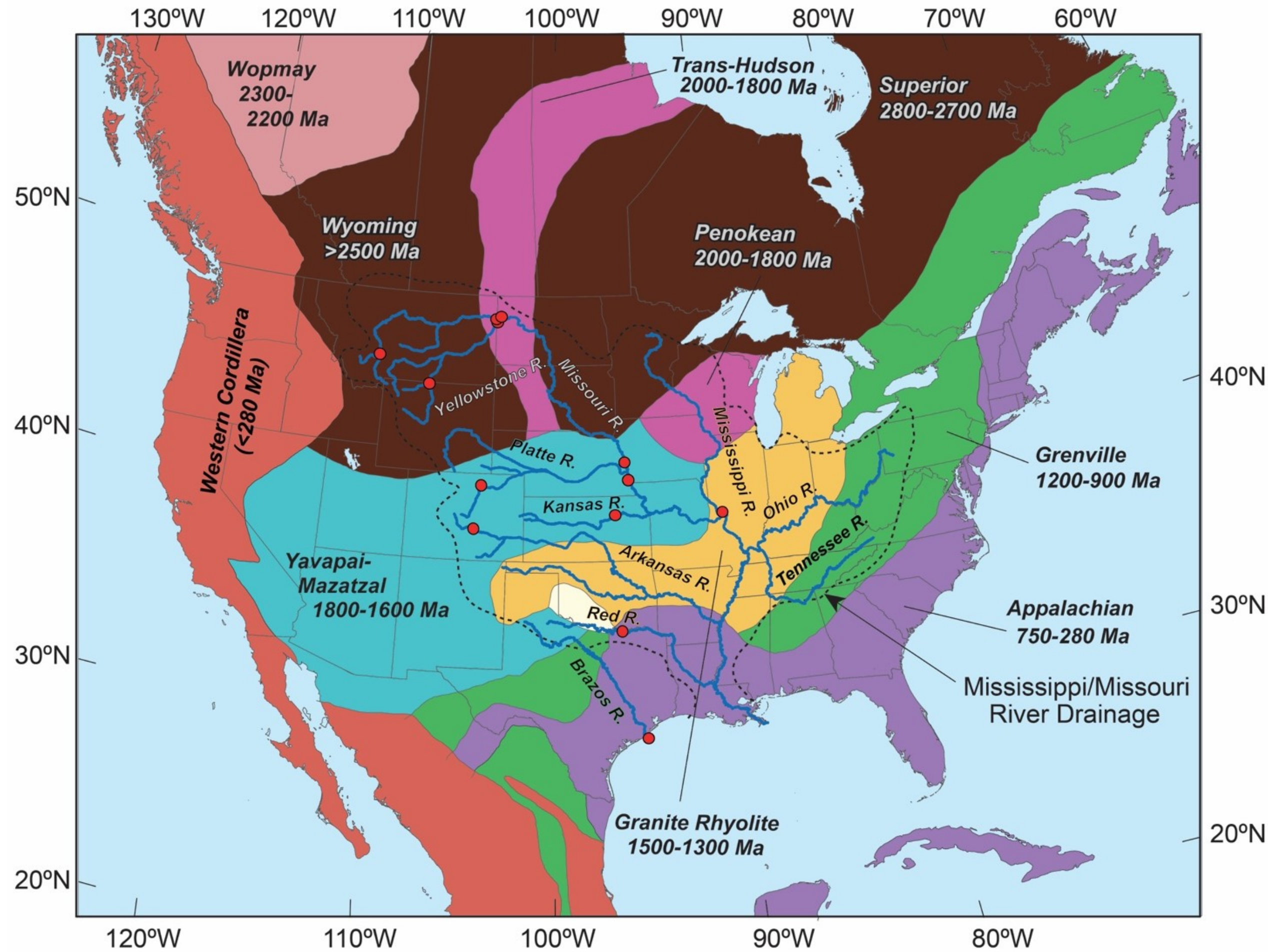

Figure 1. North American provinces with their respective age ranges overlaid by the Missouri river drainage basin represented by the black, dashed line. Red dots represent sample locations for this study. This is modified from Fildani et al., 2016.

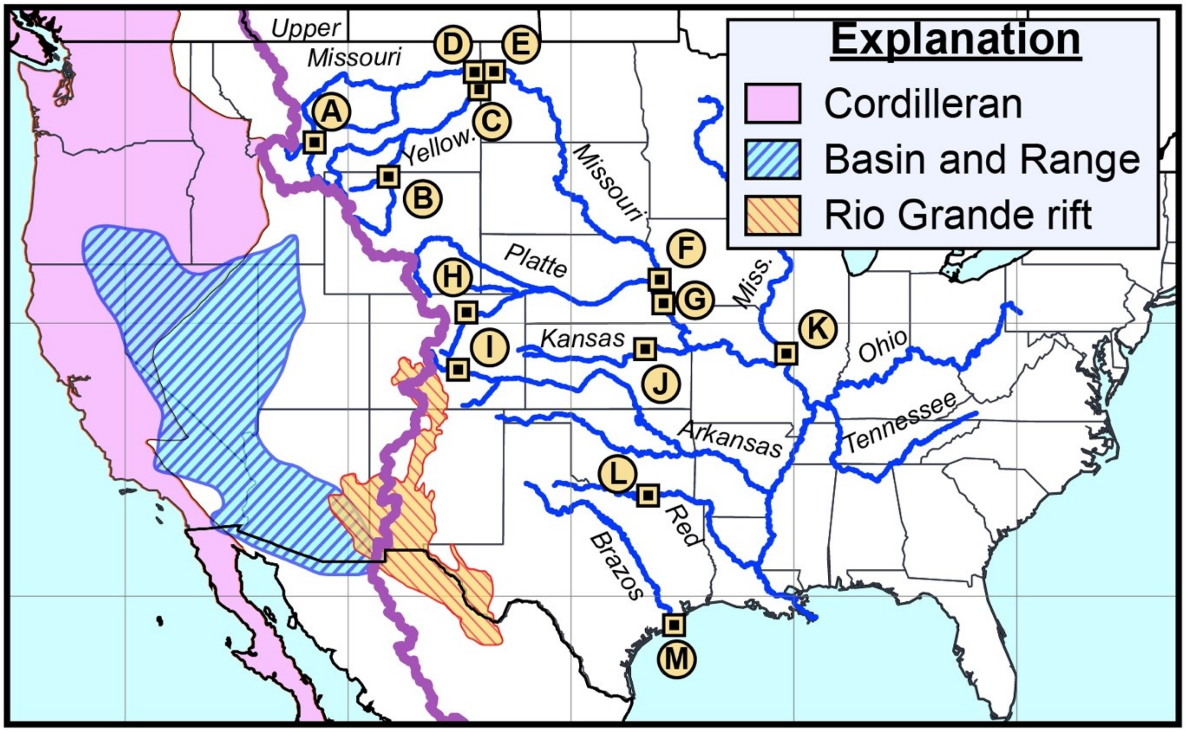

Figure 2. Simplified map showing Basin and Range, Rio Grande rift, and Cordilleran regions. Purple line represents Continental Divide. Samples are labeled as letters and are as follows: (A) 18MOSM01; (B) 18WYDS11; (C) 18YSSM10; (D) 18MOSM11; (E) 18MOSM13; (F) 18MOSM20; (G) 18MOSM24; (H) 18CODS01; (I) 18CODS02; (J) 18KSDS01; (K) 18MSSM32; (L) 18RRSM33; (M) 18BRSM37.

METHODS

Samples were collected from the modern-day Missouri/Mississippi River drainage basin from Three Forks, MT to the Gulf of Mexico. Sample sites were chosen based on grain size focusing on silty and sandy-unconsolidated deposits along river banks and channels. Sites that have undergone obvious anthropocene modification were avoided and collected upstream from major infrastructure projects (highways, bridges, dams, etc.). Zircon grains were extracted from the sand samples using a series of density separating techniques which include a Gemini gold separating water table, Franz magnetic separator, and Lithium Sodium Tungstate (LST) heavy liquid separation . All samples were placed onto tape mounts with half of the mount having grains that were indiscriminately "dumped" while the other half of the tape mount had hand-picked grains to eliminate non-zircon phases.

U-Pb Laser Ablation ICP-MS analyses were completed at the Trace Element and Radiogenic Isotope Lab (TRaiL) at the University of Arkansas using a Thermo-Scientific iCapQ quadrupole mass spectrometer coupled with an Elemental Scientific Inc. NWR 193 Excimer laser ablation system. Each zircon was ablated for ~17 seconds using a 25µm spot size for ~17 seconds with a repetition rate of 10Hz, a helium flow rate of 0.8 L/min, and a fluence of ~4.3 J/cm^2. For each analysis the following isotopes were measured (dwell time in ms): ^{201}Hg (10), ^{202}Hg (10), ^{204}Pb (30), ^{20}6Pb (10), ^{207}Pb (20), ^{208}Pb (10), ^{232}Th (10), ^{238}U (10). The primary standard for ages was Plesovice (337.13 Ma; Slama et al., 2008). Data reduction was completed using the Iolite v.3.71 (Paton et al., 2011).

RESULTS

From the raw data, zircon analyses were placed in Kernel Density Estimator plots (KDEs) to observe population groupings and what ages they fall within for each sample. Once a baseline of population groupings were observed using a single KDE for each sample, the grains were then organized by U-Pb age and Th/U values. Grains exhibiting high (>0.75) Th/U were plotted against grains exhibiting low (<0.75) Th/U to observe if chemical-age signatures exist within each sample. From observations, there was a distinct separation between KDE plots when partitioning based on Th/U in zircon and plots were created that showed the high vs. low Th/U values.

Kernel Density Estimator plots (KDEs) were plotted for samples from 0-2500 Ma. Though this 0-2500 Ma range is the focus of our study, some samples contained zircon outside this time range and are included in the descriptions below. All samples were placed in Density Plotter (Vermeesch, 2012) and set to the same bounds (bin-width = 50, bandwidth = 10, normalized to area = 0.06). Zircon populations from individual samples were evaluated based on Th/U in zircon compositions and partitioned as “high Th/U in zircon” and “low Th/U in zircon” using 0.75 as a semi arbitrary cutoff between the two chemical-age populations. This cutoff was chosen mainly due to the fact that igneous zircon has Th/U values >0.5 (Hoskin & Schaltegger, 2003) which represent extensional settings. Samples are also combined into 3 groups – Northern, Central, and Southern sections which reflect their regional affiliation. Table 1 displays the proportion of age domains by sample and includes the breakdown of high (>0.75) and low (<0.75) Th/U zircon populations. Zircon populations are further subdivided by Th/U percentage and province-based age bins.

Northern section (see Figure 3)

18MOSM01. Sample 18MOSM01 was collected from a riverbank from the Missouri River headwaters in Three Forks, MT, approximately 90 miles NW of Yellowstone National Park in SW Montana. Paleozoic sedimentary rocks are exposed in the overlooking hills (Vuke, 2006) and are underlain by >2500 Ma crystalline bedrock that correlates to the Wyoming Craton (Parks et al., 2010). The sample contains 98 zircons (*22% >0.75 Th/U; 78% <0.75 Th/U)* of which 48 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=24; 12% >0.75 Th/U; 88% <0.75 Th/U*); Appalachian (*n=6; 33% >0.75 Th/U; 67% <0.75 Th/U*); Grenville *(n=5; 20% >0.75 Th/U; 80% <0.75 Th/U*); Granite Rhyolite province (*n=1; 100% <0.75 Th/U*); Yavapai/Mazatzal (*n=4; 25% >0.75 Th/U; 75% <0.75 Th/U*); Trans-Hudson (*n=3; 100% <0.75 Th/U*); Wyoming/Superior (*n=55; 27% >0.75 Th/U; 73% <0.75*).

18WYDS11. Sample 18WYDS11 was collected from the riverbank on Bighorn River in Greybull, WY which is roughly 50 miles E of Cody, WY. Mesozoic aged sedimentary rocks dominate the hills north of Greybull (Kozimko, 1985) and are underlain by >2500 Ma crystalline bedrock that is part of the Wyoming Craton (Parks et al., 2010). The sample contains 115 zircons (*13% >0.75 Th/U; 87% <0.75 Th/U)* of which 100 fall between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=43; 9% >0.75 Th/U; 91% <0.75 Th/U*); Appalachian (*n=8; 100% <0.75 Th/U*); Grenville *(n=16; 19% >0.75 Th/U; 81% <0.75 Th/U*); Granite Rhyolite province (*n=8; 100% <0.75 Th/U*); Yavapai/Mazatzal (*n=23; 22% >0.75 Th/U; 78% <0.75 Th/U*); Wyoming/Superior (*n=17; 18% >0.75 Th/U; 82% <0.75*).

18MOSM11. Sample 18MOSM11 was collected from the riverbank on the Missouri River before its confluence with the Yellowstone River in a town called Nohly, MT, which was

on the Montana/North Dakota state line. Quaternary aged sedimentary rocks dominate the surrounding area (Colton, 1979) and are underlain by 2000-1800 Ma crystalline bedrock that is part of the Trans-Hudson province (Parks et al., 2010). The sample contains 92 zircons (*21% >0.75 Th/U; 79% <0.75 Th/U)* of which all 92 fall between the ages 0-2500 Ma on the KDEs.: Western Cordillera (*n=45; 16% >0.75 Th/U; 84% <0.75 Th/U*); Appalachian (*n=6; 33% >0.75 Th/U; 67% <0.75 Th/U*); Grenville *(n=13; 31% >0.75 Th/U; 69% <0.75 Th/U*); Granite Rhyolite province (*n=4; 50% >0.75 Th/U; 50% <0.75 Th/U*); Yavapai/Mazatzal (*n=22; 23% >0.75 Th/U; 77% <0.75 Th/U*); Wyoming/Superior (*n=6; 100% <0.75*).

18MOSM13. Sample 18MOSM13 was collected from the riverbank on the Missouri River after the Yellowstone confluence 6 miles SE of Williston, ND close to US 85. Tertiary and Quaternary age sedimentary rocks are exposed immediately south of the river (Carlson, 1985) and are underlain by 2000-1800 Ma crystalline bedrock that is part of the Trans-Hudson province (Parks et al., 2010). The sample contains 87 zircons (*17% >0.75 Th/U; 83% <0.75 Th/U)* of which 84 are between the ages 0-2500 Ma.: Western Cordillera (*n=52; 10% >0.75 Th/U; 90% <0.75 Th/U*); Appalachian (*n=7; 14% >0.75 Th/U; 86% <0.75 Th/U*); Grenville *(n=6; 100% <0.75 Th/U*); Granite Rhyolite province (*n=5; 20% >0.75 Th/U; 80% <0.75 Th/U*); Yavapai/Mazatzal (*n=12; 33% >0.75 Th/U; 67% <0.75 Th/U*); Trans-Hudson (*n=1; 100% >0.75 Th/U*); Wyoming/Superior (*n=4; 75% >0.75 Th/U; 25% <0.75*).

18YSSM10. Sample 18YSSM10 was collected from the riverbank on the Yellowstone River before the Missouri confluence 20 miles SE from Williston, ND close to ST HWY 200. Tertiary and Quaternary aged sedimentary rocks fall immediately south of the river (Carlson, 1985) and are underlain by 2000-1800 Ma crystalline bedrock that correlates to the Trans-Hudson province (Parks et al., 2010). The sample contains 109 zircons (*24% >0.75 Th/U; 76%*

<0.75) of which 94 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=55; 22% >0.75 Th/U; 78% <0.75 Th/U*); Appalachian (*n=8; 37% >0.75 Th/U; 63% <0.75 Th/U*); Grenville *(n=7; 14% >0.75 Th/U; 86% <0.75 Th/U*); Granite Rhyolite province (*n=5; 20% >0.75 Th/U; 80% <0.75 Th/U*); Yavapai/Mazatzal (*n=17; 24% >0.75 Th/U; 76% <0.75 Th/U*); Trans-Hudson (*n=1; 100% <0.75 Th/U*); Wyoming/Superior (*n=16; 31% >0.75 Th/U; 69% <0.75*).

Central section (see Figure 4)

18CODS01. Sample 18CODS01 was collected from a riverbank on the South Platte River in Northern Colorado near Greeley, CO. Cretaceous sedimentary rocks are exposed in the overlooking hills (Bjorklund and Brown, 1957). Crystalline bedrock beneath the Phanerozoic sedimentary strata are likely late Paleoproterozoic to Mesoproterozoic in age (1800-1600 Ma) and is part of the Yavapai/Mazatzal province (Mackey et al., 2012). The sample contains 96 zircons (*35% >0.75 Th/U; 65% <0.75 Th/U*) of which 96 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=5; 20% >0.75 Th/U; 80% <0.75 Th/U*); Appalachian (*n=7; 43% >0.75 Th/U; 57% <0.75 Th/U*); Grenville *(n=52; 50% >0.75 Th/U; 50% <0.75 Th/U*); Granite Rhyolite province (*n=14; 21% >0.75 Th/U; 79% <0.75 Th/U*); Yavapai/Mazatzal (*n=11; 100% <0.75 Th/U*); Trans-Hudson (*n=7; 21% >0.75 Th/U; 86% <0.75 Th/U*).

18CODS02. Sample 18CODS02 was collected from a riverbank on the Arkansas River in central/south Colorado near Florence, CO. Cretaceous sedimentary rocks are exposed immediately around the river (Scott, 1972), while the crystalline bedrock beneath the Phanerozoic sedimentary strata is likely dominated by Yavapai/Mazatzal (Gehrels et al., 2011). The sample contains 116 zircons (*23% >0.75 Th/U; 77% <0.75 Th/U)* of which 110 falls

between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=23; 61% >0.75 Th/U; 39% <0.75 Th/U*); Appalachian (*n=6; 50% >0.75 Th/U; 50% <0.75 Th/U*); Grenville *(n=14; 29% >0.75 Th/U; 71% <0.75 Th/U*); Granite Rhyolite province (*n=23; 9% >0.75 Th/U; 91% <0.75 Th/U*); Yavapai/Mazatzal (*n=40; 100% <0.75 Th/U*); Trans-Hudson (*n=4; 25% >0.75 Th/U; 75% <0.75 Th/U*); Wyoming/Superior (*n=6; 50% >0.75 Th/U; 50% <0.75*).

18KSDS01. Sample 18KSDS01 was collected from a riverbank on the Kansas River in northeastern Kansas from a town named Ogden which is about six miles SW from Manhattan, KS. Permian sedimentary rocks are exposed immediately surrounding the area (Smith and Archer, 1995) and are underlain by 1800-1600 Ma crystalline bedrock that is part of the Yavapai/Mazatzal (Gehrels et al., 2011). The sample contains 115 zircons (*33% >0.75 Th/U; 67% <0.75 Th/U)* of which 111 falls between the ages 0-2500 Ma on the KDEs. Th/U in zircon varies between provinces with a larger population found within 1200-900 Ma: Western Cordillera (*n=17; 53% >0.75 Th/U; 47% <0.75 Th/U*); Appalachian (*n=9; 22% >0.75 Th/U; 78% <0.75 Th/U*); Grenville *(n=58; 22% >0.75 Th/U; 78% <0.75 Th/U*); Granite Rhyolite province (*n=11; 73% >0.75 Th/U; 27% <0.75 Th/U*); Yavapai/Mazatzal (*n=15; 20% >0.75 Th/U; 80% <0.75 Th/U*); Trans-Hudson (*n=1; 100% <0.75 Th/U*); Wyoming/Superior (*n=4; 75% >0.75 Th/U; 25% <0.75*).

18MOSM20. Sample 18MOSM20 was collected from the riverbank on the Missouri River in Eastern Nebraska before the Platte confluence near Omaha, NB. Pleistocene sediment largely cap the overlooking hills (Miller, 1964) and are underlain by 1800-1600 Ma crystalline bedrock that is part of the Yavapai/Mazatzal (Mackey et al., 2012). The sample contains 110 zircons (*35% >0.75 Th/U; 65% <0.75 Th/U)* of which 97 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=28; 46% >0.75 Th/U; 54% <0.75 Th/U*); Appalachian (*n=18;*

28% >0.75 Th/U; 72% <0.75 Th/U); Grenville *(n=18; 22% >0.75 Th/U; 78% <0.75 Th/U*); Granite Rhyolite province (*n=10; 70% >0.75 Th/U; 30% <0.75 Th/U*); Yavapai/Mazatzal (*n=22; 14% >0.75 Th/U; 86% <0.75 Th/U*); Trans-Hudson (*n=1; 100% <0.75 Th/U*); Wyoming/Superior (*n=13; 64% >0.75 Th/U; 54% <0.75*).

18MOSM24. Sample 18MOSM24 was collected from the riverbank on the Missouri River in Eastern Nebraska after the Platte confluence roughly 20 miles south of Omaha, NB. Pennsylvanian aged rocks are exposed nearest the river banks (Burchett et al., 1972) and are underlain by 1800-1300 Ma crystalline bedrock that is part of the Yavapai/Mazatzal and Granite Rhyolite province (Mackey et al., 2012). The sample contains 116 zircons (*30% >0.75 Th/U; 70% <0.75 Th/U)* of which 102 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=37; 46% >0.75 Th/U; 54% <0.75 Th/U*); Appalachian (*n=10; 30% >0.75 Th/U; 70% <0.75 Th/U*); Grenville *(n=15; 27% >0.75 Th/U; 73% <0.75 Th/U*); Granite Rhyolite province (*n=10; 30% >0.75 Th/U; 70% <0.75 Th/U*); Yavapai/Mazatzal (*n=28; 14% >0.75 Th/U; 86% <0.75 Th/U*); Trans-Hudson (*n=1; 100% <0.75 Th/U*); Wyoming/Superior (*n=15; 27% >0.75 Th/U; 73% <0.75*).

18MSSM32. Sample 18MSSM32 was collected from a riverbank from the Mississippi River before the Missouri confluence in Northeastern Missouri near St. Louis, MO. Carboniferous aged sedimentary rocks flank both sides of the river (Harrison, 1997) and are underlain by 1500-1300 Ma crystalline bedrock that is part of the Granite Rhyolite province (Park et al., 2010). The sample contains 111 zircons (*44% >0.75 Th/U; 56% <0.75 Th/U)* of which 96 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=43; 47% >0.75 Th/U; 53% <0.75 Th/U*); Appalachian (*n=10; 30% >0.75 Th/U; 70% <0.75 Th/U*); Grenville *(n=18; 33% >0.75 Th/U; 67% <0.75 Th/U*); Granite Rhyolite province (*n=6; 67% >0.75 Th/U;*

33% <0.75 Th/U); Yavapai/Mazatzal (*n=18; 44% >0.75 Th/U; 56% <0.75 Th/U*); Wyoming/Superior (*n=16; 50% >0.75 Th/U; 50% <0.75*).

Southern section (see Figure 5)

18BRSM37. Sample 18BRSM37 was collected from the mouth of the Brazos River right as it emptied into the Gulf of Mexico about 45 miles SW of Galveston, TX. This sample is outside the Missouri River drainage basin however it is almost identical to the Red River sample so is included in this study. Quaternary aged strata dominate the entire coastline of TX (Barnes et al., 1975) and are underlain by 750-280 Ma crystalline bedrock that is part of the Appalachian (Fildani et al., 2018). The sample contains 117 zircons (*37% >0.75 Th/U; 63% <0.75 Th/U)* of which 113 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=19; 63% >0.75 Th/U; 37% <0.75 Th/U*); Appalachian (*n=34; 35% >0.75 Th/U; 65% <0.75 Th/U*); Grenville *(n=35; 26% >0.75 Th/U; 74% <0.75 Th/U*); Granite Rhyolite province (*n=12; 25% >0.75 Th/U; 75% <0.75 Th/U*); Yavapai/Mazatzal (*n=11; 36% >0.75 Th/U; 64% <0.75 Th/U*); Trans-Hudson (*n=1; 100% >0.75 Th/U);* Wyoming/Superior (*n=5; 40% >0.75 Th/U; 60% <0.75*).

18RRSM33. Sample 18RRSM33 was collected from a riverbank of the Red River on the border between Oklahoma and TX, 65 miles N of Dallas, TX in a small town called Denison, TX. Cretaceous sedimentary rocks surround the area (McGowen et al., 1967) and are underlain by 1200-900 Ma crystalline bedrock that is part of the Grenville (Park et al., 2010). The sample contains 115 zircons (*33% >0.75 Th/U; 67% <0.75 Th/U)* of which 113 falls between the ages 0-2500 Ma on the KDEs: Western Cordillera (*n=10; 40% >0.75 Th/U; 60% <0.75 Th/U*); Appalachian (*n=30; 37% >0.75 Th/U; 63% <0.75 Th/U*); Grenville *(n=42; 24% >0.75 Th/U;*

76% <0.75 Th/U); Granite Rhyolite province (*n=12; 58% >0.75 Th/U; 42% <0.75 Th/U*); Yavapai/Mazatzal (*n=13; 100% <0.75 Th/U*); Trans-Hudson (*n=5; 80% <0.75 Th/U; 20% >0.75 Th/U);* Wyoming/Superior (*n=3; 33% >0.75 Th/U; 67% <0.75*).

Table 1. This table shows each sample broken into age domains for known North American provinces and the percentages of high vs. low Th/U values within each age domain. All percentages are color coded to a corresponding gray values in the legend below the table. The age domains are as follows: Western Cordillera (W.C.) <280 Ma, Appalachian (App.) 850-280 Ma, Grenville (Gren.) 1250-850 Ma, Granite Rhyolite province (G.R.) 1550-1250 Ma, Yavapai/Mazatzal (Y/M) 1880-1550 Ma, Trans-Hudson/Penokean (T-H) 2000-1880 Ma, Wyoming Superior (W/S) >2500 Ma.

		All	W.C.	App.	Gren.	G.R.	Y/M	T-H	W/S
North Section	**18MOSM01**	**98**	**24**	**6**	**5**	**1**	**4**	**3**	**55**
	%Th/U>0.75	*22%*	*12%*	*33%*	*20%*	-	*25%*	-	*27%*
	%Th/U<0.75	*78%*	*88%*	*67%*	*80%*	*100%*	*75%*	*100%*	*73%*
	18WYDS11	**115**	**43**	**8**	**16**	**8**	**23**	-	**17**
	%Th/U>0.75	*13%*	*9%*	-	*19%*	-	*22%*	-	*18%*
	%Th/U<0.75	*87%*	*91%*	*100%*	*81%*	*100%*	*78%*	-	*82%*
	18MOSM11	**92**	**45**	**6**	**13**	**4**	**22**	-	**6**
	%Th/U>0.75	*21%*	*16%*	*33%*	*31%*	*50%*	*23%*	-	-
	%Th/U<0.75	*79%*	*84%*	*67%*	*69%*	*50%*	*77%*	-	*100%*
	18MOSM13	**87**	**52**	**7**	**6**	**5**	**12**	**1**	**4**
	%Th/U>0.75	*17%*	*10%*	*14%*	-	*20%*	*33%*	*100%*	*75%*
	%Th/U<0.75	*83%*	*90%*	*86%*	*100%*	*80%*	*67%*	-	*25%*
	18YSSM10	**109**	**55**	**8**	**7**	**5**	**17**	**1**	**16**
	%Th/U>0.75	*24%*	*22%*	*37%*	*14%*	*20%*	*24%*	-	*31%*
	%Th/U<0.75	*76%*	*78%*	*63%*	*86%*	*80%*	*76%*	*100%*	*69%*
Central Section	**18CODS01**	**96**	**5**	**7**	**52**	**14**	**11**	**7**	-
	%Th/U>0.75	*35%*	*20%*	*43%*	*50%*	*21%*	-	*14%*	-
	%Th/U<0.75	*65%*	*80%*	*57%*	*50%*	*79%*	*100%*	*86%*	-
	18CODS02	**116**	**23**	**6**	**14**	**23**	**40**	**4**	**6**
	%Th/U>0.75	*23%*	*61%*	*50%*	*29%*	*9%*	-	*25%*	*50%*
	%Th/U<0.75	*77%*	*39%*	*50%*	*71%*	*91%*	*100%*	*75%*	*50%*
	18KSDS01	**115**	**17**	**9**	**58**	**11**	**15**	**1**	**4**
	%Th/U>0.75	*33%*	*53%*	*22%*	*22%*	*73%*	*20%*	-	*75%*
	%Th/U<0.75	*67%*	*47%*	*78%*	*78%*	*27%*	*80%*	*100%*	*25%*
	18MOSM20	**110**	**28**	**18**	**18**	**10**	**22**	**1**	**13**
	%Th/U>0.75	*35%*	*46%*	*28%*	*22%*	*70%*	*14%*	-	*64%*
	%Th/U<0.75	*65%*	*54%*	*72%*	*78%*	*30%*	*86%*	*100%*	*54%*

Table 1. This table shows each sample broken into age domains for known North American provinces and the percentages of high vs. low Th/U values within each age domain. All percentages are color coded to a corresponding gray values in the legend below the table. The age domains are as follows: Western Cordillera (W.C.) <280 Ma, Appalachian (App.) 850-280 Ma, Grenville (Gren.) 1250-850 Ma, Granite Rhyolite province (G.R.) 1550-1250 Ma, Yavapai/Mazatzal (Y/M) 1880-1550 Ma, Trans-Hudson/Penokean (T-H) 2000-1880 Ma, Wyoming Superior (W/S) >2500 Ma.

Central Section	**18MOSM24**	**116**	**37**	**10**	**15**	**10**	**28**	**1**	**15**
	%Th/U>0.75	*30%*	*46%*	*30%*	*27%*	*30%*	*14%*	-	*27%*
	%Th/U<0.75	*70%*	*54%*	*70%*	*73%*	*70%*	*86%*	*100%*	*73%*
	18MSSM32	**111**	**43**	**10**	**18**	**6**	**18**	-	**16**
	%Th/U>0.75	*44%*	*47%*	*30%*	*33%*	*67%*	*44%*	-	*50%*
	%Th/U<0.75	*56%*	*53%*	*70%*	*67%*	*33%*	*56%*	-	*50%*
South Section	**18BRSM37**	**117**	**19**	**34**	**35**	**12**	**11**	**1**	**5**
	%Th/U>0.75	*37%*	*63%*	*35%*	*26%*	*25%*	*36%*	*100%*	*40%*
	%Th/U<0.75	*63%*	*37%*	*65%*	*74%*	*75%*	*64%*	-	*60%*
	18RRSM33	**115**	**10**	**30**	**42**	**12**	**13**	**5**	**3**
	%Th/U>0.75	*33%*	*40%*	*37%*	*24%*	*58%*	-	*80%*	*33%*
	%Th/U<0.75	*67%*	*60%*	*63%*	*76%*	*42%*	*100%*	*20%*	*67%*

Th/U %
0-20%
21-40%
41-60%
61-80%
81-100%

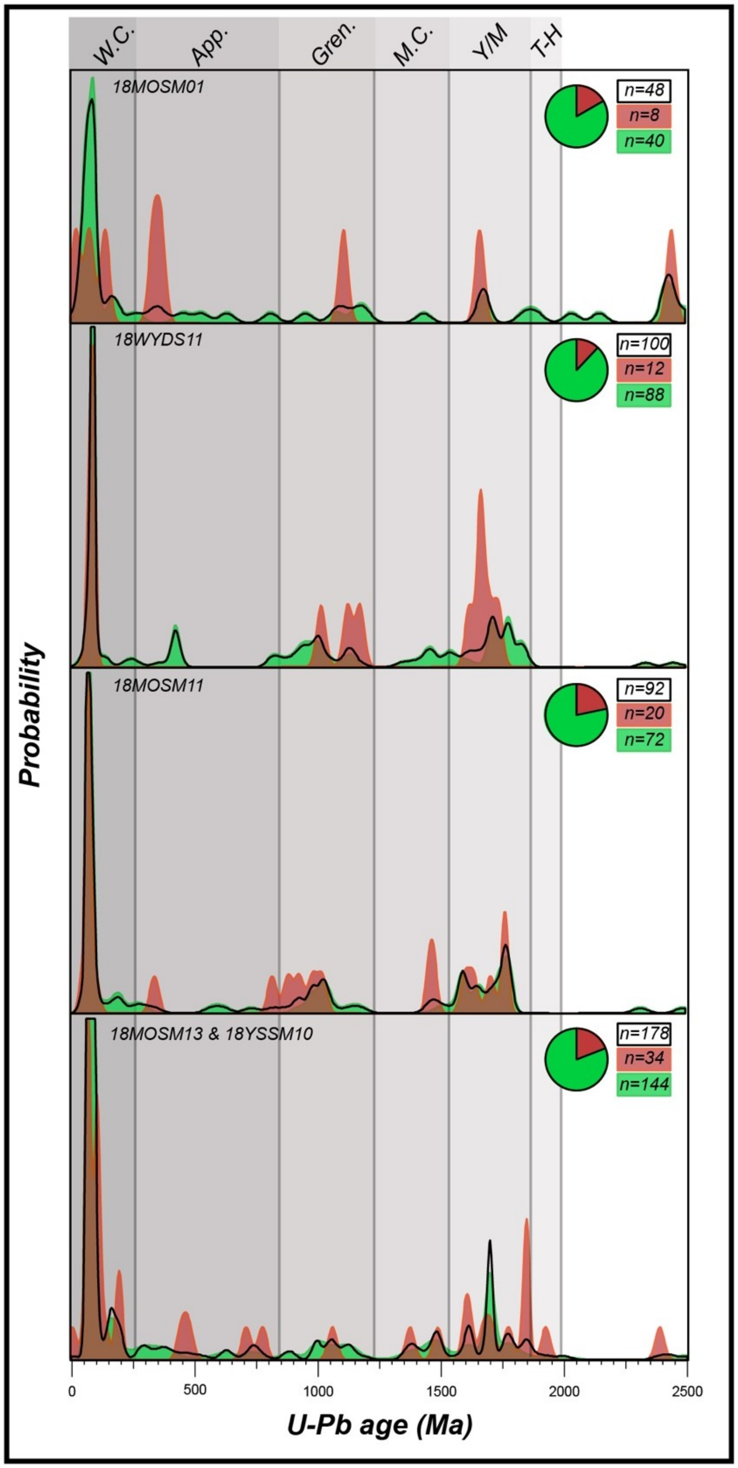

Figure 3. Kernel Density Estimation (KDE) plots for U-Pb zircon ages from Quaternary sand deposits from the Upper Missouri and Northern Rocky Mountains. Red = >0.75 Th/U zircon. Green = <0.75 Th/U zircon. Black, solid line represents collected values per sample.

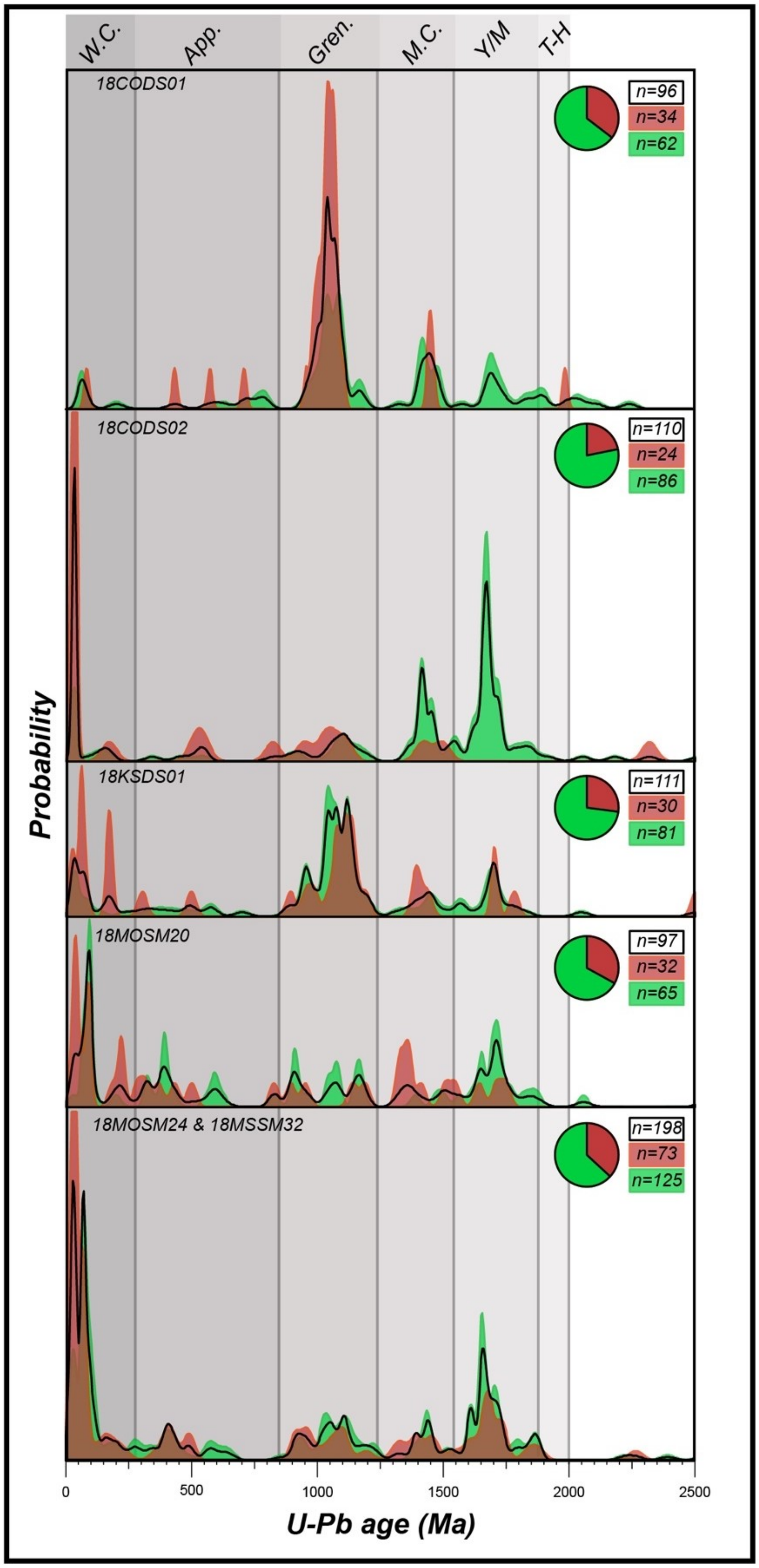

Figure 4. Kernel Density Estimation (KDE) plots for U-Pb zircon ages from Quaternary sand deposits from the Great Plains and Central Rocky Mountains. Red = >0.75 Th/U zircon. Green = <0.75 Th/U zircon. Black, solid line represents collected values per sample.

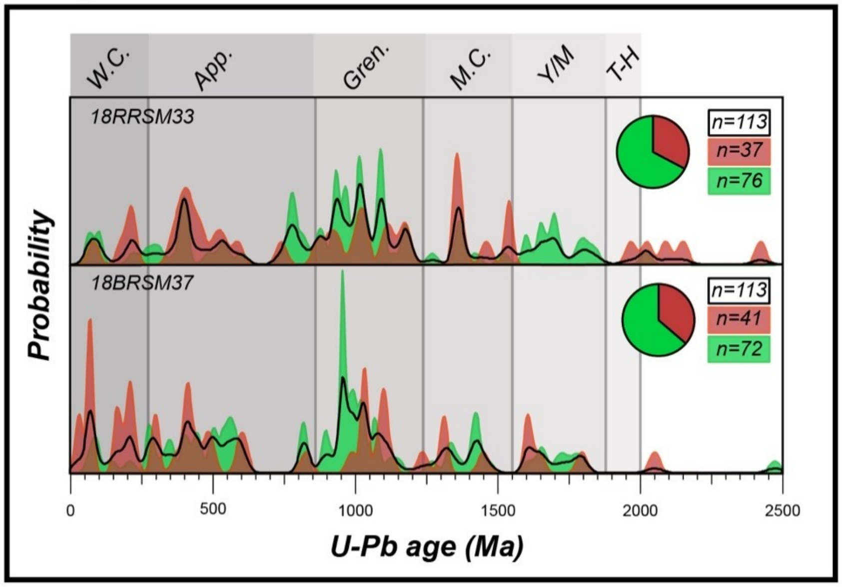

Figure 5. Kernel Density Estimation (KDE) plots for U-Pb zircon ages from Quaternary sand deposits from the Red and Brazos Rivers in the South. Red = >0.75 Th/U zircon. Green = <0.75 Th/U zircon. Black, solid line represents collected values per sample.

DISCUSSION

U-Pb

N. Rocky Mountains and Northern Plains section. (see Figure 6) Samples from the upper Missouri, Yellowstone, and Bighorn Rivers are dominated by zircon (n=219; 44% of total n) from the Western Cordillera (<280 Ma). The Cordilleran-aged zircon population in samples from the northwestern Plains and northern Rocky Mountains range in age from 115-50 Ma, which correlates to 110-40 Ma magmatism associated with the Idaho Batholith (Gaschnig et al., 2011; Foster and Fanning, 1997). There are other coeval sources that also may be supplying sediment to the drainage basin such as the Boulder Batholith for example; however, the population of grains within the northern river samples have U-Pb ages of 115-50 Ma while the Boulder Batholith was only active from 81.7-73.7 Ma (Du Bray et al., 2012). Using the Boulder Batholith as an example of a coeval source omits the possibility of the 115-50 Ma grains to be sourced from small isolated plutons with strict zircon production time ranges. This population of 115-20 Ma grains must be sourced from a large source that also had a large timeframe of zircon production and activity such as the Idaho Batholith. Grenville (1250-850 Ma; n=47; 9% of total n) and Appalachian (850-280 Ma; n=35; 7% of total n) aged grains are also present in smaller populations even though both provinces are exposed farther downstream. Additional components within the U-Pb zircon ages from the northern suite of samples include Granite Rhyolite province (1550-1250 Ma; n=23; 5% of total n), Yavapai/Mazatzal (1880-1550 Ma; n=78; 16% of total n), Trans-Hudson/Penokean (2000-1880 Ma; n=5; 1% of total n), and Wyoming/Superior (>2500 Ma; n=98; 20% of total n) age provinces. Both the Yavapai/Mazatzal and the Granite Rhyolite provinces do not directly encounter the Upper Missouri, Yellowstone, or Bighorn

Rivers. The Granite Rhyolite province, for example, outcrops ~2000 km downstream of the confluence of the Mississippi and Missouri Rivers (Rhos and Van Schmus, 2007).

Central Plains section. Samples located in Missouri, Iowa, Nebraska, Kansas, and Colorado contain variable zircon age populations with the youngest single grains having the following ages: 18CODS01-64.1 Ma, 18CODS02-23.06 Ma, 18KSDS01-24.49 Ma, 18MOSM20-28.8 Ma, 18MOSM24-12.2 Ma, 18MSSM32-8.56 Ma. These grains all fall within the likelihood of being sourced from the Western Cordillera due to their ages (<280 Ma; n=153; 23% of total grains). The Central Plains section of the drainage basin has no direct contact with the Cordilleran source yet contains two populations of grains at <50 Ma and 120-50 Ma. Although the Cordilleran source falls outside of the basin, there are coeval sources that could be supplying sediment to the system. Cretaceous-age plutons in Colorado are a viable source for 120-50 Ma aged grains draining into both the South Platte and Arkansas Rivers, while the Rio Grande Rift valley is most likely the coeval source for the <50 Ma aged grains (Fririch et al., 1998; Landman and Flowers, 2013). There are also young calderas across Wyoming and Colorado that were active during 37-23 Ma that could have supplied magmatic zircon to the Central Plains samples (Chapin, 2012). Since there are variable sources for the sediment, these possibilities present the complication of splitting the signature between coeval sources and exposes the limitations of U-Pb based provenance studies.

There is also a large population (n=175; 26% of total n) of Grenville (1250-850 Ma) aged grains which are far from the suspected source located southeast of the central region. Granite Rhyolite Province (1550-1250 Ma; n=74; 11% of total n) aged grains are also present in a large population with another large population of Yavapai/Mazatzal (1880-1550 Ma; n=134; 20% of

total n) aged grains present as well. These sources are within the drainage basin in the form of exposed bedrock and most likely were transported via fluvial processes.

Southwest section. The southwestern samples (232 total grains) exhibit different provenance trends with little to no evidence of Cordilleran source (n=29; 13% of total). Populations of Appalachian (850-280 Ma; (n=64; 28% of total)) and Grenville (1250-850 Ma; n=77; 33% of total) aged zircon represent significant age populations within the samples. Grains with ages ~600-250 Ma are most likely sourced from the Ouachita orogeny which encompasses most of central-southeast Texas and produces zircon ~500-350 Ma (Gleason et al., 2007). The Ouachita orogeny represents a coeval source for the Appalachian province which is more commonly associated with the Eastern U.S. By introducing this coeval source, it pinpoints where the Appalachian-aged grains are being sourced from and how they appear in the Red and Brazos Rivers. Grenville bedrock present in central-southwest Texas are the primary source for Grenville-aged grains present within the system.

Th/U

Th/U in zircon provides an additional tool to fingerprint the sedimentary zircon signatures in the western U.S. (Figures 2 and 6). Th/U values can be used as a proxy for tectonic settings with Basin and Range settings having highly variable and Th/U values >0.75, while accretionary settings have relatively low variability and Th/U values <0.75 (McKay et al., 2018). The Missouri/Mississippi River drainage basin and all of its major tributaries provide insight into the history of the system, however U-Pb alone is not capable of distinguishing coeval proximal sources from more distant sources which could allow a better understanding of tectonic histories and drainage patterns. By splitting zircon populations by their U-Pb ages and Th/U composition,

we can improve the signatures produced in the KDEs and separate proximal sources from distal sources.

Samples from the upper Missouri, Yellowstone, and Bighorn rivers are dominated by Cordilleran-aged zircon (<280 Ma; n=219; 44% of total grains). Of these, 87% also have Th/U values <0.75, which is compatible with being sourced from a convergent magmatic arc setting (see Table 2; McKay et al., 2018). To calculate a mean weighted age for the last influx of arc-derived sediment, the youngest population (n>3) of Th/U < 0.75 grains were isolated. The grains were excluded to achieve a weighted mean age with an mean square weighted deviation closest to 1, which would ideally represent a single population. Of the grains with Th/U values <0.75, a weighted mean was calculated to find a value of 67.65 ± 0.45 Ma (see Figure 7).With the adjacent Idaho Batholith producing zircon from ~110-40 Ma (Gaschnig et al., 2010; Moye et al., 1988), this is likely the source for Cordilleran-age zircon in the northern samples.

The Central Plains samples located in Missouri, Iowa, Nebraska, Kansas, and Colorado contain varying zircon age populations with the youngest being Cordilleran in age (<280 Ma; n=153; 23% of total grains). Of these 153 grains, 52% had Th/U values of <0.75 (convergent magmatic setting; McKay et al., 2018) which occurred ~120-50 Ma and 48% had Th/U values of >0.75 (extensional setting or Basin and Range; McKay et al., 2018) which occurred ~<50 Ma (see Table 2). Of the 52% of grains exhibiting Th/U values of <0.75 a weighted mean was calculated to be 67.44 ± 0.60 Ma (see Figure 8). Of the 48% of grains exhibiting >0.75 Th/U values, another weighted mean value of 33.23 ± 0.35 Ma (see Figure 9) was calculated.

Implications for drainage networks

N. Rocky Mountains and Northern Plains section. By combining U-Pb and Th/U values in the zircon, we know that 87% of the 219 grains have Th/U values <0.75, which is compatible with being sourced from a convergent magmatic arc setting (McKay et al., 2018). With the Idaho Batholith the likely source due to active magmatism occurring 110-40 Ma (Gaschnig et al., 2010; Moye et al., 1988), there is a question of how these grains were transported into the Missouri River drainage basin. The Holocene Continental Divide separates the Idaho Batholith from the Missouri and Yellowstone/Bighorn River drainages; therefore, eastward transport of western Cordilleran grains either: (1) predates the Laramide development of the Continental Divide (~ 84-81 Ma, Carrapa et al., 2019; Jackson et al., 2019) or (2) Cordilleran age grains were transported into the Missouri River drainage as aerial volcanic ash prior to, during, and after development of ~80 Ma and later Laramide structures. Volcanic transport, however, would continue until at least 40 Ma, coinciding with the end of Idaho Batholith magmatism (Gaschnig et al., 2010; Moye et al., 1988), which is not observed. Therefore, sediment routing into the Missouri River drainage basin must predate the development of the Continental Divide. The weighted mean of 67.65 ± 0.45 Ma for the youngest grains having Th/U values <0.75 represents the cut-off of Cordilleran-aged sediment to the system and a suggested age of Continental Divide emplacement.

In order for the Grenville (1250-850 Ma; n=47; 9% of total n) and Appalachian (850-280 Ma; n=35; 7% of total n) aged grains to appear in Montana and North Dakota requires westward transport prior to development of the modern drainage system and the Continental Divide (Figure 10; Blum and Pecha, 2014). During the Permian, westward transportation of grains is evident in zircon age populations within the Grand Canyon which were routed from Precambrian basement rocks of the Ancestral Rockies (Gehrels et al., 2011). Westward trends occurred well

into the Early Cretaceous when the Appalachian-Ouachita orogen acted as the continental divide that allowed for sediment transport from east to west to the Boreal Sea, which was the main sink for the system (Blum and Pecha, 2014).

The same methods apply for the grains sourced from the Granite Rhyolite province (1550-1250 Ma; n=23; 5% of total n) and Yavapai/Mazatzal (1880-1550 Ma; n=78; 16% of total n). The presence of these grains requires northwest-directed (Figure 11) sediment transport in the geologic past, which is compatible with the model for fluvial drainage toward the Boreal Sea in the Cretaceous (Blum and Pecha, 2014). There is also evidence of Upper Cretaceous aged rocks located in Central-Western Montana near and around the northern most rivers (Gwinn and Mutch, 1965) which again supports northwest sediment transport. While small, unidentified Granite Rhyolite and Yavapai/Mazatzal age material may exist upstream, it is unlikely major components of a sedimentary sample would be sourced from small, isolated sources.

Central Plains section. The central samples contain zircon that are Cordilleran in age (<280 Ma; n=153; 23% of total grains). Of these grains, we know that those with ages ~120-50 Ma have Th/U values indicating convergent magmatic settings (McKay et al., 2018). The youngest <0.75 Th/U population that does not correlate with known extensional magmatism has a weighted mean of 67.44 ± 0.44 Ma, identical to the weighted mean for the youngest (<280 Ma) arc magmatic sourced population in the northern samples exhibiting Th/U values <0.75. For the <50 Ma zircon exhibiting Basin and Range signatures a weighted mean was calculated to be 33.23 ± 0.35 Ma. The ideal source for these grains is the Rio Grande Rift which extends from Northern Mexico to central Colorado seen in Figure 2. The Rio Grande Rift also falls within the Missouri River drainage basin which would allow for fluvial or aerial transport of sediment. It is also well-documented that the peak activity of the northern section of the Rio Grande Rift

occurred ~28 Ma (Landman and Flowers, 2013) which directly correlates to the population of grains displaying Th/U values >0.75 in the central samples. For the Rio Grande Rift valley to be the source, there must be a northwest trend which in turn would cut off drainage to the southernmost rivers such as the Red and Brazos Rivers. The presence of Grenville (1250-850 Ma; n=175; 26% of total grains) aged grains indicates that these grains were most likely transported to the northwest during or prior to the Early Cretaceous when the drainage pattern was draining into the Boreal Sea by fluvial processes (Blum and Pecha, 2014).

Southwest section. Zircon grains (n=232) in southwestern samples contain relatively few grains of Permian or younger age even though the Rio Grande Rift Valley is a proximal source for Basin and Range zircon. The lack of zircon exhibiting both U-Pb ages and Th/U values indicating a Rio Grande Rift source, suggests that there is a northeast trend in sediment of rift material to the central samples. The abundance of >280 Ma grains implies (1) heavy recycling of material draining into the southernmost rivers and (2) rerouting of younger (<280 Ma) sediment to the Central Plains samples away from the Red and Brazos Rivers (see Figure 12).

Tectonic development of the modern Continental Divide during Rocky Mountain orogenesis

In both the North Rocky Mountain /Northern Plains and Central Plains samples, there is a weighted mean of ~67 Ma for Cordilleran aged (<280 Ma) grains exhibiting magmatic Th/U values (<0.75). These synchronous ages suggest a time of Cordilleran sourced material being cut off from the Missouri/Mississippi drainage basin therefore suggesting a new age of the Continental Divide emplacement of ~67 Ma. There are minor magmatic Cordilleran aged grains in the drainage basin, but the ~67 Ma age represents the last influx of grains being transported in

the system even though zircon production increased from 60-30 Ma (McKay et al., 2018). We can also suggest that with these ~67 Ma means present in both the North Rocky Mountain/Northern Plains and Central Plains samples, that the Northern and Central Rocky Mountains developed synchronously with the Continental Divide.

The Central Plains samples not only contain a mean of ~67 Ma, but also contain Cordilleran-age rift grains (>0.75 Th/U) with a mean of ~33 Ma. This population of younger grains in the Central Plains samples suggest extensional setting source which is likely the Rio Grande Rift valley located to the southwest of the central river samples.

Table 2. North American provinces, their n-value, and their corresponding Th/U percentages with a color coded table as a legend below.

		Arc	Extension
Province	**n =**	**<0.75 Th/U %**	**>0.75 Th/U %**
Basin and Range	67	34%	66%
Western Cordillera	332	77%	23%
Appalachian	159	69%	31%
Grenville	299	72%	28%
Granite Rhyolite province	211	38%	62%
Yavapai/Mazatzal	236	83%	17%
Trans-Hudson/Penokean	25	68%	32%
Wyoming/Superior	107	67%	33%

Th/U %
0-20%
21-40%
41-60%
61-80%
81-100%

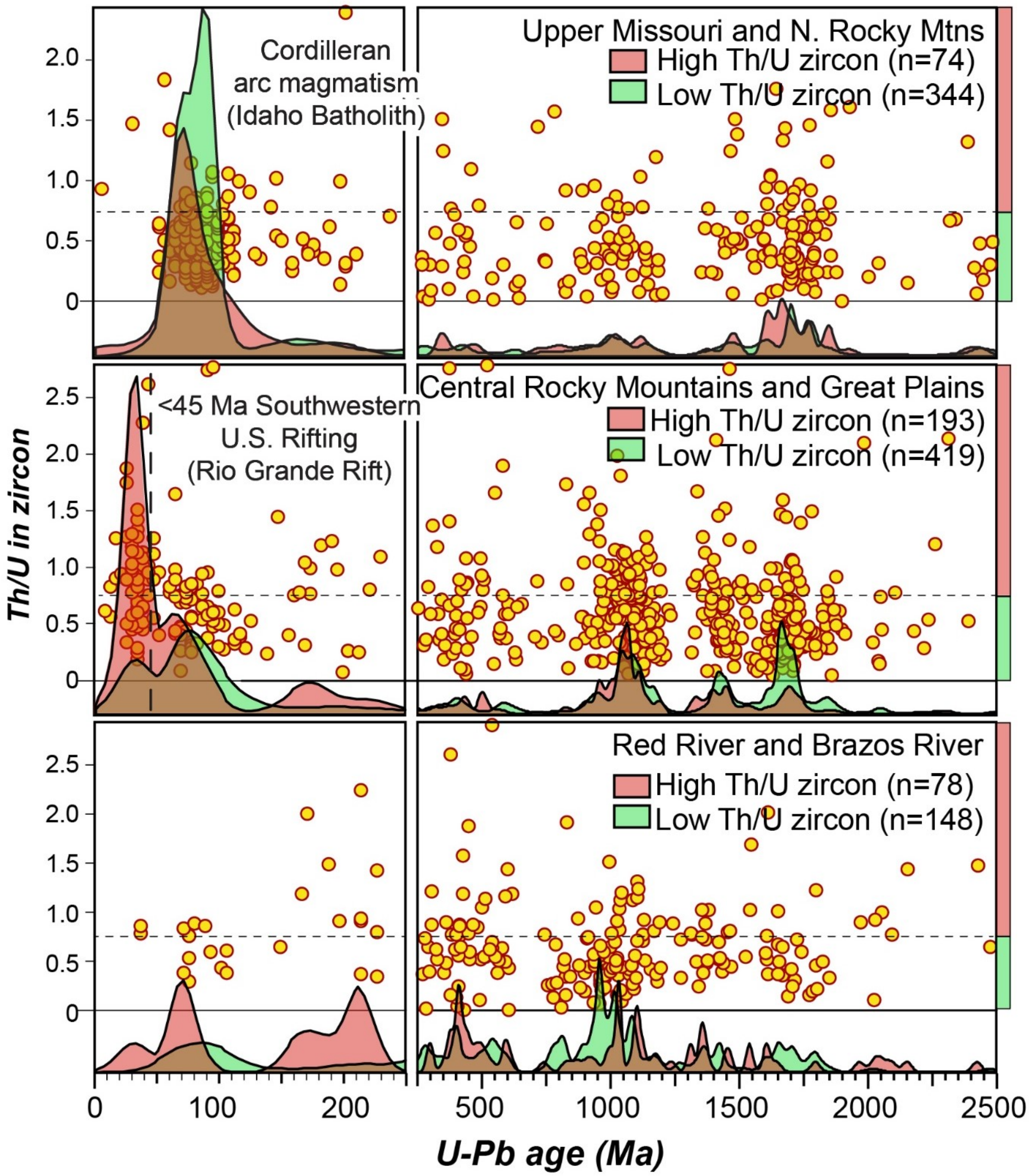

Figure 6. Grouped KDEs for the north, central, and south sections. Yellow dots represent single zircon. Dashed line represents 0.75 Th/U boundary.

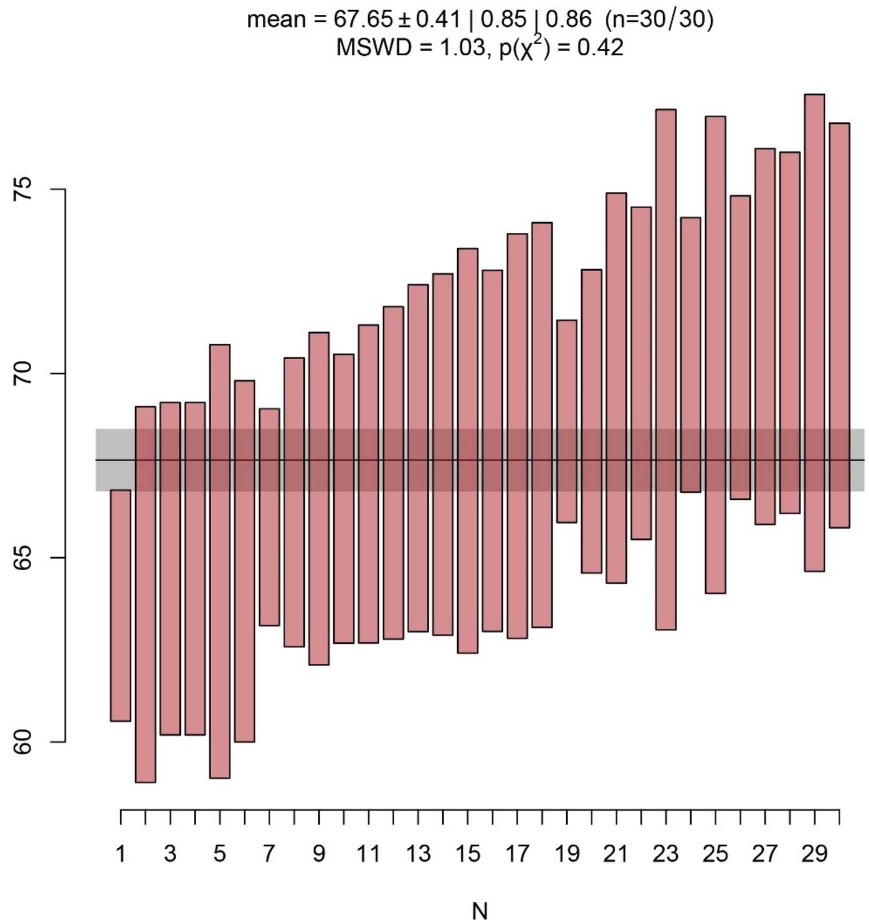

Figure 7. Weighted mean for zircon found in the Upper Missouri, Yellowstone, and Bighorn rivers. All zircon in this population represent the youngest grains within the northern samples containing Th/U values of <0.75.

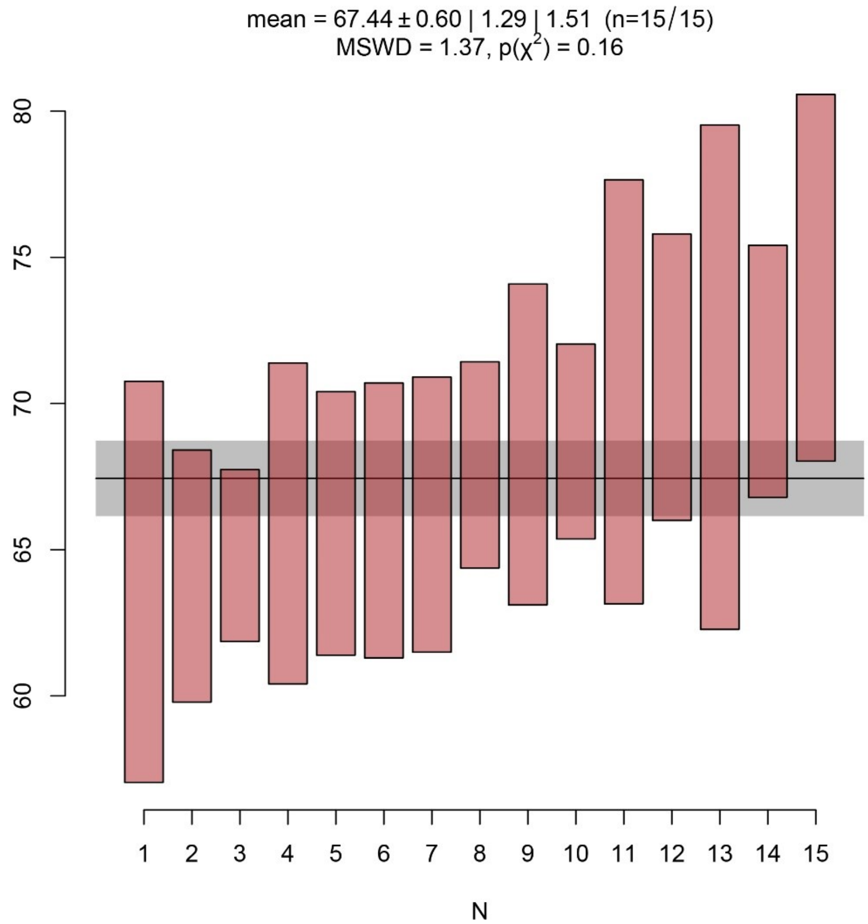

Figure 8. Weighted mean for zircon found in the Platte, Kansas, Arkansas, Missouri, and Mississippi rivers (Central samples). This population represents part of the youngest grains containing <0.75 Th/U values.

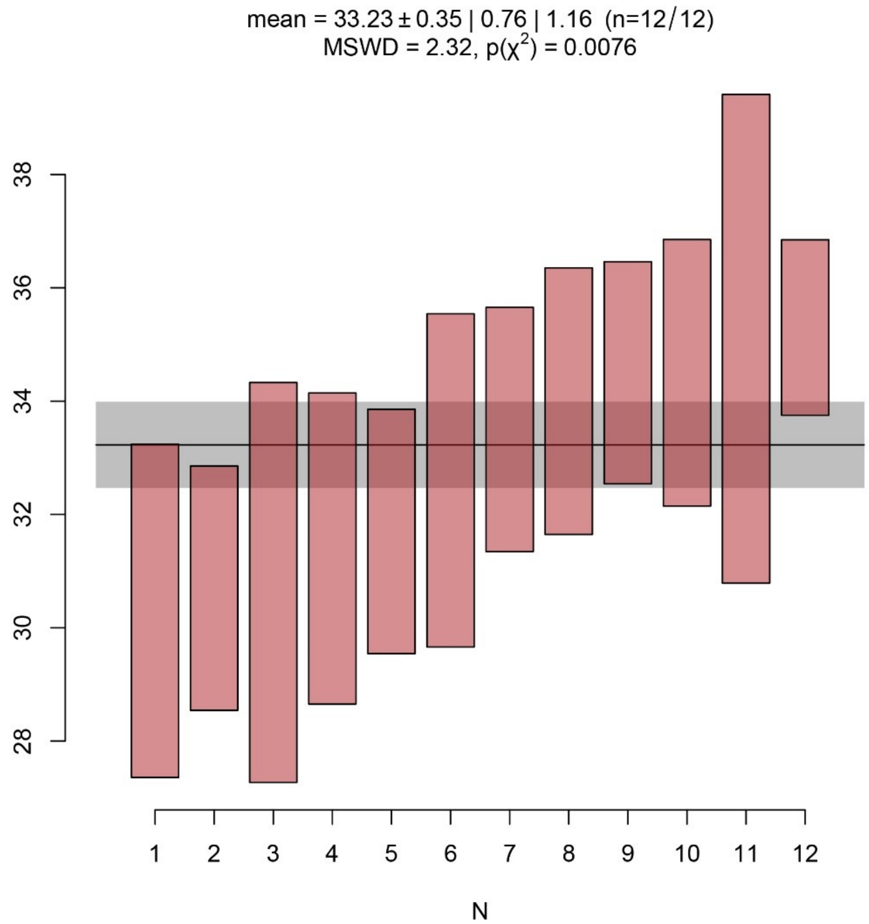

Figure 9. Weighted mean for zircon found in the Platte, Kansas, Arkansas, Missouri, and Mississippi rivers (Central samples). This population represents part of the youngest grains containing >0.75 Th/U values.

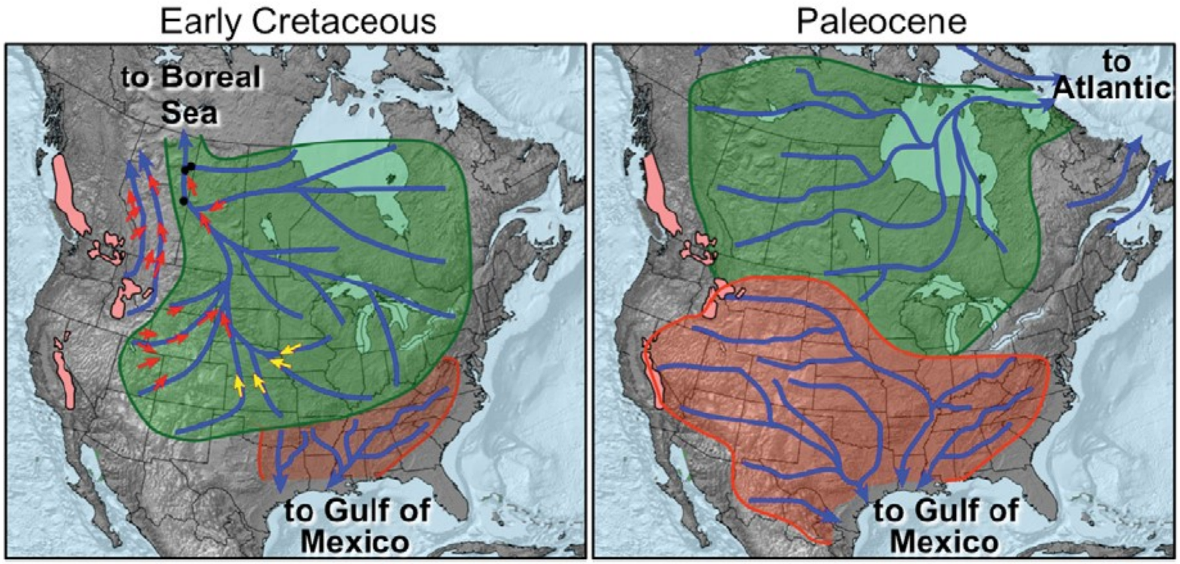

Figure 10. Early Cretaceous to Paleocene continental-scale drainage reorganization (Blum and Pecha, 2014).

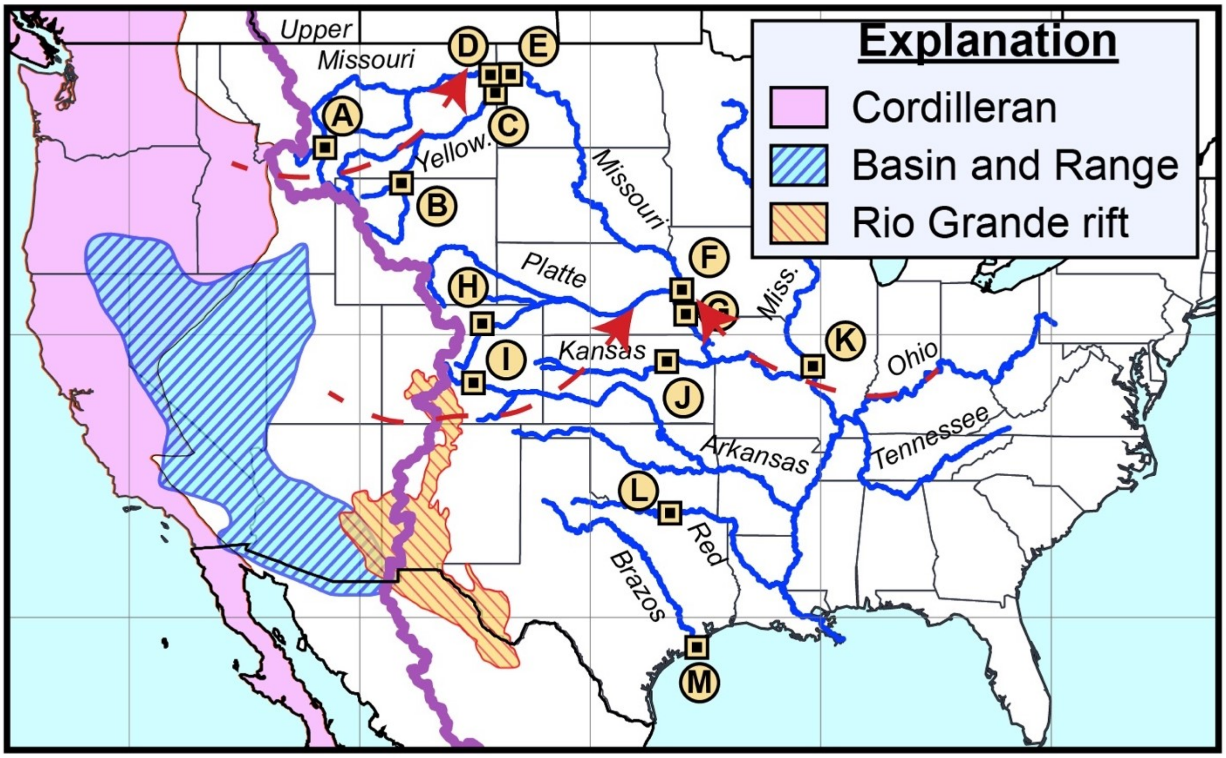

Figure 11. Map of sediment transport prior to the development of the Continental Divide (pre ~67 Ma).

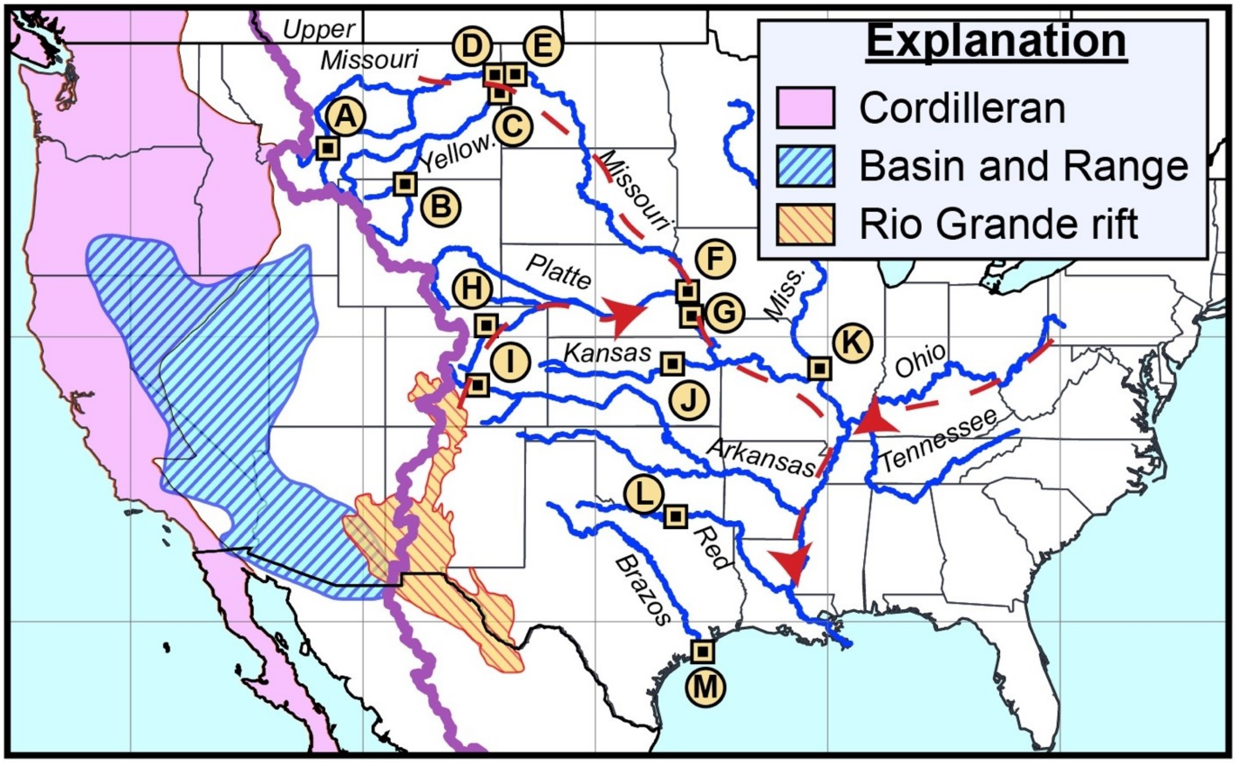

Figure 12. Map of sediment transport after the development of the Continental Divide (post ~67 Ma). Cordillera-aged grains are not being transported into the drainage basin.

CONCLUSIONS

Combining U-Pb ages and Th/U values of zircon collected from modern river sediment has provided a detailed look into drainage patterns and the tectonic history of North America. Using detrital zircon, we were able to reconstruct sediment transport patterns (see Figure 11; Blum and Pecha, 2014) and estimate the age of Continental Divide emplacement (~67 Ma), which is compatible with known ages for sediment cut-off to the drainage basin. By using weighted means for <280 Ma zircon and separating zircon based on Th/U values, we were able to find tectonic histories using modern river sediment.

Implications include (1) Cordilleran-aged zircon (<280 Ma) were transported to the Upper Missouri, Yellowstone, Bighorn, Platte, Kansas, Arkansas, and Mississippi Rivers prior to development of the proto-Continental Divide at about 67 Ma (see Figure 11 for pre ~67 Ma, and see Figure 12 for post ~67 Ma). Coeval development of the Continental Divide suggests (2) Late Laramide uplift in the easternmost portion of the Rocky Mountains was near synchronous, as evidenced by similar weighted mean averages for the youngest magmatic zircon in both the Northern and Central samples and (3) Modern river detrital petrochronology provided better constraints than hard rock or stratigraphic investigations.

REFERENCES

Fririch, C.J., Dewitt, E., Bryant, B., Richard, S., Smith, R.P., 1998, Geologic map of the collegiate peaks wilderness area and the Grizzly Peak caldera, Sawatch Range, central Colorado: U.S. Geological Survey.

Amato, J.M., Boullion, A.O., Serna, A.M., Sanders, A.E., Farmer, G.L., Gehrels, G.E., Wooden, J.L., and Mts, R., 2008, Evolution of the Mazatzal province and the timing of the Mazatzal orogeny : Insights from U-Pb geochronology and geochemistry of igneous and metasedimentary rocks in southern New Mexico: GSA Bulletin, v. 120; no. 3/4, p. 328–346, doi: 10.1130/B26200.1.

Bickford, M.E., Mueller, P.A., Kamenov, G.D., and Hill, B.M., 2008, Crustal evolution of southern Laurentia during the Paleoproterozoic: Insights from zircon Hf isotopic studies of ca. 1.75 Ga rocks in central Colorado: Geology, v. 36, p. 555–558.

Bird, P., 1998, Kinematic history of the Laramide orogeny in latitudes 35–49 N, western United States: Tectonics, v. 17, p. 780–801.

Bjorklund, L.J., and Brown, R.F., 1957, Geology and ground-water resources of the Lower South Platte River Valley between Hardin, Colorado, and Paxton, Nebraska: U.S. Geological Survey, scale 1:126,720

Blum, M., and Pecha, M., 2014, Mid-Cretaceous to Paleocene North American drainage reorganization from detrital zircons: Geology, v.42, p. 607–610, doi: 10.1130/G35513.1.

Boettcher, S.S., and Milliken, K.L., 1994, Mesozoic-Cenozoic unroofing of the southern Appalachian Basin: Apatite fission track evidence from Middle Pennsylvanian sandstones: The Journal of Geology, v. 102, p. 655–668.

Bowring, S.A., and Karlstrom, K.E., 1990, Growth, stabilization, and reactivation of Proterozoic lithosphere in the southwestern United States: Geology, v. 18, p. 1203–1206.

Brown Jr, L.F., Brewton, J.L., McGowen, J.H., Proctor, C. V, Aronow, S., and Barnes, V.E., 1975, Geologic Atlas of Texas, Beeville-Bay City Sheet: Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, scale 1:250,000

Burchett, R.R., Dreeszen, V.H., Reed, E.C., and Prichard, G.E., 1972, Bedrock geologic map showing thickness of overlying Quaternary deposits, Lincoln quadrangle and part of Nebraska City quadrangle, Nebraska and Kansas: U.S. Geological Survey, scale 1:250,000

Carlson, C.G., 1985, Geology of McKenzie County, North Dakota: part 1: North Dakota Geological Survey, scale 1:126,720

Chapin, C.E., 2012, Origin of the Colorado mineral belt: Geosphere, v. 8, p. 28–43.

Chapin, C.E., Wilks, M., and Mcintosh, W.C., 2004, Space - time patterns of Late Cretaceous to present magmatism in New Mexico — comparison with Andean volcanism and potential for future volcanism: New Mexico Bureau of Geology and Mineral Resources, Bulletin 160, p.13-40

Cherniak, D.J., 2010, Diffusion in accessory minerals: zircon, titanite, apatite, monazite and xenotime: Reviews in Mineralogy and Geochemistry, v. 72, p. 827–869.

Colton, R.B., 1979, Geologic map of the Bainville SE Quadrangle, Roosevelt and Richland counties, Montana, and Williams County, North Dakota: U.S. Geological Survey, scale 1:24,000

Davis, S.J., Mulch, A., Carroll, A.R., Horton, T.W., and Chamberlain, C.P., 2009, Paleogene landscape evolution of the central North American Cordillera: Developing topography and hydrology in the Laramide foreland: Geological Society of America Bulletin, v. 121, p. 100–116.

DeCelles, P.G., Lawton, T.F., and Mitra, G., 1995, Thrust timing, growth of structural culminations, and synorogenic sedimentation in the type Sevier orogenic belt, western United States: Geology, v. 23, p. 699–702.

Dethier, D.P., 2001, Pleistocene incision rates in the western United States calibrated using Lava Creek B tephra: Geology, v.29, p. 783–786.

Dickinson, W.R., 2004, Evolution of the North American cordillera: Annual Reviews of Earth and Planetary Sciences, v. 32, p. 13–45.

English, J.M., and Johnston, S.T., 2004, The Laramide orogeny: What were the driving forces?: International Geology Review, v. 46, p. 833–838.

Fildani, A., Hessler, A.M., Mason, C.C., McKay, M.P., and Stockli, D.F., 2018, Late Pleistocene glacial transitions in North America altered major river drainages, as revealed by deep-sea sediment: Scientific Reports, v. 8, p. 13839, doi: 10.1038/s41598-018-32268-7.

Fildani, A., McKay, M.P., Stockli, D., Clark, J., Dykstra, M.L., Stockli, L., and Hessler, A.M., 2016, The ancestral Mississippi drainage archived in the late Wisconsin Mississippi deep-sea fan: Geology, v. 44, p. 479–482, doi: 10.1130/G37657.1.

Finch, R.J., and Hanchar, J.M., 2003, Structure and chemistry of zircon and zircon-group minerals: Reviews in mineralogy and geochemistry, v. 53, p. 1–25.

Foster, D.A., and Fanning, C.M., 1997, Geochronology of the northern Idaho batholith and the Bitterroot metamorphic core complex : Magmatism preceding and contemporaneous with extension: Geological Society and America Bulletin, v.109, p. 379–394.

Galloway, W.E., Whiteaker, T.L., and Ganey-curry, P., 2011, History of Cenozoic North American drainage basin evolution , sediment yield , and accumulation in the Gulf of Mexico basin: Geosphere, v.7, p. 938–973, doi: 10.1130/GES00647.1.

Gaschnig, R.M., Vervoort, J.D., Lewis, R.S., and McClelland, W.C., 2010, Migrating magmatism in the northern US Cordillera: in situ U–Pb geochronology of the Idaho batholith: Contributions to Mineralogy and Petrology, v. 159, p. 863–883.

Gaschnig, R.M., Vervoort, J.D., Lewis, R.S., and Tikoff, B., 2011, Isotopic Evolution of the Idaho Batholith and Challis Intrusive Province, Northern US Cordillera: Journal of Petrology, v. 52, p. 2397–2429, doi: 10.1093/petrology/egr050.

Gehrels, G.E., Blakey, R., Karlstrom, K.E., Timmons, J.M., Dickinson, B., Pecha, M., Butte, T., and Angel, B., 2011, Detrital zircon U-Pb geochronology of Paleozoic strata in the Grand Canyon , Arizona: Lithosphere, v.3, p. 183–200, doi: 10.1130/L121.1.

McGowen, J.H., Hentz, T.F., Owen, D.E., Pieper, M.K., Shelby, C.A., Barnes, V.E., Humble Oil and Refining Co., Pure Oil Co., Branson, C.C., Mankin, C.J., Morgan, H.J., Cordell, R.J., Nolte, W.J., Hendricks, Leo, and Edward, H., 1991, Geologic atlas of Texas, Sherman sheet: University of Texas at Austin, Bureau of Economic Geology, scale 1:250,000

Green, A.G., Weber, W., and Hajnal, Z., 1985, Evolution of Proterozoic terrains beneath the Williston Basin: Geology, v. 13, p. 624–628.

Grimes, C.B., John, B.E., Kelemen, P.B., Mazdab, F.K., Wooden, J.L., Cheadle, M.J., Hanghøj, K., and Schwartz, J.J., 2007, Trace element chemistry of zircons from oceanic crust: A method for distinguishing detrital zircon provenance: Geology, v. 35, p. 643–646, doi: 10.1130/G23603A.1.

Grimes, C.B., Wooden, J.L., Cheadle, M.J., and John, B.E., 2015, "Fingerprinting" tectono-magmatic provenance using trace elements in igneous zircon: Contributions to Mineralogy and Petrology, v. 170, p. 1–26, doi: 10.1007/s00410-015-1199-3.

Gwinn, V.E., and Mutch, T.A., 1965, Intertongued Upper Cretaceous volcanic and nonvolcanic rocks, central-western Montana: Geological Society of America Bulletin, v. 76, p. 1125–1144.

Harrison, R.W., 1997, Bedrock geologic map of the St. Louis 30'x 60'Quadrangle, Missouri and Illinois: U.S. Geological Survey, scale 1:100,000

Heller, P.L., and Paola, C., 1989, The paradox of Lower Cretaceous gravels and the initiation of thrusting in the Sevier orogenic belt, United States Western Interior: Geological Society of America Bulletin, v. 101, p. 864–875.

Hopper, E., Fischer, K.M., Wagner, L.S., and Hawman, R.B., 2017, Reconstructing the end of the Appalachian orogeny: Geology, v. 45, p. 15–18.

Hoskin, P.W.O., and Ireland, T.R., 2000, Rare earth element chemistry of zircon and its use as a provenance indicator: Geology, v. 28, p. 627–630.

Hoskin, P.W.O., and Schaltegger, U., 2003, The composition of zircon and igneous and metamorphic petrogenesis: Reviews in mineralogy and geochemistry, v. 53, p. 27–62.

Jackson Jr, W.T., Mckay, M.P., Bartholomew, M.J., Allison, D.T., Spurgeon, D.L., and Shaulis, B., 2019, Initial Laramide tectonism recorded by Upper Cretaceous paleoseismites in the northern Bighorn Basin , USA : Field indicators of an applied end load stress: Geology, v. 47, p. 1059–1063.

Kirkland, C.L., Smithies, R.H., Taylor, R.J.M., Evans, N., and McDonald, B., 2015, Zircon Th/U ratios in magmatic environs: Lithosphere, v. 212, p. 397–414.

Kozimko, L.M., 1985, Geologic map of the Greybull North Quadrangle, Wyoming: Wyoming State Geological Survey, scale 1:24,000

Landman, R.L., and Flowers, R.M., 2013, (U-Th)/ He thermochronologic constraints on the evolution of the northern Rio Grande Rift , Gore Range , Colorado , and implications for

rift propagation models to explain late Cenozoic elevation gain of the: Geosphere, v.9, p. 170–187, doi: 10.1130/GES00826.1.

Lidiak, E.G., 1971, Buried Precambrian rocks of South Dakota: Geological Society of America Bulletin, v. 82, p. 1411–1420.

Loucks, R.G., 1986, Controls on porosity and permeability of hydrocarbon reservoirs in lower Tertiary sandstones along the Texas Gulf Coast: Virtual Landscapes of Texas

Mackey, G.N., Horton, B.K., and Milliken, K.L., 2012, Provenance of the Paleocene – Eocene Wilcox Group , western Gulf of Mexico basin : Evidence for integrated drainage of the southern Laramide Rocky Mountains and Cordilleran arc: GSA Bulletin, v.124, p. 1007–1024, doi: 10.1130/B30458.1.

McKay, M.P., Jackson, W.T., and Hessler, A.M., 2018, Tectonic stress regime recorded by zircon Th/U: Gondwana Research, v. 57, p. 1–9, doi: 10.1016/j.gr.2018.01.004.

McMillan, M.E., Angevine, C.L., and Heller, P.L., 2002, Postdepositional tilt of the Miocene-Pliocene Ogallala Group on the western Great Plains : Evidence of late Cenozoic uplift of the Rocky Mountains: Geology, v. 30, p. 63–66.

Miller, R.D., 1964, Geology of the Omaha-Council Bluffs Area, Nebraska-Iowa: US Geological Survey, scale 1:24,000

Missouri, M., and Nebraska, N., 1998, Missouri River Basin: USGS Columbia Environmental Research Center

Moye, F.J., Hackett, W.R., Blakley, J.D., and Snider, L.G., 1988, Regional Geologic Setting and Volcanic Stratigraphy of the Challis Volcanic Field , Central Idaho. Guidebook to the geology of central and southern Idaho: Idaho Geological Survey Bulletin, v.27, p. 87–98.

Park, H., Jr, D.L.B., Rickenbaker, A., Krug, D.B., Gehrels, G., The, S., January, N., Park, H., Jr, D.L.B., Rickenbaker, A., Bachmann-krug, D., and Gehrels, G., 2010, Application of Foreland Basin Detrital - Zircon Geochronology to the Reconstruction of the Southern and Central Appalachian Orogen: Geology, v. 118, p. 23–44, doi: 10.1086/648400.

Paton, C., Hellstrom, J., Paul, B., Woodhead, J., and Hergt, J., 2011, Iolite: Freeware for the visualisation and processing of mass spectrometric data: Journal of Analytical Atomic Spectrometry, v. 26, p. 2508–2518.

Gleason, J.D., Gehrels, G.E., Dickinson, W.R., Patchett, P.J., and Kring D.A., 2007, Laurentian Sources for Detrital Zircon Grains in Turbidite and Deltaic Sandstones of the Pennsylvanian Haymond Formation, Marathon Assemblage, West Texas, U.S.A.: Journal of Sedimentary Research, v. 77, p. 888–900, doi: 10.2110/jsr.2007.084.

Pollock, J.C., Hibbard, J.P., and Staal, C.R. Van, 2012, A paleogeographical review of the peri-Gondwanan realm of the Appalachian orogen: Canadian Journal of Earth Sciences, v. 49, p. 259–288, doi: 10.1139/E11-049.

Rainbird, R.H., Heaman, L.M., and Young, G., 1992, Sampling Laurentia: detrital zircon geochronology offers evidence for an extensive Neoproterozoic river system originating from the Grenville orogen: Geology, v. 20, p. 351–354, doi: 10.1130/0091-7613(1992)020<0351:SLDZGO>2.3.CO;2.

Rohs, C.R., and Van Schmus, W.R., 2007, Isotopic connections between basement rocks exposed in the St. Francois Mountains and the Arbuckle Mountains, southern mid-continent, North America: International Journal of Earth Sciences, v. 96, p. 599.

Schulz, K.J., and Cannon, W.F., 2007, The Penokean orogeny in the Lake Superior region: Precambrian Research, v. 157, p. 4–25.

Scott, G.R., 1972, Reconnaissance geologic map of the Beulah NE quadrangle, Pueblo County, Colorado: U.S Geological Survey, scale 1:24,000

Sewall, J.O., and Sloan, L.C., 2006, Come a little bit closer : A high-resolution climate study of the early Paleogene Laramide foreland: Geology, v.34, p. 81–84, doi: 10.1130/G22177.1.

Slagstad, T., Culshaw, N.G., Daly, J.S., and Jamieson, R.A., 2009, Western Grenville province holds key to midcontinental Granite-Rhyolite province enigma: Terra Nova, v. 21, p. 181–187.

Sláma, J., Košler, J., Condon, D.J., Crowley, J.L., Gerdes, A., Hanchar, J.M., Horstwood, M.S.A., Morris, G.A., Nasdala, L., and Norberg, N., 2008, Plešovice zircon—a new natural reference material for U–Pb and Hf isotopic microanalysis: Chemical Geology, v. 249, p. 1–35.

Smith, B.D, and Archer, A.W., 1995, Geologic Map of Riley County, Kansas: Kansas Geological Survey, scale 1:50,000

Vermeesch, P., 2012, On the visualisation of detrital age distributions: Chemical Geology, v. 312–313, p. 190–194, doi: 10.1016/j.chemgeo.2012.04.021.

Vuke, S.M., 2006, Geologic map of the Cenozoic deposits of the Lower Jefferson Valley, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report, v. 537, p. 42.

APPENDIX

Zircon ages and Th/U values for sample 18MOSM01

Sample ID	^{207}Pb/^{235}U Age (Ma)	± (Ma)	^{206}Pb/^{238}U Age (Ma)	± (Ma)	^{207}Pb/^{206}Pb Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18MOSM01	1911	29	1923	35	1897	56	283	0.102	1897	56	0.000360424
18MOSM01	1142	85	637	54	2334	77	4400	98	637	54	0.022272727
18MOSM01	536	53	264	43	2182	49	7300	301	264	43	0.041232877
18MOSM01	1198	32	457	19	3006	29	5650	240	457	19	0.042477876
18MOSM01	2600	72	2500	94	2685	67	1520	72	2685	67	0.047368421
18MOSM01	1654	58	1170	68	2377	32	2350	122.5	1170	68	0.05212766
18MOSM01	2312	44	2047	79	2571	30	2220	121	2571	30	0.054504505
18MOSM01	2070	41	1199	62	3131	34	2710	171	1199	62	0.063099631
18MOSM01	1904	35	1462	42	2423	54	119.9	8.19	2423	54	0.068306922
18MOSM01	2199	31	1811	44	2577	45	77.8	7.22	2577	45	0.092802057
18MOSM01	3135	15	3083	40	3162	23	549	61.7	3162	23	0.112386157
18MOSM01	79.6	5.8	78.7	2.2	60	150	466	54.2	78.7	2.2	0.116309013
18MOSM01	2365	34	2132	69	2586	25	1673	212.1	2586	25	0.126778243
18MOSM01	1605	33	815	24	2895	36	7530	1024	815	24	0.135989376
18MOSM01	1894	30	1664	32	2152	61	154	22.7	2152	61	0.147402597
18MOSM01	2247	96	1870	140	2724	31	1420	243.2	2724	31	0.171267606
18MOSM01	978	16	957	23	1010	44	941	171.6	957	23	0.182359192
18MOSM01	2807	55	2583	73	2954	65	471	86.5	2954	65	0.183651805
18MOSM01	1229	56	534	48	2898	32	3890	761	534	48	0.19562982
18MOSM01	2303	41	1913	69	2685	31	420	89	2685	31	0.211904762
18MOSM01	107.5	5.9	107.8	2.9	110	120	711	162	107.8	2.9	0.227848101
18MOSM01	41.5	4.9	45.4	2	-180	210	572	134	45.4	2	0.234265734
18MOSM01	1666	19	1632	32	1690	34	701	165	1690	34	0.235378031

18MOSM01	2181	28	1912	53	2439	34	1700	402	2439	34	0.236470588
18MOSM01	2515	71	2490	120	2573	42	387	95	2573	42	0.245478036
18MOSM01	3075	68	2610	140	3446	29	2010	500	3446	29	0.248756219
18MOSM01	80.2	2.9	70.5	1.9	329	74	3020	837	70.5	1.9	0.277152318
18MOSM01	2592	47	1870	82	3230	32	2050	577	3230	32	0.281463415
18MOSM01	2011	35	1650	50	2413	58	84.7	23.9	2413	58	0.282172373
18MOSM01	105	10	103.5	3.2	60	190	219.6	65	103.5	3.2	0.295992714
18MOSM01	2477	19	2473	43	2474	28	758	232.9	2474	28	0.307255937
18MOSM01	1760	37	1519	40	2039	70	70.7	21.9	2039	70	0.309759547
18MOSM01	3002	19	2802	52	3139	33	124.4	38.7	3139	33	0.311093248
18MOSM01	3119	20	2961	50	3217	29	300.8	95.2	3217	29	0.316489362
18MOSM01	72.2	9.5	71.3	2.8	0	240	207.7	68.3	71.3	2.8	0.328839673
18MOSM01	1687	22	1681	37	1681	42	381	155.3	1681	42	0.407611549
18MOSM01	56.2	2.2	55.5	1.6	79	74	4050	1660	55.5	1.6	0.409876543
18MOSM01	2140	110	1810	160	2628	35	1580	650	2628	35	0.411392405
18MOSM01	163	12	170.1	4.9	20	140	545	229	170.1	4.9	0.420183486
18MOSM01	2654	31	2695	67	2621	40	401	176	2621	40	0.438902743
18MOSM01	1236	23	1080	32	1517	52	235.3	105.4	1080	32	0.447938802
18MOSM01	2484	21	2421	43	2526	31	571	259.5	2526	31	0.454465849
18MOSM01	2491	22	2368	51	2571	31	457	223	2571	31	0.487964989
18MOSM01	3092	20	2964	59	3160	30	765	381.1	3160	30	0.498169935
18MOSM01	2601	27	2087	52	3030	33	790	394	3030	33	0.498734177
18MOSM01	192	29	75.1	3.5	1520	250	2010	1020	75.1	3.5	0.507462687
18MOSM01	95	4.6	92.1	3.7	153	91	1163	594	92.1	3.7	0.510748065
18MOSM01	2549	35	1441	46	3631	30	5600	2910	3631	30	0.519642857
18MOSM01	530	31	100.3	4.6	3485	94	268	141	100.3	4.6	0.526119403
18MOSM01	119	12	91.2	3.7	550	210	252	133.9	91.2	3.7	0.531349206
18MOSM01	2260	61	1886	92	2641	32	948	511	2641	32	0.539029536
18MOSM01	61.1	7.3	64.9	2.5	-150	220	320	172.5	64.9	2.5	0.5390625
18MOSM01	3210	18	3120	56	3266	27	240.1	130.2	3266	27	0.542274052
18MOSM01	2622	31	2472	52	2731	34	359	197	2731	34	0.548746518
18MOSM01	1458	24	1482	32	1438	43	482	274.9	1438	43	0.57033195
18MOSM01	2564	29	2385	51	2698	36	187	114.9	2698	36	0.614438503

18MOSM01	1003	56	183.9	9	3957	75	497	307	183.9	9	0.617706237
18MOSM01	39.4	4.9	47	2.2	-310	210	532	330	47	2.2	0.620300752
18MOSM01	65.4	3.7	64.7	2.3	80	120	1579	997	64.7	2.3	0.631412286
18MOSM01	2625	33	2568	56	2662	37	304	193.3	2662	37	0.635855263
18MOSM01	2778	82	2610	130	2948	43	685	436	2948	43	0.63649635
18MOSM01	88	15	45.8	1.9	930	290	472.9	302	45.8	1.9	0.638612815
18MOSM01	2612	20	2463	49	2725	40	253.6	163.1	2725	40	0.643138801
18MOSM01	3199	27	3081	67	3264	47	75.9	48.9	3264	47	0.644268775
18MOSM01	2903	25	2550	61	3156	24	716	467	3156	24	0.652234637
18MOSM01	2921	30	2514	65	3216	28	946	640	3216	28	0.67653277
18MOSM01	90.4	6.9	96.3	2.9	-70	150	342.4	232	96.3	2.9	0.677570093
18MOSM01	1833	25	1817	37	1848	56	99.9	67.8	1848	56	0.678678679
18MOSM01	136	17	91.3	3	710	190	686	466	91.3	3	0.679300292
18MOSM01	3138	17	2938	47	3262	30	271	186	3262	30	0.686346863
18MOSM01	2912	32	2458	73	3237	27	628	432	3237	27	0.687898089
18MOSM01	2736	20	2742	40	2724	33	107.5	74.5	2724	33	0.693023256
18MOSM01	100.9	7.4	93.8	3.1	180	140	544	382	93.8	3.1	0.702205882
18MOSM01	3025	20	2884	41	3120	28	358	253	3120	28	0.706703911
18MOSM01	2165	55	1649	90	2737	32	2960	2130	2737	32	0.719594595
18MOSM01	1492	25	1363	33	1666	45	224.4	170	1666	45	0.757575758
18MOSM01	3159	25	3114	66	3174	29	326	248	3174	29	0.760736196
18MOSM01	2655	22	2557	45	2724	37	129.2	98.3	2724	37	0.760835913
18MOSM01	373	16	370	12	366	97	355.6	275	370	12	0.773340832
18MOSM01	2623	23	2607	44	2615	35	179	141	2615	35	0.787709497
18MOSM01	3098	30	3007	75	3163	29	721	580	3163	29	0.80443828
18MOSM01	2586	48	2485	70	2658	43	354	289	2658	43	0.816384181
18MOSM01	94.1	8.2	77.8	2.9	400	190	334	287	77.8	2.9	0.859281437
18MOSM01	2663	17	2586	36	2714	30	492	431	2714	30	0.87601626
18MOSM01	2689	19	2613	49	2736	38	105.1	92.9	2736	38	0.883920076
18MOSM01	880	140	142	18	3070	500	78.8	80	142	18	1.015228426
18MOSM01	2300	120	1570	180	3313	40	1250	1290	3313	40	1.032
18MOSM01	1130	19	1112	21	1147	58	295.5	305	1112	21	1.0321489
18MOSM01	3151	16	3046	46	3207	26	846	906	3207	26	1.070921986

18MOSM01	2636	22	2527	48	2716	34	240	261	2716	34	1.0875
18MOSM01	2709	19	2650	44	2750	30	511	588	2750	30	1.150684932
18MOSM01	2784	23	2894	44	2692	36	133	166	2692	36	1.248120301
18MOSM01	2374	30	1913	64	2766	30	2660	3840	2766	30	1.443609023
18MOSM01	44.3	4.6	23.2	1.2	1120	230	575	848	23.2	1.2	1.474782609
18MOSM01	329	25	338	13	230	180	70.7	106.9	338	13	1.512022631
18MOSM01	2665	27	2559	51	2742	36	345	553	2742	36	1.602898551
18MOSM01	2332	42	1921	57	2705	63	39.1	92.5	2705	63	2.3657289
18MOSM01	2042	36	1659	47	2445	57	64.1	360	2445	57	5.616224649

Zircon ages and Th/U values for sample 18WYDS11

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18WYDS11	1557	28	1541	46	1583	47	770	12.84	1583	47	0.016675325
18WYDS11	1530	42	901	41	2573	35	2600	102.7	901	41	0.0395
18WYDS11	922	46	819	48	1581	48	4620	340	819	48	0.073593074
18WYDS11	1654	18	1689	35	1624	50	385	31.38	1624	50	0.081506494
18WYDS11	2272	27	1863	47	2671	35	1750	164.1	2671	35	0.093771429
18WYDS11	387	12	363.5	8.5	517	89	867	91.7	363.5	8.5	0.105767013
18WYDS11	3027	70	2860	130	3115	73	16.5	2	3115	73	0.121212121
18WYDS11	85.5	5.8	89.9	4.2	400	120	2010	259	89.9	4.2	0.128855721
18WYDS11	1525	29	1364	34	1781	51	2400	323	1781	51	0.134583333
18WYDS11	1191	34	1142	42	1259	57	536	74.3	1142	42	0.138619403
18WYDS11	92.2	4.4	88.9	3	170	100	1720	255	88.9	3	0.148255814
18WYDS11	871	20	832	17	978	65	333	55.4	832	17	0.166366366
18WYDS11	94.9	6.7	88.4	2.7	220	160	675	117	88.4	2.7	0.173333333
18WYDS11	1737	18	1744	34	1715	40	751	136.8	1715	40	0.182157124
18WYDS11	2449	21	2448	50	2451	33	366	66.9	2451	33	0.182786885
18WYDS11	89.8	8.6	80.9	3.2	150	150	914	182.1	80.9	3.2	0.199234136

18WYDS11	1669	25	1578	40	1777	38	1055	228	1777	38	0.216113744
18WYDS11	136	20	106.5	4.1	380	210	338.2	74	106.5	4.1	0.218805441
18WYDS11	1340	25	1292	36	1405	44	740	165	1405	44	0.222972973
18WYDS11	2437	28	2003	53	2839	34	903	208	2839	34	0.2303433
18WYDS11	1443	53	1253	82	1842	46	1740	408	1842	46	0.234482759
18WYDS11	453	16	418	12	600	120	733	179	418	12	0.24420191
18WYDS11	1276	16	1235	26	1351	45	787	193.6	1351	45	0.245997459
18WYDS11	1200	17	1226	26	1134	52	576	144.6	1134	52	0.251041667
18WYDS11	2030	110	1500	160	2812	34	1540	393	2812	34	0.255194805
18WYDS11	3017	51	2860	100	3099	42	645	168.3	3099	42	0.260930233
18WYDS11	92.1	5.7	87.9	3.4	200	130	1390	402	87.9	3.4	0.289208633
18WYDS11	1721	21	1681	39	1746	55	253.1	77.7	1746	55	0.306993283
18WYDS11	1470	110	940	130	2670	41	2520	781	940	130	0.309920635
18WYDS11	77.1	2.8	58.6	2	1078	85	2640	824	58.6	2	0.312121212
18WYDS11	1037	24	1039	35	1032	65	428	134.3	1039	35	0.313785047
18WYDS11	491	22	425	27	845	65	2040	668	425	27	0.32745098
18WYDS11	494	88	129.7	9.6	2230	390	544	191	129.7	9.6	0.351102941
18WYDS11	353	71	260	50	740	180	519	190	260	50	0.366088632
18WYDS11	1727	26	1723	41	1725	50	198	73.2	1725	50	0.36969697
18WYDS11	78.1	7.5	71.1	7	250	180	574	212.4	71.1	7	0.370034843
18WYDS11	1482	20	1443	32	1550	44	841	312.9	1550	44	0.372057075
18WYDS11	1840	25	1826	38	1854	46	132.2	50.4	1854	46	0.381240545
18WYDS11	1183	23	1060	31	1419	48	893	346	1060	31	0.387458007
18WYDS11	1011	21	1004	28	1048	51	405	157	1004	28	0.387654321
18WYDS11	111.9	9.6	102.4	4.4	220	210	243	94.3	102.4	4.4	0.388065844
18WYDS11	923	18	876	21	1028	54	725	283.4	876	21	0.390896552
18WYDS11	103.6	6.3	93.9	3.9	350	120	2370	930	93.9	3.9	0.392405063
18WYDS11	99.4	4.4	93.2	3.3	290	120	2090	835	93.2	3.3	0.399521531
18WYDS11	2724	30	2502	66	2905	36	369	153	2905	36	0.414634146
18WYDS11	91.9	5.3	88.3	2.8	160	120	1196	499	88.3	2.8	0.41722408
18WYDS11	1700	19	1703	28	1709	38	469	196.2	1709	38	0.418336887
18WYDS11	1184	29	1012	25	1477	77	279	118.1	1012	25	0.423297491
18WYDS11	2452	29	2335	56	2549	39	683	290.3	2549	39	0.425036603

18WYDS11	999	25	969	27	1035	77	253.9	108	969	27	0.425364317
18WYDS11	106.2	8.8	92.5	3.1	310	180	317.4	135.7	92.5	3.1	0.427536232
18WYDS11	124	12	91.8	2.7	590	180	367	159	91.8	2.7	0.433242507
18WYDS11	94.2	6	95	7	70	140	782	339.4	95	7	0.434015345
18WYDS11	1017	19	932	22	1211	62	658	289	932	22	0.439209726
18WYDS11	1334	25	1253	33	1468	49	299	132.3	1468	49	0.442474916
18WYDS11	117	12	89.5	4.3	500	190	1081	487	89.5	4.3	0.450508788
18WYDS11	105.6	6.3	93.2	3.1	340	110	1544	702	93.2	3.1	0.454663212
18WYDS11	474	21	444	13	610	130	150.6	68.8	444	13	0.456839309
18WYDS11	154.6	9.1	100.3	5.9	1040	140	1420	650	100.3	5.9	0.457746479
18WYDS11	2753	28	2684	67	2824	42	686	319	2824	42	0.465014577
18WYDS11	2423	30	2181	73	2629	39	1332	626	2629	39	0.46996997
18WYDS11	1394	22	1380	33	1443	48	745	353	1443	48	0.473825503
18WYDS11	96.7	5.3	87.7	3	290	110	950	453	87.7	3	0.476842105
18WYDS11	1400	36	1349	33	1508	79	220.8	106.4	1508	79	0.481884058
18WYDS11	1427	22	1413	33	1462	59	233	113	1462	59	0.484978541
18WYDS11	112	16	91.4	4	350	260	167.3	82.4	91.4	4	0.492528392
18WYDS11	2230	260	1700	200	2650	320	116	57.4	2650	320	0.494827586
18WYDS11	89.9	6.4	89.7	3.1	40	150	571	285	89.7	3.1	0.499124343
18WYDS11	58	11	48.7	2.7	200	320	182	91.5	48.7	2.7	0.502747253
18WYDS11	1973	76	1430	110	2744	38	1550	806	2744	38	0.52
18WYDS11	1758	27	1768	49	1754	61	112.6	59	1754	61	0.523978686
18WYDS11	1033	21	990	23	1103	66	252	132.9	990	23	0.527380952
18WYDS11	501	43	141	6.7	2790	190	210	113	141	6.7	0.538095238
18WYDS11	440	21	430	13	450	120	160	86.4	430	13	0.54
18WYDS11	1619	20	1551	35	1721	41	865	472	1721	41	0.54566474
18WYDS11	1795	21	1765	45	1832	51	236	130.7	1832	51	0.553813559
18WYDS11	84.1	4.7	81.8	2.7	120	120	1251	698	81.8	2.7	0.557953637
18WYDS11	1776	20	1758	46	1787	41	392	219	1787	41	0.558673469
18WYDS11	83	12	78	10	300	230	690	389.5	78	10	0.564492754
18WYDS11	794	86	431	13	1680	270	435	247	431	13	0.567816092
18WYDS11	1678	21	1667	34	1701	45	337.7	193.5	1701	45	0.572993781
18WYDS11	1427	30	1342	32	1539	70	228	130.8	1539	70	0.573684211

18WYDS11	140	9	94.5	3.2	900	150	852	490	94.5	3.2	0.575117371
18WYDS11	124	11	95.5	3.7	540	170	1099	640	95.5	3.7	0.582347589
18WYDS11	126	16	86.6	2.9	700	190	883	538.7	86.6	2.9	0.610079275
18WYDS11	1700	16	1631	30	1797	33	1282	789	1797	33	0.615444618
18WYDS11	115.8	6	87.5	2.4	660	130	789	515	87.5	2.4	0.652724968
18WYDS11	115.1	8.6	92.4	2.6	490	150	1136	763	92.4	2.6	0.67165493
18WYDS11	92	5.6	93.4	3.2	50	120	818	552	93.4	3.2	0.674816626
18WYDS11	108	11	100.7	3.9	190	200	372	252	100.7	3.9	0.677419355
18WYDS11	2020	200	1970	210	2340	140	594	403	2340	140	0.678451178
18WYDS11	1060	44	961	36	1250	130	71.1	48.5	961	36	0.682137834
18WYDS11	89	10	82.4	4	140	180	363	248.5	82.4	4	0.684573003
18WYDS11	244	14	235	6.5	330	120	419	294.5	235	6.5	0.702863962
18WYDS11	97	10	91.1	2.8	120	120	1315	930	91.1	2.8	0.707224335
18WYDS11	124	26	95.7	7.1	320	250	247	178	95.7	7.1	0.720647773
18WYDS11	1731	19	1703	35	1777	35	485	350	1777	35	0.721649485
18WYDS11	83	10	71.1	3.3	330	260	187	135	71.1	3.3	0.721925134
18WYDS11	1693	24	1598	34	1822	52	176	127.2	1822	52	0.722727273
18WYDS11	2582	21	2430	46	2694	29	422	315.2	2694	29	0.746919431
18WYDS11	1135	14	1121	19	1163	42	597	467	1121	19	0.782244556
18WYDS11	85.5	7.4	76.7	2.2	250	180	566	452	76.7	2.2	0.798586572
18WYDS11	1593	25	1527	43	1693	54	459	371	1693	54	0.808278867
18WYDS11	2973	49	2590	100	3249	31	594	484	3249	31	0.814814815
18WYDS11	68.3	6.8	67.2	2.4	80	200	353	299	67.2	2.4	0.847025496
18WYDS11	1074	42	1013	30	1183	99	169	147.1	1013	30	0.870414201
18WYDS11	87.4	4.4	85.9	2.1	100	100	2170	1950	85.9	2.1	0.898617512
18WYDS11	2616	19	2489	50	2719	36	264.4	243.6	2719	36	0.921331316
18WYDS11	1455	35	1314	53	1658	82	83.9	79.4	1658	82	0.94636472
18WYDS11	1419	23	1235	37	1733	51	605	586	1733	51	0.968595041
18WYDS11	86.4	3.8	87.6	3.6	170	110	1680	1730	87.6	3.6	1.029761905
18WYDS11	1540	25	1490	39	1617	45	374	392	1617	45	1.048128342
18WYDS11	1241	15	1171	26	1354	52	495	591	1171	26	1.193939394
18WYDS11	1664	24	1643	43	1665	53	131.3	174.7	1665	53	1.330540746
18WYDS11	2710	150	2650	190	2670	220	3.29	6	2670	220	1.823708207

Zircon ages and Th/U values for sample 18MOSM11

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18MOSM11	2720	42	1932	75	3360	83	20.06	0.215	3360	83	0.010717846
18MOSM11	1774	27	1731	37	1794	31	1074	87.2	1794	31	0.081191806
18MOSM11	1552	12	1466	19	1647	21	2805	251.3	1647	21	0.089590018
18MOSM11	1658	15	1574	23	1751	29	1029	101.3	1751	29	0.098445092
18MOSM11	889	13	623	14	1640	26	1877	238	623	14	0.126798082
18MOSM11	805	31	193.4	7.7	3370	110	126.1	17.77	193.4	7.7	0.140919905
18MOSM11	92.9	9	71.7	5.4	830	260	1195	169.3	71.7	5.4	0.14167364
18MOSM11	212	27	76.1	7.6	630	180	898	144	76.1	7.6	0.160356347
18MOSM11	78.3	4	75.2	1.7	140	110	1934	337	75.2	1.7	0.174250259
18MOSM11	69.8	9.5	68.1	5.3	190	300	2680	521	68.1	5.3	0.194402985
18MOSM11	138.8	6.4	89.4	3.6	1040	150	2550	539	89.4	3.6	0.211372549
18MOSM11	1258	31	985	32	1634	49	1392	297.7	985	32	0.213864943
18MOSM11	1527	19	1361	24	1749	30	1900	428	1749	30	0.225263158
18MOSM11	1248	39	1181	41	1375	33	2670	671	1181	41	0.251310861
18MOSM11	211	17	153.6	6.3	760	200	324	83.4	153.6	6.3	0.257407407
18MOSM11	90	15	72	5.1	330	190	702	187	72	5.1	0.266381766
18MOSM11	1452	18	1249	23	1770	25	2180	581	1770	25	0.266513761
18MOSM11	78	12	78.9	3.8	-40	290	180.1	49.1	78.9	3.8	0.272626319
18MOSM11	1461	24	1453	28	1559	35	888	248	1559	35	0.279279279
18MOSM11	266	36	198	22	720	110	1590	457	198	22	0.287421384
18MOSM11	1751	16	1714	29	1775	28	498.6	148.6	1775	28	0.298034497
18MOSM11	881	31	574	17	1696	59	522	156	574	17	0.298850575
18MOSM11	443	35	290	27	1520	180	206	62	290	27	0.300970874
18MOSM11	281	12	259.1	5.6	390	110	797	246.2	259.1	5.6	0.308908407
18MOSM11	1391	48	1135	46	1794	44	490	163.9	1135	46	0.334489796

18MOSM11	1616	14	1568	22	1664	33	572	192.9	1664	33	0.337237762
18MOSM11	2700	17	2635	46	2739	23	558	188.2	2739	23	0.337275986
18MOSM11	119.5	6.9	75.7	2	990	140	3410	1152	75.7	2	0.337829912
18MOSM11	864	27	736	21	1148	97	133.9	46	736	21	0.343539955
18MOSM11	1641	17	1572	28	1723	30	836	295.7	1723	30	0.353708134
18MOSM11	1735	24	1686	31	1785	36	536	191	1785	36	0.356343284
18MOSM11	49.8	4.9	47.2	1.7	80	190	733	265	47.2	1.7	0.361527967
18MOSM11	1585	38	1554	34	1592	82	62.9	23.5	1592	82	0.373608903
18MOSM11	1207	37	989	43	1470	62	653	244	989	43	0.373660031
18MOSM11	72	5.2	67.9	2.5	130	160	1170	443	67.9	2.5	0.378632479
18MOSM11	1077	19	1044	24	1118	54	476	185.3	1044	24	0.389285714
18MOSM11	136.7	8.5	124.2	3.4	320	130	1180	460	124.2	3.4	0.389830508
18MOSM11	1692	13	1604	20	1787	29	520	210.8	1787	29	0.405384615
18MOSM11	1535	17	1467	25	1616	36	433	182.6	1616	36	0.421709007
18MOSM11	2949	30	2945	46	2929	26	211	95.3	2929	26	0.451658768
18MOSM11	80.7	4	79.5	1.5	110	110	1895	870	79.5	1.5	0.459102902
18MOSM11	96.1	8.5	74.4	2.5	520	200	490	231	74.4	2.5	0.471428571
18MOSM11	2460	16	2394	35	2491	22	588	289.7	2491	22	0.492687075
18MOSM11	1445	21	1321	25	1595	31	1183	590	1595	31	0.498732037
18MOSM11	66.6	9.1	64.9	3	-10	250	331	169	64.9	3	0.510574018
18MOSM11	1371	18	1222	23	1591	42	464	237	1591	42	0.510775862
18MOSM11	86	11	77.1	4.3	170	210	382.8	195.9	77.1	4.3	0.511755486
18MOSM11	1067	23	1033	18	1115	62	279.7	145.8	1033	18	0.521272792
18MOSM11	90.9	4.7	86.2	2.4	170	110	1583	828	86.2	2.4	0.523057486
18MOSM11	1167	24	1062	24	1352	70	180.3	95	1062	24	0.526899612
18MOSM11	128	22	89.4	5.9	470	210	498	263.1	89.4	5.9	0.528313253
18MOSM11	417	68	97.8	6	2230	360	1003	531	97.8	6	0.529411765
18MOSM11	110	5.3	83.4	1.7	630	110	2014	1090	83.4	1.7	0.541211519
18MOSM11	1486	13	1331	21	1705	31	900	490	1705	31	0.544444444
18MOSM11	93.4	5.7	93.2	2.5	60	120	1315	718	93.2	2.5	0.546007605
18MOSM11	95.1	7.2	88.5	2.7	160	150	663	365.9	88.5	2.7	0.55188537
18MOSM11	139.4	5	63.1	1.1	1742	79	8430	4700	63.1	1.1	0.557532622
18MOSM11	68.3	6.1	72.8	2.2	-40	170	808	452	72.8	2.2	0.559405941

18MOSM11	75	12	70.5	3.3	60	320	216.1	122.9	70.5	3.3	0.568718186
18MOSM11	67	6.9	66.6	2.3	20	210	497.1	283	66.6	2.3	0.569301951
18MOSM11	70.6	5.3	68.7	2.1	90	160	792	453	68.7	2.1	0.571969697
18MOSM11	90.1	4.4	92	2.2	40	110	1557	916	92	2.2	0.588310854
18MOSM11	2550	25	2433	46	2623	30	492	294	2623	30	0.597560976
18MOSM11	60.8	5.6	60.5	2.1	80	190	517	316	60.5	2.1	0.611218569
18MOSM11	961	22	935	19	971	69	202.9	124.9	935	19	0.615574174
18MOSM11	74	11	70.1	3.6	230	300	649	423	70.1	3.6	0.651771957
18MOSM11	1539	18	1400	29	1739	47	213	139	1739	47	0.65258216
18MOSM11	74.1	8	64	2.6	280	230	492	321.5	64	2.6	0.653455285
18MOSM11	1619	27	1567	41	1666	58	168	109.8	1666	58	0.653571429
18MOSM11	89	6.3	79.8	1.9	240	150	791	521	79.8	1.9	0.658659924
18MOSM11	86.7	8.1	73.7	2.7	320	200	523	350	73.7	2.7	0.669216061
18MOSM11	1821	19	1407	27	2319	28	2758	1855	2319	28	0.672588832
18MOSM11	1473	24	1439	26	1506	55	153.8	106.8	1506	55	0.694408322
18MOSM11	161	47	104	21	250	320	235	163.8	104	21	0.697021277
18MOSM11	92	6.6	88.4	2.5	100	150	747	527	88.4	2.5	0.705488621
18MOSM11	1177	23	1025	25	1466	45	411	291.7	1025	25	0.70973236
18MOSM11	1039	26	1025	21	1049	78	197.9	154.7	1025	21	0.781707933
18MOSM11	1531	25	1355	42	1767	48	383	303	1767	48	0.791122715
18MOSM11	1421	22	1289	28	1604	50	244	197	1604	50	0.807377049
18MOSM11	1334	35	985	41	1962	29	1220	989	985	41	0.810655738
18MOSM11	88.4	9.6	68.4	3.6	650	220	676	564	68.4	3.6	0.834319527
18MOSM11	80.8	4	83.4	2.1	10	110	2020	1720	83.4	2.1	0.851485149
18MOSM11	76.6	6.7	68.4	2.3	240	200	571	507.1	68.4	2.3	0.888091068
18MOSM11	1586	26	1528	30	1710	36	760	687	1710	36	0.903947368
18MOSM11	1147	26	885	23	1530	58	773	706	885	23	0.913324709
18MOSM11	1294	30	821	18	2169	39	937	861	821	18	0.918890075
18MOSM11	967	18	931	14	1019	52	428.6	412	931	14	0.961269249
18MOSM11	141.5	8.7	101.4	2.3	840	130	1762	1858	101.4	2.3	1.054483541
18MOSM11	67.3	6.1	71.5	2.2	-90	170	755	863	71.5	2.2	1.143046358
18MOSM11	1399	21	1344	26	1462	39	501	621	1462	39	1.239520958
18MOSM11	507	45	342	8.1	1110	170	1100	1372	342	8.1	1.247272727

18MOSM11	1498	27	1308	33	1770	36	1108	1620	1770	36	1.462093863
18MOSM11	1377	21	1294	20	1478	53	192.2	289	1478	53	1.50364204
18MOSM11	1520	21	1412	28	1640	39	551	969	1640	39	1.75862069
18MOSM11	165	14	51.6	3	2270	250	292.5	536	51.6	3	1.832478632
18MOSM11	81.6	4.4	73.6	1.7	240	120	1935	124600	73.6	1.7	64.39276486

Zircon ages and Th/U values for sample 18MOSM13

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18MOSM13	555	33	535	18	560	140	69.1	0.692	535	18	0.010014472
18MOSM13	1307	69	1240	87	1472	46	1620	104.4	1472	46	0.064444444
18MOSM13	1038	28	997	39	1134	49	958	73.7	997	39	0.076931106
18MOSM13	1267	58	1001	74	1830	34	2030	229	1001	74	0.112807882
18MOSM13	1654	17	1614	31	1695	32	962	137.2	1695	32	0.142619543
18MOSM13	110.5	9.7	83.4	2.5	610	190	428	64.9	83.4	2.5	0.151635514
18MOSM13	52.6	3	53.6	2.3	19	94	2300	375	53.6	2.3	0.163043478
18MOSM13	821	78	636	66	1410	74	990	166.4	636	66	0.168080808
18MOSM13	87.8	6	83.8	2.7	170	150	482	99.8	83.8	2.7	0.207053942
18MOSM13	1176	46	1078	53	1377	42	507	111	1078	53	0.218934911
18MOSM13	1720	18	1720	30	1707	38	379	87.9	1707	38	0.231926121
18MOSM13	84.8	6.6	79.5	2.5	140	160	532.4	124.4	79.5	2.5	0.233658903
18MOSM13	66	6.4	68.3	2.8	-40	200	363	85.4	68.3	2.8	0.235261708
18MOSM13	1687	37	1532	56	1877	40	483	116.1	1877	40	0.240372671
18MOSM13	1375	29	1369	47	1387	41	940	229	1387	41	0.243617021
18MOSM13	90.7	4.1	68.7	1.4	651	87	5659	1554	68.7	1.4	0.274606821
18MOSM13	938	49	893	51	1033	67	176	48.7	893	51	0.276704545
18MOSM13	85.5	5.6	81.1	2.3	170	150	536.9	153	81.1	2.3	0.284969268
18MOSM13	82.5	5.8	58.1	1.8	750	170	555	163	58.1	1.8	0.293693694
18MOSM13	71.8	5.5	70	2.3	100	160	464	138.4	70	2.3	0.298275862

18MOSM13	100.2	9.4	99	3.7	70	200	305	94.9	99	3.7	0.311147541
18MOSM13	900	110	743	92	1330	140	452	146	743	92	0.32300885
18MOSM13	82.3	4.8	68.6	2.8	430	120	1379	451	68.6	2.8	0.327048586
18MOSM13	970	140	880	130	1170	180	580	193.2	880	130	0.333103448
18MOSM13	114	7.6	106.1	3	210	140	523	189	106.1	3	0.361376673
18MOSM13	98.7	6.1	94.9	2.6	170	130	521	194.3	94.9	2.6	0.37293666
18MOSM13	1720	18	1656	29	1789	37	495.7	185.5	1789	37	0.374218277
18MOSM13	73.5	2.6	66.1	1.5	268	84	3750	1440	66.1	1.5	0.384
18MOSM13	93.2	5.1	90.7	2.8	120	110	740	299	90.7	2.8	0.404054054
18MOSM13	167	17	166.4	7	100	230	73.3	30.7	166.4	7	0.418826739
18MOSM13	1655	17	1676	29	1619	30	567	239	1619	30	0.421516755
18MOSM13	147	16	86.4	3.2	960	210	471	199.1	86.4	3.2	0.422717622
18MOSM13	1223	31	1052	26	1528	90	103.7	44	1052	26	0.424300868
18MOSM13	80.4	2.4	63.7	1.6	587	86	3990	1700	63.7	1.6	0.426065163
18MOSM13	115	13	64.7	2.3	1150	180	798	354	64.7	2.3	0.443609023
18MOSM13	75.9	4.8	69.6	2.7	230	110	1680	758	69.6	2.7	0.451190476
18MOSM13	1669	19	1640	31	1697	42	237.2	110	1697	42	0.463743676
18MOSM13	178	16	170.5	6	170	190	281	131	170.5	6	0.466192171
18MOSM13	86.3	5.7	87.9	2.3	20	150	427	200.5	87.9	2.3	0.469555035
18MOSM13	1354	17	1255	21	1501	33	599	290	1501	33	0.484140234
18MOSM13	96.2	7	92.6	3	140	150	463	227	92.6	3	0.490280778
18MOSM13	70.5	7	67.3	2.3	120	210	286	142	67.3	2.3	0.496503497
18MOSM13	72.2	2.7	70.7	2.1	121	79	2900	1449	70.7	2.1	0.499655172
18MOSM13	65.6	4.3	60.4	1.8	170	130	935	469	60.4	1.8	0.501604278
18MOSM13	141	13	147.4	4.3	40	180	187	94.2	147.4	4.3	0.503743316
18MOSM13	95.8	4.7	88.6	2.4	240	120	981	500	88.6	2.4	0.509683996
18MOSM13	88.3	4.5	88.8	2.2	50	110	832	430	88.8	2.2	0.516826923
18MOSM13	161	11	161.7	4.8	120	140	315	164.3	161.7	4.8	0.521587302
18MOSM13	72.4	4	67.7	2.4	170	120	1183	619	67.7	2.4	0.523245985
18MOSM13	110	6.7	89.5	2.7	510	150	524	287	89.5	2.7	0.547709924
18MOSM13	103.2	5.9	79.2	2.1	590	130	721	405	79.2	2.1	0.561719834
18MOSM13	321.4	9.8	311.3	8.2	370	69	821	463	311.3	8.2	0.563946407
18MOSM13	125.9	7	87.3	2.2	880	120	716	413	87.3	2.2	0.576815642

18MOSM13	135	12	94.1	4	790	160	780	451	94.1	4	0.578205128
18MOSM13	60.4	3.4	59.5	1.5	100	120	1142	662	59.5	1.5	0.579684764
18MOSM13	102	5.3	104.4	3.1	20	100	973	567	104.4	3.1	0.582733813
18MOSM13	106	15	84.7	3.9	520	270	171	99.8	84.7	3.9	0.583625731
18MOSM13	67.8	6	66.5	2	30	180	414	243.4	66.5	2	0.587922705
18MOSM13	449	22	404	23	640	86	366	217.4	404	23	0.593989071
18MOSM13	1353	15	1341	23	1362	39	336	203	1362	39	0.604166667
18MOSM13	77.1	4.8	74.5	2	140	130	578	352	74.5	2	0.60899654
18MOSM13	70	8	61.8	2.6	240	230	279	172	61.8	2.6	0.616487455
18MOSM13	1712	25	1687	30	1735	55	126.5	78.8	1735	55	0.622924901
18MOSM13	1612	22	1540	43	1708	35	672	423	1708	35	0.629464286
18MOSM13	104.2	6.2	94.4	2.5	300	130	833	529	94.4	2.5	0.635054022
18MOSM13	1080	97	744	85	2120	100	475	306	744	85	0.644210526
18MOSM13	95.8	4.2	94	2.7	126	99	1130	737	94	2.7	0.652212389
18MOSM13	2344	34	1976	59	2685	28	549	365.6	2685	28	0.665938069
18MOSM13	64.2	7.7	67	2.2	-100	220	346	237	67	2.2	0.684971098
18MOSM13	89.4	4.8	86.6	2.4	150	120	566	401	86.6	2.4	0.708480565
18MOSM13	72.3	5.5	66.6	2	210	160	509	361	66.6	2	0.709233792
18MOSM13	84.3	5.2	84.7	2.4	60	130	777	578	84.7	2.4	0.743886744
18MOSM13	2526	67	2330	120	2735	26	1060	820	2735	26	0.773584906
18MOSM13	530	130	480	120	580	220	278	219	480	120	0.787769784
18MOSM13	101	5.6	99.6	3.2	90	110	684	547	99.6	3.2	0.799707602
18MOSM13	1505	31	1270	36	1850	44	731	600	1850	44	0.820793434
18MOSM13	1394	37	1208	58	1707	31	1430	1210	1707	31	0.846153846
18MOSM13	281	40	117.9	5.3	1480	290	579	526	117.9	5.3	0.908462867
18MOSM13	1601	22	1463	35	1776	37	568	520	1776	37	0.915492958
18MOSM13	1535	20	1483	28	1601	41	259.7	243.7	1601	41	0.938390451
18MOSM13	197.4	7.8	193.8	6.2	213	76	1256	1242	193.8	6.2	0.988853503
18MOSM13	117.5	6.8	110.8	3.4	190	130	551	545	110.8	3.4	0.989110708
18MOSM13	2428	27	2437	46	2390	38	61.1	80.5	2390	38	1.317512275
18MOSM13	1563	22	1612	35	1489	43	453	625	1489	43	1.379690949
18MOSM13	57	5.4	55.7	2	40	190	440	625	55.7	2	1.420454545
18MOSM13	1593	31	1364	53	1927	36	846	1360	1927	36	1.607565012

18MOSM13	2703	25	2650	54	2738	45	52.99	146.4	2738	45	2.762785431

Zircon ages and Th/U values for sample 18YSSM10

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18YSSM10	465	47	284	32	1567	41	3220	30.2	284	32	0.009378882
18YSSM10	1194	41	1108	57	1323	37	1580	120	1108	57	0.075949367
18YSSM10	357	86	292	73	620	150	1436	121	292	73	0.084261838
18YSSM10	2146	30	1655	50	2669	29	1920	298	2669	29	0.155208333
18YSSM10	2640	18	2434	44	2797	23	532.7	87.2	2797	23	0.163694387
18YSSM10	1581	28	1496	47	1701	29	1240	237	1701	29	0.191129032
18YSSM10	78.3	4.5	76.4	2	110	130	505	99	76.4	2	0.196039604
18YSSM10	1545	48	1259	72	2001	63	1440	293	2001	63	0.203472222
18YSSM10	1706	26	1649	42	1766	42	685	153.8	1766	42	0.224525547
18YSSM10	84.6	5.5	84.4	2.5	60	130	569	131.2	84.4	2.5	0.230579965
18YSSM10	100.5	9.8	77	2.2	570	200	434	102.4	77	2.2	0.2359447
18YSSM10	1728	45	1686	66	1802	31	803	192.8	1802	31	0.240099626
18YSSM10	1542	30	1434	47	1703	34	724	175	1703	34	0.241712707
18YSSM10	75	5.2	74.5	3.2	80	140	1140	276	74.5	3.2	0.242105263
18YSSM10	84.4	5.6	84.3	2.4	60	130	597	147.1	84.3	2.4	0.24639866
18YSSM10	1602	15	1531	25	1687	32	785	203.8	1687	32	0.259617834
18YSSM10	70.8	3.6	67.9	2.8	112	93	1716	467	67.9	2.8	0.272144522
18YSSM10	74	4	74.8	3.6	88	85	1860	516	74.8	3.6	0.277419355
18YSSM10	2626	43	2464	98	2793	35	2150	603	2793	35	0.280465116
18YSSM10	92.1	5.5	88.7	3.2	190	140	568	160.8	88.7	3.2	0.283098592
18YSSM10	79.5	7.1	83.2	2.6	-50	180	362	102.5	83.2	2.6	0.283149171
18YSSM10	1737	70	1207	90	2518	30	2820	820	2518	30	0.290780142
18YSSM10	425	62	338	48	824	93	1590	463	338	48	0.291194969
18YSSM10	1669	18	1635	33	1699	36	469	138.3	1699	36	0.294882729

18YSSM10	92.3	5.6	84.1	2.6	260	130	667	198	84.1	2.6	0.296851574
18YSSM10	110	7.7	94.4	2.8	380	160	508	157	94.4	2.8	0.309055118
18YSSM10	2408	42	2001	76	2785	36	1076	334	2785	36	0.310408922
18YSSM10	3151	32	3007	74	3245	27	501	160	3245	27	0.319361277
18YSSM10	211	20	155	12	790	130	400	128.4	155	12	0.321
18YSSM10	202	7.4	196.8	5.1	232	90	573	184	196.8	5.1	0.321116928
18YSSM10	1639	34	1663	56	1620	43	305	98.6	1620	43	0.323278689
18YSSM10	2852	21	2791	56	2899	33	198.7	66	2899	33	0.332159034
18YSSM10	1246	27	1182	39	1362	44	903	311	1182	39	0.34440753
18YSSM10	179.1	7.1	182.5	4	140	110	576	203.2	182.5	4	0.352777778
18YSSM10	3037	64	3490	160	2787	26	531	189	2787	26	0.355932203
18YSSM10	110	11	88.6	3.3	410	170	930	332	88.6	3.3	0.356989247
18YSSM10	993	18	996	17	986	56	278	99.5	996	17	0.357913669
18YSSM10	1723	19	1747	39	1694	40	512	188.2	1694	40	0.367578125
18YSSM10	122.3	8.6	83.7	3.2	940	170	1151	431	83.7	3.2	0.374456994
18YSSM10	1667	14	1628	29	1710	32	534.9	202.5	1710	32	0.378575435
18YSSM10	77.2	6.3	85.6	3.2	-120	160	270	102.6	85.6	3.2	0.38
18YSSM10	169.2	6.7	166.1	4	179	86	655	252	166.1	4	0.384732824
18YSSM10	214	14	207.5	5.4	230	140	180	69.3	207.5	5.4	0.385
18YSSM10	1120	28	1128	32	1130	76	107	41.6	1128	32	0.388785047
18YSSM10	100.1	6.8	95.1	3.5	180	140	574	224	95.1	3.5	0.390243902
18YSSM10	75.1	3.7	67.8	2.5	269	90	2130	833	67.8	2.5	0.391079812
18YSSM10	1701	19	1697	30	1699	43	237.5	94.3	1699	43	0.397052632
18YSSM10	1516	28	1575	36	1439	42	300	121.9	1439	42	0.406333333
18YSSM10	2295	89	1740	150	2942	32	1100	451	2942	32	0.41
18YSSM10	98.8	8.1	99.7	3.4	80	170	449	185	99.7	3.4	0.412026726
18YSSM10	68.8	3.5	71.1	2.5	2	99	2180	906	71.1	2.5	0.41559633
18YSSM10	71.6	5	71	2.6	60	120	1300	556	71	2.6	0.427692308
18YSSM10	80.3	7.8	78.9	2.5	70	200	215.9	92.4	78.9	2.5	0.427975915
18YSSM10	206	23	100.8	4.2	1340	200	1070	468	100.8	4.2	0.437383178
18YSSM10	1273	22	1131	21	1513	43	242.4	107.4	1131	21	0.443069307
18YSSM10	99.1	7	92.6	2.3	190	130	1066	482	92.6	2.3	0.452157598
18YSSM10	80.5	4.7	79.4	3	110	120	934	432	79.4	3	0.462526767

18YSSM10	2468	24	2487	47	2438	36	308	147.9	2438	36	0.480194805
18YSSM10	372	12	368.3	9.3	366	75	687	333	368.3	9.3	0.484716157
18YSSM10	96.2	5	97.1	2.8	50	110	1023	505	97.1	2.8	0.493646139
18YSSM10	86.6	5	86.4	3.1	70	100	1088	540	86.4	3.1	0.496323529
18YSSM10	78.1	6.6	74.5	2.3	110	170	290	148.3	74.5	2.3	0.51137931
18YSSM10	112.5	7.2	106	3.5	190	140	570	293	106	3.5	0.514035088
18YSSM10	1479	20	1468	28	1489	43	407	209.5	1489	43	0.514742015
18YSSM10	1741	25	1703	44	1769	31	1094	568	1769	31	0.519195612
18YSSM10	1398	20	1347	33	1475	44	801	418	1475	44	0.52184769
18YSSM10	103.9	7.5	101	3	130	150	294	153.5	101	3	0.522108844
18YSSM10	97	5.1	93.7	3.1	160	100	1090	588	93.7	3.1	0.539449541
18YSSM10	112.1	7.2	92.1	3	480	120	956	517	92.1	3	0.540794979
18YSSM10	1063	18	1048	19	1076	49	482.3	276.8	1048	19	0.573916649
18YSSM10	2486	41	2369	67	2585	44	283	163.1	2585	44	0.576325088
18YSSM10	169	11	74.5	2.8	1760	120	393	226.6	74.5	2.8	0.576590331
18YSSM10	1293	19	1220	28	1411	46	425	252.9	1411	46	0.595058824
18YSSM10	94.6	9.3	93.5	3.4	40	190	242	145	93.5	3.4	0.599173554
18YSSM10	1656	19	1724	35	1565	43	329	204	1565	43	0.62006079
18YSSM10	94.9	5.1	94	2.3	100	120	579	361	94	2.3	0.623488774
18YSSM10	71.3	4	75	2.1	-30	110	871	558	75	2.1	0.640642939
18YSSM10	99.6	6.3	94	2.4	180	140	572	374.2	94	2.4	0.654195804
18YSSM10	614	14	627	12	545	63	415	274	627	12	0.660240964
18YSSM10	1598	18	1581	35	1610	43	208	141	1610	43	0.677884615
18YSSM10	460	100	384	87	690	190	316	225	384	87	0.712025316
18YSSM10	168	17	99.3	2.9	1040	180	599	430	99.3	2.9	0.717863105
18YSSM10	72	4.3	72.4	2.5	50	130	443	323	72.4	2.5	0.729119639
18YSSM10	67.1	6.4	67.9	2.8	30	180	323	244.9	67.9	2.8	0.758204334
18YSSM10	1069	24	1062	23	1054	77	107	82.2	1062	23	0.768224299
18YSSM10	1313	17	1274	26	1377	47	399.3	308	1377	47	0.771349862
18YSSM10	136.5	9.5	137.6	4.3	80	150	287	224	137.6	4.3	0.780487805
18YSSM10	68.3	4.9	64.5	1.7	130	150	557	436	64.5	1.7	0.782764811
18YSSM10	160.5	8.1	66.4	2.6	1912	89	865	689	66.4	2.6	0.796531792
18YSSM10	77.9	5.6	74.1	2.4	200	170	386	313	74.1	2.4	0.810880829

18YSSM10	69.3	6.2	77.1	2.6	-170	160	458	374	77.1	2.6	0.816593886
18YSSM10	77.2	7.5	70.5	3.6	210	210	463	386	70.5	3.6	0.833693305
18YSSM10	2287	32	1800	69	2758	33	716	624	2758	33	0.87150838
18YSSM10	104.2	7.8	100.5	3.2	140	160	358	313	100.5	3.2	0.874301676
18YSSM10	2657	20	2699	48	2621	32	255	226	2621	32	0.88627451
18YSSM10	2761	31	2664	67	2798	37	408	394	2798	37	0.965686275
18YSSM10	1654	23	1678	31	1617	45	176.3	181.2	1617	45	1.027793534
18YSSM10	155	19	87	3	1040	250	273	291	87	3	1.065934066
18YSSM10	773	14	450	12	1870	40	2357	2585	450	12	1.096733135
18YSSM10	2677	23	2631	49	2716	33	111.2	123.2	2716	33	1.107913669
18YSSM10	1874	21	1899	35	1841	42	231	266	1841	42	1.151515152
18YSSM10	1709	30	1725	43	1675	57	85.5	122.3	1675	57	1.430409357
18YSSM10	1224	81	712	77	2352	35	2610	3780	712	77	1.448275862
18YSSM10	617	50	778	67	50	140	84.8	133.1	778	67	1.569575472
18YSSM10	1831	24	1813	37	1853	41	156.6	248	1853	41	1.583652618
18YSSM10	2681	25	2642	45	2705	39	79.3	128.4	2705	39	1.619167718
18YSSM10	249	13	198.6	6.2	690	130	313.5	1096	198.6	6.2	3.496012759
18YSSM10	693	29	111.4	6	3970	120	53.2	250.3	111.4	6	4.704887218

Zircon ages and Th/U values for sample 18CODS01

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18CODS01	73.6	7.7	65.9	2.8	230	210	325	30	65.9	2.8	0.092307692
18CODS01	1647	23	1351	24	2046	51	86.7	12.05	2046	51	0.138985006
18CODS01	924	26	627	25	1761	50	2350	363	627	25	0.154468085
18CODS01	1239	23	1012	28	1676	34	895	146	1012	28	0.163128492
18CODS01	1371	12	1315	24	1486	25	2380	477.9	1486	25	0.200798319
18CODS01	1621	16	1552	22	1717	27	789	168.2	1717	27	0.213181242
18CODS01	1410.8	9.1	1392	15	1427	26	635	146.4	1427	26	0.230551181

18CODS01	1503	15	1513	25	1484	30	538	128.4	1484	30	0.23866171
18CODS01	1773	32	1716	53	1847	47	562	143.8	1847	47	0.255871886
18CODS01	1100	36	203.7	4.2	4072	83	4290	1118	203.7	4.2	0.260606061
18CODS01	1515	24	1357	35	1753	35	560	148.8	1753	35	0.265714286
18CODS01	1498	33	1465	35	1576	67	492	141	1576	67	0.286585366
18CODS01	1709	11	1714	18	1689	23	600	178.9	1689	23	0.298166667
18CODS01	1767	15	1805	21	1733	30	419	125.4	1733	30	0.29928401
18CODS01	1283	21	1168	23	1540	42	1409	428	1168	23	0.303761533
18CODS01	1592	28	1286	18	2022	72	540	164.5	2022	72	0.30462963
18CODS01	1388	15	729	38	2650	73	1495	456	729	38	0.305016722
18CODS01	1413	14	1373	13	1456	35	260.5	83.5	1456	35	0.320537428
18CODS01	1673	16	1664	25	1690	25	755	254	1690	25	0.336423841
18CODS01	1558	11	1482	18	1666	17	19150	6607	1666	17	0.345013055
18CODS01	1238	19	957	28	1779	62	285	101	957	28	0.354385965
18CODS01	1087	11	1086	13	1098	32	1050	373	1086	13	0.355238095
18CODS01	1001	12	794	12	1492	38	955	347.8	794	12	0.364188482
18CODS01	1324	27	1308	25	1329	72	98.3	38	1329	72	0.386571719
18CODS01	1091	16	1071	14	1110	46	263.6	106.5	1071	14	0.404021244
18CODS01	951	18	781	21	1377	50	509	206.7	781	21	0.406090373
18CODS01	68	11	64.1	2.2	60	210	378	157.3	64.1	2.2	0.416137566
18CODS01	1655	18	1466	31	1902	45	518	216	1902	45	0.416988417
18CODS01	1384	15	1350	15	1412	35	334.3	144.9	1412	35	0.433443015
18CODS01	1367	10	1335	16	1419	24	1330	584.6	1419	24	0.439548872
18CODS01	1511	21	1531	25	1475	39	197	88.4	1475	39	0.448730964
18CODS01	1429	13	1424	17	1419	36	215.2	99	1419	36	0.460037175
18CODS01	1077	22	1118	21	1079	60	451	208	1118	21	0.461197339
18CODS01	1084	23	1076	28	1118	55	388	183.7	1076	28	0.473453608
18CODS01	75.3	5.8	67.9	1.8	220	150	975	466.5	67.9	1.8	0.478461538
18CODS01	1389	68	1185	31	1640	110	198.1	98.2	1185	31	0.495709238
18CODS01	1077	13	1084	13	1077	36	389.8	193.6	1084	13	0.496664956
18CODS01	1760	48	1376	31	2241	91	111.8	56.1	2241	91	0.501788909
18CODS01	1188	29	1102	31	1441	76	407	216	1102	31	0.530712531
18CODS01	1093	14	1099	13	1085	40	378	203	1099	13	0.537037037

18CODS01	1551	15	1464	23	1679	25	1107	604	1679	25	0.54561879
18CODS01	1050	18	1006	15	1133	59	161.8	88.7	1006	15	0.548207664
18CODS01	1051	17	1058	15	1000	59	127.3	70.5	1058	15	0.553809898
18CODS01	1266	20	971	17	1838	49	528	295	971	17	0.558712121
18CODS01	1799	37	1698	50	1893	50	467	271	1893	50	0.580299786
18CODS01	1732	12	1665	20	1828	22	1118	666	1828	22	0.595706619
18CODS01	1120	35	1165	27	1040	100	46.2	27.7	1165	27	0.5995671
18CODS01	1372	14	1336	20	1443	39	297.6	180	1443	39	0.60483871
18CODS01	1255	37	1034	19	1637	76	416	257	1034	19	0.617788462
18CODS01	1104	25	1108	18	1142	71	247	156	1108	18	0.631578947
18CODS01	1183	16	1043	21	1435	40	937	594	1043	21	0.6339381
18CODS01	1047	17	1037	17	1043	62	182	118.7	1037	17	0.652197802
18CODS01	1026	18	1025	20	1017	58	215	142.6	1025	20	0.663255814
18CODS01	1706	16	1711	24	1708	34	226	154	1708	34	0.681415929
18CODS01	1098	35	1095	27	1100	100	84.6	58.1	1095	27	0.686761229
18CODS01	1066	21	1081	21	1060	67	126.7	87.5	1081	21	0.690607735
18CODS01	1016	14	993	14	1072	45	319	227.2	993	14	0.712225705
18CODS01	1052	18	1054	17	1030	64	224	161.3	1054	17	0.720089286
18CODS01	1074	15	1039	14	1154	48	405	292	1039	14	0.720987654
18CODS01	1085	24	1050	19	1142	65	312.4	230.3	1050	19	0.737195903
18CODS01	1391	23	1385	26	1404	56	214	158	1404	56	0.738317757
18CODS01	1736	63	1426	57	2110	120	23.2	17.2	2110	120	0.74137931
18CODS01	1431	15	1426	22	1450	38	386	294	1450	38	0.761658031
18CODS01	86.8	6.3	85.1	3.7	130	130	2770	2120	85.1	3.7	0.76534296
18CODS01	1144	19	1070	13	1308	53	328	253	1070	13	0.771341463
18CODS01	1048	19	1065	17	1021	63	166	129	1065	17	0.777108434
18CODS01	1038	26	1061	23	981	78	132.8	104	1061	23	0.78313253
18CODS01	1016	21	1042	20	965	72	212	173	1042	20	0.816037736
18CODS01	1085	18	1079	17	1077	55	195	162	1079	17	0.830769231
18CODS01	464	24	435.3	9.1	610	130	135.1	112.8	435.3	9.1	0.834937084
18CODS01	1045	27	711	16	1886	63	472	400	711	16	0.847457627
18CODS01	1035	25	1029	21	1101	60	128.2	109	1029	21	0.850234009
18CODS01	1082	25	1060	18	1163	71	121.3	105	1060	18	0.865622424

18CODS01	1082	21	1036	20	1153	60	192.9	171.5	1036	20	0.88906169
18CODS01	1085	16	1072	15	1099	51	161	144.2	1072	15	0.895652174
18CODS01	1115	23	1074	18	1197	59	177	165.4	1074	18	0.934463277
18CODS01	1053	30	1046	24	1078	85	93.9	88.2	1046	24	0.939297125
18CODS01	1059	25	1046	21	1095	77	87.5	82.8	1046	21	0.946285714
18CODS01	1005	27	1015	21	949	96	89.5	85	1015	21	0.94972067
18CODS01	1190	34	1054	25	1455	97	75.5	72.2	1054	25	0.956291391
18CODS01	1076	17	1001	14	1236	48	267.3	257.5	1001	14	0.963337074
18CODS01	1020	18	988	15	1110	52	208	203	988	15	0.975961538
18CODS01	1034	17	1005	16	1073	53	200	195.9	1005	16	0.9795
18CODS01	1026	23	985	19	1103	73	107.1	105	985	19	0.980392157
18CODS01	1069	25	1063	19	1052	85	73.5	75.1	1063	19	1.021768707
18CODS01	1087	20	1083	17	1095	57	130	133.9	1083	17	1.03
18CODS01	1109	20	1105	16	1092	60	130.3	138.5	1105	16	1.062931696
18CODS01	1044	19	1037	17	1042	64	101.8	112.5	1037	17	1.105108055
18CODS01	1046	17	1043	17	1046	56	199	221	1043	17	1.110552764
18CODS01	1020	25	1015	20	1032	78	126	141.5	1015	20	1.123015873
18CODS01	1335	14	1259	17	1461	35	577	695	1461	35	1.204506066
18CODS01	1117	13	958	25	1438	65	614	900	958	25	1.465798046
18CODS01	1423	21	1420	21	1445	49	184	273	1445	49	1.483695652
18CODS01	1044	33	1037	18	1020	100	56	99	1037	18	1.767857143
18CODS01	947	10	575	10	1942	25	1532	2850	575	10	1.860313316
18CODS01	1787	32	1640	25	1987	64	42.83	88.4	1987	64	2.06397385

Zircon ages and Th/U values for sample 18CODS02

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18DSCO02	1557	20	1490	25	1631	26	1866	29.6	1631	26	0.015862808
18DSCO02	1398	17	1432	22	1405	27	1980	90.8	1405	27	0.045858586

18DSCO02	1316	16	1277	20	1375	35	952	54	1375	35	0.056722689
18DSCO02	1598	15	1527	32	1712	29	2112	120.1	1712	29	0.05686553
18DSCO02	1557	18	1478	28	1673	30	2021	156.4	1673	30	0.077387432
18DSCO02	1429	21	1346	28	1558	34	1648	129.9	1558	34	0.078822816
18DSCO02	2187	82	1425	50	2990	140	77	6.23	2990	140	0.080909091
18DSCO02	1387	23	1077	40	1912	47	1330	136	1077	40	0.102255639
18DSCO02	766	19	542	26	1517	38	6150	669	542	26	0.108780488
18DSCO02	1593	20	1517	30	1715	32	3130	352	1715	32	0.112460064
18DSCO02	1618	35	1577	38	1664	35	1770	250	1664	35	0.141242938
18DSCO02	796	23	344	15	2407	31	2170	332.1	344	15	0.153041475
18DSCO02	1305	13	1192	31	1487	30	4100	637	1192	31	0.155365854
18DSCO02	1376	28	1255	32	1544	52	1681	278	1544	52	0.165377751
18DSCO02	1642	16	1576	29	1702	31	2010	342	1702	31	0.170149254
18DSCO02	46.1	3.3	34.5	1	550	140	7900	1455	34.5	1	0.184177215
18DSCO02	1414	29	1268	39	1649	52	2250	443	1649	52	0.196888889
18DSCO02	1480	38	1126	40	2004	28	1190	240	1126	40	0.201680672
18DSCO02	216	26	139	14	940	110	1930	461	139	14	0.238860104
18DSCO02	1626	17	1584	25	1660	35	677	162.9	1660	35	0.240620384
18DSCO02	1696	23	1552	25	1857	42	1360	339.4	1857	42	0.249558824
18DSCO02	1471	67	1170	110	2220	130	2180	547	1170	110	0.250917431
18DSCO02	1436	24	1407	26	1452	44	790	201	1452	44	0.25443038
18DSCO02	1583	31	1566	41	1624	28	1030	267.4	1624	28	0.25961165
18DSCO02	1644	18	1554	28	1745	39	892	238	1745	39	0.266816143
18DSCO02	1630	20	1555	22	1694	33	519	138.9	1694	33	0.267630058
18DSCO02	1607	20	1546	29	1676	36	939	252	1676	36	0.268370607
18DSCO02	1634	18	1588	27	1680	35	1412	397.7	1680	35	0.281657224
18DSCO02	1380	35	1101	37	1816	30	3710	1063	1101	37	0.286522911
18DSCO02	1672	19	1653	25	1689	31	605	185.3	1689	31	0.306280992
18DSCO02	1519	26	1445	28	1615	45	510	157	1615	45	0.307843137
18DSCO02	1413	17	1401	22	1415	42	349	108.5	1415	42	0.310888252
18DSCO02	1654	24	1654	26	1633	39	410	130.1	1633	39	0.317317073
18DSCO02	1364	20	1332	28	1416	38	1485	479	1416	38	0.322558923
18DSCO02	1328	20	1261	26	1423	47	402	130.9	1423	47	0.325621891

18DSCO02	1620	23	1580	28	1669	36	1347	452	1669	36	0.335560505
18DSCO02	1455	18	1391	25	1510	30	1526	518	1510	30	0.339449541
18DSCO02	1612	17	1553	24	1657	34	557	190.1	1657	34	0.341292639
18DSCO02	1117	39	456	27	1581	39	5460	1910	456	27	0.34981685
18DSCO02	1033	20	1054	21	971	48	697	244.2	1054	21	0.35035868
18DSCO02	1771	19	1708	23	1827	29	724	254	1827	29	0.350828729
18DSCO02	1717	18	1687	24	1724	40	354	125.5	1724	40	0.354519774
18DSCO02	1599	20	1523	29	1681	33	934	338.5	1681	33	0.3624197
18DSCO02	1022	21	922	17	1200	63	567	208	922	17	0.366843034
18DSCO02	1426	26	1389	27	1463	52	433	161.4	1463	52	0.372748268
18DSCO02	1355	18	1323	22	1424	31	1490	561	1424	31	0.376510067
18DSCO02	1570	15	1491	31	1672	20	2910	1099	1672	20	0.37766323
18DSCO02	1370	27	1142	38	1738	32	2870	1088	1142	38	0.379094077
18DSCO02	1645	21	1438	24	1915	29	1139	433	1915	29	0.380158033
18DSCO02	1552	19	1385	38	1792	37	711	278	1792	37	0.390998594
18DSCO02	1677	26	1264	32	2183	52	527	209.2	2183	52	0.396963947
18DSCO02	1519	34	1351	48	1781	36	1960	788	1781	36	0.402040816
18DSCO02	1346	16	1302	24	1412	39	1189	489	1412	39	0.411269975
18DSCO02	1552	20	1482	25	1612	46	488.6	209.8	1612	46	0.429390094
18DSCO02	1586	24	1499	37	1692	44	385	166.1	1692	44	0.431428571
18DSCO02	1561	20	1484	28	1659	32	1576	682	1659	32	0.432741117
18DSCO02	34.5	1.9	35.3	0.79	-10	110	4660	2087	35.3	0.79	0.447854077
18DSCO02	1613	20	1539	25	1720	32	1820	817	1720	32	0.448901099
18DSCO02	1425	28	1095	36	1962	38	2490	1127	1095	36	0.452610442
18DSCO02	1823	22	1792	31	1840	37	478	216.8	1840	37	0.453556485
18DSCO02	29.2	1	27.22	0.5	202	73	13340	6120	27.22	0.5	0.458770615
18DSCO02	1462	19	1314	27	1660	44	438	207.1	1660	44	0.47283105
18DSCO02	1417	17	1370	31	1453	41	1232	586	1453	41	0.475649351
18DSCO02	1518	30	1472	35	1545	42	586	280	1545	42	0.4778157
18DSCO02	1622	21	1581	25	1652	37	821	394	1652	37	0.479902558
18DSCO02	1385	16	1324	26	1458	32	1163	566	1458	32	0.486672399
18DSCO02	1700	21	1723	32	1672	37	880	437	1672	37	0.496590909
18DSCO02	1864	42	1313	35	2516	86	59.4	29.6	2516	86	0.498316498

18DSCO02	1391	15	1387	23	1376	40	749	379	1376	40	0.506008011
18DSCO02	1426	17	1415	21	1408	36	504	259	1408	36	0.513888889
18DSCO02	1646	18	1591	28	1691	33	809	416	1691	33	0.51421508
18DSCO02	1181	21	891	29	1767	29	1139	597	891	29	0.524143986
18DSCO02	1688	25	1691	28	1678	32	890	489	1678	32	0.549438202
18DSCO02	1669	19	1610	33	1719	34	3370	1870	1719	34	0.554896142
18DSCO02	1364	25	1360	32	1358	59	393	220	1358	59	0.559796438
18DSCO02	32.4	3.2	34.5	1.2	-150	180	1066	601	34.5	1.2	0.563789869
18DSCO02	1560	18	1475	34	1676	28	2033	1184	1676	28	0.582390556
18DSCO02	1658	26	1589	39	1728	55	409	239	1728	55	0.584352078
18DSCO02	107	7.2	89.9	2.4	420	150	1121	674	89.9	2.4	0.601248885
18DSCO02	1629	19	1583	26	1671	33	1095	662	1671	33	0.60456621
18DSCO02	1486	27	1370	47	1660	71	392	247.2	1660	71	0.630612245
18DSCO02	1360	23	1310	32	1453	56	352	227	1453	56	0.644886364
18DSCO02	51.4	4.9	33.5	1.1	850	180	1889	1224	33.5	1.1	0.647961885
18DSCO02	1440	26	1405	27	1437	53	275	188	1437	53	0.683636364
18DSCO02	1744	20	1481	31	2054	46	302	213	2054	46	0.705298013
18DSCO02	33.1	2.4	30.7	1.1	200	150	2540	1815	30.7	1.1	0.714566929
18DSCO02	2850	150	1470	70	3700	150	22.5	16.7	3700	150	0.742222222
18DSCO02	1321	20	1259	27	1413	50	666	496	1413	50	0.744744745
18DSCO02	412	16	158.1	8.4	2316	63	1532	1148	158.1	8.4	0.749347258
18DSCO02	154	12	39.7	2.3	2710	180	330	248	39.7	2.3	0.751515152
18DSCO02	310	21	172	12	1554	58	2630	2010	172	12	0.764258555
18DSCO02	2270	140	1651	59	2810	180	603	469	2810	180	0.777777778
18DSCO02	33	3.8	31.9	1.3	40	230	1003	797	31.9	1.3	0.794616152
18DSCO02	1401	30	1316	36	1497	70	140.1	113.5	1497	70	0.810135617
18DSCO02	45	4.8	34.3	1.2	460	200	1470	1213	34.3	1.2	0.825170068
18DSCO02	1327	28	1113	46	1678	23	2288	1970	1113	46	0.861013986
18DSCO02	1090	34	1061	21	1090	110	107.1	93.7	1061	21	0.874883287
18DSCO02	37.1	3.4	33	1.3	200	190	1850	1800	33	1.3	0.972972973
18DSCO02	35.9	4.5	32.3	1.3	110	250	730	729	32.3	1.3	0.998630137
18DSCO02	195	23	41.1	1.8	2800	210	831	852	41.1	1.8	1.025270758
18DSCO02	36.6	4	33	1.3	180	210	1316	1434	33	1.3	1.089665653

18DSCO02	44.7	5.3	35.7	1.8	340	260	918	1040	35.7	1.8	1.132897603
18DSCO02	37.3	3.2	30.1	1.1	450	200	1548	1824	30.1	1.1	1.178294574
18DSCO02	30.9	2.7	30.5	1.3	80	180	1800	2400	30.5	1.3	1.333333333
18DSCO02	1870	130	946	54	2190	170	186	251	946	54	1.349462366
18DSCO02	36.1	4.4	33.1	1.1	110	240	805	1145	33.1	1.1	1.422360248
18DSCO02	1356	14	1318	20	1420	36	854	1217	1420	36	1.425058548
18DSCO02	37.2	6.3	32.9	1.7	50	310	451	683	32.9	1.7	1.514412417
18DSCO02	1248	17	547	14	1920	44	1039	1680	547	14	1.616939365
18DSCO02	993	27	823	32	1394	30	3470	5900	823	32	1.700288184
18DSCO02	64.4	4.5	23.06	0.8	960	170	3150	5490	23.06	0.8	1.742857143
18DSCO02	3037	69	1025	73	5100	130	16.02	31.24	1025	73	1.950062422
18DSCO02	1709	65	1236	34	2320	100	236.1	497	2320	100	2.105040237
18DSCO02	2316	85	1404	51	3030	110	52.4	143	3030	110	2.729007634
18DSCO02	1003	52	514	27	2260	150	104.9	290	514	27	2.764537655
18DSCO02	1960	59	1306	39	2720	90	1654	7040	2720	90	4.256348247

Zircon ages and Th/U values for sample 18KSDS01

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18KSDS01	444	19	431	12	490	110	236.7	5.04	431	12	0.021292776
18KSDS01	1079	20	1124	28	1007	47	1417	69	1124	28	0.048694425
18KSDS01	1580	18	1582	33	1571	35	974	50.9	1571	35	0.052258727
18KSDS01	1454	24	1435	34	1481	57	190.8	16.12	1481	57	0.084486373
18KSDS01	1049	21	1052	31	1040	46	576	56.6	1052	31	0.098263889
18KSDS01	1883	23	1746	36	2049	41	225	25.6	2049	41	0.113777778
18KSDS01	1064	37	951	36	1350	110	465	63	951	36	0.135483871
18KSDS01	1454	60	1405	76	1567	48	1540	225.8	1567	48	0.146623377
18KSDS01	1777	36	1868	60	1676	73	210	33.4	1676	73	0.159047619
18KSDS01	1248	27	1267	32	1211	61	218	40.5	1211	61	0.185779817

18KSDS01	1093	29	1063	34	1152	45	582	120	1063	34	0.206185567
18KSDS01	372.3	9.9	382	8	325	72	965	201	382	8	0.208290155
18KSDS01	1300	19	1293	24	1315	45	239	52.6	1315	45	0.220083682
18KSDS01	1607	21	1600	33	1624	46	704	160.3	1624	46	0.227698864
18KSDS01	1477	21	1481	34	1448	52	412	94.7	1448	52	0.229854369
18KSDS01	3080	77	3240	130	3007	65	186	43.1	3007	65	0.23172043
18KSDS01	1438	20	1431	33	1452	40	1038	258.2	1452	40	0.248747592
18KSDS01	1041	23	1052	28	1006	71	239	65.1	1052	28	0.272384937
18KSDS01	1106	21	1079	35	1170	54	1009	297	1079	35	0.294350842
18KSDS01	1184	23	1196	30	1134	57	370	109.9	1196	30	0.297027027
18KSDS01	1039	25	1041	26	1014	76	191	56.8	1041	26	0.297382199
18KSDS01	1287	31	943	39	1969	60	999	301	943	39	0.301301301
18KSDS01	1088	23	1132	35	1055	53	701	224	1132	35	0.319543509
18KSDS01	766	27	568	31	1473	50	2250	752	568	31	0.334222222
18KSDS01	79	11	76.9	2.7	20	190	460	156.2	76.9	2.7	0.339565217
18KSDS01	1076	24	1072	26	1085	68	252	86.2	1072	26	0.342063492
18KSDS01	942	54	700	52	1622	69	418	148	700	52	0.354066986
18KSDS01	1175	21	1174	34	1191	50	641	243.7	1174	34	0.380187207
18KSDS01	1727	21	1709	40	1764	46	613	245	1764	46	0.399673736
18KSDS01	1109	24	1122	31	1094	60	248	103.3	1122	31	0.416532258
18KSDS01	947	25	955	27	916	68	210	92	955	27	0.438095238
18KSDS01	1136	19	1120	22	1173	59	188.5	83.3	1120	22	0.441909814
18KSDS01	1053	27	991	21	1168	77	298	135	991	21	0.453020134
18KSDS01	1059	32	1082	31	970	99	90	41.2	1082	31	0.457777778
18KSDS01	1458	21	1494	44	1415	39	813	380	1415	39	0.467404674
18KSDS01	956	22	933	22	1019	61	244	116.8	933	22	0.478688525
18KSDS01	30.7	4.6	32.6	1.5	-200	240	641	309	32.6	1.5	0.482059282
18KSDS01	1062	20	1063	27	1055	55	398	199.3	1063	27	0.500753769
18KSDS01	1695	24	1706	39	1684	46	403	202	1684	46	0.501240695
18KSDS01	1038	26	1057	24	1012	63	182.1	91.8	1057	24	0.504118616
18KSDS01	1597	18	1495	31	1710	35	742	381.6	1710	35	0.514285714
18KSDS01	1046	20	1032	21	1074	60	302.9	157.2	1032	21	0.518983163
18KSDS01	1009	33	1004	29	1020	110	64.9	33.7	1004	29	0.519260401

18KSDS01	32.8	5.3	35.1	2.2	-160	280	326	169.5	35.1	2.2	0.51993865
18KSDS01	1860	24	1901	42	1827	47	397	208	1827	47	0.523929471
18KSDS01	921	22	883	20	1008	72	307	160.9	883	20	0.524104235
18KSDS01	1096	19	1112	25	1059	57	333	176	1112	25	0.528528529
18KSDS01	1204	33	1220	34	1162	93	82.8	43.9	1162	93	0.530193237
18KSDS01	128.7	8.6	125.3	3.6	180	150	645	342	125.3	3.6	0.530232558
18KSDS01	1091	20	1094	25	1079	64	319	169.6	1094	25	0.531661442
18KSDS01	1637	21	1596	34	1689	51	271.4	145	1689	51	0.534266765
18KSDS01	1104	19	1098	27	1094	62	318	171.3	1098	27	0.538679245
18KSDS01	1024	22	1017	25	1042	56	510	280.1	1017	25	0.549215686
18KSDS01	1062	24	1083	24	999	66	312	172.8	1083	24	0.553846154
18KSDS01	593	21	583	15	610	110	184.6	103.3	583	15	0.559588299
18KSDS01	1138	27	1148	29	1093	87	79.3	44.4	1148	29	0.559899117
18KSDS01	1741	18	1735	35	1736	38	659	373	1736	38	0.566009105
18KSDS01	1044	36	1034	32	1060	100	135.3	76.8	1034	32	0.567627494
18KSDS01	84.1	9.9	78	3	100	220	295	169	78	3	0.572881356
18KSDS01	983	23	962	26	1039	72	145.7	86.5	962	26	0.593685655
18KSDS01	332	11	244	18	1100	110	2990	1800	244	18	0.602006689
18KSDS01	500	16	490	13	530	100	298.8	183.2	490	13	0.613119143
18KSDS01	1055	28	1039	31	1040	100	118.9	75.1	1039	31	0.631623213
18KSDS01	1039	17	1039	23	1045	51	330.3	211.1	1039	23	0.639115955
18KSDS01	35.9	3.6	37.2	1.3	-90	190	666	430	37.2	1.3	0.645645646
18KSDS01	1414	32	1244	41	1700	40	1524	996	1700	40	0.653543307
18KSDS01	1714	21	1714	34	1718	47	396.6	260.9	1718	47	0.657841654
18KSDS01	1060	20	1027	22	1121	54	305.6	205	1027	22	0.670811518
18KSDS01	985	27	971	26	1017	79	148.6	100	971	26	0.67294751
18KSDS01	361	10	337	10	490	68	1180	795	337	10	0.673728814
18KSDS01	1082	30	1041	27	1152	93	91.4	61.9	1041	27	0.677242888
18KSDS01	1133	19	1129	36	1103	67	148.1	101.3	1129	36	0.683997299
18KSDS01	1113	25	1138	24	1061	82	123	84.2	1138	24	0.684552846
18KSDS01	1503	22	1495	34	1515	59	129.3	88.8	1515	59	0.686774942
18KSDS01	1128	24	1116	28	1117	78	128.8	88.7	1116	28	0.688664596
18KSDS01	87	12	30.8	1.8	1830	300	642	445	30.8	1.8	0.693146417

18KSDS01	1109	49	1109	35	1120	130	45.3	32.1	1109	35	0.708609272
18KSDS01	1039	25	1067	24	978	83	112.5	80.2	1067	24	0.712888889
18KSDS01	1399	41	1395	41	1360	110	90	64.3	1360	110	0.714444444
18KSDS01	1102	17	1080	26	1141	52	476	341.5	1080	26	0.717436975
18KSDS01	1615	22	1578	42	1663	48	216.9	159.4	1663	48	0.734900876
18KSDS01	1125	18	1104	23	1163	47	519	383	1104	23	0.737957611
18KSDS01	1013	16	988	22	1054	49	577	437	988	22	0.757365685
18KSDS01	504	19	499	16	523	89	432	329	499	16	0.761574074
18KSDS01	1981	28	2032	58	2503	44	175.8	135.2	2503	44	0.769055745
18KSDS01	1094	32	1079	33	1140	110	140	109.8	1079	33	0.784285714
18KSDS01	27.7	2.9	28.8	1.2	-10	220	450	354	28.8	1.2	0.786666667
18KSDS01	1447	19	1458	26	1439	51	359	292	1439	51	0.813370474
18KSDS01	1087	25	1095	24	1049	63	213.2	175	1095	24	0.820825516
18KSDS01	1390	22	1394	32	1402	54	275	230	1402	54	0.836363636
18KSDS01	1094	32	1113	29	1060	100	88.5	75.8	1113	29	0.856497175
18KSDS01	81	14	79	15	240	330	103.1	88.5	79	15	0.858389913
18KSDS01	1089	20	1111	26	1046	56	362	323	1111	26	0.892265193
18KSDS01	1082	15	1073	23	1092	52	856	768	1073	23	0.897196262
18KSDS01	1367	19	1357	28	1386	51	297	276	1386	51	0.929292929
18KSDS01	74	7.4	61	2.9	410	240	186.1	182.6	61	2.9	0.981192907
18KSDS01	1104	26	1135	28	1040	68	201	200	1135	28	0.995024876
18KSDS01	236	20	173.1	6	770	180	272.5	272	173.1	6	0.998165138
18KSDS01	1682	30	1656	35	1703	74	68.2	68.3	1703	74	1.001466276
18KSDS01	957	24	954	27	943	84	207.8	213	954	27	1.025024062
18KSDS01	1747	32	1773	46	1705	67	91.5	94.5	1705	67	1.032786885
18KSDS01	167	12	166.8	4.7	130	150	439	456	166.8	4.7	1.038724374
18KSDS01	1625	43	1154	33	2293	87	52.7	55.4	1154	33	1.051233397
18KSDS01	1089	22	1047	26	1179	64	312.6	340.1	1047	26	1.087971849
18KSDS01	189	27	179	46	390	280	96	114.6	179	46	1.19375
18KSDS01	1117	25	1138	30	1066	80	117	144.5	1138	30	1.235042735
18KSDS01	2635	23	2568	51	2690	41	178.5	224.4	2690	41	1.257142857
18KSDS01	1330	220	304	65	3600	450	94	125	304	65	1.329787234
18KSDS01	2364	26	2093	42	2612	40	327	444	2612	40	1.357798165

18KSDS01	1779	23	1778	34	1783	43	187.8	274.9	1783	43	1.463791267
18KSDS01	977	24	893	24	1171	74	194.1	296	893	24	1.52498712
18KSDS01	63.3	7.1	61.5	2.6	40	220	280.5	463.4	61.5	2.6	1.652049911
18KSDS01	26	2.4	24.49	0.92	120	180	987	1854	24.49	0.92	1.878419453
18KSDS01	409	19	63.6	5.5	3820	140	152.4	1122	63.6	5.5	7.362204724
18KSDS01	1283	15	1192	24	1435	39	7520	310200	1192	24	41.25

Zircon ages and Th/U values for sample 18MOSM20

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18MOSM20	1212	21	429	10	3130	28	3670	212.7	429	10	0.057956403
18MOSM20	454	38	409	21	700	170	1952	150	409	21	0.076844262
18MOSM20	945	12	832	17	1222	31	2600	209	832	17	0.080384615
18MOSM20	1635	15	1648	16	1612	35	519	48.8	1612	35	0.094026975
18MOSM20	1262	17	1048	16	1656	28	2221	210	1048	16	0.094552004
18MOSM20	1011	17	961	19	1111	45	977	127.3	961	19	0.130296827
18MOSM20	1957	49	925	39	3350	110	33.2	4.55	925	39	0.137048193
18MOSM20	1157	23	1171	31	1133	42	840	146.6	1171	31	0.17452381
18MOSM20	1174	20	1158	21	1198	56	258.3	52.2	1158	21	0.202090592
18MOSM20	668	35	624	35	793	88	598	127.4	624	35	0.213043478
18MOSM20	1745	20	1796	31	1696	28	980	209	1696	28	0.213265306
18MOSM20	1751	13	1765	24	1729	28	1284	300	1729	28	0.23364486
18MOSM20	1744	13	1683	22	1817	29	638	164.8	1817	29	0.25830721
18MOSM20	472.7	7.4	201.1	3.5	2162	35	5614	1500	201.1	3.5	0.26718917
18MOSM20	129	10	104.1	3	470	160	572	161.2	104.1	3	0.281818182
18MOSM20	1038	20	1039	18	1001	66	247.7	70.2	1039	18	0.283407348
18MOSM20	73	10	76.6	3.3	-120	250	274.9	87.5	76.6	3.3	0.318297563
18MOSM20	319	11	327.5	7.4	252	94	666	216	327.5	7.4	0.324324324
18MOSM20	1625	16	1550	22	1714	32	405	132.3	1714	32	0.326666667

18MOSM20	2521	21	2116	31	2698	29	336	111	2698	29	0.330357143
18MOSM20	955	62	588	46	1976	84	175	58.9	588	46	0.336571429
18MOSM20	1881	86	1410	100	2539	28	1840	627	2539	28	0.34076087
18MOSM20	876	26	899	16	815	91	321	111.1	899	16	0.346105919
18MOSM20	1793	17	1079	26	2770	25	2465	888	1079	26	0.360243408
18MOSM20	1384	20	1332	24	1472	43	485	177	1472	43	0.364948454
18MOSM20	416	22	389	11	480	140	251	94.3	389	11	0.375697211
18MOSM20	568	14	562.5	8.7	554	77	606	230	562.5	8.7	0.379537954
18MOSM20	1365	36	1180	47	1682	40	883	336	1180	47	0.380520951
18MOSM20	115.3	7.2	116.4	2.9	100	140	636	249.2	116.4	2.9	0.391823899
18MOSM20	1769	21	1775	28	1754	30	921	362	1754	30	0.393051031
18MOSM20	2070	22	2078	37	2058	37	244	100.4	2058	37	0.41147541
18MOSM20	835	25	392	13	2280	81	608	257	392	13	0.422697368
18MOSM20	1611	16	1491	21	1772	27	1740	773	1772	27	0.444252874
18MOSM20	1320	130	909	84	2080	230	18.6	8.4	909	84	0.451612903
18MOSM20	59.8	7.1	68.6	2.8	-210	210	397	184	68.6	2.8	0.463476071
18MOSM20	1671	11	1702	25	1634	27	654	309	1634	27	0.472477064
18MOSM20	1372	15	1150	26	1739	24	2231	1074	1150	26	0.481398476
18MOSM20	92.9	9.2	95.4	4.8	-20	160	834	403	95.4	4.8	0.483213429
18MOSM20	1700	16	1731	24	1656	34	474	231	1656	34	0.487341772
18MOSM20	104.5	5.2	102.6	2.7	130	110	1131	557	102.6	2.7	0.492484527
18MOSM20	30	4.3	30.3	1.5	-30	270	484	239	30.3	1.5	0.493801653
18MOSM20	931	22	913	20	960	86	211	104.6	913	20	0.495734597
18MOSM20	1803	24	1731	20	1877	46	1525	770	1877	46	0.504918033
18MOSM20	118.9	8.7	97.5	3.3	480	170	551	278.6	97.5	3.3	0.505626134
18MOSM20	1483	16	1317	18	1717	32	860	437	1717	32	0.508139535
18MOSM20	111	5.8	93.4	2	450	120	1414	752	93.4	2	0.531824611
18MOSM20	442	12	393.5	8.2	680	76	758	408	393.5	8.2	0.538258575
18MOSM20	1715	17	1716	27	1709	30	849	460	1709	30	0.541813899
18MOSM20	97.3	6.3	85.8	2.3	310	140	979	531	85.8	2.3	0.542390194
18MOSM20	325.9	9.8	321.7	5.5	336	74	1013	565.2	321.7	5.5	0.557946693
18MOSM20	76	11	74.3	3.2	-10	260	308.2	172	74.3	3.2	0.558079169
18MOSM20	1204	23	1087	21	1459	74	267.1	152.4	1087	21	0.570572819

18MOSM20	2588	13	2451	32	2691	23	344	197.5	2691	23	0.574127907
18MOSM20	1352	16	1325	19	1389	38	422	244.4	1389	38	0.579146919
18MOSM20	99.4	4.7	92.4	2.5	260	120	1360	843	92.4	2.5	0.619852941
18MOSM20	1612	13	1544	19	1695	34	638	397	1695	34	0.622257053
18MOSM20	1700	16	1670	27	1731	32	576	360	1731	32	0.625
18MOSM20	377	11	368.2	8.1	405	80	882	559	368.2	8.1	0.633786848
18MOSM20	636	22	597	12	740	100	210.1	136	597	12	0.647310804
18MOSM20	155	20	87	3.1	1150	230	443	288	87	3.1	0.650112867
18MOSM20	1642	18	1616	21	1663	42	357	234	1663	42	0.655462185
18MOSM20	1566	12	1476	20	1689	22	1145	770	1689	22	0.672489083
18MOSM20	2300	36	1965	67	2634	18	2731	1860	2634	18	0.681069205
18MOSM20	1538	15	1315	24	1849	30	810	559	1849	30	0.690123457
18MOSM20	63.7	7.1	66	2.4	-90	210	492	340	66	2.4	0.691056911
18MOSM20	1389	25	1277	30	1565	42	279	195	1565	42	0.698924731
18MOSM20	2562	24	2521	40	2588	39	254	178	2588	39	0.700787402
18MOSM20	2294	20	1901	32	2660	27	867	609	2660	27	0.702422145
18MOSM20	1897	46	1234	87	2797	43	1694	1190	2797	43	0.702479339
18MOSM20	1064	17	1069	16	1045	57	417.6	298.3	1069	16	0.714319923
18MOSM20	1550	31	1468	34	1649	76	67	49.8	1649	76	0.743283582
18MOSM20	1438	38	1394	32	1501	77	163.2	122.1	1501	77	0.748161765
18MOSM20	59.2	9	66.3	3.2	-240	260	288.9	219	66.3	3.2	0.758047767
18MOSM20	1602	15	1487	22	1750	27	923	709	1750	27	0.768147346
18MOSM20	1580	18	1590	21	1549	49	291.6	225.7	1549	49	0.774005487
18MOSM20	361	10	285	13	902	69	2540	2020	285	13	0.795275591
18MOSM20	1333	18	1333	20	1322	47	406	326	1322	47	0.802955665
18MOSM20	221.5	6.5	220.9	3.9	221	82	1299	1045	220.9	3.9	0.804464973
18MOSM20	1076	29	827	21	1620	60	768	626	827	21	0.815104167
18MOSM20	37.2	5.2	34.2	1.4	90	260	687	567	34.2	1.4	0.825327511
18MOSM20	2551	18	2177	39	2893	26	343	284	2893	26	0.827988338
18MOSM20	1433	14	1377	18	1509	36	453	382	1509	36	0.843267108
18MOSM20	901	20	501	18	1902	29	5260	4470	501	18	0.849809886
18MOSM20	2642	16	2470	31	2773	23	486	429	2773	23	0.882716049
18MOSM20	1211	16	1190	16	1243	45	344.4	325.8	1190	16	0.945993031

18MOSM20	57	12	49.7	2.9	80	350	215.8	206	49.7	2.9	0.954587581
18MOSM20	1595	19	1554	23	1644	46	250.8	239.5	1644	46	0.954944179
18MOSM20	124.2	8.5	90.3	2.5	760	150	920	880	90.3	2.5	0.956521739
18MOSM20	966	39	894	14	1100	120	193.7	194	894	14	1.001548787
18MOSM20	1636	21	1565	26	1712	50	217	222	1712	50	1.023041475
18MOSM20	432	10	433	7.4	432	67	1014	1055	433	7.4	1.040433925
18MOSM20	2679	19	2679	39	2672	32	160.2	174.4	2672	32	1.088639201
18MOSM20	1335	17	1311	25	1367	42	561	616	1367	42	1.098039216
18MOSM20	1332	15	1140	18	1648	39	662	740	1140	18	1.117824773
18MOSM20	93	10	35	1.8	1770	230	559	634	35	1.8	1.134168157
18MOSM20	316	21	319.2	9.4	220	160	238.4	274.1	319.2	9.4	1.149748322
18MOSM20	2640	15	2603	36	2680	26	613	722	2680	26	1.177814029
18MOSM20	954	32	953	28	950	100	92.3	109.9	953	28	1.190682557
18MOSM20	284	24	187.4	5	1000	190	424	523	187.4	5	1.233490566
18MOSM20	1369	20	1377	22	1358	50	402	496	1358	50	1.233830846
18MOSM20	48	12	23.8	1.9	580	510	253	322	23.8	1.9	1.272727273
18MOSM20	610	25	369	18	1654	25	5430	7440	369	18	1.370165746
18MOSM20	2564	14	2348	36	2740	20	920	1332	2740	20	1.447826087
18MOSM20	1363	33	1367	29	1335	85	90.8	148.6	1335	85	1.636563877
18MOSM20	405	11	222.7	5.5	1623	79	1177	2260	222.7	5.5	1.920135939
18MOSM20	2658	17	2630	34	2684	31	228.7	456.5	2684	31	1.996064714
18MOSM20	1340	18	1298	19	1412	46	488	1018	1412	46	2.086065574
18MOSM20	59	13	41.4	2.1	320	360	567	1480	41.4	2.1	2.610229277
18MOSM20	179	19	88.5	3.9	1360	260	181.1	510.8	88.5	3.9	2.820541137
18MOSM20	142	24	94.2	3.9	650	260	491	1393	94.2	3.9	2.83706721

Zircon ages and Th/U values for sample 18MOSM24

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U

18MOSM24	1044	44	1068	45	920	120	42.4	0.87	1068	45	0.020518868
18MOSM24	1441	22	1318	33	1612	38	2291	179.9	1612	38	0.078524662
18MOSM24	65.2	3.9	65.9	2.3	60	120	1074	102.1	65.9	2.3	0.095065177
18MOSM24	1671	25	1631	36	1715	38	1317	129.4	1715	38	0.098253607
18MOSM24	1520	24	1470	36	1588	45	323	32.4	1588	45	0.100309598
18MOSM24	1110	23	1106	24	1088	48	428	47.1	1106	24	0.110046729
18MOSM24	952	20	932	19	981	58	437	61.4	932	19	0.140503432
18MOSM24	1607	24	1580	42	1623	41	656	127.5	1623	41	0.194359756
18MOSM24	1558	39	1385	58	1801	39	1240	247	1801	39	0.199193548
18MOSM24	1476	23	1341	36	1665	41	2140	441	1665	41	0.206074766
18MOSM24	1645	19	1653	34	1606	38	984	209.6	1606	38	0.21300813
18MOSM24	1666	22	1650	39	1649	50	405	86.4	1649	50	0.213333333
18MOSM24	1708	23	1716	44	1694	46	388	89.2	1694	46	0.229896907
18MOSM24	1848	43	1267	59	2594	36	3080	725	2594	36	0.23538961
18MOSM24	1171	20	1188	26	1125	63	229	54.8	1188	26	0.23930131
18MOSM24	196.3	9.9	213	10	433	76	1387	349.4	213	10	0.251910598
18MOSM24	30.6	3.5	31.7	1.1	-100	190	952	241.4	31.7	1.1	0.253571429
18MOSM24	1186	31	1091	36	1387	62	645	164	1091	36	0.254263566
18MOSM24	2252	24	2256	43	2223	36	230.6	59.6	2223	36	0.258456201
18MOSM24	396	21	393	12	350	140	176	45.5	393	12	0.258522727
18MOSM24	62.2	6.6	66.2	2.4	-110	190	466	123	66.2	2.4	0.263948498
18MOSM24	1775	18	1783	33	1773	42	689	193	1773	42	0.28011611
18MOSM24	349	15	348.2	9.8	360	110	243.8	68.7	348.2	9.8	0.281788351
18MOSM24	77.5	3.3	77.4	2	41	77	3870	1101	77.4	2	0.284496124
18MOSM24	35.1	2.5	34	1.2	120	150	1679	486.3	34	1.2	0.289636689
18MOSM24	122	13	118.4	4.4	90	210	209.5	61	118.4	4.4	0.291169451
18MOSM24	2374	52	1610	69	3060	120	14.25	4.33	3060	120	0.303859649
18MOSM24	169.8	7.4	168.4	5.1	183	92	1046	332	168.4	5.1	0.317399618
18MOSM24	97.3	7.2	110.3	6.5	180	170	479	159	110.3	6.5	0.331941545
18MOSM24	81.1	7.3	82.1	7.3	40	170	858	286	82.1	7.3	0.333333333
18MOSM24	1458	24	1424	38	1512	53	430	144.7	1512	53	0.336511628
18MOSM24	1734	31	1764	58	1700	40	808	273	1700	40	0.337871287
18MOSM24	2708	24	2432	40	2907	39	360	122	2907	39	0.338888889

18MOSM24	1796	27	1732	42	1845	50	210	71.3	1845	50	0.33952381
18MOSM24	1659	27	1600	45	1705	41	906	312	1705	41	0.344370861
18MOSM24	1216	34	1126	50	1382	97	920	341	1126	50	0.370652174
18MOSM24	2568	20	2559	45	2557	34	352.4	132.8	2557	34	0.376844495
18MOSM24	353	35	336	12	310	200	100.5	38	336	12	0.378109453
18MOSM24	97.9	9.4	90.3	3.8	260	220	269.1	102.5	90.3	3.8	0.380899294
18MOSM24	167	11	153.4	5.1	320	160	255.1	101.7	153.4	5.1	0.398667189
18MOSM24	47.4	3.1	49.7	1.9	-80	130	1359	545	49.7	1.9	0.401030169
18MOSM24	1726	28	1720	46	1721	50	152.1	62.6	1721	50	0.411571335
18MOSM24	405	17	406	11	370	100	355	146.9	406	11	0.413802817
18MOSM24	1481	19	1498	32	1450	37	779	341.3	1450	37	0.438125802
18MOSM24	71.4	5.1	71.1	2.2	90	140	1560	690	71.1	2.2	0.442307692
18MOSM24	1554	18	1503	30	1611	41	324.8	145.6	1611	41	0.448275862
18MOSM24	1703	19	1557	36	1878	33	904	409	1878	33	0.452433628
18MOSM24	1124	22	1115	25	1140	59	299	135.7	1115	25	0.453846154
18MOSM24	1631	19	1609	28	1649	50	301.6	137.5	1649	50	0.455901857
18MOSM24	1671	20	1673	29	1654	41	329.8	151.8	1654	41	0.460278957
18MOSM24	1403	24	1383	32	1427	54	524	241.2	1427	54	0.460305344
18MOSM24	1474	33	1345	46	1650	56	192	90.4	1650	56	0.470833333
18MOSM24	2698	17	2694	41	2695	29	326	155.8	2695	29	0.47791411
18MOSM24	1113	28	946	26	1453	79	247.2	119.7	946	26	0.484223301
18MOSM24	2826	23	2838	55	2805	30	695	338	2805	30	0.486330935
18MOSM24	1800	36	1382	37	2395	69	253	123.5	2395	69	0.488142292
18MOSM24	2689	42	2801	83	2594	35	325	160	2594	35	0.492307692
18MOSM24	1672	24	1636	31	1709	50	242	123.4	1709	50	0.509917355
18MOSM24	2503	18	2441	48	2538	38	400.1	207.3	2538	38	0.51812047
18MOSM24	1728	18	1799	40	1616	46	415	217.7	1616	46	0.524578313
18MOSM24	1684	26	1690	43	1654	48	254	136	1654	48	0.535433071
18MOSM24	609	12	597	14	596	71	454.2	251.2	597	14	0.553060326
18MOSM24	2575	23	2359	53	2736	34	2084	1159	2736	34	0.556142035
18MOSM24	1443	17	1374	32	1527	41	875	494	1527	41	0.564571429
18MOSM24	507	20	479	11	620	120	291.4	166	479	11	0.569663693
18MOSM24	2668	29	2582	61	2718	39	100.2	57.4	2718	39	0.572854291

18MOSM24	1014	23	1036	23	951	70	300	174	1036	23	0.58
18MOSM24	1657	20	1646	31	1653	48	250	147	1653	48	0.588
18MOSM24	1269	17	1293	28	1225	35	683	403	1225	35	0.590043924
18MOSM24	98.2	7	94.1	2.9	170	150	568	336	94.1	2.9	0.591549296
18MOSM24	111	10	98.7	3.6	250	170	607	366.6	98.7	3.6	0.603953871
18MOSM24	1427	17	1409	28	1437	41	500	312	1437	41	0.624
18MOSM24	1745	29	1800	52	1671	75	290	183	1671	75	0.631034483
18MOSM24	123	14	113	15	330	160	571	361	113	15	0.632224168
18MOSM24	647	17	652	16	613	69	282	180.4	652	16	0.639716312
18MOSM24	1317	21	1274	43	1391	55	274.5	177.1	1391	55	0.645173042
18MOSM24	41.4	7.3	38.4	1.9	-60	220	745	484.5	38.4	1.9	0.65033557
18MOSM24	85.9	9.3	83.6	3	30	160	506	332	83.6	3	0.656126482
18MOSM24	1476	29	1514	35	1395	70	104	71.9	1395	70	0.691346154
18MOSM24	70.3	8.7	70.4	3.7	-60	240	194.4	141.7	70.4	3.7	0.728909465
18MOSM24	1122	25	1164	27	1024	83	154	114.4	1164	27	0.742857143
18MOSM24	1450	20	1450	34	1453	45	493	371	1453	45	0.752535497
18MOSM24	1117	43	1195	37	920	120	51.9	39.3	1195	37	0.757225434
18MOSM24	65.8	4	57.3	2	320	140	1490	1170	57.3	2	0.785234899
18MOSM24	65.5	7.6	71.5	3	-180	200	351	284	71.5	3	0.809116809
18MOSM24	35	12	12.2	4.5	1550	660	303	251	12.2	4.5	0.828382838
18MOSM24	77.5	6.7	75.8	2.1	60	180	590	493	75.8	2.1	0.83559322
18MOSM24	2702	18	2698	48	2694	32	358	305.7	2694	32	0.853910615
18MOSM24	1724	23	1768	41	1679	48	574	495	1679	48	0.862369338
18MOSM24	2456	22	2394	49	2840	34	537	469	2840	34	0.873370577
18MOSM24	1447	26	1484	39	1392	54	369	325	1392	54	0.880758808
18MOSM24	1886	21	1889	39	1881	35	349	309	1881	35	0.885386819
18MOSM24	71	9.1	43.1	3	880	260	450	400	43.1	3	0.888888889
18MOSM24	475	35	495	20	360	190	73.5	65.4	495	20	0.889795918
18MOSM24	35.2	5.3	34.5	1.9	-30	260	314	280	34.5	1.9	0.891719745
18MOSM24	48.7	8.2	44	11	330	340	259	231	44	11	0.891891892
18MOSM24	18.5	6.2	14.9	1.6	-660	600	151.7	137.2	14.9	1.6	0.904416612
18MOSM24	86.3	6.9	84.4	4.2	60	170	702	661	84.4	4.2	0.941595442
18MOSM24	1732	19	1104	23	2609	30	3620	3410	1104	23	0.94198895

18MOSM24	27.8	4.2	21.6	1.1	280	290	507	481	21.6	1.1	0.948717949
18MOSM24	46	16	28.9	5.3	140	470	242	236	28.9	5.3	0.975206612
18MOSM24	217	57	194	22	-150	570	19.6	19.2	194	22	0.979591837
18MOSM24	28.7	2.6	26.2	1.1	190	180	824	820	26.2	1.1	0.995145631
18MOSM24	81	19	38.8	4.6	870	360	662	678	38.8	4.6	1.024169184
18MOSM24	532	24	491	17	688	94	227	235.7	491	17	1.038325991
18MOSM24	1047	28	1055	28	1010	100	101.8	111.2	1055	28	1.092337917
18MOSM24	2778	23	2658	46	2853	36	157.9	188.7	2853	36	1.195060165
18MOSM24	14.3	1.8	13.73	0.54	-10	230	1283	1619	13.73	0.54	1.261886204
18MOSM24	35.9	3.6	33.3	1	80	160	1527	1950	33.3	1	1.277013752
18MOSM24	1456	39	1278	58	1741	40	809	1100	1741	40	1.359703337
18MOSM24	1669	27	1673	41	1663	59	111.4	159.3	1663	59	1.429982047
18MOSM24	194	16	147.3	6.4	660	180	210	303	147.3	6.4	1.442857143
18MOSM24	943	26	913	31	1078	88	217	352	913	31	1.622119816
18MOSM24	1911	44	1446	62	2812	38	1810	3420	2812	38	1.889502762
18MOSM24	1353	26	1270	25	1463	68	119.7	325.8	1463	68	2.721804511
18MOSM24	355	21	365.8	9.8	200	150	166.1	555	365.8	9.8	3.341360626

Zircon ages and Th/U values for sample 18MSSM32

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18MSSM32	1865	13	1857	24	1862	24	939	12.9	1862	24	0.013738019
18MSSM32	965	69	199	18	3770	210	50.6	3.79	199	18	0.074901186
18MSSM32	2248	16	1699	29	2616	17	2323	218.3	2616	17	0.09397331
18MSSM32	1596	17	1126	30	2296	35	1333	145	1126	30	0.108777194
18MSSM32	813	33	436	28	1952	28	7370	1760	436	28	0.23880597
18MSSM32	74.4	3	75.3	1.4	50	85	2730	704	75.3	1.4	0.257875458
18MSSM32	317	13	269.5	5.6	370	100	614	170	269.5	5.6	0.276872964
18MSSM32	1742	13	1695	27	1798	28	1054	297	1798	28	0.281783681

18MSSM32	933	34	861	21	1080	100	184	53.3	861	21	0.289673913
18MSSM32	1029	28	1031	20	994	90	169.6	50.3	1031	20	0.296580189
18MSSM32	127	11	99.3	4	520	170	792	235	99.3	4	0.296717172
18MSSM32	1622	18	1529	29	1737	39	330	100.7	1737	39	0.305151515
18MSSM32	984	33	977	22	960	120	93	29.4	977	22	0.316129032
18MSSM32	1605	25	1580	48	1661	46	862	278.7	1661	46	0.323317865
18MSSM32	1405	16	1372	25	1440	38	441	144	1440	38	0.326530612
18MSSM32	273	22	277	12	140	170	268	88.3	277	12	0.329477612
18MSSM32	2032	61	1288	41	2934	99	26.34	8.69	2934	99	0.329916477
18MSSM32	2462	39	1585	67	3154	25	1720	575	3154	25	0.334302326
18MSSM32	1302	26	1154	27	1541	58	283	96.7	1154	27	0.341696113
18MSSM32	29.1	1.4	25.61	0.53	280	100	7190	2470	25.61	0.53	0.343532684
18MSSM32	113	15	109.7	5.1	10	260	191.8	70.1	109.7	5.1	0.36548488
18MSSM32	1704	18	1738	29	1673	36	382	149.6	1673	36	0.391623037
18MSSM32	1436	20	1431	23	1439	52	313	123.5	1439	52	0.39456869
18MSSM32	956	22	924	21	1019	88	255	101.2	924	21	0.396862745
18MSSM32	72.7	5.4	68.7	1.7	130	150	911	364	68.7	1.7	0.399560922
18MSSM32	125.2	7.2	116.9	2.5	240	120	1274	529	116.9	2.5	0.41522763
18MSSM32	622	19	567	12	790	82	712	301	567	12	0.422752809
18MSSM32	65.5	3.9	64.8	1.5	70	130	1521	677	64.8	1.5	0.445101907
18MSSM32	2698	17	2687	37	2703	28	613	308	2703	28	0.502446982
18MSSM32	33.6	5.5	22.3	1.2	540	340	549	276	22.3	1.2	0.50273224
18MSSM32	1031	23	1019	20	1045	74	211	108	1019	20	0.511848341
18MSSM32	1132	21	1091	25	1194	46	461	237.3	1091	25	0.514750542
18MSSM32	446	17	434.8	8.8	456	92	432	222.9	434.8	8.8	0.515972222
18MSSM32	2296	45	1805	65	2773	31	415	216	2773	31	0.520481928
18MSSM32	1679	19	1634	27	1723	37	311	163.8	1723	37	0.526688103
18MSSM32	1271	32	1280	25	1233	94	80.6	43.9	1233	94	0.544665012
18MSSM32	121	18	76.7	4.7	670	350	151.5	83.3	76.7	4.7	0.549834983
18MSSM32	241	66	45.8	9.1	2210	530	199	109.8	45.8	9.1	0.551758794
18MSSM32	2550	21	2335	49	2722	33	175	97.1	2722	33	0.554857143
18MSSM32	307.9	8.6	293.8	5.2	374	81	1085	607	293.8	5.2	0.559447005
18MSSM32	2471	45	2150	74	2756	33	195	110.4	2756	33	0.566153846

18MSSM32	2603	15	2555	34	2634	21	661	375	2634	21	0.567322239
18MSSM32	12	10	10.5	1.9	-7100	6900	109.8	62.3	10.5	1.9	0.567395264
18MSSM32	1613	23	1572	29	1672	52	212	121.8	1672	52	0.574528302
18MSSM32	35.2	6.3	28.5	1.8	80	370	398	229.3	28.5	1.8	0.576130653
18MSSM32	99.8	7.6	89.9	2.6	270	150	874	511	89.9	2.6	0.584668192
18MSSM32	1864	22	1851	31	1871	43	146.1	86.5	1871	43	0.592060233
18MSSM32	1051	14	1052	16	1032	42	581	347	1052	16	0.597246127
18MSSM32	99.2	9.1	91.5	3.3	230	200	365	219	91.5	3.3	0.6
18MSSM32	33.8	5.3	31.4	1.4	10	280	639	385	31.4	1.4	0.602503912
18MSSM32	635	15	634	14	625	69	871	533	634	14	0.611940299
18MSSM32	1705	32	1721	47	1688	55	373	229	1688	55	0.613941019
18MSSM32	23.2	5	8.56	0.83	750	590	401.5	249.7	8.56	0.83	0.621917808
18MSSM32	1530	30	1421	32	1658	71	153	97	1658	71	0.633986928
18MSSM32	438	20	399.6	9.3	570	110	221	147.3	399.6	9.3	0.666515837
18MSSM32	73	7.5	70.9	2.5	30	210	577	401	70.9	2.5	0.694974003
18MSSM32	583	14	575	13	600	62	881	627	575	13	0.71169126
18MSSM32	1150	39	1023	23	1410	110	272	193.8	1023	23	0.7125
18MSSM32	75	14	76.4	4.3	-170	310	203	144.9	76.4	4.3	0.713793103
18MSSM32	1086	24	1056	20	1120	91	164.5	119.3	1056	20	0.725227964
18MSSM32	97	17	70.9	4.4	540	370	274	199.2	70.9	4.4	0.727007299
18MSSM32	68	11	63.9	3.5	-10	310	178.5	131.7	63.9	3.5	0.737815126
18MSSM32	1737	17	1646	24	1845	41	457	345	1845	41	0.754923414
18MSSM32	967	42	960	32	910	150	58.1	44.1	960	32	0.759036145
18MSSM32	422	14	415.2	8.5	427	97	397	305	415.2	8.5	0.768261965
18MSSM32	82	16	72.6	5.4	20	370	109.3	84.8	72.6	5.4	0.775846295
18MSSM32	155	15	161.6	4.4	0	180	304.1	236	161.6	4.4	0.776060506
18MSSM32	2541	18	2346	41	2698	27	268.3	210.5	2698	27	0.784569512
18MSSM32	92.1	6.6	96	2.6	10	140	693	547	96	2.6	0.789321789
18MSSM32	1585	27	1497	38	1695	66	163	128.8	1695	66	0.790184049
18MSSM32	1644	28	1661	29	1606	62	135.1	109.2	1606	62	0.808290155
18MSSM32	1141	19	1109	23	1209	57	186.7	151.2	1109	23	0.809855383
18MSSM32	454	15	432	10	561	85	719	589	432	10	0.819193324
18MSSM32	989	23	1002	17	948	69	224.4	184.8	1002	17	0.823529412

18MSSM32	82.5	8	70.1	2.7	330	200	389	323	70.1	2.7	0.83033419
18MSSM32	415	28	59	2.9	3846	89	954	795	59	2.9	0.833333333
18MSSM32	1317	20	1306	20	1318	47	247.8	207	1318	47	0.83535109
18MSSM32	1541	72	960	74	2530	33	1630	1382	960	74	0.847852761
18MSSM32	1737	25	1729	34	1738	56	122.6	104	1738	56	0.848287113
18MSSM32	404	21	405.4	8.3	350	130	246	210	405.4	8.3	0.853658537
18MSSM32	97	16	75.9	3.5	330	320	261	223	75.9	3.5	0.85440613
18MSSM32	1245	34	1200	30	1337	89	92.6	82.2	1337	89	0.887688985
18MSSM32	77	6	62.9	1.8	460	150	3440	3060	62.9	1.8	0.889534884
18MSSM32	25	3.4	23.3	0.93	0	230	914	814	23.3	0.93	0.89059081
18MSSM32	27.2	3.6	25.7	1.1	20	250	864	777	25.7	1.1	0.899305556
18MSSM32	1156	36	1071	22	1290	110	98	89	1071	22	0.908163265
18MSSM32	1698	18	1670	23	1723	34	271	250.7	1723	34	0.925092251
18MSSM32	38.9	6.7	41.3	2.1	-240	270	720	688	41.3	2.1	0.955555556
18MSSM32	1555	24	1495	24	1622	52	241.3	232.1	1622	52	0.961873187
18MSSM32	2728	16	2749	40	2708	26	253.7	248.8	2708	26	0.980685849
18MSSM32	2660	23	2695	40	2629	36	97.2	99.9	2629	36	1.027777778
18MSSM32	1392	37	1390	38	1401	89	64.8	67	1401	89	1.033950617
18MSSM32	35.5	5.4	29.2	1.6	200	300	527	545	29.2	1.6	1.034155598
18MSSM32	159	33	39.1	3.2	1790	460	211	229	39.1	3.2	1.085308057
18MSSM32	246	18	227.4	6.4	370	160	291	319	227.4	6.4	1.096219931
18MSSM32	61	13	47.6	2.9	110	360	280	312	47.6	2.9	1.114285714
18MSSM32	139	34	32.2	3.2	1550	410	641	727	32.2	3.2	1.134165367
18MSSM32	36.8	5.9	27.6	1.2	360	320	516	589	27.6	1.2	1.141472868
18MSSM32	1617	28	1651	31	1543	76	100.4	115.5	1543	76	1.150398406
18MSSM32	2633	19	2520	38	2715	28	210.6	243.4	2715	28	1.155745489
18MSSM32	2199	41	2112	50	2268	45	227	265	2268	45	1.167400881
18MSSM32	2767	20	2739	39	2777	31	208.4	249	2777	31	1.194817658
18MSSM32	1171	28	915	27	1694	68	208	261.4	915	27	1.256730769
18MSSM32	43.3	4.1	44.7	1.6	-60	190	1008	1274	44.7	1.6	1.263888889
18MSSM32	2809	21	2768	43	2830	38	82.1	104.4	2830	38	1.271619976
18MSSM32	39.2	6.9	26.4	1.6	610	400	598	778	26.4	1.6	1.301003344
18MSSM32	1633	40	1605	48	1686	54	180	253	1686	54	1.405555556

18MSSM32	1661	23	1634	24	1670	59	149	233	1670	59	1.563758389
18MSSM32	2636	25	1816	36	3339	42	79.5	156.3	3339	42	1.966037736
18MSSM32	74	30	36.8	6.6	90	840	73.4	167	36.8	6.6	2.27520436
18MSSM32	590	35	59.6	5.2	4880	320	68.4	326.2	59.6	5.2	4.769005848

Zircon ages and Th/U values for sample 18RRSM33

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18RRSM33	757	29	604	22	1270	110	1003	14.8	604	22	0.014755733
18RRSM33	818	11	807	12	845	37	1777	58.1	807	12	0.032695554
18RRSM33	1007	16	954	17	1115	42	896	72	954	17	0.080357143
18RRSM33	952	12	934	12	981	39	1410	127	934	12	0.090070922
18RRSM33	1054	14	1041	17	1068	39	1000	98.7	1041	17	0.0987
18RRSM33	501	24	487	11	550	150	456.4	50.6	487	11	0.11086766
18RRSM33	1876	20	1755	40	2024	26	1052	117	2024	26	0.11121673
18RRSM33	460	11	399.5	8.1	755	81	1028	139.6	399.5	8.1	0.135797665
18RRSM33	811	29	776	39	952	57	693	100.3	776	39	0.144733045
18RRSM33	1724	17	1769	34	1689	22	2130	315	1689	22	0.147887324
18RRSM33	1038	25	1024	27	1062	51	399.3	67.8	1024	27	0.169797145
18RRSM33	372	16	374.2	7.9	340	110	418	71.3	374.2	7.9	0.170574163
18RRSM33	1057	27	1057	24	1052	87	195	33.7	1057	24	0.172820513
18RRSM33	1800	13	1816	25	1785	26	736	147	1785	26	0.199728261
18RRSM33	1022	16	1038	16	982	50	617	129.3	1038	16	0.209562399
18RRSM33	1109	23	1091	22	1154	51	746	168	1091	22	0.225201072
18RRSM33	1647	24	1534	41	1801	30	920	210	1801	30	0.22826087
18RRSM33	902	18	881	23	974	42	870	208	881	23	0.23908046
18RRSM33	1013	24	974	28	1101	32	1830	439	974	28	0.23989071
18RRSM33	1675	16	1644	25	1704	35	741	188.6	1704	35	0.254520918
18RRSM33	842	33	752	48	1160	77	1150	301	752	48	0.26173913

18RRSM33	957	37	773	31	1414	66	262	72.1	773	31	0.27519084
18RRSM33	1080	19	1085	16	1049	55	404.3	111.9	1085	16	0.276774672
18RRSM33	827	51	788	43	880	120	251	73	788	43	0.290836653
18RRSM33	1240	20	1271	23	1180	56	339	103	1180	56	0.303834808
18RRSM33	68	13	71.1	3.7	-180	340	150.8	46.1	71.1	3.7	0.305702918
18RRSM33	2263	22	1539	28	3004	25	272.2	89.9	3004	25	0.330271859
18RRSM33	1092	13	1096	16	1078	35	877	295.7	1096	16	0.337172178
18RRSM33	1360	33	1409	35	1273	79	120	40.9	1273	79	0.340833333
18RRSM33	1586	21	1407	50	1848	47	1290	447	1848	47	0.346511628
18RRSM33	1118	15	841	15	1701	37	1961	681	841	15	0.3472718
18RRSM33	217.1	6.2	222.4	4	145	80	1241	443	222.4	4	0.356970185
18RRSM33	1001	18	974	18	1059	35	1795	649	974	18	0.361559889
18RRSM33	1689	17	1735	30	1650	27	1034	386	1650	27	0.373307544
18RRSM33	1206	29	1174	29	1257	79	130.1	48.9	1174	29	0.375864719
18RRSM33	266.6	9.4	267.8	4.5	229	90	951	365	267.8	4.5	0.383806519
18RRSM33	1329	21	1305	24	1360	51	316	122	1360	51	0.386075949
18RRSM33	93	15	67.2	4.1	450	310	175.2	68.7	67.2	4.1	0.392123288
18RRSM33	223	37	103.2	4.2	1110	320	379	149.7	103.2	4.2	0.394986807
18RRSM33	1003	33	999	22	970	120	96.8	38.5	999	22	0.397727273
18RRSM33	2376	48	2083	84	2633	58	139	55.6	2633	58	0.4
18RRSM33	400.5	9	295	10	1076	68	1826	747	295	10	0.409090909
18RRSM33	1699	17	1694	25	1702	36	415	178.8	1702	36	0.430843373
18RRSM33	1391	18	1194	29	1717	34	2204	963	1194	29	0.436932849
18RRSM33	1002	38	1005	28	960	120	85.7	37.8	1005	28	0.441073512
18RRSM33	1038	35	1018	27	1040	120	107.7	48.5	1018	27	0.450324977
18RRSM33	952	17	938	16	976	58	478	223.7	938	16	0.467991632
18RRSM33	1120	28	1081	35	1165	66	339	158.7	1081	35	0.468141593
18RRSM33	1030	16	877	17	1362	49	487.2	229.7	877	17	0.471469622
18RRSM33	1708	21	1604	23	1823	48	384	191.3	1823	48	0.498177083
18RRSM33	1626	20	1597	22	1653	44	316.4	158.9	1653	44	0.502212389
18RRSM33	981	23	936	22	1077	75	297	151.1	936	22	0.508754209
18RRSM33	1006	18	1019	18	955	67	244.3	125.1	1019	18	0.512075317
18RRSM33	1080	31	1133	28	970	93	263	135	1133	28	0.513307985

18RRSM33	1312	15	1271	22	1376	31	785	405.6	1376	31	0.516687898
18RRSM33	1554	20	1513	28	1606	46	507	268	1606	46	0.528599606
18RRSM33	916	18	818	22	1169	44	1724	920	818	22	0.533642691
18RRSM33	1382	20	1357	23	1423	44	368	201.4	1423	44	0.547282609
18RRSM33	1491	14	1463	23	1524	32	748	416	1524	32	0.556149733
18RRSM33	574	14	548	11	670	66	650	362	548	11	0.556923077
18RRSM33	412	11	404.9	8.5	445	76	864	487	404.9	8.5	0.563657407
18RRSM33	1097	18	1094	18	1088	51	435	246	1094	18	0.565517241
18RRSM33	929	21	931	15	914	69	312.7	179.4	931	15	0.573712824
18RRSM33	1587	20	1569	25	1600	44	345	205.9	1600	44	0.596811594
18RRSM33	983	14	970	16	1011	46	805	490	970	16	0.608695652
18RRSM33	101	10	102.4	3.8	20	210	369.8	229.7	102.4	3.8	0.621146566
18RRSM33	534	17	530	12	525	98	314	197	530	12	0.627388535
18RRSM33	468	14	395.2	8.1	855	75	641	403	395.2	8.1	0.628705148
18RRSM33	444	26	319.5	7.7	1050	140	465	294.7	319.5	7.7	0.633763441
18RRSM33	1667	20	1664	22	1668	45	281.4	183	1668	45	0.650319829
18RRSM33	448	25	414	11	570	150	195.2	127.7	414	11	0.65420082
18RRSM33	1111	35	959	20	1387	98	303.6	200.7	959	20	0.661067194
18RRSM33	779	28	785	21	710	110	128	87.5	785	21	0.68359375
18RRSM33	1037	17	1015	17	1063	52	683	479	1015	17	0.701317716
18RRSM33	1105	22	1100	21	1099	65	239.4	171.1	1100	21	0.714703425
18RRSM33	1677	17	1636	25	1723	36	305	221.9	1723	36	0.727540984
18RRSM33	1294	18	1251	22	1368	46	419	306	1368	46	0.730310263
18RRSM33	896	27	906	21	825	98	149.1	110.5	906	21	0.741113347
18RRSM33	946	21	911	15	1002	71	324.8	244.2	911	15	0.751847291
18RRSM33	1371	16	1376	19	1354	40	401.3	304	1354	40	0.757538001
18RRSM33	985	15	743	28	1590	53	2100	1630	743	28	0.776190476
18RRSM33	626	44	382	17	1630	180	254	198	382	17	0.779527559
18RRSM33	431	26	397	9.6	520	150	247.7	194	397	9.6	0.783205491
18RRSM33	1713	21	1421	30	2093	32	988	777	2093	32	0.786437247
18RRSM33	993	54	1003	38	900	180	23.5	18.57	1003	38	0.790212766
18RRSM33	452	11	444.1	8.7	465	72	1056	835	444.1	8.7	0.790719697
18RRSM33	1473	28	1167	27	1932	89	453	368	1167	27	0.812362031

18RRSM33	1348	22	1273	24	1463	44	486	396	1463	44	0.814814815
18RRSM33	104	10	83.3	6.3	460	220	577	501	83.3	6.3	0.868284229
18RRSM33	454	13	411.2	8.3	661	83	706	614	411.2	8.3	0.869688385
18RRSM33	441	26	465	13	320	160	119.7	104.9	465	13	0.876357561
18RRSM33	1299	20	1259	20	1366	53	343	307	1366	53	0.895043732
18RRSM33	1994	17	2021	32	1970	27	417	376	1970	27	0.901678657
18RRSM33	379	12	359.7	8.4	477	77	814	734	359.7	8.4	0.901719902
18RRSM33	1344	49	1187	18	1580	120	230.4	210	1187	18	0.911458333
18RRSM33	1018	19	1024	16	994	62	303	277	1024	16	0.914191419
18RRSM33	1232	36	1127	28	1394	99	100.1	93.1	1127	28	0.93006993
18RRSM33	1964	26	1905	36	2027	49	112.9	105.5	2027	49	0.93445527
18RRSM33	885	59	871	35	860	240	29.7	28	871	35	0.942760943
18RRSM33	203	17	212.5	8	100	190	220	208	212.5	8	0.945454545
18RRSM33	1338	19	1305	22	1380	46	508	521	1380	46	1.025590551
18RRSM33	1458	28	1398	31	1541	46	601	618	1541	46	1.02828619
18RRSM33	1339	39	1322	34	1356	96	85.3	88.4	1356	96	1.036342321
18RRSM33	984	42	940	27	1020	150	60.2	63.5	940	27	1.054817276
18RRSM33	538	20	511	14	640	110	244.6	278.9	511	14	1.140228945
18RRSM33	641	16	589	10	826	64	522	614	589	10	1.176245211
18RRSM33	678	19	425	14	1640	86	2110	2530	425	14	1.199052133
18RRSM33	1107	19	1039	23	1248	48	310	374	1039	23	1.206451613
18RRSM33	1112	36	1106	25	1090	110	75.8	94.8	1106	25	1.250659631
18RRSM33	225	13	223.3	5.7	210	130	430	616	223.3	5.7	1.43255814
18RRSM33	1871	23	1623	32	2154	47	398	577	2154	47	1.449748744
18RRSM33	2283	27	2117	36	2426	50	81.5	120.8	2426	50	1.482208589
18RRSM33	443	30	183.6	5.3	2070	160	1353	2020	183.6	5.3	1.492978566
18RRSM33	1346	30	1227	27	1544	73	102.6	174.3	1544	73	1.698830409
18RRSM33	525	19	539	12	420	100	236.6	804	539	12	3.398140321

Zircon ages and Th/U values for sample 18BRSM37

Sample ID	$^{207}Pb/^{235}U$ Age (Ma)	± (Ma)	$^{206}Pb/^{238}U$ Age (Ma)	± (Ma)	$^{207}Pb/^{206}Pb$ Age (Ma)	± (Ma)	U ppm	Th ppm	Best Age (Ma)	± (Ma)	Th/U
18BRSM37	1186	28	429	12	3075	70	163.2	2.27	429	12	0.013909314
18BRSM37	334.6	7.1	278.4	4.9	737	50	4150	95.4	278.4	4.9	0.022987952
18BRSM37	438	16	403	10	599	57	2035	108	403	10	0.053071253
18BRSM37	1774	18	1770	31	1773	39	393	64.5	1773	39	0.164122137
18BRSM37	999	35	822	48	1437	44	3280	559	822	48	0.170426829
18BRSM37	1046.9	9.7	896	13	1370	28	1860	373.6	896	13	0.200860215
18BRSM37	1062	26	963	15	1256	76	358	79	963	15	0.220670391
18BRSM37	585	17	405.6	9.9	1342	49	2359	595	405.6	9.9	0.252225519
18BRSM37	1264	20	1210	18	1341	41	642	164	1341	41	0.255451713
18BRSM37	1082	19	957	15	1338	78	1210	337	957	15	0.278512397
18BRSM37	981	12	957	11	1023	40	813.1	258.4	957	11	0.317796089
18BRSM37	1635	16	1567	25	1715	33	485	155.7	1715	33	0.321030928
18BRSM37	985	14	977	15	993	44	552.3	185.8	977	15	0.336411371
18BRSM37	975	17	958	14	1008	55	532	187.4	958	14	0.352255639
18BRSM37	909	17	825	33	1163	66	1091	391	825	33	0.358386801
18BRSM37	1042	11	1030	11	1069	30	1064	384	1030	11	0.360902256
18BRSM37	1686	19	1702	29	1665	34	522	192	1665	34	0.367816092
18BRSM37	1081	14	1070	17	1104	35	1042	389	1070	17	0.373320537
18BRSM37	1637	40	1670	63	1612	35	1250	475	1612	35	0.38
18BRSM37	379.9	7.5	211.9	7.1	1604	48	4450	1708	211.9	7.1	0.383820225
18BRSM37	407	12	349	10	735	67	1900	731	349	10	0.384736842
18BRSM37	914	21	897	14	942	69	230	90.4	897	14	0.393043478
18BRSM37	565	21	558	14	550	100	340	134.7	558	14	0.396176471
18BRSM37	985	32	965	22	980	110	111.3	44.21	965	22	0.397214735
18BRSM37	1388	13	1355	22	1432	37	939	382.7	1432	37	0.407561235
18BRSM37	1061	22	1070	17	1023	80	194.4	83.1	1070	17	0.427469136
18BRSM37	1199	24	1155	19	1266	67	160.8	68.9	1155	19	0.428482587
18BRSM37	2412	37	1858	44	2919	64	49.3	21.4	2919	64	0.434077079
18BRSM37	995	18	978	13	1017	68	313	137.6	978	13	0.439616613
18BRSM37	123	10	96.2	2.9	510	180	757	336.2	96.2	2.9	0.444121532
18BRSM37	596	32	602	15	500	150	102.3	45.5	602	15	0.444770283

18BRSM37	1463	19	1042	29	2146	35	1011	454	1042	29	0.449060336
18BRSM37	989	22	915	12	1128	62	620.6	278.9	915	12	0.449403803
18BRSM37	1457	15	1443	20	1469	38	441	202	1469	38	0.458049887
18BRSM37	1027	20	995	17	1083	60	303	139	995	17	0.458745875
18BRSM37	866	21	813	18	986	63	592	272	813	18	0.459459459
18BRSM37	1673	21	1571	27	1798	33	521	243	1798	33	0.466410749
18BRSM37	1170	14	1079	17	1332	35	916	427.3	1079	17	0.466484716
18BRSM37	1049	10	1023	12	1091	33	1028	499	1023	12	0.48540856
18BRSM37	370	17	357.2	8.5	410	120	317	156.6	357.2	8.5	0.494006309
18BRSM37	1327	15	1295	20	1370	35	1136	562	1370	35	0.49471831
18BRSM37	1409	18	1380	23	1435	55	218.1	108.2	1435	55	0.496102705
18BRSM37	1313	20	1295	18	1331	57	304.6	151.6	1331	57	0.497701904
18BRSM37	600	13	589	10	625	57	902	460	589	10	0.509977827
18BRSM37	605	20	564	19	760	110	288	148.5	564	19	0.515625
18BRSM37	993	24	957	15	1040	77	169.8	89.3	957	15	0.525912839
18BRSM37	1004	12	1007	15	997	38	1013	536	1007	15	0.529121422
18BRSM37	497	24	493	13	460	140	191.5	101.4	493	13	0.529503916
18BRSM37	480	16	451.3	8.5	574	95	412.3	219	451.3	8.5	0.531166626
18BRSM37	478.8	9.7	323.9	5.1	1300	59	1407	749	323.9	5.1	0.532338308
18BRSM37	1388	16	1359	24	1418	38	762	407	1418	38	0.534120735
18BRSM37	1035	20	1022	19	1044	69	203.5	110.4	1022	19	0.542506143
18BRSM37	74.9	5.8	69.9	1.7	0	160	902	490	69.9	1.7	0.543237251
18BRSM37	1170	120	511	30	2440	290	288	157.9	511	30	0.548263889
18BRSM37	639	12	505.5	7	1133	46	1638	902	505.5	7	0.550671551
18BRSM37	1193	10	990	19	1577	35	1440	804	990	19	0.558333333
18BRSM37	1027	14	953	14	1175	38	692	389	953	14	0.562138728
18BRSM37	962	15	940	14	996	45	688	407	940	14	0.591569767
18BRSM37	2775	18	2686	37	2836	30	198	119	2836	30	0.601010101
18BRSM37	494	13	448.2	8.3	697	79	763	460	448.2	8.3	0.602883355
18BRSM37	1814	27	1883	34	1739	59	165	100	1739	59	0.606060606
18BRSM37	111.9	8.9	87.2	3	650	190	934	567	87.2	3	0.607066381
18BRSM37	553	21	574	12	420	100	256	162.9	574	12	0.636328125
18BRSM37	575	16	538.9	8	704	81	465	298	538.9	8	0.640860215

18BRSM37	1810	150	1420	150	2476	69	800	519	2476	69	0.64875
18BRSM37	235	17	146.4	3	1070	160	843	548	146.4	3	0.650059312
18BRSM37	1482	74	290	20	4316	69	205	134	290	20	0.653658537
18BRSM37	1150	16	999	17	1429	49	784	515	999	17	0.656887755
18BRSM37	1384	24	1224	35	1651	32	695	471	1651	32	0.677697842
18BRSM37	540	17	538	8.8	511	92	553	388	538	8.8	0.701627486
18BRSM37	1458	31	1463	32	1417	83	86.1	60.6	1417	83	0.703832753
18BRSM37	1142	21	1122	18	1171	63	234.9	169.1	1122	18	0.7198808
18BRSM37	1285	17	1289	18	1272	48	356.4	261.4	1272	48	0.733445567
18BRSM37	273	11	276	4.3	224	98	860	634	276	4.3	0.737209302
18BRSM37	1533	19	1479	20	1606	45	229.3	175.5	1606	45	0.765372874
18BRSM37	96.2	4	71.2	1.2	449	93	3160	2440	71.2	1.2	0.772151899
18BRSM37	77.1	7.5	70.7	2.5	220	220	608	469.9	70.7	2.5	0.772861842
18BRSM37	408	25	411	12	380	150	175	135.4	411	12	0.773714286
18BRSM37	1284	19	1261	20	1316	49	292.2	228.3	1316	49	0.781314168
18BRSM37	1253	21	1123	33	1475	44	421	329	1123	33	0.781472684
18BRSM37	1331	13	1344	16	1312	31	1031	815	1312	31	0.790494665
18BRSM37	36.5	2.5	32.69	0.83	230	140	2680	2120	32.69	0.83	0.791044776
18BRSM37	214	17	225.9	6.9	50	170	304.8	244	225.9	6.9	0.800524934
18BRSM37	1435	19	1412	21	1453	50	300	240.4	1453	50	0.801333333
18BRSM37	1380	110	1034	33	1840	190	391	326	1034	33	0.833759591
18BRSM37	74	6.7	68.5	1.9	170	190	627	532	68.5	1.9	0.848484848
18BRSM37	563	13	480	11	897	61	806	690	480	11	0.856079404
18BRSM37	47.6	5.4	33.1	1.4	600	250	813	706	33.1	1.4	0.868388684
18BRSM37	611	36	301	10	1910	200	1383	1210	301	10	0.874909617
18BRSM37	396	13	410.2	7.5	292	90	663	583	410.2	7.5	0.87933635
18BRSM37	193	29	75.4	3.6	1610	240	603	538	75.4	3.6	0.892205638
18BRSM37	1243	13	1238	19	1239	38	938	842	1239	38	0.897654584
18BRSM37	201.5	8.9	191.9	3.9	280	100	898	825	191.9	3.9	0.918708241
18BRSM37	226	11	209.9	4.6	330	110	534	492	209.9	4.6	0.921348315
18BRSM37	2400	64	2120	110	2698	37	109	102	2698	37	0.935779817
18BRSM37	2072	22	2088	32	2054	41	128.9	130	2054	41	1.008533747
18BRSM37	1532	20	1472	23	1648	38	372	381	1648	38	1.024193548

18BRSM37	1037	33	1034	22	1010	110	74.9	78	1034	22	1.041388518
18BRSM37	486	18	497	11	390	100	356.9	376.6	497	11	1.055197534
18BRSM37	1040	22	1038	19	1029	62	175.7	198.9	1038	19	1.132043256
18BRSM37	1079	53	1083	46	990	180	40.7	46.3	1083	46	1.137592138
18BRSM37	1148	50	1103	29	1170	150	53.6	62.3	1103	29	1.162313433
18BRSM37	693	26	614	14	910	110	167.4	199.5	614	14	1.191756272
18BRSM37	170	11	165.2	5	200	140	523	628	165.2	5	1.200764818
18BRSM37	312	17	300.7	7.2	340	130	256.7	311.8	300.7	7.2	1.214647448
18BRSM37	1779	23	1756	26	1799	58	147.4	181.4	1799	58	1.230664858
18BRSM37	1141	21	1101	17	1201	63	279	370.1	1101	17	1.326523297
18BRSM37	626	21	597	13	686	99	222.7	322	597	13	1.445891334
18BRSM37	1004	29	992	22	1010	100	127.6	193.8	992	22	1.518808777
18BRSM37	425	13	424.5	7.7	429	82	503	797	424.5	7.7	1.584493042
18BRSM37	447	13	444.5	6.3	426	75	628.8	1185	444.5	6.3	1.884541985
18BRSM37	843	45	830	28	790	160	65.3	126	830	28	1.929555896
18BRSM37	199	21	166.3	6.1	390	230	229	460	166.3	6.1	2.008733624
18BRSM37	1580	15	1556	24	1611	31	342.5	693	1611	31	2.023357664
18BRSM37	942	77	213	12	3520	160	195.8	440	213	12	2.247191011
18BRSM37	917	25	377.7	7.8	2587	95	1045	2740	377.7	7.8	2.622009569
18BRSM37	3360	51	2810	110	3723	85	14.66	59.7	3723	85	4.072305593