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Abstract

U–Pb detrital zircon ages in variably metamorphosed, dominantly fine-grained clastic successions are used in northeastern Australia to identify two major successions along the East Gondwana margin. The older succession is of probable Late Neoproterozoic age and is considered part of a passive margin associated with rifting at c. 600 Ma. Most detrital zircons have ages in the range 1000–1300 Ma and were probably derived from an extension of a Late Mesoproterozoic (1050–1200 Ma) orogenic belt from the central Australian Musgrave Complex located 1500 km to the west. No evidence has been found for 600–800 Ma rifting of a Rodinian supercontinent and therefore it is suggested that breakup must have occurred well outboard of the present Early Palaeozoic East Gondwana margin. The younger succession is of Early Palaeozoic age and contains the distinctive 500–600 Ma detrital zircon signature that is widespread in East Gondwana in addition to some samples with ages in the range 460–510 Ma consistent with local igneous sources. The younger succession is related to the active margin of Gondwana that developed on the former passive margin in a back-arc setting, and the source of 510–600 Ma zircons is considered to be a composite of rift-related and back-arc volcanic sources.

Keywords

Detrital, zircon, ages, Neoproterozoic, Ordovician, siliciclastic, rocks, northeastern, Australia, implications, for, tectonic, history, East, Gondwana, continental, margin, GeoQUEST

Disciplines

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Detrital zircon ages in Neoproterozoic to Ordovician siliciclastic rocks, northeastern Australia: implications for the tectonic history of the East Gondwana continental margin

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Abstract: U–Pb detrital zircon ages in variably metamorphosed, dominantly fine-grained clastic successions are used in northeastern Australia to identify two major successions along the East Gondwana margin. The older succession is of probable Late Neoproterozoic age and is considered part of a passive margin associated with rifting at *c.* 600 Ma. Most detrital zircons have ages in the range 1000–1300 Ma and were probably derived from an extension of a Late Mesoproterozoic (1050–1200 Ma) orogenic belt from the central Australian Musgrave Complex located 1500 km to the west. No evidence has been found for 600–800 Ma rifting of a Rodinian supercontinent and therefore it is suggested that breakup must have occurred well outboard of the present Early Palaeozoic East Gondwana margin. The younger succession is of Early Palaeozoic age and contains the distinctive 500–600 Ma detrital zircon signature that is widespread in East Gondwana in addition to some samples with ages in the range 460–510 Ma consistent with local igneous sources. The younger succession is related to the active margin of Gondwana that developed on the former passive margin in a backarc setting and the source of 510–600 Ma zircons is considered a composite of rift-related and backarc volcanic sources.

Keywords: Eastern Australia, Gondwana, passive margin, zircons.

Development of East Gondwana has resulted from initial continental aggregation in the late Mesoproterozoic, followed by an episode of continental fragmentation and additional collision to produce the Palaeozoic supercontinent and its active Pacific margin (Fig. 1, Fitzsimons 2003; Pisarevsky *et al.* 2003; Boger & Miller 2004). Timing of the episode of continental fragmentation has been problematic with some authors opting for separation at *c.* 600 Ma in eastern Australia (Lindsay *et al.* 1987), after rifting in the Ross Orogen of East Antarctica at *c.* 650 Ma (Goode *et al.* 2002, 2004), and others arguing for a much older breakup at *c.* 800 Ma (Li & Powell 2001). Recently, it has been argued that a passive margin developed at *c.* 600 Ma in eastern Australia closely following a continental rifting event (Crawford *et al.* 2003; Direen & Crawford 2003a, b). Detrital zircon age spectra in Neoproterozoic to Early Palaeozoic sedimentary units from the East Gondwana continental margin appear to support the younger age of continental separation. They indicate a major change in provenance in the Cambrian, with Neoproterozoic to Lower Cambrian units derived from Palaeoproterozoic to Mesoproterozoic cratonic sources whereas uppermost Lower

Cambrian quartzose strata and younger units have abundant detrital zircons with ages in the range 500–600 Ma (Ireland *et al.* 1998; Goodge *et al.* 2002, 2004; Wysoczanski & Allibone 2004).

We report here new detrital U–Pb zircon ages obtained using the sensitive high-resolution ion microprobe (SHRIMP) from Neoproterozoic and Early Palaeozoic metasedimentary and sedimentary rocks in the Tasman Fold Belt System of northeastern Australia. The new age data, in addition to those from Fergusson *et al.* (2001), allow us to constrain the breakup of the supercontinent that predated the formation of Gondwana and the development of East Gondwana's active Pacific margin.

Neoproterozoic – Early Palaeozoic geology of northeastern Australia

In northeastern Australia, the Tasman Line is the boundary between the Palaeoproterozoic–Mesoproterozoic craton in the west and the Palaeozoic Tasman Fold Belt System to the east (Veevers 2000; Figs. 2, 3). The Tasman Line is also exposed in parts of the Delamerian Orogen of southeastern Australia (Fig. 2), but elsewhere its extent is inferred from geophysical databases such as gravity and magnetics. The oldest rock units of the northern Tasman Fold Belt System are Cambrian–Ordovician metamorphic complexes comprised of metasedimentary schist and gneiss, mafic and ultramafic rocks, deformed granite and migmatite (Withnall *et al.* 1995; Hutton *et al.* 1997; Nishiya *et al.* 2003). These units include the Argentine and Cape River Metamorphics of the Charters Towers Province, the Halls Reward Metamorphics and other units of the southeastern Georgetown Inlier, and the Anakie Metamorphic Group of the Anakie Inlier (Fig. 3). These metamorphic complexes are intensely deformed with greenschist to amphibolite metamorphism and most sedimentary structures are transposed parallel to foliation and metamorphic layering. Relationships between metaigneous and metasedimentary units and the depositional environments of the sedimentary protoliths are therefore poorly known.

Deformation and metamorphism affected the Anakie Metamorphic Group and Halls Reward Metamorphics in the Delamerian Orogeny at *c.* 500 Ma and these units are a northeastern extension of the Ross–Delamerian orogenic belt that formed along the palaeo-Pacific margin of Gondwana in the Middle to Late Cambrian (Fig. 1; Withnall *et al.* 1996; Nishiya *et al.* 2003). Within the Charters Towers Province, the Argentine Metamorphics and Cape River Metamorphics are intruded by variably deformed granitoids containing the main foliation in the surrounding metamorphic rocks and have U–Pb zircon ages in the range 455–510 Ma. Part of their deformational history therefore post-dated the Delamerian Orogeny (Hutton *et al.* 1997; Blewett *et al.* 1998).

Metasedimentary rocks in the Argentine Metamorphics (Fig. 3) are mainly schist and banded gneiss with some quartzite and were largely derived from intercalated quartzose to quartzo-feldspathic sandstone and shale. Metasandstone is quartzose, with subordinate plagioclase, microcline, biotite and muscovite. Metasandstone and schist dominate the Cape River Metamorphics (Fig. 3). The former has relict clasts of quartz, plagioclase, alkali feldspar and recrystallised lithic fragments consisting of fine-grained aggregates of quartz, biotite and muscovite (Withnall *et al.* 1997). Many metasandstones had a calcareous component now represented by epidote, amphibole and some relict calcite. They have low SiO₂/Al₂O₃ ratios consistent with sediment immaturity and chemically they indicate derivation from a continental granitic source (Withnall *et al.* 1997). Quartzite is common in the structurally higher part of the Cape River Metamorphics. Preliminary geochronology on detrital zircons from one lithic metasandstone sample has identified Late Mesoproterozoic

ages of 1180–1300 Ma (Hutton *et al.* 1997; Blewett *et al.* 1998). Orthogneiss and foliated granodiorite of the Fat Hen Complex intrude the Cape River Metamorphics and have U–Pb zircon ages in the range of 455–493 Ma (Hutton *et al.* 1997).

The Anakie Metamorphic Complex occurs in central Queensland (Figs. 3, 4) and consists of a number of units including a lower unit of mixed pelitic schist, quartzite, quartz-rich clastics, mafic schist and rare serpentinite (Bathampton Metamorphics) and an upper unit of Wynyard Metamorphics with micaceous metasandstone and muscovite-biotite schist (Withnall *et al.* 1995). Three samples of quartzose metasandstone to metaconglomerate in the Bathampton Metamorphics have most detrital zircon ages in the range 1000–1300 Ma (Fergusson *et al.* 2001). Detrital zircon ages in one sample from the Wynyard Metamorphics have a prominent peak of 510–600 Ma and another sample has detrital monazite grains with ages at 540 and 580 Ma (Fergusson *et al.* 2001).

In the southern Anakie Inlier (Fig. 3), the Upper Ordovician Fork Lagoons beds occur southeast of, and in fault contact with, the Anakie Metamorphic Group. They are a mixed unit with very low-grade metamorphism and consist of slate, quartz sandstone, quartz-lithic sandstone, mafic volcanic rocks, minor gabbro, silicic volcanoclastic rocks, sparse serpentinite, and marble (Withnall *et al.* 1995). Rare limestone with Late Ordovician corals and conodonts occurs in the unit which formed in deep to shallow marine environments. Sandstones include both quartz-rich and quartz intermediate types with subordinate feldspar and lithic fragments. Some samples contain volcanic quartz and silicic volcanoclastics and primary volcanic rocks also occur in the unit (Withnall *et al.* 1995).

Detrital zircon ages

Zircons have been separated from three samples of quartzite and three samples of immature quartz-feldspathic sandstone (one of each from the Argentine Metamorphics, Cape River Metamorphics and Fork Lagoons beds) using standard separation techniques (crushing, magnetic separation and heavy liquids). Zircon analysis followed standard procedures on SHRIMP I and SHRIMP RG at the Australian National University (Williams 1998). Cathodoluminescence (CL) images were taken to examine the internal structure of the sectioned zircon grains, thereby enabling the ion beam to be placed within single domains and so avoid analysing areas of mixed ages.

The analyses consist of four scans through the mass range with a spot size of *c.* 20–30 μm . In some cases, analyses were duplicated as a check for consistency. U–Pb ratios were calibrated relative to the 1099 Ma Duluth Gabbro (sample FC1 of Paces & Miller 1993). Data were reduced using SQUID Excel Macro of Ludwig (2000) with plots constructed with the Isoplot/Ex program (Ludwig 1999). For zircons that are older than *c.* 800 Ma, and for areas in zircon with very high U, the correction for common Pb was made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For younger zircons (*<* *c.* 800 Ma) it is difficult to determine the $^{204}\text{Pb}/^{206}\text{Pb}$ ratio and so the correction for common Pb was made by the “ ^{207}Pb correction” method (see Williams 1998, and references therein). The data (Table 1; see Table 2 in data repository) have been plotted as probability density plots together with stacked histograms (Fig. 5). Where ≥ 3 analyses are within analytical uncertainty, this is recognised as a cluster and considered to represent a significant zircon crystallisation event. An isolated analysis or even two analyses with like ages are considered insufficient evidence to indicate a significant zircon crystallisation event in the source region. This is particularly the case for the younger part of the age spectrum as the youngest cluster of analyses will place constraints on the time of deposition of the sediment.

Results

Sample CR44 of quartzo-feldspathic-biotite metasandstone from the Cape River Metamorphics has had 59 grains analysed. Most of the analyses have ages in the range 1110–1265 Ma (44 grains) with 4 forming a minor peak in the age range 1550–1580 Ma. A quartzite sample (CR190) from the Cape River Metamorphics has had 62 grains analysed. A number of the areas analysed are either significantly enriched in common Pb (e.g. 34 and 55, Table 2) or are clearly discordant (e.g. 40 and 56, Table 2), and these have been excluded. Overall, a remarkably diffuse pattern of ages is recorded, which probably reflects long-lived transport and textural maturity. The most significant peak occurs in the range 1800–1895 Ma (14 grains) with less significant clusters between *c.* 1110–1265 Ma (8 grains) and *c.* 905–920 Ma (4 grains).

Additional data from a sample of biotite-bearing quartzo-feldspathic metasandstone (IWH043) from the upper part of the Cape River Metamorphics, for which a preliminary age spectrum was presented by Blewett *et al.* (1998), support these results. It has 21 of 23 detrital ages in the range 1150–1250 Ma. Detrital ages from the Cape River Metamorphics have much in common with those reported by Fergusson *et al.* (2001) from three closely spaced samples of quartz-rich metasandstone from the lower Anakie Metamorphic Group (Bathampton Metamorphics); 115 of 167 grains from these samples have ages in the range 1000–1300 Ma. Of the 8 younger grains 5 are in the age range 615–665 Ma and 3 in the age range 565–580 Ma.

A sample of quartzose psammite, originally a quartz-lithic sandstone, from the Argentine Metamorphics (AM129A) has had 60 grains analysed and 7 grains (8, 30, 36, 39, 40, 45 and 48, Table 2) are discounted because they are anomalous, poor analyses, or they are discordant. Most analyses provide ages in the range 1000–1305 Ma (30 of 53 grains) with 5 grains between *c.* 1595–1610 Ma, and 4 between *c.* 1755–1770 Ma.

Fifty six grains have been analysed from sample AM57, a quartzite from the Argentine Metamorphics. A number of the areas analysed are enriched in common Pb and yield interpreted discordant young ages (grains 15, 17, 43 and 50, Table 2) that have been excluded. The majority of ages recorded are in the range *c.* 490–670 Ma (26 of 52 grains, Fig. 5), with a prominent peak at *c.* 490–505 Ma (weighted mean of 9 grains gives 501 ± 5 Ma). Less prominent older age clusters are in the range 1000–1100 Ma (7 grains) and 1500–1600 Ma (4 grains). This sample records a similar provenance age spectrum to sample EC04 reported by Fergusson *et al.* (2001) from the upper Anakie Metamorphic Group with a broad age peak at 510–600 Ma.

Samples R4 and R19A are quartz and quartz-lithic sandstones respectively from the Upper Ordovician Fork Lagoons beds and have detrital age patterns that have much in common to those of sample AM57 from the Argentine Metamorphics and sample EC05 from the upper Anakie Metamorphic Group even though they are from a younger sedimentary unit above a major metamorphic discontinuity. The analyses of sample R4 mostly fall within the age range 435–540 Ma, with the youngest clusters at *c.* 460–470 Ma and *c.* 445–455 Ma (32 of 59 grains, Fig. 5). Note that one of the analyses (grain 31 of Table 2) has been excluded on the basis of discordance. The grain population that records ages between 460 Ma and 480 Ma is consistent with derivation from older granites in the Charters Towers Province (Hutton *et al.* 1997; Blewett *et al.* 1998). For sample R19A, 53 grains have been analysed, but 6 (16, 33, 46, 48, 51 and 52, Table 2) have been excluded on the basis of high common Pb or interpreted discordance. The youngest cluster is at *c.* 465 Ma (4 grains). Sample R19A also has a prominent peak in the range 560–600 Ma (8 grains) whereas it is notable that sample R4 has

only one zircon in this range. Sample R4 has 9 grains in the interval 900–1150 Ma whilst sample R19A has 7 grains with ages in this interval.

Stratigraphy and depositional ages

From the detrital zircon ages and U–Pb zircon ages on deformed and undeformed granites in the region (Hutton *et al.* 1997; Blewett *et al.* 1998; unpub. data of the authors) two major sedimentary successions are recognised. The older succession is characterised by abundant Late Mesoproterozoic zircons (Cape River Metamorphics, part of the Argentine Metamorphics and the Bathampton Metamorphics). A cluster of grains with ages in the range 907–920 Ma from sample CR190 in the Cape River Metamorphics suggests a Neoproterozoic age for the succession. A U–Pb zircon 495 Ma age for the oldest granites of the Fat Hen Creek Complex constrains the minimum depositional age (Hutton *et al.* 1997), and the lack of 500–600 Ma detrital zircons is consistent with a Neoproterozoic rather than an Early Palaeozoic age. A cluster of 5 grains in the age range 615–665 Ma from two closely spaced samples (A532 and A537) indicate a Late Neoproterozoic age for the Bathampton Metamorphics of the lower Anakie Metamorphic Group (Fergusson *et al.* 2001) consistent with the lack of a prominent 500–600 Ma signature in these rocks. Overall, a Late Neoproterozoic age is inferred for the older succession. In the younger succession the 500–600 Ma age cluster is well represented in all samples and was also reported for detrital monazite and zircon samples in the Wynyard Metamorphics of the Anakie Inlier (Fergusson *et al.* 2001). The quartzite sample from the Argentine Metamorphics (AM57) has a Cambrian depositional age as the Argentine Metamorphics are intruded by granites with ages as old as *c.* 480 Ma (unpub. data of authors).

Provenance

The quartzose nature of the clastic rocks indicates continental derivation for all the units sampled with significant reworking required to produce the quartzite in the Argentine Metamorphics and Fork Lagoons beds (samples AM57 and R4 respectively). Detrital zircons from the quartzite of the Cape River Metamorphics (sample CR190) has an age spectrum indicating very mixed sources compared to the other samples, and is consistent with far travelled and/or multiply recycled sediment. For both successions CL images show that the zircons consist of a mixture of igneous grains with well-developed oscillatory zonation (Fig. 6) and grains with no zonation interpreted to be of metamorphic origin. Younger detrital zircons in the range 450–500 Ma from the Upper Ordovician Fork Lagoon beds have fine zonation typical of igneous derivation. They were probably derived from local sources now in the sub-surface but represented by exposed silicic volcanic rocks of the Upper Cambrian to Lower Ordovician Seventy Mile Range Group (Henderson 1986) and granitoids of the Lolworth and Ravenswood Batholiths in the Charters Towers Province (Hutton *et al.* 1997).

Late Mesoproterozoic source

Our data from the Cape River Metamorphics and one sample in the Argentine Metamorphics, in addition to the samples from the Bathampton Metamorphics of the Anakie Inlier (Fergusson *et al.* 2001), indicate that a Late Mesoproterozoic, mixed igneous and metamorphic terrane provided the source of sediment for units of Neoproterozoic age in

northeastern Australia (Fig. 5). Detrital zircon ages for the Neoproterozoic succession only have minor input from sources on the adjoining north Australian craton, such as the Barramundi Orogeny that was widespread in northern Australia at 1840–1870 Ma (Betts *et al.* 2002), and abundant Early Mesoproterozoic (1550–1600 Ma) silicic igneous activity in the Georgetown and Mt Isa Inliers (Scott *et al.* 2000; Black *et al.* 2005).

In central Australia, a Late Neoproterozoic to Early Cambrian clastic wedge occurs in the Amadeus Basin locally derived from the Musgrave Complex to the south consistent with the prominent Late Mesoproterozoic detrital zircon age signature (most grains in the range 1050–1200 Ma, Camacho *et al.* 2002). The Musgrave Complex was uplifted during the short-duration Petermann Orogeny at ~550 Ma indicated by $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages but no zircon of this age has been identified (Maboko *et al.* 1992). Basement zircon ages from the Musgrave Complex are mainly in the range 1050–1200 Ma and include some ages in the range 900–1000 Ma attributed to radiogenic Pb loss (Camacho *et al.* 2002).

An eastern extension of the Musgrave Complex beneath younger cover in central Queensland is the most likely source of the detrital zircons in the metamorphosed sedimentary successions of the Anakie Inlier and Charters Towers Province (Figs. 1, 7). Thick Palaeozoic to Mesozoic sedimentary basins obscures basement geophysical patterns in central and southern Queensland. Magnetic and gravity trends associated with the Palaeoproterozoic to Lower Mesoproterozoic Mount Isa Inlier extend to the south-southeast under cover and are sharply terminated at a northeast-trending interpreted fault (Fig. 2). Timing of faulting is poorly constrained to post Early Mesoproterozoic and pre-Middle Palaeozoic (Murray 1994). The fault has been previously interpreted as representing the East Gondwanan Neoproterozoic rifted margin and part of the Tasman Line (Veevers 2000) although it is implicit in other reconstructions that it is a Late Mesoproterozoic structure (Wingate *et al.* 2002). The older age is supported by data indicating a transition to lower S-wave speeds in the upper mantle in western Queensland, implying that thick ancient (Mesoproterozoic and older) crust extends well to the east of the Tasman Line as presently drawn in southwest Queensland (Fig. 2; Kennett *et al.* 2004). An eastward extension to the Musgrave Complex also accounts for Late Mesoproterozoic zircons that occur in parts of the Neoproterozoic to Cambrian sedimentary succession of the Delamerian Orogen in southeastern Australia in addition to locally derived zircons from the adjoining Gawler Craton (Ireland *et al.* 1998).

Gondwana source

Our results confirm that the 500–600 Ma detrital zircon signature occurs in quartzose sedimentary rocks in even the extremity of the Gondwanan margin as represented in northeastern Australia. These sedimentary materials have been derived from a source with abundant silicic igneous activity of 500–600 Ma in addition to a persistent but smaller 900–1300 Ma detrital signature indicating a Late Mesoproterozoic igneous and metamorphic source in common with the Neoproterozoic succession. The presence of common micaceous detritus, probably formed from lithic fragments, in the younger part of the Anakie Metamorphic Group (Wynyard Metamorphics) and the Fork Lagoon beds indicate textural immaturity. This is also consistent with high U contents of zircons with 22%–55% of analyses in all samples from the younger succession having U contents >400 ppm. This implies that the younger succession is less mature and unlikely to have endured prolonged sedimentary reworking (Hallsworth *et al.* 2000).

The 500–600 Ma detrital zircon signature is widely represented throughout Early Palaeozoic sedimentary successions in East Gondwana (e.g. Ireland *et al.* 1998; Goodge *et al.* 2002). It has been related to two main sources: plutonic and metamorphic rocks in ‘Pan-

African' orogenic belts formed during assembly of Gondwana and the development of the palaeo-Pacific facing, active margin of Gondwana (Veevers 2000, 2004; Goodge *et al.* 2002, 2004). Another potential source in eastern Australia for these 500–600 Ma zircons is a volcanic succession related to rifting and passive margin formation in the western Tasman Fold Belt System (Crawford *et al.* 1997; Fergusson *et al.* 2001; Direen & Crawford 2003b). For example, the Wonominta Block of western New South Wales (Fig. 2) has two main volcanic assemblages: a 5000 m thick Neoproterozoic volcanic and sedimentary succession with abundant mafic rocks (transitional alkaline and rift tholeiites) including more evolved lava units with a SHRIMP U–Pb zircon age of 586 ± 7 Ma, and a low-Nb, calc-alkaline suite ranging from basalt to silicic volcanics with an Early Cambrian age based on macrofossils from associated sedimentary rocks and a SHRIMP U–Pb zircon age of 525 ± 8 Ma (Crawford *et al.* 1997). The older assemblage has been regarded as part of a passive margin also developed in western Victoria and Tasmania (Direen & Crawford 2003a, b) and may also occur beneath younger cover in western Queensland (Fergusson *et al.* 2001). The younger assemblage has also been related to a rift-related setting with an evolved arc setting considered less likely (Crawford *et al.* 1997). A problem with such interpretations is that most of the exposed volcanic rocks in southeastern Australia are basaltic in composition and unlikely to provide abundant detrital zircons. Nevertheless, the existence of protracted volcanism at this time, and the potential for development of significant volumes of silicic igneous rocks due to crustal melting, provides the simplest explanation for the 500–600 Ma detrital zircon signature in northeastern Australia.

Voluminous Ordovician quartz-rich sandstones of the Lachlan Fold Belt of southeastern Australia contain abundant detrital zircons in the age range 500–600 Ma, but also include detrital muscovite with an age of some 500 Ma, consistent with derivation from the Ross-Delamerian orogenic belt to the west and southwest (Turner *et al.* 1996; Ireland *et al.* 1998). Abundant, relatively pristine, angular, well-zoned zircons, many of which are relatively high in U, occur in the Early to Middle Cambrian siliciclastic molasse of the Ross Orogen in the central Transantarctic Mountains and indicate a source of these rocks from a relatively proximal volcanic succession. No exposure of such rocks has been found in the Ross Orogen, suggesting that this volcanic source has been removed by erosion (Goodge *et al.* 2002, 2004).

Discussion

Breakup of a supercontinent to form East Gondwana

Continental fragmentation of the supercontinent Rodinia in the interval 600–800 Ma formed East Gondwana (Australia and the greater part of East Antarctica) and another presently contentious continental fragment (Pisarevsky *et al.* 2003). Some authors have opted for a fit between eastern Australia and western North America (AUSWUS of Burret & Berry 2000) in contrast to the popular reconstruction of the southwest USA with a conjugate margin in East Antarctica (SWEAT, Dalziel 1997). Alternatively, Wingate *et al.* (2002) proposed a connection between eastern Australia and Mexico (AUSMEX) based on palaeomagnetic data (Pisarevsky *et al.* 2003). They also cited the 1180–1300 Ma zircons of the Cape River Metamorphics (Blewett *et al.* 1998) as support and suggested that a Late Mesoproterozoic orogenic belt was continuous from southwest and central Australia into northeastern Australia. This orogenic belt would also be connected to the Grenville Orogen of Mexico and eastern North America in the AUSMEX reconstruction of Rodinia. The data we report here supports the existence of an extension of the Musgrave Complex into northeastern Australia.

The Neoproterozoic successions of the Delamerian Orogen in South Australia provide the only sedimentary succession in southeastern Australia that encompasses the 600–800 Ma continental fragmentation event. Splitting of Rodinia at *c.* 800 Ma has been related to the 827 Ma mafic dykes of the Gairdner Dyke Swarm in the northeastern Gawler Craton and associated Willouran magmatism in the Delamerian Orogen (Wingate *et al.* 1998). The problem with this suggestion, as pointed out by Direen and Crawford (2003a, b), is that no passive margin succession of an appropriate age occurs along the ancient Pacific margin of East Gondwana. In Antarctica, passive margin development has been recognised in the Neoproterozoic after *c.* 670 Ma (Goodge *et al.* 2002, 2004) whereas in eastern Australia passive margin development occurred at *c.* 600 Ma (see below).

Evidence for rifting and deposition associated with a breakup episode for Rodinia in the interval 700 Ma to 800 Ma is missing from northeastern Australia. Detrital zircon populations of an appropriate age reflecting igneous activity associated with continental separation are lacking, and there is no unambiguous sedimentary succession related to either rifting or subsequent passive margin sedimentation. Given the poor constraints on the depositional age of the Cape River Metamorphics, these rocks could be related to such a margin but we consider it more likely that this succession is a temporal equivalent of the Late Neoproterozoic succession in the lower Anakie Metamorphic Group. If a *c.* 800 Ma event occurred, rifting and continental splitting must have been located well to the east of the Anakie Inlier with evidence for it being obscured by younger rock systems

Late Neoproterozoic passive margin

Our data, in addition to interpretation of data in Fergusson *et al.* (2001), indicate development of thick siliciclastic successions with associated mafic igneous activity at *c.* 600 Ma in the Anakie Metamorphic Group and possibly the Cape River Metamorphics and older part of the Argentine Metamorphics. All these metamorphic units contain amphibolites derived from mafic igneous rocks that have trace and rare earth element characteristics of tholeiitic and alkaline basalts consistent with a passive margin setting (Withnall *et al.* 1995; Hutton *et al.* 1997). They are interpreted as part the East Gondwana passive margin that developed following rifting (Fig. 7). The inference, based on surface wave tomography that thick Precambrian crust extends well to the east of the Tasman Line in western Queensland (Kennett *et al.* 2004) is consistent with this hypothesis.

We regard the Neoproterozoic succession of northeastern Australia as part of the rifted margin succession that must have formed prior to and during breakup at *c.* 600 Ma, consistent with evidence for extension-induced subsidence of intracratonic sedimentary basins in central Australia (Lindsay *et al.* 1987). A deep ocean must have existed east and north of the Delamerian Orogen by *c.* 575 Ma as indicated by the development of deep canyons in the Wonoka Formation (Preiss 2000). Volcanic assemblages associated with marine sedimentary rocks in the western part of the Tasman Fold Belt System of New South Wales, Victoria and Tasmania have been interpreted as igneous activity related to latest Neoproterozoic passive margin formation (570–600 Ma; Direen & Crawford 2003a, b). In northeastern Australia, development of the 500–600 Ma detrital zircon signature in the younger succession, implies a silicic volcanic source existed in western and central Queensland and has either been removed by erosion or is buried in the subsurface.

Cambrian to Ordovician active margin

Middle-Late Cambrian deformation in northeastern Australia, the temporal equivalent of the Delamerian Orogeny of southeastern Australia, is indicated by 500 Ma ages for deformation and associated metamorphism in the Anakie Inlier and southeast Georgetown Inlier (Withnall *et al.* 1996; Nishiya *et al.* 2003). Other metamorphic complexes, such as the Argentine Metamorphics, have undergone deformation and metamorphism in the Earliest Ordovician soon after the Delamerian Orogeny. In the Late Cambrian to Early Ordovician, Delamerian deformation was followed by predominantly silicic calc-alkaline volcanism in the Seventy Mile Range Group that has a magmatic and depositional character consistent with a subduction-related backarc basin setting (Henderson 1986; Stolz 1995). Granites with ages as old as 510 Ma are located in the Lolworth and Ravenswood Batholiths of the Charters Towers Province and are consistent with a backarc setting (Hutton *et al.* 1997). Overall, a subduction-related backarc extensional setting occurred from *c.* 510 Ma and associated igneous activity has provided detrital zircon ages in the range 430–510 Ma in the Upper Ordovician Fork Lagoons beds.

The timing of initiation of subduction associated with this backarc development in northeastern Australia is poorly constrained. Detrital zircon and monazite grains in the Middle Cambrian and younger units provide some constraints on the transition between these settings (Fergusson *et al.* 2001; data herein). The 500–600 Ma detrital zircon signature itself shows that an igneous source had been active throughout this time and as discussed above may have been related to silicic igneous activity associated with the passive margin. However, such long-lived (100 Ma) igneous activity along an ancient passive margin has no Mesozoic–Cenozoic analogues; this anomaly may be accounted for by the development of several successive rifting events and it is also probable that subduction was initiated much earlier than 510 Ma. Metamorphism, recorded by detrital monazites with ages of *c.* 540 Ma (overprinting *c.* 580 Ma parts of the same grains) from the Middle Cambrian Wynyard Metamorphics (Fergusson *et al.* 2001), is attributed to convergence implying the initiation of subduction prior to 540 Ma.

It is clear that the Delamerian Orogeny, and the broadly contemporaneous Ross Orogeny in Antarctica, induced uplift, erosion, sedimentary transport and deposition of thick and widespread successions in the East Gondwana margin such as the vast Bengal Fan style Ordovician quartzose turbidite pile of the Lachlan Fold Belt (Turner *et al.* 1996). Early to Late Cambrian (500–530 Ma) juvenile island arc crust, with island arcs, backarc basin sea floor and primitive boninitic volcanic assemblages, developed outboard to the east of the *c.* 600 Ma rifted margin in response to subduction in the palaeo-Pacific Ocean (Aitchison *et al.* 1992; Crawford *et al.* 2003).

In contrast to southeastern Australia, convergence along the Pacific margin of Antarctica is regarded as having initiated by *c.* 580 Ma on the basis of abundant juvenile, igneous, 500–600 Ma zircons although a clastic wedge did not develop until Middle Cambrian deformation and uplift (515 Ma; Goodge *et al.* 2002, 2004). The lack of volcanoclastic detritus in all the sedimentary units along the East Gondwana margin containing the prominent, largely igneous derived, 500–600 Ma zircon signature is puzzling and perhaps an indication of accentuated chemical weathering during the late Neoproterozoic and Early Cambrian. Rifting that formed the thick upper Lower Cambrian Kanmantoo Group in the Delamerian Orogen of South Australia (Flöttmann *et al.* 1998) and the Lower Cambrian volcanic and sedimentary succession in the Wonominta Block of western New South Wales (Crawford *et al.* 1997) are interpreted as induced by rollback associated with a newly formed active margin.

Supercontinents and detrital zircon signatures

The most prominent detrital zircon age signatures of siliciclastic sediments in northeastern Australia are similar to the major periods of supercontinent assembly of Rodinia and Gondwana. Late Mesoproterozoic detrital zircons are dominant in sediment recycled as much as 400 million years after the source rocks formed in mobile belts associated with Rodinian accretion. Uplift of these rocks is related to reactivation of the Late Mesoproterozoic orogenic belt during the pan-African events associated with the assembly of Gondwana (Camacho *et al.* 2002). Significant uplift of the rift shoulder during the 600 Ma rifting event that formed the East Gondwana passive margin is unlikely as the detrital zircons of 1550–1660 Ma age are scarce in the Neoproterozoic succession yet is the dominant age of igneous rocks in the neighbouring Georgetown Inlier (Black *et al.* 2005).

The 500–600 Ma detrital zircon signature is represented in younger samples, some of which show additional significant local input from igneous rocks of 445–510 Ma age. The source of the 500–600 Ma zircons in northeastern Australia is probably composite with a source from silicic volcanic rocks associated with a volcanic passive margin at *c.* 550–600 Ma and followed by a convergent margin volcanic assemblage (*c.* 500–540 Ma) in the western Tasman Fold Belt System. Volcanic source rocks have probably been largely removed by erosion whereas plutonic equivalents must be buried in the subsurface under younger sedimentary basins. The Late Mesoproterozoic detrital zircon source is buried in the same region, as detrital zircons derived from it are abundant in the Neoproterozoic passive margin succession and also occur in the Cambrian to Ordovician succession. Thus the paradoxical situation has developed whereby the Late Mesoproterozoic detrital signature originates from reactivation of the orogenic belt of this age formed during the assembly of Gondwana whereas the 500–600 Ma detrital zircons reflect breakup followed by convergent margin processes in East Gondwana.

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Figures

Fig. 1. Major basement units of East Gondwana (reconstructions after Müller *et al.* 2000; Fitzsimons 2003; Boger & Miller 2004). Eastern (subsurface) extension of the Musgrave Complex is shown into northeastern Australia (see Discussion). Much of East Antarctica is obscured by ice – an inferred extension of the Neoproterozoic to Cambrian Orogen from Denham Glacier into interior of East Antarctica is shown. See Figures 2 and 3 for detail of eastern Australia and northeastern Australia respectively.

Fig. 2. Geophysical and geological features of central and eastern Australia related to the eastern Neoproterozoic to Early Palaeozoic margin of east Gondwana. Tasman Line is exposed in northeastern Australia, east of the Broken Hill Block and in southeastern South Australia and divides Palaeoproterozoic–Mesoproterozoic orogens (Mt Isa, Georgetown, Broken Hill) from dominantly Palaeozoic orogens (Lachlan Fold Belt, New England Fold Belt, Hodgkinson and Broken River Provinces) to the east. Recent work indicates that thick Palaeoproterozoic–Mesoproterozoic crust may extend as far east as TLH (Tasman Line of Hill, Kennett *et al.* 2004). See Fig. 2 for detail of northeastern Australia. Abbreviations: BHB = Broken Hill Block, GZ = Glenelg Zone, MT = Melbourne Trough, WB = Wonominta Block. Delamerian Orogen includes Wonominta Block, Glenelg Zone and western Tasmania. Unpatterned area is all post-Ordovician to Recent cover.

Fig. 3. Northeastern Australia with Tasman Line located in outcrop along the Palmerville Fault and Lynd Mylonite Zone. Locations of detrital zircon samples are shown along with samples A532, A537, A542 and EC04 from Fergusson *et al.* (2001). Unpatterned area is mainly post-Ordovician rocks and sediments.

Fig. 4. Stratigraphic diagram showing successions east of the Tasman Line in northeastern Australia with new samples (Withnall *et al.* 1995, 1996; Hutton *et al.* 1997; Fergusson *et al.* 2001; data herein; unpub. data of authors) and comparison with the Adelaide Fold Belt in southeastern Australia (Preiss 2000) and the Central Transantarctic Mountains of East Antarctica (Goodge *et al.* 2002, 2004). Note that primary rock types are shown for metamorphic units.

Fig. 5. Histograms and probability plots of U–Pb SHRIMP ages of detrital zircons from northeastern Australia. Samples CR44, CR190, AM129A and IWH043B are from the older stratigraphic succession and samples AM57, R4 and R19A are from the younger stratigraphic succession.

Fig. 6. CL images of zircons from two samples from northeastern Australia (numbered ellipses indicate position of SHRIMP analyses). (a) Sample CR44 with Late Mesoproterozoic detrital zircons. (b) Sample AM57 with 500–600 Ma zircons with some older zircons.

Fig. 7. (a) Reconstruction of the Late Neoproterozoic (*c.* 600 Ma) passive margin in northeastern Australia. Late Mesoproterozoic orogen in western and central Queensland is shown by trend lines and is an eastern extension of the Musgrave Complex (Fig. 1). Arrows show inferred movement of sediment with abundant 1000–1300 Ma detrital zircons towards the passive margin. Volcanism is indicated on the passive margin by mafic schist in the Anakie Inlier, amphibolite in the Cape River Metamorphics and the high-Nb suite of mafic volcanics in the Wonominta Block all with passive margin magmatic affinity (Withnall *et al.* 1995, 1997; Crawford *et al.* 1997). (b) Cross section of passive margin (east-west through the Anakie Inlier). Arrow indicates sediment path for Late Neoproterozoic sediments in the Anakie Inlier and Cape River Metamorphics.

Fig. 8. Schematic maps and cross sections of the East Gondwana margin for Neoproterozoic and earliest Palaeozoic time showing the crustal architecture, principal sedimentary systems and sedimentary provenance determined from detrital age spectra reported herein and by Turner *et al.* 1996; Ireland *et al.* 1998; Goodge *et al.* 2004; Wysoczanski & Allibone 2004). Note that Late Cambrian tectonism, although dominated by contractional orogenesis, also included short-lived regional episodes of extension (Squire & Wilson 2005).

Table 1. Summary of detrital zircon ages, Neoproterozoic to Ordovician successions, northeastern Australia

Stratigraphic unit	Sample	Number of grains (analyses in brackets)	Major zircon populations (Ma) (number of grains in brackets)	Youngest age cluster (Ma)	Maximum depositional age	Late Mesoproterozoic grains (1–1.35 Ga) (%)	Gondwana grains (500–600 Ma) (%)
Cape River Metamorphics	CR44	59	1116–1267 (44), 831–904 (4), 1549–1580 (4)	1116–1267 (44)	Late Mesoproterozoic	76	0
Cape River Metamorphics	CR190	62	1799–1893 (14), 1073–1176 (9), 1256–1395 (7), 1691–1763 (5), 1448–1528 (5), 907–920 (4), 983–1036 (3)	907–920 (4)	Neoproterozoic	24	0
Cape River Metamorphics	IWH043	23 (24)	1163–1245 (21)	1163–1198 (6)	Late Mesoproterozoic	91	0
Argentine Metamorphics	AM129	60	1000–1305 (30), 1595–1610 (5), 1755–1770 (4)	999–1012 (3)	Neoproterozoic	50	3
Argentine Metamorphics	AM57	56 (59)	494–594 (21), 1015–1084 (7), 636–669 (4), 1506–1569 (4)	494–495 (3)	Late Cambrian	20	32
Fork Lagoons beds	R4	60 (66)	438–537 (21), 1019–1126 (9), 982–1032 (9)	445–453 (6)	Ordovician	15	15
Fork Lagoons beds	R19A	53	435–506 (12), 542–630 (12), 930–948 (3), 1084–1135 (3), 1808–1877 (3)	457–467 (4)	Ordovician	6	19

Summary of SHRIMP U-Pb zircon results.
Sample CR44

						Total Ratios				Radiogenic Ratios								Age (Ma)				
Grain spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	$\frac{^{206}\text{Pb}}{^{206}\text{Pb}}$	f_{206} %	$\frac{^{238}\text{U}}{^{206}\text{Pb}}$	$\pm$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	$\pm$	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	$\pm$	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\pm$	$\frac{^{206}\text{Pb}}{^{207}\text{Pb}}$	$\pm$	$\square$	$\frac{^{238}\text{U}}{^{206}\text{Pb}}$	$\pm$	$\frac{^{206}\text{Pb}}{^{207}\text{Pb}}$	$\pm$	% Disc
1.1	134	41	0.31	24.0	0.000074	0.12	4.792	0.078	0.0824	0.0014	0.2084	0.0034	2.339	0.083	0.0814	0.0026	0.465	1221	18	1231	62	1
2.1	116	143	1.23	19.3	0.000244	0.41	5.184	0.087	0.0791	0.0018	0.1929	0.0032	2.103	0.060	0.0791	0.0018	0.583	1137	22	1174	46	3
3.1	249	175	0.70	42.2	0.000227	0.38	5.067	0.076	0.0811	0.0009	0.1966	0.0030	2.112	0.061	0.0779	0.0019	0.523	1157	16	1144	49	-1
4.1	95	118	1.24	17.4	0.000268	0.45	4.692	0.082	0.0813	0.0016	0.2128	0.0037	2.351	0.062	0.0801	0.0016	0.660	1244	24	1200	39	-4
5.1	367	255	0.69	66.2	0.000034	0.06	4.761	0.062	0.0803	0.0008	0.2102	0.0028	2.350	0.039	0.0811	0.0008	0.799	1230	16	1223	19	-1
6.1	92	76	0.82	15.3	0.000304	0.51	5.175	0.096	0.0826	0.0016	0.1923	0.0036	2.076	0.105	0.0783	0.0037	0.374	1134	20	1155	93	2
7.1	640	347	0.54	112.3	0.000144	0.24	4.894	0.062	0.0904	0.0054	0.2039	0.0026	2.485	0.157	0.0884	0.0055	0.203	1196	14	1391	118	14
8.1	414	288	0.70	71.4	0.000017	0.03	4.979	0.060	0.0803	0.0007	0.2008	0.0024	2.217	0.032	0.0801	0.0007	0.828	1180	13	1199	16	2
9.1	177	121	0.68	30.8	0.000107	0.18	4.943	0.078	0.0805	0.0010	0.2019	0.0032	2.199	0.055	0.0790	0.0015	0.627	1186	17	1171	39	-1
10.1	219	179	0.82	39.2	-	<0.01	4.798	0.064	0.0811	0.0009	0.2085	0.0028	2.345	0.044	0.0816	0.0011	0.711	1221	15	1235	26	1
11.1	224	112	0.50	38.9	0.000201	0.34	4.939	0.066	0.0821	0.0010	0.2018	0.0027	2.208	0.042	0.0794	0.0011	0.709	1185	16	1181	26	0
12.1	209	206	0.99	26.3	0.000301	0.51	6.825	0.098	0.0768	0.0011	0.1458	0.0021	1.458	0.060	0.0726	0.0028	0.357	877	12	1002	78	12
13.1	364	237	0.65	61.6	0.000043	0.07	5.080	0.063	0.0799	0.0007	0.1967	0.0025	2.149	0.037	0.0792	0.0010	0.722	1158	13	1178	24	2
14.1	95	76	0.80	16.1	0.000111	0.19	5.069	0.087	0.0808	0.0014	0.1969	0.0034	2.150	0.075	0.0792	0.0024	0.495	1159	18	1177	60	2
15.1	189	144	0.76	31.6	0.000049	0.08	5.125	0.074	0.0800	0.0010	0.1950	0.0028	2.133	0.045	0.0793	0.0012	0.678	1148	15	1181	31	3
16.1	336	365	1.09	59.9	-	<0.01	4.820	0.060	0.0798	0.0007	0.2080	0.0026	2.352	0.037	0.0820	0.0008	0.796	1218	16	1246	18	2
17.1	1128	290	0.26	160.6	0.000280	0.47	6.031	0.065	0.0821	0.0004	0.1650	0.0018	1.777	0.029	0.0781	0.0009	0.672	985	10	1149	24	14
18.1	167	81	0.49	29.4	0.000079	0.13	4.875	0.071	0.0804	0.0010	0.2052	0.0030	2.286	0.044	0.0808	0.0010	0.756	1203	17	1216	25	1
19.1	97	81	0.83	14.7	0.000258	0.44	5.638	0.099	0.0761	0.0014	0.1770	0.0031	1.817	0.048	0.0744	0.0015	0.668	1051	20	1053	39	0
20.1	103	24	0.23	14.1	-	<0.01	6.307	0.109	0.0762	0.0015	0.1587	0.0028	1.685	0.048	0.0770	0.0017	0.609	950	15	1121	45	15
21.1	433	205	0.47	71.1	0.000036	0.06	5.226	0.063	0.0788	0.0008	0.1913	0.0023	2.065	0.034	0.0783	0.0009	0.732	1128	12	1154	22	2
23.1	280	248	0.88	45.4	0.000128	0.21	5.303	0.071	0.0794	0.0009	0.1882	0.0025	2.013	0.040	0.0776	0.0012	0.668	1112	14	1136	30	2
24.1	214	173	0.81	38.4	0.000046	0.08	4.778	0.067	0.0782	0.0009	0.2092	0.0029	2.236	0.045	0.0775	0.0011	0.687	1224	16	1135	29	-8
25.1	75	111	1.47	31.9	-	<0.01	2.034	0.055	0.0828	0.0015	0.5056	0.0137	7.375	0.296	0.1058	0.0031	0.676	2638	87	1728	54	-53
26.1	208	211	1.01	38.0	0.000001	<0.01	4.704	0.066	0.0810	0.0009	0.2126	0.0030	2.373	0.060	0.0810	0.0017	0.561	1242	16	1221	41	-2
27.1	183	133	0.73	31.9	0.000161	0.27	4.916	0.078	0.0821	0.0010	0.2029	0.0032	2.233	0.063	0.0799	0.0018	0.567	1191	17	1193	46	0
28.1	1551	1054	0.68	302.6	0.000043	0.07	4.403	0.047	0.0846	0.0003	0.2269	0.0024	2.629	0.031	0.0840	0.0005	0.891	1318	13	1293	11	-2
29.1	316	158	0.50	54.3	0.000059	0.10	5.006	0.063	0.0799	0.0008	0.1996	0.0025	2.175	0.036	0.0790	0.0009	0.753	1173	14	1173	22	0
30.1	391	146	0.37	65.4	0.000444	0.75	5.135	0.064	0.0809	0.0008	0.1935	0.0024	2.019	0.037	0.0757	0.0010	0.683	1141	14	1086	27	-5
31.1	213	158	0.74	25.9	-	<0.01	7.060	0.103	0.0679	0.0011	0.1421	0.0021	1.381	0.043	0.0705	0.0019	0.475	856	12	943	56	9
32.1	133	116	0.87	24.6	0.000090	0.15	4.655	0.081	0.0814	0.0012	0.2145	0.0038	2.369	0.062	0.0801	0.0016	0.667	1253	20	1199	39	-4
33.1	419	341	0.81	72.4	0.000006	0.01	4.973	0.060	0.0797	0.0006	0.2011	0.0024	2.208	0.032	0.0796	0.0006	0.831	1181	13	1188	16	1
34.1	245	163	0.66	56.0	0.000031	0.05	3.759	0.050	0.0938	0.0009	0.2659	0.0036	3.423	0.065	0.0934	0.0012	0.711	1520	18	1495	25	-2
35.1	153	164	1.07	25.7	0.000328	0.55	5.124	0.080	0.0808	0.0012	0.1951	0.0031	2.172	0.047	0.0807	0.0012	0.722	1149	20	1215	29	5
36.1	328	112	0.34	92.6	0.000064	0.10	3.042	0.037	0.1127	0.0008	0.3284	0.0040	5.065	0.078	0.1119	0.0010	0.800	1831	20	1830	17	0
37.1	108	69	0.64	18.9	0.000636	1.09	4.897	0.085	0.0795	0.0015	0.2027	0.0035	2.050	0.058	0.0733	0.0017	0.606	1190	21	1023	46	-16
38.1	487	134	0.28	89.4	0.000376	0.63	4.678	0.055	0.0854	0.0006	0.2124	0.0025	2.345	0.048	0.0800	0.0014	0.574	1242	13	1198	33	-4
39.1	293	258	0.88	46.2	0.000081	0.13	5.434	0.079	0.0825	0.0011	0.1838	0.0027	2.062	0.048	0.0814	0.0015	0.628	1088	15	1230	35	12
40.1	77	70	0.91	13.2	-	<0.01	5.013	0.092	0.0800	0.0015	0.1995	0.0037	2.208	0.059	0.0802	0.0015	0.692	1173	20	1203	38	3
41.1	314	153	0.49	53.1	-	<0.01	5.083	0.065	0.0793	0.0008	0.1971	0.0025	2.195	0.041	0.0808	0.0011	0.686	1160	14	1216	27	5
42.1	120	157	1.31	20.9	-	<0.01	4.915	0.078	0.0813	0.0012	0.2036	0.0032	2.301	0.052	0.0820	0.0013	0.709	1195	17	1245	31	4
43.1	223	120	0.54	42.8	0.000243	0.39	4.480	0.058	0.1001	0.0009	0.2223	0.0029	2.966	0.064	0.0967	0.0017	0.609	1294	15	1562	32	17
44.1	166	106	0.64	29.5	0.000005	0.01	4.826	0.071	0.0797	0.0010	0.2072	0.0030	2.276	0.047	0.0797	0.0012	0.703	1214	16	1189	29	-2
45.1	350	320	0.91	59.5	-	<0.01	5.057	0.068	0.0800	0.0007	0.1979	0.0026	2.194	0.036	0.0804	0.0008	0.810	1164	14	1207	19	4
46.1	728	291	0.40	133.4	0.000121	0.20	4.690	0.053	0.0814	0.0005	0.2131	0.0024	2.372	0.031	0.0807	0.0005	0.864	1245	14	1215	13	-2
47.1	226	229	1.01	39.6	0.000046	0.08	4.902	0.066	0.0816	0.0009	0.2038	0.0028	2.275	0.044	0.0809	0.0011	0.700	1196	15	1220	27	2
48.1	188	129	0.68	33.0	0.000217	0.36	4.899	0.070	0.0822	0.0010	0.2034	0.0029	2.218	0.047	0.0791	0.0012	0.672	1194	16	1175	31	-2
49.1	410	257	0.63	73.4	-	<0.01	4.804	0.063	0.0775	0.0007	0.2082	0.0028	2.231	0.036	0.0777	0.0007	0.818	1219	15	1140	18	-7
50.1	75	114	1.52	10.0																		

Sample CR190

Grain spot	U (ppm)	Th (ppm)	Th/U (ppm)	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios				Age (Ma)				%		
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁶ Pb/ ²⁰⁶ Pb	±	□	²⁰⁶ Pb/ ²³⁸ U		²⁰⁷ Pb/ ²⁰⁶ Pb	±
1.1	236	88	0.37	58.8	0.000268	0.42	3.453	0.045	0.1109	0.0009	0.2884	0.0038	4.266	0.084	0.1073	0.0016	0.666	1634	19 1754	27	7
2.1	160	67	0.42	44.2	0.000496	0.77	3.117	0.045	0.1172	0.0013	0.3184	0.0046	4.851	0.127	0.1105	0.0024	0.553	1782	23 1808	40	1
3.1	75	54	0.72	12.4	0.000087	0.15	5.207	0.098	0.0796	0.0015	0.1918	0.0036	2.072	0.084	0.0784	0.0028	0.466	1131	20 1156	72	2
4.1	207	98	0.47	44.0	-	<0.01	4.049	0.056	0.0856	0.0009	0.2474	0.0034	2.960	0.052	0.0868	0.0009	0.798	1425	19 1356	20	-5
5.1	65	41	0.63	9.8	0.000406	0.70	5.721	0.112	0.0757	0.0016	0.1764	0.0034	2.028	0.060	0.0834	0.0018	0.663	1047	21 1278	43	18
6.1	65	42	0.65	18.5	0.000387	0.61	3.001	0.056	0.1123	0.0016	0.3330	0.0062	5.126	0.119	0.1116	0.0016	0.799	1853	33 1826	25	-1
7.1	43	18	0.41	13.1	-	<0.01	2.842	0.062	0.1271	0.0020	0.3532	0.0077	6.351	0.189	0.1304	0.0026	0.736	1950	37 2103	35	7
8.1	65	70	1.08	25.1	0.000395	0.56	2.228	0.040	0.1662	0.0017	0.4463	0.0080	9.922	0.228	0.1612	0.0023	0.784	2379	36 2469	24	4
9.1	181	132	0.73	43.7	-	<0.01	3.559	0.049	0.1018	0.0009	0.2816	0.0039	4.025	0.075	0.1037	0.0013	0.747	1599	20 1691	23	5
10.1	631	406	0.64	101.9	0.001726	2.80	5.319	0.064	0.1157	0.0010	0.1827	0.0023	2.311	0.101	0.0917	0.0039	0.281	1082	12 1462	80	26
11.1	942	356	0.38	141.4	0.000017	0.03	5.725	0.063	0.0754	0.0005	0.1746	0.0019	1.810	0.024	0.0752	0.0005	0.836	1038	11 1073	14	3
12.1	501	123	0.25	73.0	0.000119	0.20	5.891	0.070	0.0740	0.0006	0.1697	0.0020	1.727	0.025	0.0738	0.0006	0.825	1011	12 1036	16	2
13.1	137	25	0.18	20.1	0.000118	0.20	5.875	0.104	0.0782	0.0011	0.1699	0.0030	1.793	0.048	0.0766	0.0015	0.669	1011	17 1110	40	9
14.1	355	333	0.94	116.5	0.000035	0.05	2.616	0.032	0.1512	0.0007	0.3820	0.0046	7.938	0.105	0.1507	0.0008	0.914	2086	22 2354	9	11
15.1	165	152	0.92	24.7	0.001305	2.20	5.748	0.085	0.0949	0.0012	0.1701	0.0026	1.792	0.110	0.0764	0.0046	0.250	1013	14 1105	119	8
16.1	217	441	2.03	28.5	0.000149	0.26	6.534	0.091	0.0714	0.0009	0.1527	0.0021	1.458	0.040	0.0693	0.0016	0.516	916	12 907	48	-1
17.1	74	73	0.98	12.4	-	<0.01	5.154	0.098	0.0810	0.0016	0.1944	0.0037	2.210	0.079	0.0825	0.0025	0.538	1145	20 1256	59	9
18.1	262	148	0.56	62.7	-	<0.01	3.594	0.051	0.1107	0.0009	0.2784	0.0040	4.266	0.072	0.1111	0.0010	0.852	1583	20 1818	16	13
19.1	77	119	1.55	18.8	0.000108	0.17	3.519	0.064	0.1064	0.0015	0.2837	0.0052	4.103	0.114	0.1049	0.0022	0.657	1610	26 1713	38	6
20.1	97	45	0.47	12.8	0.000297	0.51	6.504	0.117	0.0746	0.0016	0.1530	0.0028	1.483	0.081	0.0703	0.0036	0.336	918	16 937	106	2
21.1	200	155	0.77	70.1	0.000161	0.24	2.452	0.034	0.1447	0.0011	0.4068	0.0057	7.998	0.137	0.1426	0.0014	0.818	2200	26 2259	17	3
22.1	218	215	0.99	51.8	0.000669	1.03	3.611	0.049	0.1249	0.0011	0.2741	0.0037	4.378	0.104	0.1159	0.0022	0.577	1561	19 1893	35	18
23.1	48	31	0.66	12.6	0.000521	0.81	3.253	0.074	0.1170	0.0021	0.3049	0.0071	4.622	0.258	0.1100	0.0056	0.420	1715	35 1799	92	5
24.1	436	229	0.53	96.2	0.000043	0.07	3.891	0.046	0.0956	0.0006	0.2568	0.0031	3.363	0.048	0.0950	0.0007	0.844	1473	16 1528	14	4
25.1	111	97	0.87	26.7	-	<0.01	3.569	0.057	0.0989	0.0012	0.2803	0.0045	3.842	0.078	0.0994	0.0012	0.788	1593	23 1613	23	1
26.1	260	151	0.58	74.1	0.000064	0.10	3.017	0.039	0.1127	0.0008	0.3312	0.0042	5.106	0.079	0.1118	0.0010	0.825	1844	21 1829	16	-1
27.1	367	143	0.39	34.9	0.000183	0.32	9.036	0.116	0.0627	0.0008	0.1106	0.0014	0.951	0.018	0.0624	0.0008	0.697	676	9 686	28	1
28.1	129	31	0.24	20.7	0.000693	1.17	5.329	0.086	0.0874	0.0013	0.1855	0.0030	1.983	0.093	0.0776	0.0034	0.352	1097	17 1135	87	3
29.1	125	209	1.67	35.3	0.000015	0.02	3.042	0.048	0.1143	0.0012	0.3286	0.0052	5.169	0.098	0.1141	0.0012	0.826	1832	25 1866	19	2
30.1	224	304	1.36	58.8	0.000277	0.39	3.269	0.044	0.1631	0.0011	0.3047	0.0041	6.707	0.111	0.1596	0.0015	0.815	1715	20 2452	16	30
31.1	715	371	0.52	178.9	0.000047	0.07	3.435	0.038	0.1064	0.0005	0.2909	0.0032	4.244	0.052	0.1058	0.0005	0.917	1646	16 1728	9	5
32.1	45	48	1.07	5.9	0.000232	0.39	6.464	0.159	0.0792	0.0029	0.1534	0.0038	1.522	0.075	0.0720	0.0031	0.498	920	26 985	87	7
33.1	801	155	0.19	102.5	0.001079	1.82	6.712	0.075	0.0920	0.0006	0.1463	0.0017	1.548	0.055	0.0767	0.0026	0.322	880	9 1114	67	21
34.1	203	99	0.49	23.4	0.003617	5.92	7.476	0.143	0.1388	0.0176	0.1223	0.0023	1.110	0.362	0.0659	0.0214	0.059	744	25 802	682	7
35.1	211	120	0.57	35.7	0.000075	0.13	5.074	0.069	0.0802	0.0009	0.1968	0.0027	2.148	0.051	0.0791	0.0015	0.579	1158	14 1176	38	2
36.1	1008	19	0.02	150.9	0.000017	0.03	5.739	0.065	0.0913	0.0005	0.1742	0.0020	2.187	0.028	0.0911	0.0005	0.885	1035	11 1448	11	29
37.1	147	55	0.38	37.9	0.000115	0.18	3.337	0.052	0.1144	0.0012	0.2991	0.0046	4.653	0.098	0.1128	0.0016	0.736	1687	23 1845	26	9
38.1	239	199	0.83	70.4	0.000078	0.12	2.917	0.038	0.1224	0.0008	0.3424	0.0045	5.728	0.089	0.1213	0.0010	0.841	1898	21 1976	15	4
39.1	253	113	0.45	61.5	0.000128	0.20	3.533	0.047	0.1127	0.0009	0.2825	0.0037	4.321	0.075	0.1109	0.0012	0.768	1604	19 1815	20	12
40.1	222	147	0.66	40.8	0.001019	1.44	4.670	0.063	0.1746	0.0014	0.2111	0.0029	4.706	0.115	0.1617	0.0033	0.568	1234	16 2474	34	50
41.1	592	371	0.63	97.7	0.000053	0.09	5.202	0.060	0.0797	0.0006	0.1920	0.0022	2.089	0.034	0.0789	0.0009	0.708	1132	12 1170	23	3
42.1	219	57	0.26	40.1	0.000015	0.02	4.699	0.067	0.0868	0.0010	0.2127	0.0031	2.539	0.048	0.0866	0.0011	0.760	1243	16 1351	24	8
43.1	112	41	0.36	22.2	0.000394	0.66	4.325	0.071	0.0870	0.0012	0.2316	0.0038	2.829	0.061	0.0886	0.0013	0.756	1343	21 1395	27	4
44.1	179	160	0.90	28.0	0.000185	0.31	5.483	0.081	0.0795	0.0011	0.1818	0.0027	1.928	0.051	0.0769	0.0017	0.560	1077	15 1119	44	4
45.1	190	92	0.49	38.5	0.000787	1.23	4.242	0.058	0.1185	0.0011	0.2328	0.0032	3.462	0.099	0.1078	0.0027	0.486	1349	17 1763	46	23
46.1	126	76	0.61	21.4	0.000119	0.20	5.051	0.081	0.0788	0.0012	0.1979	0.0032	2.147	0.047	0.0787	0.0012	0.727	1164	19 1164	30	0
47.1	199	126	0.63	43.2	0.000052	0.08	3.967	0.055	0.1146	0.0010	0.2519	0.0035	3.955	0.072	0.1139	0.0013	0.771	1448	18 1862	21	22
48.1	115	57	0.49	24.0	0.000148	0.24	4.117	0.066	0.0960	0.0013	0.2423	0.0039	3.140	0.081	0.0940	0.0019	0.630	1399	20 1508	38	7
49.1	109	35	0.32	31.5	0.000255	0.40	2.969	0.047	0.1148	0.0012	0.3369	0.0053	5.339	0.102	0.1149	0.0012	0.831	1872	27 1879	19	0
50.1	95	57	0.59																		

Sample AM129A

Grain spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	$^{206}\text{Pb}/^{238}\text{U}$		f_{206} %	$^{235}\text{U}/^{238}\text{U}$		Total Ratios $^{207}\text{Pb}/^{235}\text{U}$			$^{206}\text{Pb}/^{235}\text{U}$			Radiogenic Ratios $^{207}\text{Pb}/^{235}\text{U}$					$^{206}\text{Pb}/^{238}\text{U}$		Age (Ma)		% Disc
					^{206}Pb	^{238}U		$\pm$	^{206}Pb	$\pm$	^{206}Pb	^{238}U	$\pm$	^{235}U	$\pm$	^{206}Pb	$\pm$	$\square$	^{206}Pb	^{238}U	$\pm$	^{206}Pb	$\pm$		
1.1	354	176	0.50	133	0.000068	0.10		2.294	0.026	0.1579	0.0005	0.4355	0.0050	9.431	0.114	0.1571	0.0006	0.945	2331	22	2424	7	4		
2.1	385	226	0.59	40	0.005270	10.37		8.192	0.099	0.1470	0.0070	0.1094	0.0023						669	14					
3.1	259	98	0.38	39	0.000055	0.09		5.639	0.068	0.0767	0.0006	0.1772	0.0021	1.856	0.030	0.0760	0.0008	0.762	1051	12	1094	21	4		
4.1	623	68	0.11	85	0.000027	0.05		6.260	0.069	0.0723	0.0006	0.1597	0.0018	1.584	0.024	0.0719	0.0007	0.743	955	10	984	20	3		
5.1	349	352	1.01	56	0.001409	2.39		5.316	0.062	0.0946	0.0009	0.1836	0.0022	1.886	0.091	0.0745	0.0035	0.248	1087	12	1055	95	-3		
6.1	146	145	0.99	27	0.000305	0.51		4.646	0.060	0.0856	0.0009	0.2141	0.0028	2.401	0.060	0.0813	0.0017	0.520	1251	15	1230	42	-2		
7.1	168	130	0.77	26	0.000067	0.11		5.651	0.073	0.0760	0.0007	0.1768	0.0023	1.829	0.043	0.0750	0.0015	0.553	1049	13	1070	40	2		
8.1	455	252	0.55	57	0.000584	0.98		6.806	0.077	0.0851	0.0006	0.1455	0.0017	1.540	0.038	0.0768	0.0017	0.459	876	9	1115	44	21		
9.1	258	196	0.76	70	0.000021	0.03		3.185	0.038	0.1140	0.0006	0.3139	0.0037	4.923	0.066	0.1138	0.0007	0.891	1760	18	1860	11	5		
10.1	869	328	0.38	127	0.000208	0.35		5.866	0.063	0.0790	0.0004	0.1699	0.0018	1.781	0.026	0.0761	0.0007	0.747	1011	10	1097	19	8		
11.1	898	193	0.21	68	0.000015	0.44		11.299	0.127	0.0620	0.0004	0.0881	0.0010						544	6					
12.1	634	84	0.13	98	0.000020	0.03		5.549	0.060	0.0771	0.0004	0.1802	0.0020	1.909	0.024	0.0769	0.0005	0.878	1068	11	1118	12	4		
13.1	242	126	0.52	33	0.000004	0.01		6.401	0.078	0.0746	0.0007	0.1562	0.0019	1.606	0.026	0.0746	0.0008	0.768	936	11	1057	21	11		
14.1	597	78	0.13	145	0.000134	0.21		3.532	0.039	0.1092	0.0004	0.2826	0.0032	4.184	0.051	0.1074	0.0005	0.912	1604	16	1756	9	9		
15.1	343	212	0.62	58	0.003102	5.28		5.115	0.062	0.1179	0.0027	0.1852	0.0024	1.880	0.188	0.0737	0.0073	0.130	1095	13	1032	200	-6		
16.1	444	263	0.59	102	0.000079	0.13		3.751	0.042	0.1000	0.0004	0.2663	0.0030	3.632	0.046	0.0989	0.0006	0.885	1522	15	1604	11	5		
17.1	497	102	0.20	87	0.000301	0.51		4.927	0.057	0.0798	0.0006	0.2031	0.0024	2.254	0.031	0.0805	0.0006	0.838	1192	13	1209	15	1		
18.1	255	38	0.15	39	-	<0.01		5.667	0.072	0.0754	0.0006	0.1766	0.0023	1.856	0.032	0.0762	0.0009	0.730	1048	12	1100	24	5		
19.1	232	79	0.34	94	-	<0.01		2.130	0.027	0.1376	0.0012	0.4696	0.0059	8.916	0.137	0.1377	0.0012	0.818	2482	26	2199	15	-13		
20.1	403	253	0.63	59	-	<0.01		5.895	0.067	0.0724	0.0005	0.1699	0.0019	1.728	0.028	0.0738	0.0008	0.706	1012	11	1035	23	2		
21.1	922	98	0.11	394	0.000013	0.02		2.010	0.022	0.1520	0.0005	0.4974	0.0055	10.417	0.119	0.1519	0.0005	0.955	2603	23	2367	6	-10		
22.1	114	137	1.20	19	0.000114	0.19		5.059	0.072	0.0800	0.0011	0.1973	0.0028	2.132	0.049	0.0784	0.0014	0.626	1161	15	1156	36	0		
23.1	120	49	0.40	18	0.000195	0.33		5.905	0.081	0.0755	0.0009	0.1688	0.0023	1.692	0.052	0.0727	0.0020	0.453	1005	13	1005	55	0		
24.1	105	158	1.51	17	-	<0.01		5.153	0.072	0.0803	0.0010	0.1942	0.0027	2.167	0.046	0.0809	0.0013	0.654	1144	15	1220	32	6		
25.1	1060	792	0.75	148	0.001665	2.81		6.164	0.065	0.1004	0.0009	0.1577	0.0017	1.668	0.078	0.0767	0.0035	0.227	944	9	1115	91	15		
26.1	94	72	0.77	7	-	0.36		11.859	0.211	0.0607	0.0017	0.0840	0.0015						520	9					
27.1	167	198	1.19	34	0.000154	0.26		4.183	0.067	0.0781	0.0010	0.2395	0.0038	2.627	0.054	0.0796	0.0010	0.774	1384	24	1186	26	-17		
28.1	180	187	1.04	47	0.000028	0.04		3.254	0.040	0.1084	0.0007	0.3072	0.0038	4.576	0.069	0.1080	0.0009	0.825	1727	19	1767	16	2		
29.1	436	232	0.53	78	0.000038	0.06		4.789	0.057	0.0751	0.0007	0.2087	0.0025	2.145	0.036	0.0745	0.0008	0.726	1222	13	1056	23	-16		
30.1	105	124	1.18	23	0.000234	0.40		3.949	0.075	0.0786	0.0016	0.2522	0.0048	2.617	0.101	0.0752	0.0025	0.495	1450	25	1075	67	-35		
31.1	72	90	1.25	13	-	<0.01		4.710	0.099	0.0802	0.0020	0.2127	0.0045	2.391	0.092	0.0816	0.0026	0.550	1243	24	1235	63	-1		
32.1	195	933	4.78	41	-	<0.01		4.136	0.054	0.0855	0.0009	0.2419	0.0032	2.874	0.051	0.0862	0.0010	0.738	1397	17	1342	23	-4		
33.1	210	170	0.81	50	0.000063	0.10		3.580	0.046	0.0972	0.0008	0.2797	0.0036	3.793	0.058	0.0984	0.0008	0.831	1590	20	1593	16	0		
34.1	215	124	0.58	66	0.000116	0.19		2.809	0.047	0.0963	0.0011	0.3582	0.0060	4.997	0.103	0.1012	0.0012	0.805	1973	30	1646	23	-20		
35.1	31	24	0.78	6	0.000488	0.82		4.424	0.125	0.0856	0.0023	0.2242	0.0066	2.432	0.223	0.0787	0.0068	0.319	1304	34	1164	172	-12		
36.1	842	822	0.98	113	0.001452	2.42		6.429	0.079	0.1010	0.0010	0.1518	0.0019	1.686	0.083	0.0805	0.0038	0.258	911	11	1210	94	25		
37.1	257	91	0.35	41	-	<0.01		5.353	0.073	0.0751	0.0010	0.1873	0.0026	1.992	0.058	0.0771	0.0020	0.469	1107	14	1125	52	2		
38.1	182	108	0.59	34	-	<0.01		4.560	0.073	0.0738	0.0012	0.2201	0.0036	2.341	0.100	0.0771	0.0030	0.380	1283	19	1124	79	-14		
39.1	544	208	0.38	249	0.000726	1.07		1.879	0.027	0.1483	0.0011	0.5264	0.0076	10.075	0.216	0.1388	0.0022	0.673	2726	32	2212	27	-23		
40.1	793	271	0.34	142	0.000115	0.20		4.806	0.060	0.0719	0.0007	0.2077	0.0026	2.012	0.050	0.0703	0.0015	0.509	1216	14	936	44	-30		
41.1	635	94	0.15	99	0.000047	0.08		5.481	0.062	0.0758	0.0005	0.1824	0.0021	1.905	0.025	0.0757	0.0005	0.849	1080	11	1088	14	1		
42.1	611	186	0.30	145	-	<0.01		3.627	0.042	0.1042	0.0005	0.2740	0.0032	3.743	0.053	0.0991	0.0008	0.818	1561	17	1607	15	3		
43.1	442	135	0.30	178	0.000010	0.01		2.134	0.024	0.1568	0.0011	0.4686	0.0053	10.124	0.133	0.1567	0.0011	0.858	2477	23	2420	11	-2		
44.1	82	87	1.06	22	0.000073	0.12		3.252	0.055	0.1002	0.0014	0.3071	0.0052	4.200	0.106	0.0992	0.0019	0.664	1727	26	1609	35	-7		
45.1	223	236	1.06	53	0.000179	0.30		3.620	0.061	0.0820	0.0014	0.2754	0.0047	3.019	0.083	0.0795	0.0017	0.618	1568	24	1185	43	-32		
46.1	88	75	0.85	18	0.000208	0.35		4.296	0.083	0.0799	0.0017	0.2329	0.0045	2.583	0.074	0.0804	0.0								

Sample IWH043B

Grain spot (ppm)		U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios						Age (Ma)					% Disc		
								²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	□	²³⁸ U	±		²⁰⁶ Pb	±
																				1229	18	1152	31	-7	
1.1	73	58	0.79	13	0.000267	0.45	4.744	0.066	0.0815	0.0011	0.2100	0.0029	2.264	0.047	0.0782	0.0012	0.671	1229	18	1152	31	-7			
2.1	104	78	0.75	19	0.000036	0.06	4.706	0.061	0.0798	0.0009	0.2131	0.0028	2.416	0.042	0.0822	0.0010	0.740	1245	16	1251	23	0			
3.1	199	75	0.38	35	0.000043	0.07	4.941	0.059	0.0803	0.0007	0.2022	0.0024	2.222	0.034	0.0797	0.0007	0.791	1187	13	1190	18	0			
4.1	257	69	0.27	45	-	<0.01	4.922	0.056	0.0786	0.0006	0.2032	0.0023	2.210	0.030	0.0789	0.0006	0.834	1193	12	1168	15	-2			
5.1	333	219	0.66	59	0.000029	0.05	4.887	0.054	0.0804	0.0005	0.2045	0.0023	2.257	0.029	0.0800	0.0005	0.857	1200	12	1197	13	0			
6.1	381	151	0.40	68	0.000020	0.03	4.828	0.053	0.0792	0.0005	0.2071	0.0023	2.258	0.028	0.0791	0.0005	0.872	1213	13	1174	12	-3			
7.1	108	109	1.02	19	0.000082	0.14	4.870	0.062	0.0797	0.0009	0.2051	0.0026	2.227	0.038	0.0787	0.0009	0.742	1203	17	1166	23	-3			
8.1	107	84	0.78	19	0.000041	0.07	4.867	0.065	0.0793	0.0009	0.2053	0.0028	2.228	0.042	0.0787	0.0010	0.716	1204	15	1164	26	-3			
9.1	159	127	0.80	39	0.000058	0.09	3.501	0.041	0.0976	0.0008	0.2853	0.0034	3.807	0.058	0.0968	0.0009	0.779	1618	17	1562	18	-4			
10.1	258	190	0.73	46	0.000017	0.03	4.815	0.054	0.0801	0.0006	0.2077	0.0023	2.297	0.031	0.0802	0.0006	0.837	1216	14	1202	15	-1			
11.1	189	107	0.57	33	-	<0.01	4.860	0.057	0.0804	0.0007	0.2058	0.0024	2.287	0.033	0.0806	0.0007	0.807	1206	13	1212	17	0			
12.1	47	64	1.36	8	-	<0.01	4.851	0.076	0.0784	0.0014	0.2066	0.0032	2.286	0.054	0.0802	0.0014	0.666	1211	17	1203	34	-1			
13.1	154	137	0.89	27	0.000036	0.06	4.894	0.059	0.0804	0.0008	0.2042	0.0025	2.251	0.036	0.0799	0.0008	0.765	1198	13	1195	20	0			
14.1	124	236	1.91	23	0.000061	0.10	4.711	0.059	0.0803	0.0010	0.2120	0.0027	2.323	0.042	0.0795	0.0010	0.696	1240	14	1184	26	-5			
15.1	191	478	2.50	33	0.000020	0.03	4.982	0.058	0.0791	0.0011	0.2007	0.0024	2.180	0.039	0.0788	0.0011	0.652	1179	13	1167	27	-1			
16.1	430	186	0.43	97	0.000023	0.04	3.793	0.042	0.0934	0.0005	0.2636	0.0029	3.384	0.041	0.0931	0.0005	0.906	1508	15	1490	10	-1			
17.1	59	44	0.75	11	-	<0.01	4.813	0.073	0.0809	0.0014	0.2078	0.0032	2.317	0.053	0.0809	0.0014	0.667	1217	17	1218	34	0			
17.2	195	162	0.83	34	-	<0.01	4.950	0.058	0.0803	0.0007	0.2021	0.0024	2.251	0.033	0.0808	0.0007	0.807	1187	13	1216	17	2			
18.1	62	64	1.04	11	0.000105	0.18	4.909	0.072	0.0803	0.0012	0.2033	0.0030	2.210	0.053	0.0788	0.0015	0.617	1193	16	1168	37	-2			
19.1	104	61	0.59	19	0.000085	0.14	4.808	0.063	0.0797	0.0010	0.2082	0.0027	2.308	0.041	0.0804	0.0010	0.736	1219	16	1207	24	-1			
20.1	115	196	1.71	20	0.000107	0.18	4.837	0.062	0.0806	0.0009	0.2064	0.0026	2.251	0.040	0.0791	0.0010	0.713	1209	14	1175	25	-3			
21.1	355	608	1.71	63	0.000017	0.03	4.870	0.054	0.0801	0.0005	0.2053	0.0023	2.259	0.029	0.0798	0.0005	0.855	1204	12	1192	13	-1			
22.1	234	456	1.95	40	0.000055	0.09	5.052	0.058	0.0788	0.0006	0.1978	0.0023	2.127	0.031	0.0780	0.0007	0.797	1163	12	1147	17	-1			
23.1	130	53	0.40	24	0.000043	0.07	4.735	0.059	0.0788	0.0008	0.2110	0.0026	2.274	0.038	0.0782	0.0009	0.740	1234	14	1151	22	-7			

Sample AM57

Grain spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios					Age (Ma)				% Disc		
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁶ Pb/ ²⁰⁷ Pb	±	□	²³⁸ U ±	²⁰⁶ Pb ±		²⁰⁷ Pb ±	
1.1	624	137	0.22	54	0.000624	1.20	9.900	0.109	0.0701	0.0005	0.0998	0.0011				613	7					
2.1	98	56	0.57	14	0.000519	0.88	6.220	0.104	0.0823	0.0016	0.1594	0.0028	1.646	0.091	0.0749	0.0040	0.311	953	15	1066	106	12
3.1	227	105	0.46	15	0.000294	0.54	13.360	0.187	0.0571	0.0012	0.0744	0.0011				463	7					
4.1	120	130	1.09	43	0.000087	0.12	2.387	0.038	0.1564	0.0012	0.4184	0.0066	8.957	0.163	0.1553	0.0014	0.869	2253	30	2405	15	7
5.1	162	107	0.66	11	-	<0.01	12.295	0.160	0.0572	0.0009	0.0813	0.0011				504	6					
6.1	1112	38	0.03	255	0.000015	0.02	3.749	0.042	0.1041	0.0004	0.2666	0.0030	3.818	0.045	0.1039	0.0004	0.940	1524	15	1694	7	11
7.1	1031	140	0.14	96	0.000069	0.12	9.251	0.104	0.0627	0.0007	0.1080	0.0012				661	7					
8.1	431	208	0.48	31	0.000043	0.02	11.823	0.153	0.0580	0.0005	0.0846	0.0011				523	7					
9.1	72	83	1.16	6	0.001378	2.58	10.779	0.221	0.0629	0.0019	0.0904	0.0020				558	12					
10.1	1624	272	0.17	127	0.003187	6.18	10.988	0.119	0.1083	0.0008	0.0854	0.0012				528	7					
11.1	550	132	0.24	45	0.000907	1.62	10.488	0.124	0.0715	0.0007	0.0938	0.0011				578	7					
12.1	802	405	0.50	71	0.000081	0.14	9.635	0.110	0.0631	0.0006	0.1036	0.0012				636	7					
13.1	394	80	0.20	91	0.000000	0.00	3.723	0.044	0.0980	0.0006	0.2686	0.0032	3.628	0.049	0.0979	0.0006	0.877	1534	16	1585	12	3
14.1	361	191	0.53	85	0.000025	0.04	3.628	0.043	0.0989	0.0006	0.2755	0.0033	3.745	0.053	0.0986	0.0008	0.838	1569	17	1598	15	2
15.1	1422	417	0.29	79	0.007572	14.11	15.378	0.165	0.1672	0.0007	0.0559	0.0013				350	8					
16.1	62	139	2.26	9	0.000642	1.12	5.778	0.103	0.0751	0.0016	0.1718	0.0031	1.637	0.051	0.0691	0.0018	0.573	1022	27	902	53	-13
17.1	584	269	0.46	32	0.004695	8.70	15.503	0.225	0.1241	0.0090	0.0589	0.0013				369	8					
18.1	583	97	0.17	40	0.000081	0.17	12.536	0.139	0.0584	0.0005	0.0796	0.0009				494	5					
19.1	443	426	0.96	35	0.000033	0.06	10.752	0.129	0.0604	0.0007	0.0929	0.0011				573	7					
20.1	617	325	0.53	43	-	0.08	12.209	0.135	0.0581	0.0005	0.0818	0.0009				507	5					
21.1	481	155	0.32	72	0.000051	0.09	5.741	0.068	0.0756	0.0006	0.1740	0.0021	1.797	0.028	0.0749	0.0007	0.771	1034	11	1065	20	3
22.1	418	100	0.24	32	0.002671	4.94	11.336	0.137	0.0879	0.0027	0.0839	0.0011				519	7					
22.2	838	4	0.00	59	0.000046	0.05	12.292	0.147	0.0577	0.0004	0.0813	0.0010				504	6					
23.1	403	306	0.76	98	0.000010	0.02	3.539	0.042	0.1080	0.0006	0.2826	0.0033	4.201	0.055	0.1078	0.0006	0.891	1604	17	1763	11	10
24.1	276	124	0.45	41	0.000079	0.14	5.848	0.091	0.0735	0.0009	0.1708	0.0027	1.703	0.034	0.0723	0.0009	0.791	1016	15	996	25	-2
25.1	115	56	0.49	22	0.000251	0.41	4.467	0.067	0.0982	0.0017	0.2229	0.0034	2.913	0.085	0.0948	0.0024	0.515	1297	18	1523	47	17
26.1	309	76	0.25	145	0.000003	0.00	1.827	0.024	0.1971	0.0007	0.5474	0.0071	14.873	0.200	0.1970	0.0008	0.958	2815	29	2802	6	0
27.1	146	285	1.94	24	0.000004	0.01	5.266	0.074	0.0795	0.0011	0.1899	0.0027	2.080	0.042	0.0795	0.0012	0.696	1121	14	1184	29	6
28.1	1400	173	0.12	109	0.002860	5.05	11.035	0.122	0.1026	0.0010	0.0860	0.0010				532	6					
28.2	714	343	0.48	71	0.002228	4.55	8.594	0.093	0.0995	0.0006	0.1111	0.0014				679	8					
29.1	512	393	0.77	36	-	0.06	12.391	0.138	0.0577	0.0005	0.0807	0.0009				500	5					
30.1	635	203	0.32	89	0.000026	0.04	6.099	0.072	0.0739	0.0005	0.1639	0.0019	1.662	0.024	0.0735	0.0006	0.834	978	11	1029	16	5
31.1	157	56	0.36	24	0.000127	0.22	5.593	0.117	0.0762	0.0010	0.1784	0.0037	1.831	0.057	0.0744	0.0017	0.675	1058	20	1053	46	0
32.1	158	128	0.81	26	0.000177	0.30	5.206	0.072	0.0817	0.0010	0.1915	0.0027	2.092	0.067	0.0792	0.0023	0.438	1130	15	1177	57	4
33.1	162	56	0.34	11	0.000078	0.06	12.510	0.177	0.0576	0.0009	0.0799	0.0012				495	7					
34.1	278	49	0.18	25	0.000147	0.26	9.626	0.133	0.0644	0.0009	0.1036	0.0014				636	8					
35.1	616	359	0.58	44	0.000023	0.03	11.941	0.131	0.0579	0.0005	0.0837	0.0009				518	6					
36.1	425	232	0.55	67	0.000122	0.21	5.451	0.064	0.0755	0.0006	0.1831	0.0022	1.862	0.031	0.0738	0.0009	0.710	1084	12	1035	24	-5
37.1	226	227	1.00	21	0.000090	0.16	9.134	0.126	0.0677	0.0011	0.1093	0.0015				669	9					
38.1	177	174	0.99	85	-	<0.01	1.788	0.033	0.2397	0.0011	0.5597	0.0103	18.527	0.351	0.2401	0.0011	0.969	2865	43	3121	7	9
39.1	652	215	0.33	100	-	<0.01	5.597	0.065	0.0748	0.0005	0.1788	0.0021	1.853	0.025	0.0752	0.0005	0.861	1060	11	1074	14	1
40.1	294	149	0.51	130	0.000037	0.05	1.943	0.023	0.1864	0.0007	0.5145	0.0062	13.191	0.167	0.1860	0.0008	0.948	2676	26	2707	7	1
41.1	882	178	0.20	65	0.000068	0.12	11.643	0.135	0.0591	0.0005	0.0858	0.0010				531	6					
42.1	350	144	0.41	26	0.000011	0.22	11.670	0.136	0.0598	0.0006	0.0855	0.0010				529	6					
43.1	1283	1111	0.87	94	0.009839	19.09	11.677	0.129	0.2101	0.0026	0.0693	0.0022				432	13					
44.1	86	52	0.61	24	0.000166	0.25	3.106	0.046	0.1244	0.0013	0.3212	0.0048	5.412	0.118	0.1222	0.0019	0.685	1796	23	1989	28	11
45.1	144	121	0.84	12	0.000080	0.14	10.630	0.153	0.0602	0.0012	0.0939	0.0014	0.764	0.046	0.0590	0.0034	0.250	579	8			
46.1	317	178	0.56	72	0.000046	0.07	3.797	0.046	0.0977	0.0009	0.2632	0.0032	3.522	0.055	0.0970	0.0010	0.775	1506	16	1568	18	4
47.1	510	373	0.73	35	-	<0.01	12.551	0.140	0.0569	0.0005	0.0797	0.0009				494	5					
48.1	162	97	0.60	30	-	<0.01	4.634	0.088	0.0821	0.0009	0.2160	0.0041	2.466	0.056	0.0828	0.0010	0.841	1261	22	1265	24	0
49.1	632	66	0.10	186	-	<0.01	2.917	0.034	0.1164	0.0004	0.3428	0.0040	5.504	0.067	0.1164	0.0004	0.950	1900	19	1902	7	0
50.1	1151	134	0.12	79	0.009370	16.70	12.592	0.151	0.1946	0.0048	0.0662	0.0012				413	7					
51.1	359	250	0.70	30	0.001078	1.96	10.152	0.147	0.0683	0.0029	0.0966	0.0015				594	9					
52.1	158	89	0.57	50	-	<0.01	2.722	0.036	0.1659	0.0012	0.3462	0.0046	5.720	0.309	0.1198	0.0063	0.246	1916	28	1954	93	2
53.1	919	76	0.08	136	0.000454	0.77	5.821	0.064	0.0817	0.0004	0.1705	0.0019	1.768	0.034	0.0752	0.0012	0.570	1015	10	1074	32	6
54.1	415	16	0.04	29	0.000194	0.35	12.122	0.151	0.0598	0.0008	0.0822	0.0010				509	6					
54.2	306	15	0.05	24	0.000052	<0.01	10.846	0.152	0.0585	0.0006	0.											

Sample R4

Grain spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆	Total Ratios				Radiogenic Ratios					Age (Ma)				% Disc		
							²³⁸ U/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb		²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²³⁵ U		²⁰⁷ Pb/ ²⁰⁶ Pb	□	²⁰⁶ Pb/ ²³⁸ U		²⁰⁷ Pb/ ²⁰⁶ Pb					
								±	±		±	±			±	±	±	±				
1.1	221	92	0.42	14	0.000382	0.07	13.251	0.207	0.0570	0.0016	0.0754	0.0012					469	7				
2.1	458	367	0.80	29	0.000756	0.64	13.744	0.182	0.0611	0.0033	0.0723	0.0010					450	6				
3.1	311	183	0.59	20	-	0.28	13.450	0.195	0.0585	0.0014	0.0741	0.0011					461	7				
4.1	105	69	0.66	7	0.000479	0.44	12.183	0.234	0.0610	0.0023	0.0817	0.0016					506	10				
5.1	430	257	0.60	27	0.000150	<0.01	13.735	0.184	0.0557	0.0011	0.0728	0.0010					453	6				
6.1	198	58	0.29	48	-	-0.06	3.586	0.050	0.1158	0.0013	0.2791	0.0039	4.475	0.080	0.1163	0.0013	0.776	1587	20	1900	20	16
7.1	192	93	0.48	13	0.000441	<0.01	13.113	0.206	0.0563	0.0016	0.0763	0.0012					474	7				
8.1	95	45	0.47	18	-	<0.01	4.546	0.077	0.0812	0.0017	0.2206	0.0037	2.542	0.068	0.0836	0.0017	0.635	1285	21	1282	40	0
8.2	149	84	0.57	23	0.000271	0.46	5.553	0.079	0.0780	0.0011	0.1792	0.0026	1.832	0.063	0.0741	0.0023	0.420	1063	14	1045	63	-2
9.1	481	55	0.11	33	0.000123	0.16	12.369	0.174	0.0585	0.0011	0.0807	0.0012					500	7				
10.1	237	154	0.65	15	0.000132	0.10	13.714	0.230	0.0568	0.0015	0.0728	0.0012					453	8				
10.2	150	98	0.66	9	0.000385	0.47	13.557	0.203	0.0599	0.0015	0.0734	0.0011					457	7				
11.1	246	172	0.70	16	0.000279	0.27	13.290	0.198	0.0585	0.0015	0.0750	0.0011					466	7				
12.1	447	234	0.52	32	0.000278	0.58	11.858	0.227	0.0624	0.0010	0.0838	0.0016					519	10				
13.1	367	205	0.56	24	0.000218	<0.01	12.923	0.178	0.0557	0.0012	0.0775	0.0011					481	7				
14.1	652	135	0.21	48	0.000242	1.62	11.715	0.152	0.0709	0.0014	0.0840	0.0011					520	7				
15.1	79	58	0.73	5	0.001077	0.38	12.571	0.267	0.0601	0.0026	0.0792	0.0017					492	10				
16.1	240	113	0.47	100	0.000033	0.05	2.062	0.027	0.1661	0.0011	0.4847	0.0064	11.073	0.163	0.1657	0.0011	0.890	2548	28	2515	11	-1
17.1	135	59	0.44	53	0.000036	0.05	2.205	0.033	0.1861	0.0017	0.4533	0.0067	11.603	0.201	0.1856	0.0017	0.851	2410	30	2704	15	11
18.1	196	122	0.62	48	0.000053	0.08	3.490	0.048	0.1009	0.0012	0.2863	0.0039	3.955	0.073	0.1002	0.0012	0.749	1623	20	1628	23	0
19.1	390	311	0.80	25	0.000416	0.70	13.429	0.183	0.0619	0.0012	0.0739	0.0010					460	6				
20.1	117	130	1.11	17	0.000329	0.56	5.762	0.095	0.0709	0.0016	0.1742	0.0029	1.781	0.049	0.0741	0.0016	0.597	1035	19	1045	45	1
21.1	201	149	0.74	58	0.000124	0.19	2.975	0.044	0.1172	0.0015	0.3355	0.0049	5.345	0.108	0.1155	0.0016	0.726	1865	24	1888	25	1
22.1	226	187	0.83	35	0.000110	0.19	5.611	0.087	0.0745	0.0012	0.1779	0.0028	1.787	0.050	0.0729	0.0017	0.557	1055	15	1011	47	-4
23.1	255	78	0.31	18	0.000241	<0.01	12.465	0.188	0.0570	0.0020	0.0802	0.0012					498	7				
23.2	123	61	0.50	8	-	0.10	12.871	0.205	0.0575	0.0016	0.0776	0.0013					482	8				
24.1	788	81	0.10	48	-	<0.01	13.990	0.172	0.0548	0.0008	0.0716	0.0009					446	5				
25.1	281	205	0.73	17	0.000057	0.06	13.984	0.204	0.0563	0.0014	0.0715	0.0011					445	6				
26.1	329	179	0.54	52	0.000069	0.12	5.435	0.071	0.0766	0.0010	0.1838	0.0024	1.917	0.035	0.0757	0.0010	0.705	1088	13	1086	26	0
27.1	420	325	0.78	24	0.000112	0.31	15.053	0.202	0.0575	0.0014	0.0662	0.0009					413	5				
28.1	233	331	1.42	29	0.000163	0.28	6.956	0.097	0.0687	0.0012	0.1437	0.0020	1.349	0.030	0.0681	0.0012	0.621	865	15	872	36	1
29.1	598	395	0.66	44	0.000105	0.17	11.597	0.151	0.0594	0.0009	0.0861	0.0011					532	7				
30.1	178	82	0.46	13	0.000681	1.02	12.130	0.207	0.0656	0.0021	0.0816	0.0014					506	9				
31	146	128	0.88	12	0.009218	13.09	10.204	0.184	0.1645	0.0037	0.0852	0.0023					527	14				
31.1b	211	168	0.80	13	0.002656	7.44	14.185	0.259	0.1150	0.0236	0.0653	0.0025					408	15				
32.1	196	155	0.79	13	0.000265	0.34	13.184	0.227	0.0592	0.0018	0.0756	0.0013					470	8				
32.2	209	141	0.67	13	0.000075	0.03	13.384	0.191	0.0565	0.0012	0.0747	0.0011					464	7				
33.1	269	170	0.63	16	-	<0.01	14.255	0.229	0.0546	0.0014	0.0702	0.0011					438	7				
34.1	380	81	0.21	38	-	<0.01	8.508	0.111	0.0667	0.0010	0.1171	0.0015	1.026	0.022	0.0635	0.0011	0.607	714	9	726	36	2
34.2	215	72	0.34	30	0.000094	0.16	6.134	0.088	0.0721	0.0015	0.1628	0.0024	1.587	0.050	0.0707	0.0020	0.458	972	13	949	57	-2
35.1	281	158	0.56	20	0.000280	0.62	11.987	0.171	0.0626	0.0014	0.0829	0.0012					513	7				
36.1	325	76	0.23	37	0.000086	0.15	7.448	0.120	0.0745	0.0021	0.1332	0.0021	1.246	0.046	0.0678	0.0023	0.433	806	13	864	70	7
37.1	224	75	0.34	25	0.000218	0.38	7.687	0.117	0.0733	0.0015	0.1296	0.0020	1.254	0.034	0.0702	0.0016	0.563	786	11	933	46	16
38.1	184	66	0.36	30	0.000131	0.22	5.288	0.078	0.0777	0.0013	0.1887	0.0028	1.973	0.052	0.0758	0.0017	0.560	1114	15	1091	44	-2
39.1	146	82	0.56	10	0.000256	0.47	13.152	0.258	0.0603	0.0024	0.0757	0.0015					470	9				
40.1	300	90	0.30	45	0.000071	0.12	5.710	0.085	0.0746	0.0013	0.1749	0.0026	1.774	0.044	0.0735	0.0014	0.607	1039	14	1029	39	-1
41.1	221	144	0.65	36	0.000152	0.26	5.226	0.082	0.0777	0.0014	0.1909	0.0030	1.989	0.051	0.0756	0.0016	0.608	1126	16	1084	41	-4
42.1	272	196	0.72	71	0.000030	0.05	3.312	0.048	0.1058	0.0012	0.3018	0.0044	4.385	0.096	0.1054	0.0017	0.663	1700	22	1721	30	1
43.1	307	192	0.63	20	0.000069	0.35	13.439	0.212	0.0591	0.0016	0.0741	0.0012					461	7				
44.1	265	176	0.66	17	0.000186	0.32	13.387	0.220	0.0589	0.0017	0.0745	0.0013					463	8				
45.1	768	182	0.24	97	0.000065	0.11	6.777	0.091	0.0722	0.0008	0.1474	0.0020	1.449	0.026	0.0713	0.0009	0.741	886	11	965	25	8
46.1	288	204	0.71	18	-	<0.01	13.890	0.224	0.0551	0.0016	0.0721	0.0012					449	7				
47.1	167	189	1.13	13	0.000228	<0.01	10.886	0.205	0.0589	0.0021	0.0919	0.0018					567	10				
48.1	912	111	0.12	68	0.000000	<0.01	11.539	0.157	0.0568	0.0009	0.0868	0.0012					537	7				
49.1	151	111	0.74	9	0.000424	0.98	14.054	0.305	0.0636	0.0032	0.0705	0.0016					439	10				
50.1	125	131	1.04	18	-	<0.01	5.840	0.110	0.0751	0.0020	0.1712	0.0032	1.773	0.058	0.0751	0.0020	0.579	1019	18	1071	54	5
51.1	252	135	0.54	16	-	0.34	13.286															

Sample R19A

Grain spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios						Age (Ma)				% Disc		
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁶ Pb/ ²⁰⁶ Pb	±	□	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U		±	
1.1	182	103	0.57	11.7	0.000037	0.02	13.329	0.192	0.0565	0.0011	0.0750	0.0011							466	7			
2.1	103	66	0.64	6.6	-	0.33	13.334	0.269	0.0590	0.0019	0.0747	0.0015							465	9			
3.1	284	106	0.37	28.6	0.002873	5.89	8.508	0.123	0.1104	0.0017	0.1106	0.0019							676	11			
4.1	119	59	0.49	8.2	0.000528	<0.01	12.421	0.282	0.0569	0.0018	0.0805	0.0019							499	11			
5.1	173	97	0.56	14.8	0.000233	<0.01	10.033	0.208	0.0591	0.0016	0.0998	0.0021							613	12			
6.1	296	92	0.31	19.7	0.000849	2.90	12.919	0.201	0.0799	0.0024	0.0752	0.0012							467	7			
7.1	208	138	0.67	13.9	0.000090	0.33	12.813	0.202	0.0595	0.0013	0.0778	0.0013							483	7			
8.1	154	101	0.66	12.5	0.000249	1.12	10.546	0.196	0.0684	0.0020	0.0938	0.0018							578	11			
9.1	445	127	0.28	60.5	0.000004	0.01	6.312	0.079	0.0732	0.0007	0.1584	0.0020	1.599	0.026	0.0732	0.0007	0.778	948	11	1019	21	7	
10.1	256	155	0.60	16.4	0.000559	1.21	13.446	0.213	0.0659	0.0014	0.0735	0.0012							457	7			
11.1	727	541	0.74	70.4	0.000679	0.75	8.866	0.115	0.0685	0.0016	0.1119	0.0015							684	9			
12.1	242	181	0.75	17.0	0.000202	0.13	12.227	0.187	0.0585	0.0012	0.0817	0.0013							506	8			
13.1	470	308	0.66	37.5	-	0.31	10.765	0.128	0.0617	0.0007	0.0926	0.0011							571	7			
14.1	418	112	0.27	96.6	-	<0.01	3.716	0.043	0.0974	0.0005	0.2691	0.0031	3.615	0.046	0.0974	0.0005	0.899	1536	16	1575	10	2	
15.1	404	175	0.43	183.0	0.000087	0.12	1.896	0.021	0.1622	0.0006	0.5268	0.0059	11.701	0.140	0.1611	0.0007	0.936	2728	25	2467	7	-11	
16.1	976	440	0.45	61.9	0.004780	10.15	13.545	0.148	0.1371	0.0008	0.0663	0.0012							414	7			
17.1	133	152	1.14	10.1	-	0.14	11.381	0.175	0.0595	0.0012	0.0877	0.0014							542	8			
18.1	236	102	0.43	65.1	0.000031	0.05	3.115	0.042	0.1088	0.0007	0.3209	0.0044	4.795	0.074	0.1084	0.0008	0.885	1794	21	1772	13	-1	
19.1	564	136	0.24	83.1	0.000118	0.20	5.831	0.068	0.0775	0.0016	0.1712	0.0020	1.788	0.046	0.0758	0.0017	0.453	1018	11	1089	46	6	
20.1	266	187	0.70	17.8	0.000098	<0.01	12.858	0.167	0.0562	0.0009	0.0778	0.0010							483	6			
21.1	601	208	0.35	96.8	0.001418	2.40	5.331	0.059	0.0958	0.0010	0.1831	0.0021	1.910	0.085	0.0757	0.0033	0.254	1084	11	1086	86	0	
22.1	602	393	0.65	73.5	0.002149	3.58	7.033	0.080	0.1122	0.0010	0.1371	0.0016	1.548	0.093	0.0819	0.0048	0.198	828	9	1242	115	33	
23.1	64	24	0.38	9.6	0.000086	0.15	5.710	0.098	0.0722	0.0013	0.1749	0.0030	1.712	0.056	0.0710	0.0020	0.528	1039	17	958	57	-8	
24.1	405	197	0.49	28.1	0.000110	0.25	12.392	0.161	0.0592	0.0007	0.0805	0.0011							499	6			
25.1	233	101	0.43	15.7	0.000229	0.09	12.712	0.171	0.0577	0.0009	0.0786	0.0011							488	6			
26.1	322	120	0.37	43.0	0.000048	0.08	6.438	0.077	0.0686	0.0006	0.1552	0.0019	1.454	0.022	0.0679	0.0006	0.794	930	10	867	19	-7	
27.1	376	262	0.70	22.9	-	0.07	14.109	0.171	0.0563	0.0007	0.0708	0.0009							441	5			
28.1	364	85	0.23	82.7	0.000937	1.45	3.784	0.046	0.1246	0.0009	0.2605	0.0032	4.018	0.093	0.1119	0.0022	0.533	1492	16	1830	35	18	
29.1	420	280	0.67	65.8	0.000201	0.34	5.479	0.063	0.0804	0.0005	0.1819	0.0021	1.945	0.034	0.0776	0.0010	0.670	1077	12	1135	26	5	
30.1	239	30	0.12	18.9	-	0.38	10.855	0.137	0.0621	0.0010	0.0918	0.0012							566	7			
31.1	224	156	0.69	68.1	0.000005	0.01	2.834	0.034	0.1368	0.0007	0.3529	0.0043	6.652	0.088	0.1367	0.0007	0.914	1948	20	2186	9	11	
32.1	241	56	0.23	19.2	-	0.14	10.763	0.140	0.0602	0.0009	0.0928	0.0012							572	7			
33.1	3185	377	0.12	218.3	0.011397	24.63	12.535	0.131	0.2530	0.0007	0.0601	0.0025							376	15			
34.1	293	191	0.65	17.8	0.000423	1.56	14.118	0.185	0.0682	0.0011	0.0697	0.0009							435	6			
35.1	224	303	1.35	19.7	0.000012	<0.01	9.769	0.127	0.0591	0.0009	0.1026	0.0014							629	8			
36.1	35	34	0.98	4.7	0.001176	1.97	6.309	0.175	0.0954	0.0043	0.1554	0.0054	1.687	0.400	0.0788	0.0185	0.147	931	30	1166	465	20	
37.1	275	51	0.19	24.8	0.002700	5.66	9.499	0.116	0.1065	0.0010	0.0993	0.0015							610	9			
38.1	206	150	0.73	65.8	0.000216	0.33	2.688	0.033	0.1177	0.0008	0.3708	0.0046	5.870	0.096	0.1148	0.0012	0.751	2033	21	1877	19	-8	
39.1	429	260	0.61	50.1	0.003221	7.45	7.361	0.084	0.1262	0.0017	0.1257	0.0020							763	11			
40.1	149	97	0.65	39.9	0.000040	0.06	3.217	0.041	0.0999	0.0008	0.3106	0.0040	4.254	0.065	0.0993	0.0008	0.837	1744	20	1612	16	-8	
41.1	252	22	0.09	22.2	0.000080	0.07	9.754	0.124	0.0613	0.0008	0.1024	0.0013							629	8			
42.1	85	256	3.03	6.8	0.000143	<0.01	10.624	0.171	0.0586	0.0013	0.0942	0.0016							580	9			
43.1	578	456	0.79	39.3	0.005138	8.90	12.633	0.147	0.1280	0.0008	0.0721	0.0012							449	7			
44.1	85	43	0.50	6.7	0.000898	0.32	10.953	0.279	0.0614	0.0033	0.0910	0.0024							562	14			
45.1	96	62	0.65	26.6	0.000267	0.42	3.094	0.047	0.1120	0.0012	0.3226	0.0049	4.917	0.091	0.1105	0.0012	0.819	1802	26	1808	19	0	
46.1	2864	1349	0.47	113.5	0.009496	19.91	21.669	0.230	0.2103	0.0007	0.0370	0.0012							234	8			
47.1	270	44	0.16	96.2	-	<0.01	2.409	0.028	0.1457	0.0007	0.4152	0.0049	8.358	0.107	0.1460	0.0007	0.917	2239	22	2299	9	3	
48.1	958	209	0.22	63.0	0.013441	25.36	13.059	0.141	0.2582	0.0047	0.0572	0.0026							358	16			
49.1	154	22	0.14	19.2	0.002061	3.53	6.870	0.093	0.1004	0.0017	0.1398	0.0019	1.292	0.087	0.0670	0.0044	0.199	844	12	838	138	-1	
50.1	353	359	1.02	29.0	0.000012	<0.01	10.449	0.118	0.0591	0.0008	0.0958	0.0011							590	6			
51.1	506	311	0.61	28.2	0.006426	11.90	15.416	0.173	0.1496	0.0010	0.0571	0.0012							358	7			
52.1	1496	233	0.16	96.2	0.010012	18.72	13.362	0.139	0.2054	0.0007	0.0608	0.0019							381	11			
53.1	459	605	1.32	38.6	-	0.06	10.236	0.114	0.0604	0.0005	0.0976	0.0011							601	7			

- Notes :
- Uncertainties given at the one σ level.
 - Error in FC1 Reference zircon calibration was 0.95% for the analytical session.
(not included in above errors but required when comparing data from different mounts).
 - f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
 - For areas older than ~800 Ma correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
 - For areas younger than ~800 Ma correction for common Pb made using the measured ²³⁸U/²⁰⁶Pb and ²⁰⁷Pb/²⁰⁶Pb ratios following Tera and Wasserburg (1972) as outlined in Williams (1998).
 - For % Disc, 0% denotes a concordant analysis.