# Testing the Provenance of Santonian-Maastrichtian lobe of the Ceduna Delta

Thesis submitted in accordance with the requirements of the University of Adelaide for an Honours Degree in Geology

Jarred Cain Lloyd

November 2014


THE UNIVERSITY of ADELAIDE

## TITLE

Testing the Provenance of Santonian-Maastrichtian lobe of the Ceduna Delta

## RUNNING TITLE

Provenance of the Upper Ceduna Delta Lobe

## ABSTRACT

The Ceduna Delta represents a vast Cretaceous stacked delta system located in the Bight Basin and is currently the focus of considerable petroleum exploration. Two competing models have been suggested for the source of the upper Santonian-Maastrichtian delta lobe. Originally, it was proposed that both the upper and lower lobes of the delta were sourced from the Australian Eastern Highlands via a continent scale river. A recent study suggested that the two lobes had different sources, with the upper lobe instead being sourced proximally from the western Eromanga Basin and within present day South Australia. This new model was primarily based on existing and new, but sparse apatite fission track data. This study tested the two competing models, by comparing the detrital zircon U/Pb age distribution and Lu-Hf isotopic composition of samples from the Late Cretaceous Winton Formation in the eastern Eromanga Basin (part of the proposed source of the upper Ceduna delta) with samples from the Gnarlyknots-1A well within the Ceduna Sub-basin of the Bight Basin. Zircon U/Pb data and hafnium isotopic data from the Gnarlyknots-1A well and eastern Eromanga Winton Formation demonstrates the similarity in provenance of the two formations and that both ultimately are sourced from the Australian Eastern Highlands.

## KEYWORDS

Provenance, U-Pb Age, Hafnium Isotopes, Geochemistry, Ceduna Delta, Bight Basin

## TABLE OF CONTENTS

## LIST OF FIGURES AND TABLES

## INTRODUCTION

The Ceduna Sub-basin (Figure 1) is one of eight depocentres in the large Bight Basin off the southern Australian coast. It contains two deltaic sequences that are represented by the Hammerhead Supersequence, which contains the Potoroo and Wigunda formations, and the White Pointer Supersequence, containing the Platypus formation.

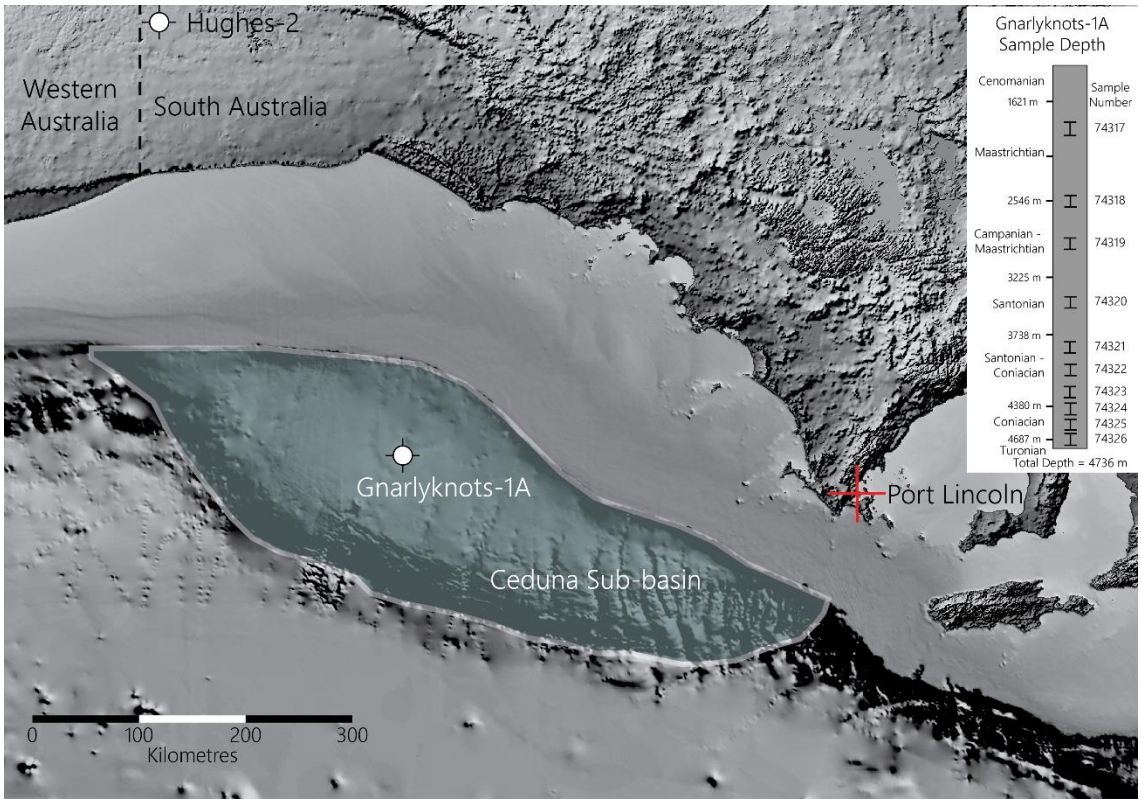



**Figure 1: Location of Gnarlyknots-1A drill hole, Hughes-2 drill hole, the Ceduna sub-basin and Gnarlyknots-1A sample depths**

These supersequences have formed a very large and conspicuous bathymetric expression, colloquially referred to as the Ceduna Delta. Although this delta is as large as the modern Niger Delta, and has high petroleum prospectivity (King and Mee 2004), very little is known about the origin, source and demise of the delta (MacDonald et al. 2013b). This is primarily due to the lack of exploration wells, and thus access to samples, because of the delta being located in a high-risk area. Extensive seismic and

structural analyses have been conducted on the Ceduna Sub-basin, identifying two structurally and temporally separated delta lobes (Totterdell et al. 2003, MacDonald et al. 2013a). The older Cenomanian lobe (100.5-93.9 Ma) contains the White Pointer Supersequence (Totterdell et al. 2003) and the younger Santonian-Maastrichtian (86.3-72.1 Ma) lobe, mainly consists of the Hammerhead Supersequence (Totterdell et al. 2003).

The source of the delta sediments is currently not well understood. Initial models indicated a provenance in northeast Australia (Veevers 2000, King and Mee 2004). However, MacDonald et al. (2013b) conducted a provenance study using U-Pb geochronology on detrital zircons sampled from the Gnarlyknots-1 exploration well and their results provided evidence that led them to propose an alternative model where the Santonian-Maastrichtian sediments of the Ceduna Delta are sourced more proximally, from within present-day South Australia, and not from a trans-continental river system as theorised earlier.

Although U-Pb geochronology on detrital zircons has been widely used for provenance and is generally effective, it has become increasingly realised that provenance studies solely based on zircon U-Pb ages are limiting, as zircon growth events may not be unique to specific terranes (Howard et al. 2009). Additional isotopic constraints, such as Lu-Hf data, may overcome this issue by providing a separate, independent, data set to compare detritus with source terrane. The MacDonald et al. (2013b) study demonstrates this limitation, whereby two possible spatially distant source regions are suggested for a population of zircons; however, there is little supplementary evidence that assists in the determination of which source region is more probable. As such, further investigation is

required to gain a more detailed and accurate understanding of the origin of the Ceduna Delta.

Based on detrital apatite fission track data MacDonald et al. (2013b) suggested that a regional arcuate-shaped exhumation event encompassing the southern Musgrave Block, western Eromanga Basin, Officer Basin, Flinders Ranges, Yorke Peninsula, Southern Adelaide Fold Belt and Kangaroo Island began between 100 and 80 Ma. This late Cretaceous exhumation event is suggested to have resulted in 1-2 kilometres of erosion providing a source of Permian, Jurassic and Cretaceous detritus. In combination with the suggested exhumation event, the seismic character of the delta, specifically high-angle bedforms that are interpreted to indicate rapid deposition, is used to reason the upper delta lobe was sourced more proximally than previously suggested. It must be noted, however, that in situ fission track data is absent from much of the inland parts of this proposed uplift area, so much inference had to be made using data from coastal Australia.

This study has concentrated on providing new zircon Lu-Hf data from previously studied core samples of both the Ceduna Sub-Basin, the Loongana Formation of the Madura Shelf and from the Winton Formation in the Eromanga Basin where U-Pb data had already been obtained (MacDonald et al. 2013a; Justin MacDonald and Simon Holford personal communication) to better understand the provenance and evolution of the source areas to these regions and to test their similarities as whether they are feasibly part of the same sedimentary system. Previously collected U-Pb data (both published and unpublished) were (re)processed and newly plotted. In addition, new U-Pb data were collected from two samples to complement the existing datasets. In particular, I test whether the Santonian-Maastrichtian delta lobe is distally sourced from

the Australian Eastern Highlands by a continental scale southeast flowing river, instead of the more proximal Adelaide Rift Complex and western Eromanga Basin as suggested by MacDonald et al. (2013b). The source of the Ceduna Delta sediments has implications on the reservoir rock quality and; therefore, gaining a better understanding of the source and evolution of the Ceduna Delta has implications on petroleum exploration within the Ceduna Sub-basin, and Bight Basin. It will also provide further insight into the paleogeography of Australia, by reconstructing part of the fluvial system in Australia in the Late Cretaceous.

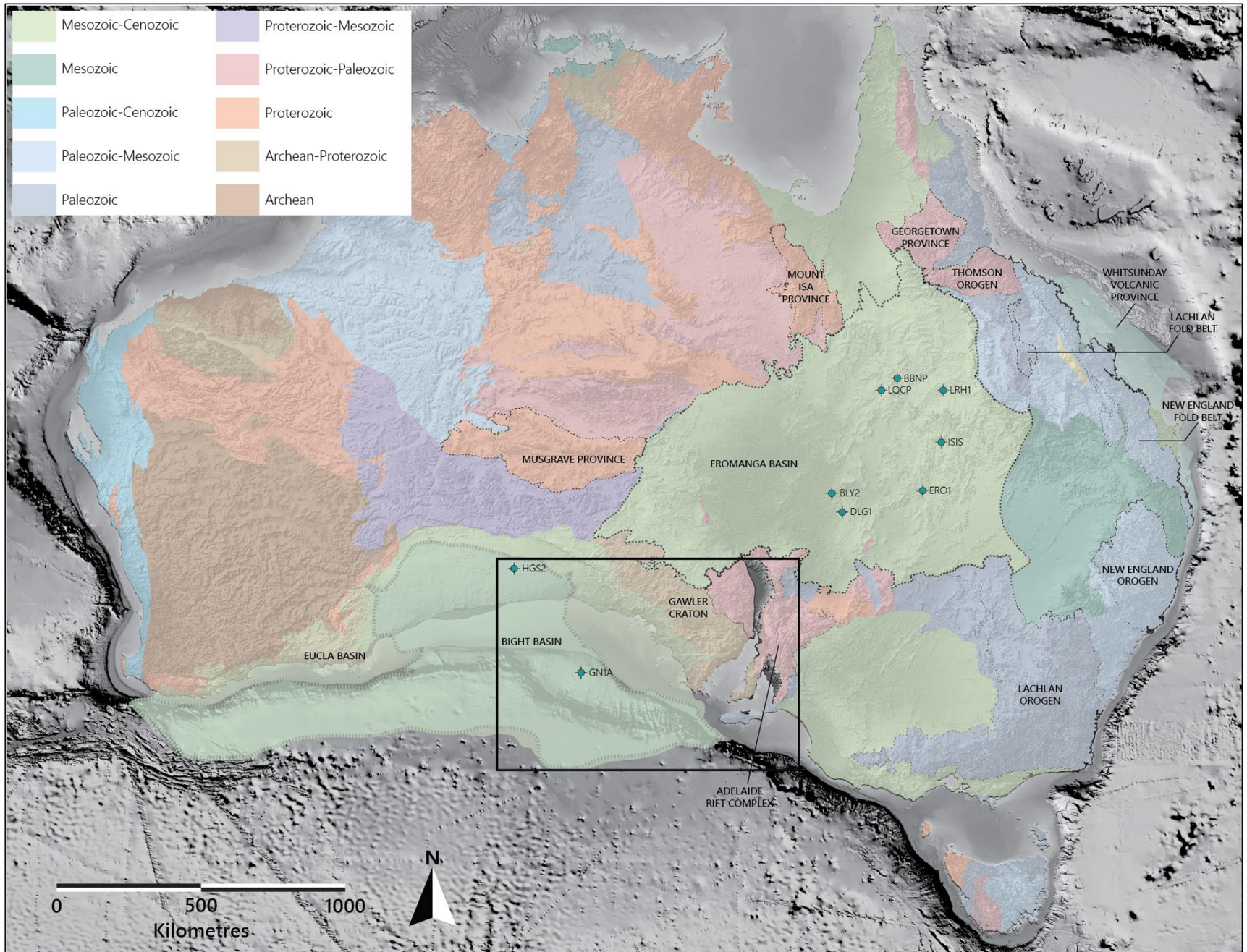



**Figure 2: Map of Australia showing the locations where uranium-lead and hafnium isotope data was sourced, major basins of Australia coloured according to age. The black box represents the inset for Figure 1. The major basins of interest, the Eromanga and Bight Basins, are outlined in black.**

## BACKGROUND

It has been widely theorised, though neither proved nor disproved, that the Ceduna Delta sediments were deposited by a continent-scale south-west flowing river system. In these models, the primary source of detritus in the Ceduna delta is thought to be either erosional detritus from the Eromanga basin (King and Mee 2004) or the Australian Eastern Highlands (Veevers 2000, Krassay and Totterdell 2003). In particular the late Albian-Cenomanian Winton Formation sediments (Tucker et al. 2013) yield similar zircon age characteristics to the younger, Santonian-Maastrichtian, sedimentary rocks of the upper Ceduna Delta. MacDonald et al. (2013b) recently published new detrital zircon uranium-lead (U-Pb) age data from samples obtained from the Gnarlyknots-1A drill hole. Their findings challenge this theory, and suggest that, at the least, the sediments from the younger Santonian-Maastrichtian lobe of the delta have a more proximal provenance than previously anticipated. The proximal model was suggested based primarily on the seismic characteristics of the delta and a suggested broad, late Cretaceous exhumation event thought to have restricted the catchment area. The U-Pb and fission-track zircon data obtained by MacDonald et al. (2013b) for the Gnarlyknots-1A drill core provided the sole constraints on the provenance of the deltaic sediments. As noted in MacDonald et al. (2013b) no well with available samples has penetrated the older, Cenomanian aged, lobe of the Ceduna Delta. The Potoroo-1 well was abandoned at 2924 m, in what is described as the equivalent of the Pretty Hill and Geltwood Beach (Eumeralla) formations ("Shell" 1975) and Gnarlyknots-1A abandoned at 4736 m (Willis 2003) in the Wigunda Formation, meaning that the source of the Cenomanian delta lobe can only be speculated.

## Geological Setting

Of particular importance to this study are the Ceduna Sub-basin and the Cretaceous sediments of the Eromanga Basin, which are thought to be a potential source rocks for the upper Ceduna Delta lobe. The following section discusses the sedimentary records of both the Ceduna and Eromanga basins, aiming to understand their potential relationship in the provenance model.

### BIGHT BASIN

Formation of the Bight Basin occurred in two successive periods of extension and thermal subsidence commencing in the Middle to Late Jurassic (Totterdell et al. 2003), with the Middle Cretaceous extensional phase being associated with the Late Santonian break-up of Australia and Antarctica (Totterdell et al. 2003, MacDonald et al. 2013b). Between the Jurassic and Early Cretaceous, the Bight Basin contains dominantly non-marine sediments. However, from the late Aptian until the end of the Cretaceous, deposition occurred in marine and deltaic environments. The relationships between basin phases, lithostratigraphy, sequence stratigraphy and time are shown in Figure 3.

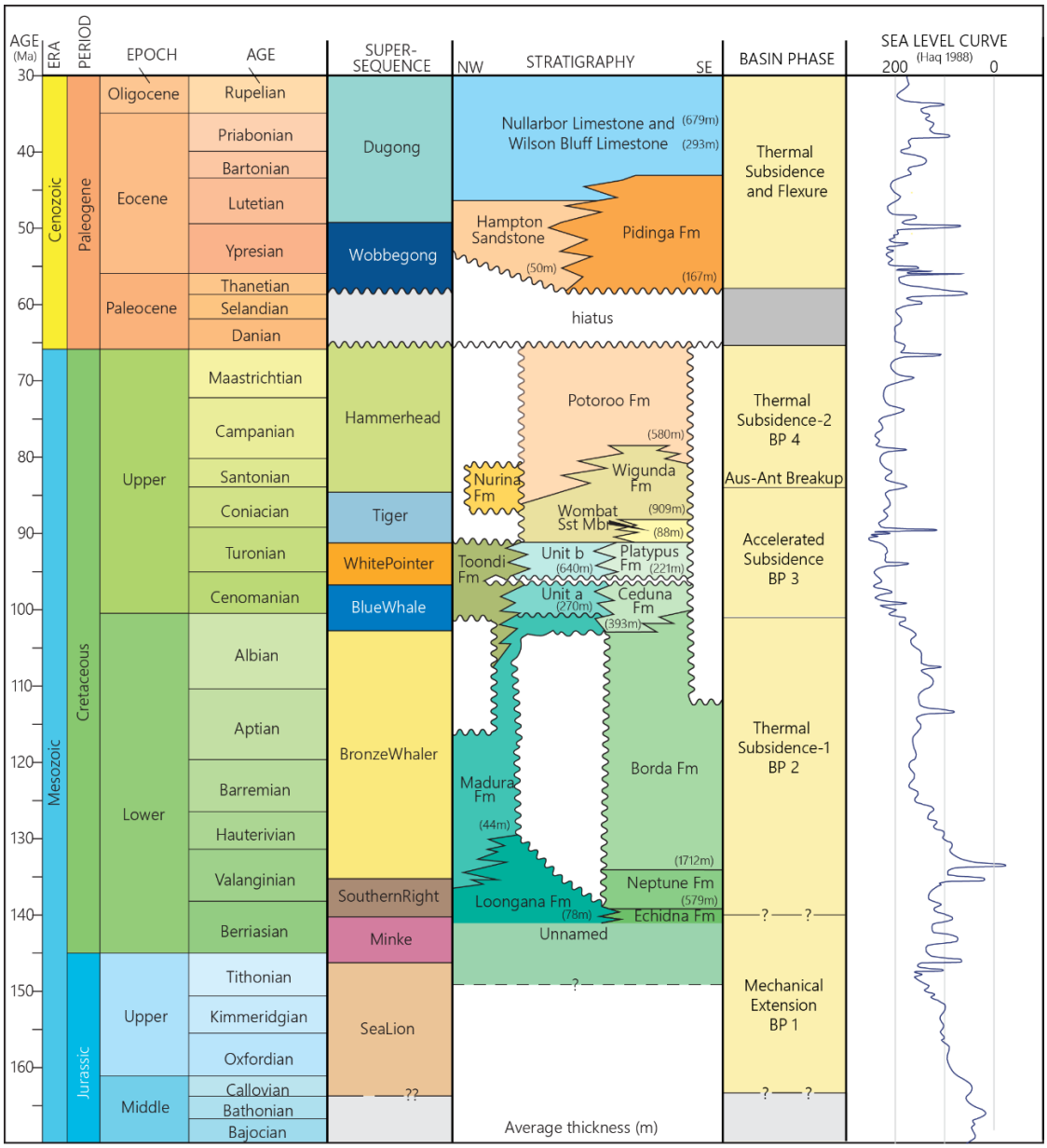



**Figure 3: Bight Basin correlation chart showing link between the sea level curve, lithostratigraphy, sequence stratigraphy and basin phases. After Totterdell et al. (2003)**

## Ceduna Sub-Basin

The west-northwest trending Ceduna Sub-basin (Figure 1) is the major depocentre of the Bight Basin and is the largest of the sub-basins in the Bight Basin. The sub-basin consists of middle Jurassic to Late Cretaceous sedimentary rocks that locally exceed 12 km in total thickness (Totterdell et al. 2003, MacDonald 2013). The Ceduna Sub-basin lies beneath the distinctly visible Ceduna Terrace with water depths between 200 and

5200 m. It is characterised by two periods of deltaic progradation, an Albian-Cenomanian delta and a Santonian-Maastrichtian lobe. The structural architecture of the Albian-Cenomanian delta consist of a system of gravity-driven, detached extensional and contractional faults and mud diapirism (Totterdell et al. 2003). The primary deltaic sediments that form the distinct Ceduna Delta of the Ceduna Sub-basin are the White Pointer and Hammerhead supersequences (Totterdell et al. 2003, MacDonald 2013) The Late Santonian-Maastrichtian delta is a sand-rich system featuring strongly progradational stratal geometries and includes simple planar normal faults (Totterdell et al. 2003). Both deltaic systems contain potential structural and stratigraphic traps, with the later Santonian-Maastrichtian delta containing especially good potential hydrocarbon reservoirs.

## EROMANGA BASIN

The Mesozoic Eromanga Basin is a large oil and gas producing, intracratonic sedimentary basin covering a large portion of northeast central Australia. Overlying the Permo-Carboniferous Arckaringa, Cooper and Pedirka Basins (Cotton et al. 2006a). Deposition in the Eromanga Basin was relatively continuous and widespread throughout the Early Jurassic to Late Cretaceous, controlled by subsidence rates and plate tectonic events on the Australia Plate margins (Cotton et al. 2006a). The sedimentary record of the Eromanga Basin can be divided into three packages: lower non-marine, marine and upper non-marine. Of particular importance for this study are the upper non-marine formations, primarily the coal bearing Winton Formation, but also to a lesser extent the Cadna-owie Formation and Mackunda Formation, (and “Mt Howie Sandstone”) as they provide potential source lithologies, with a similar age as for the Ceduna Delta sedimentary rocks.

### Winton Formation

The Winton Formation is described as being interbedded fine to coarse-grained sandstone, carbonaceous and pyritic shale, siltstone and coal seams with intraclast conglomerates (Cotton et al. 2006a). The sandstone beds contain abundant fresh volcanogenic debris, as well as lithics, feldspar, and traces of apatite, mica and ferromagnesian minerals. It is Late Albian-Cenomanian in age (Cotton et al. 2006a, Tucker et al. 2013), making it of similar age as the lower delta in the Ceduna Sub-Basin. Many macrofossils are present in the formation. The thickness of the formation varies, but is generally greater than 400 m, up to 1200 m (Cotton et al. 2006a, Alley et al. 2011).

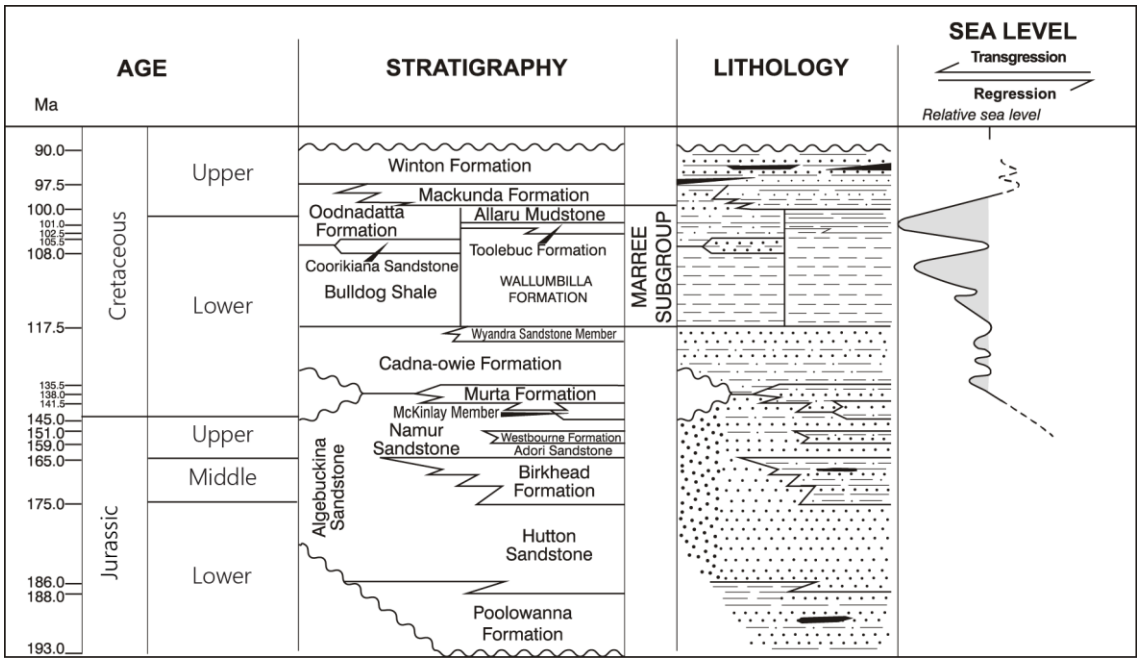



**Figure 4: Stratigraphic chart of the Eromanga Basin showing the relationship to sea level curve. After Cotton et al. (2006b)**

## METHODS

The main part of the project involved Hf isotopic analyses that were conducted via Laser Ablation Multi-Collector Inductively Coupled Plasma Mass Spectrometry (LA-MC-ICP-MS) on selected samples from the Gnarlyknots-1A core, from which U-Pb age

data had previously been obtained (MacDonald et al. 2012a). These data are shown in supplementary tables 3-8. A Thermo-Scientific Neptune Multi-Collector Inductively Coupled Plasma Mass Spectrometer attached at a New Wave UP193 Excimer laser located at a joint University of Adelaide and Commonwealth Scientific and Industrial Research Organisation (CSIRO) facility at the University of Adelaide's Waite Campus was used for the Hf isotopic analysis. Data processing was completed using a macro-driven Excel™ workbook, HfTRaX V3.2, written by Dr. Justin Payne. Epsilon Hf, $Hf_i$ and hafnium model ages were calculated using a modified Excel™ workbook originally developed by the ARC National Key Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC) at Macquarie University, Sydney.

Additional samples were analysed for U-Pb geochronology via a Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) using a New Wave UP-213 laser attached to an Agilent 7500cx Inductively Coupled Plasma Mass Spectrometer (ICP-MS) at Adelaide Microscopy, the University of Adelaide. Zircons were imaged under cathodoluminescence prior to U-Pb analysis by previous reserachers. Age calculations and corrections were completed using the software GLITTER with use of the primary zircon standard GJ-1, TIMS normalization data $^{207}Pb/^{206}Pb$ = 608.3 Ma, $^{206}Pb/^{238}U$ = 600.7 Ma and $^{207}Pb/^{235}U$ = 602.2 Ma (Jackson et al. 2004). Instrument drift was also corrected for in GLITTER via standard bracketing every 15-20 unknowns and application of a linear correction. Accuracy of the methodology was verified by repeat analysis of Plešovice zircon, $^{206}Pb/^{238}U$ = 337.13±0.37 (Sláma et al. 2008). Isotope ratios are presented uncorrected for common lead, with Concordia plots generated using Isoplot 4.15.

Kernel density estimates, probability density plots and histograms were all plotted using Density Plotter, a java program developed by and described in Vermeesch (2012). An adaptive bandwidth was used for the kernel density estimates. A fixed age range of 0-3500 Ma and histogram bin width of 100 Ma was used for consistency across all plots. Data used was ±10% concordant.

Detailed methods are shown in Appendix A and the raw U-Pb and Hf isotope data are shown in Appendix B.

## OBSERVATIONS AND RESULTS

### Existing U-Pb detrital zircon data

GNARLYKNOTS-1A SAMPLE 74317 (DATA FROM MACDONALD ET AL. (2013B))

This sample was sourced from the Potoroo Formation. In this sample five discrete age populations were observed (Figure 5A), the most significant population ca. 400-100 Ma zircons contained 38 (52.1%) of the <10% discordant grains. The next major population of 19 zircons (26.2%) had ages ranging from ca. 690-490 Ma. The remaining populations ca. 1255-960, 1940-1370 and 2340-2120 Ma contained 7 (9.5%), 7 (9.5%) and 2 (2.7%) zircons respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 103.5±4.7 Ma (Lower Cretaceous, Albian) and is taken as the maximum depositional age.

GNARLYKNOTS-1A SAMPLE 74318 (DATA FROM MACDONALD ET AL. (2013B))

This sample was sourced from the Potoroo Formation. In this sample six discrete age populations were observed (Figure 5B), the most significant population ca. 370-98 Ma zircons contained 26 (46.4%) of the <10% discordant grains. The next major population

of 19 zircons (33.9%) had ages ranging from ca. 775-465 Ma. The remaining populations ca. 1030-960, 1145-1140, 1445 and 1740 Ma contained 7 (12.5%), 2 (3.6%), 1 (1.8%) and 1 (1.8%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 98.9±2.0 Ma (Upper Cretaceous, Cenomanian) and is taken as the maximum depositional age.

GNARLYKNOTS-1A SAMPLE 74319 (DATA FROM MACDONALD ET AL. (2013B))

This sample was also sourced from the Potoroo Formation. In this sample eight discrete age populations were observed (Figure 5C), the most significant population ca. 340-100 Ma zircons contained 26 (44.1%) of the <10% discordant grains. The next major population of 16 zircons (27.1%) had ages ranging from ca. 690-450 Ma. The remaining populations ca. 790-770, 965-900, 1300-1060, 1570-1445, 1900 and 2860 Ma contained 2 (3.4%), 2 (3.4%), 8 (13.6%), 3 (5.1%), 1 (1.7%) and 1 (1.7%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 100.6±2.4 Ma (Lower Cretaceous, Albian) and is taken as the maximum depositional age.

GNARLYKNOTS-1A SAMPLE 74320 (DATA FROM MACDONALD ET AL. (2013B))

This sample was sourced from the Wigunda Formation. In this sample six discrete age populations were observed (Figure 5D), the most significant population ca. 690-430 Ma zircons contained 18 (41.9%) of the <10% discordant grains. The next major population of 11 zircons (25.6%) had ages ranging from ca. 305-100 Ma. The remaining populations ca. 1150-840, 1490, 1770-1640 and 2015 Ma contained 10 (23.3%), 1 (2.3%), 2 (4.7%) and 1 (2.3%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 101.6±1.7 Ma (Lower Cretaceous, Albian) and is taken as the maximum depositional age.

### GNARLYKNOTS-1A SAMPLE 74321 (DATA FROM MACDONALD ET AL. (2013B))

This sample was sourced from the Wigunda Formation. In this sample nine discrete age populations were observed (Figure 5E), the most significant population ca. 620-480 Ma zircons contained 18 (36%) of the <10% discordant grains. The next major population of 9 zircons (18%) had ages ranging from ca. 290-240 Ma. The remaining populations ca. 195-85, 803, 970-920, 1170-1100, 1645-1535, 2110-1860 and 2980-2960 Ma contained 8 (16%), 1 (2%), 3 (6%), 3 (6%), 3 (6%), 3 (6%) and 2 (4%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 85±1.9 Ma (Upper Cretaceous, Santonian) and is taken as the maximum depositional age.

### GNARLYKNOTS-1A SAMPLE 74323 (DATA FROM MACDONALD ET AL. (2013B))

This sample was sourced from the Wigunda Formation. In this sample five age populations were observed (Figure 5G), the most significant population ca. 630-510 Ma zircons contained 32 (51.6%) of the <10% discordant grains. The next major population of 23 zircons (37.1%) had ages ranging from ca. 310-95 Ma. The remaining populations ca. 740-705, 1005-885 and 1360 Ma contained 3 (4.8%), 3 (4.8%) and 1 (1.6%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 95.1±2.3 Ma (Upper Cretaceous, Cenomanian) and is taken as the maximum depositional age.

### GNARLYKNOTS-1A SAMPLE 74324 (DATA FROM MACDONALD ET AL. (2013B))

This sample was sourced from the Wigunda Formation. In this sample five age populations were observed (Figure 5H), the most significant population ca. 810-510 Ma zircons contained 34 (54.8%) of the <10% discordant grains. The next major population of 21 zircons (33.9%) had ages ranging from ca. 385-105 Ma. The remaining populations ca. 975-890, 1634 and 2000-1930 Ma contained 4 (6.5%), 1 (1.6%) and 2

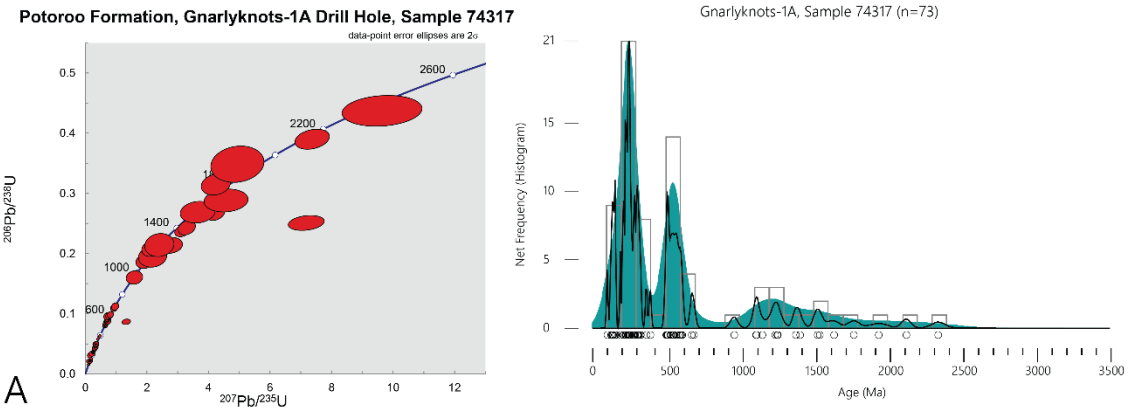
(3.2%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 105.4±5.6 Ma (Lower Cretaceous, Albian) and is taken as the maximum depositional age.

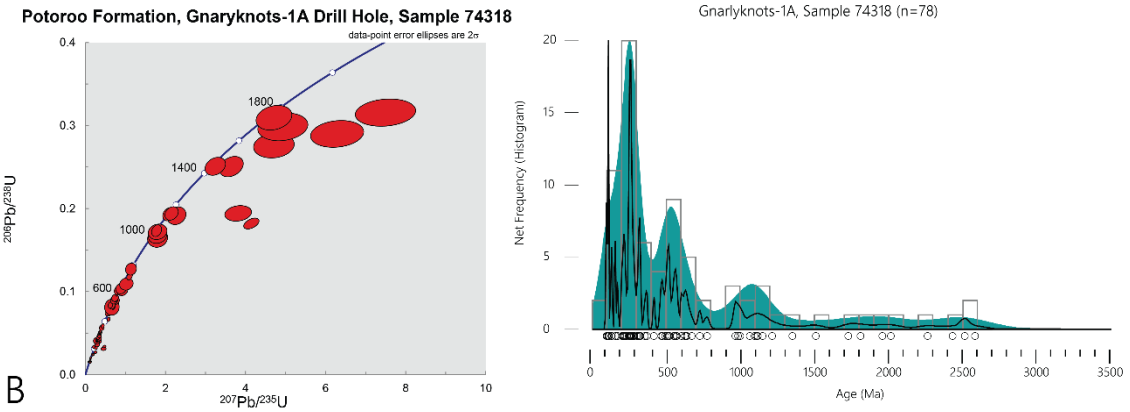
GNARLYKNOTS-1A SAMPLE 74325 (DATA FROM MACDONALD ET AL. (2013B))

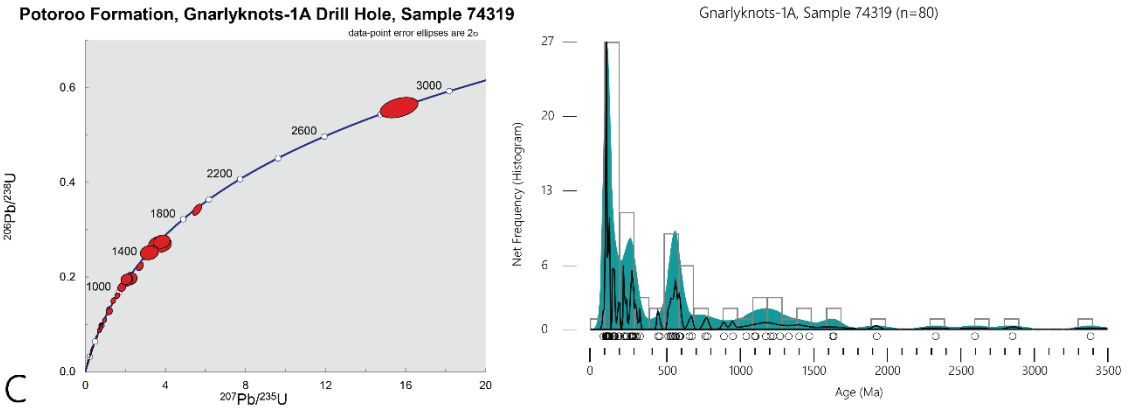
This sample was sourced from the Wigunda Formation. In this sample six discrete age populations were observed (Figure 5I), the two most significant populations 335-235 Ma and 615-525 Ma each contained 12 (26.1%) of the <10% discordant grains. The next major population of 10 zircons (21.7%) had ages ranging from ca. 1280-820 Ma. The remaining two populations' ca. 430 and 2450-1690 Ma contained 1 (2.2%) and 5 (10.9%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 99.3±3.1 Ma (Upper Cretaceous, Cenomanian) and is taken as the maximum depositional age.

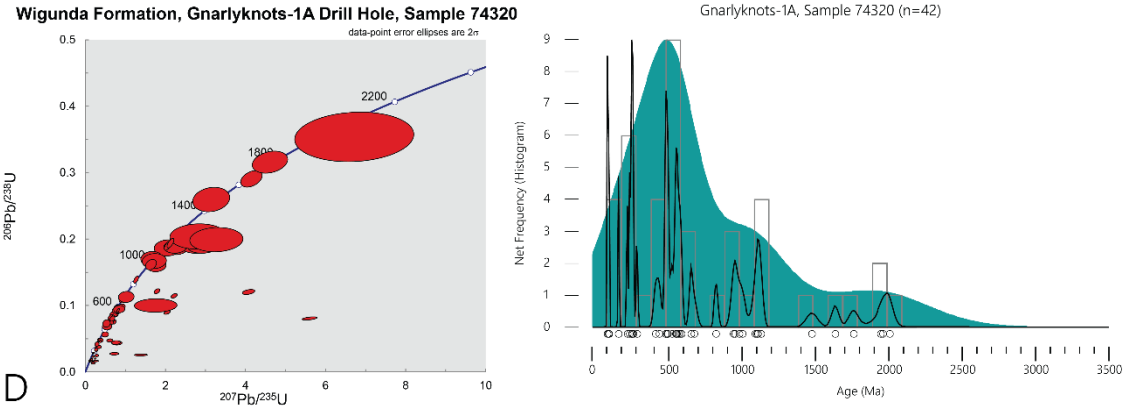
GNARLYKNOTS-1A SAMPLE 74326 (DATA FROM MACDONALD ET AL. (2013B))

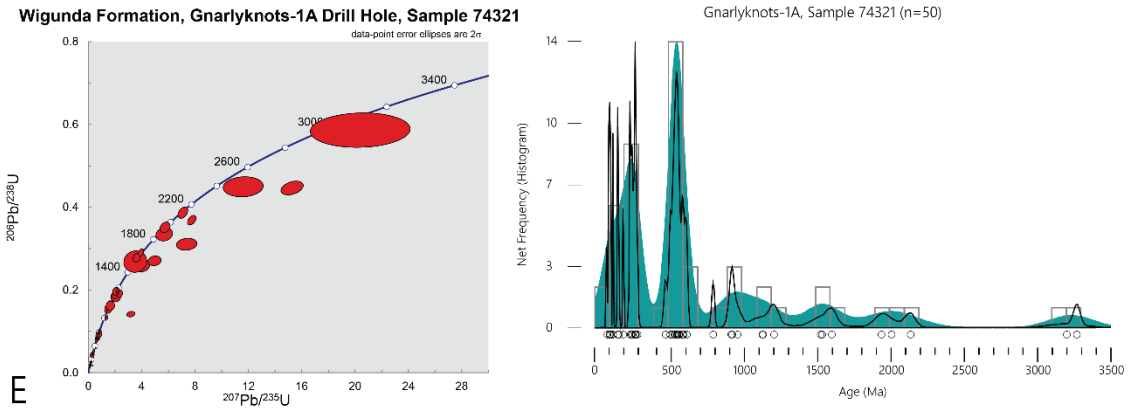
This sample was sourced from the Wigunda Formation. n this sample six discrete age populations were observed (Figure 5J), the most significant population ca. 895-500 Ma zircons contained 29 (42.6%) of the <10% discordant grains. The next major population of 28 zircons (41.2%) had ages ranging from ca. 425-88 Ma. The remaining populations ca. 1260-1120, 1650-1595, 2070-1855 and 2705-2370 Ma contained 2 (2.9%), 3 (4.4%), 3 (4.4%) and 3 (4.4%) zircons respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 88.2±4.5 Ma (Upper Cretaceous, Coniacian) and is taken as the maximum depositional age.


Potoroo Formation, Gnarlyknots-1A Drill Hole, Sample 74317
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
600
1000
1400
2200
2600
A
Gnarlyknots-1A, Sample 74317 (n=73)
Net Frequency (Histogram)
Age (Ma)

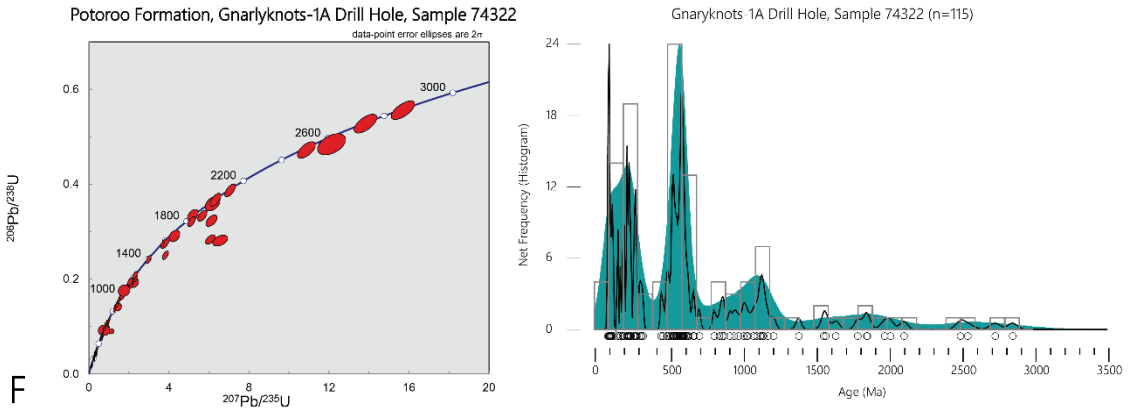

Potoroo Formation, Gnaryknots-1A Drill Hole, Sample 74318
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
600
1000
1400
1800
B
Gnarlyknots-1A, Sample 74318 (n=78)
Net Frequency (Histogram)
Age (Ma)


Potoroo Formation, Gnarlyknots-1A Drill Hole, Sample 74319
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
1000
1400
1800
2200
2600
3000
C
Gnarlyknots-1A, Sample 74319 (n=80)
Net Frequency (Histogram)
Age (Ma)

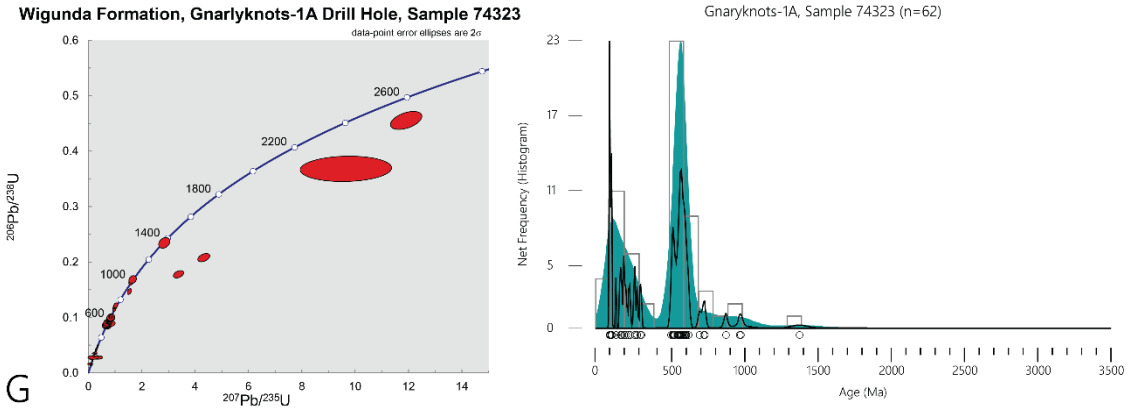

Wigunda Formation, Gnarlyknots-1A Drill Hole, Sample 74320
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
600
1000
1400
1800
2200
D
Gnarlyknots-1A, Sample 74320 (n=42)
Net Frequency (Histogram)
Age (Ma)


Wigunda Formation, Gnarlyknots-1A Drill Hole, Sample 74321
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
3400
3000
2600
2200
1800
1400
Gnarlyknots-1A, Sample 74321 (n=50)
Net Frequency (Histogram)
Age (Ma)

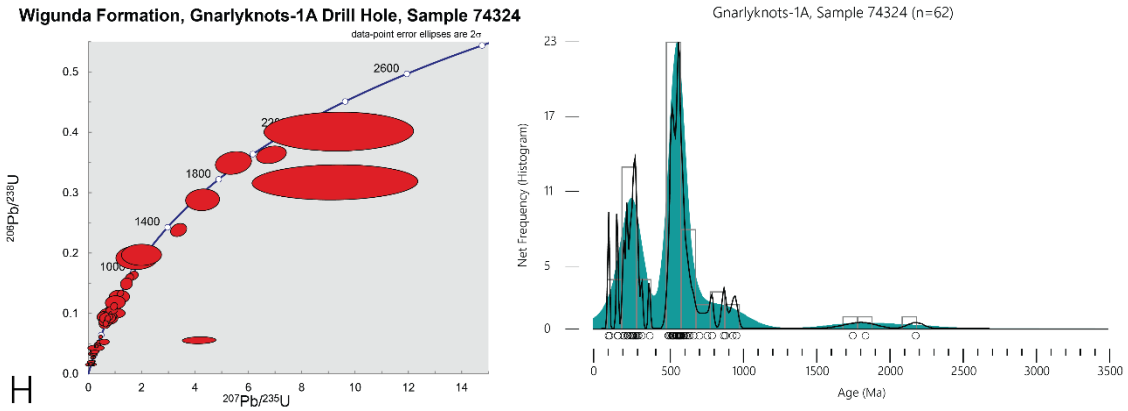
E


Potoroo Formation, Gnarlyknots-1A Drill Hole, Sample 74322
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
3000
2600
2200
1800
1400
1000
Gnaryknots-1A Drill Hole, Sample 74322 (n=115)
Net Frequency (Histogram)
Age (Ma)

F


Wigunda Formation, Gnarlyknots-1A Drill Hole, Sample 74323
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
2600
2200
1800
1400
1000
600
Gnaryknots-1A, Sample 74323 (n=62)
Net Frequency (Histogram)
Age (Ma)

G


Wigunda Formation, Gnarlyknots-1A Drill Hole, Sample 74324
data-point error ellipses are 2σ
206Pb/238U
207Pb/235U
2600
1800
1400
Gnarlyknots-1A, Sample 74324 (n=62)
Net Frequency (Histogram)
Age (Ma)

H

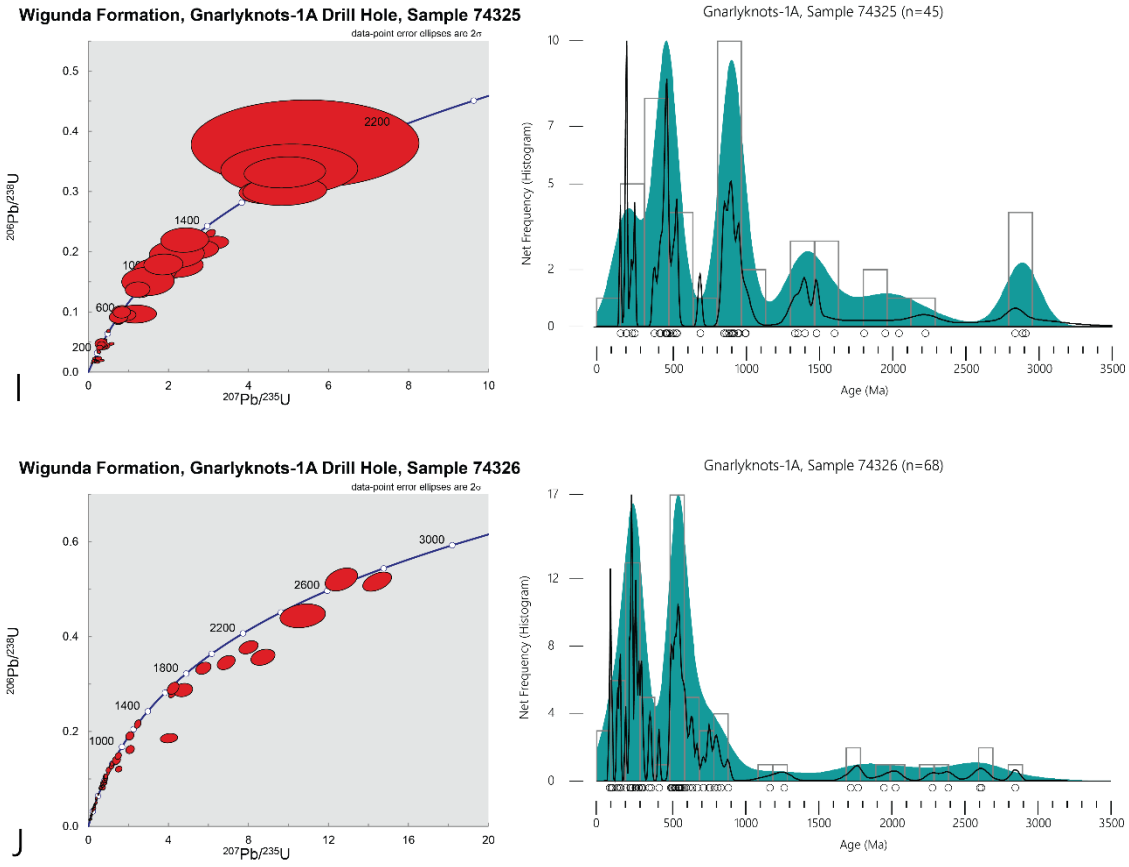



**Figure 5A-J: Uranium-lead Concordia plots showing all data for each Gnarlyknots-1A sample with corresponding kernel density estimate (green shading, adaptive bandwidth), probability density plot (black line) and histogram (grey boxes, net frequency on Y-axis, 100 Ma bin width) using 90-110 concordant data with each datum represented by a black circle on the X-axis.**

## WINTON FORMATION SAMPLES 8622-61 AND 8642-168 (DATA FROM MACDONALD AND HOLFORD PERS. COMM. 2014)

These two samples are sourced from the Winton Formation in western Eromanga basin drill holes, Burley-2 and Dullingari-1.

There were six discrete age populations in sample 8622-61 (Figure 6A). The most significant population ca. 570-205 Ma zircons contained 45 (62.5%) of the <10% discordant grains. The other major population of 12 (16.7%) grains had ages ranging from ca. 2055-1560 Ma. The remaining populations ca. 170-120, 930-790, 1370-1200 and 2700-2300 Ma contained 5 (6.9%), 4 (5.6%), 2 (2.8%) and 4 (5.6%) zircons

respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ grain is 120.3±1.8 Ma (Lower Cretaceous, Aptian) and is taken as the maximum depositional age.

In sample 8642-168, six discrete age populations were identified (Figure 6B). The most significant population ca. 125-90 Ma zircons contained 14 (29.2%) of the <10% discordant grains. The next major population of 13 (27.1%) grains had ages ranging from ca. 700-410 Ma. The remaining populations ca. 380-180, 1260-890, 1611 and 2840 Ma contained 12 (25%), 7 (14.6%), 1 (2.1%) and 1 (2.1%) zircon(s) respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ grain is 94.2±1.7 Ma (Upper Cretaceous, Cenomanian) and is taken as the maximum depositional age.

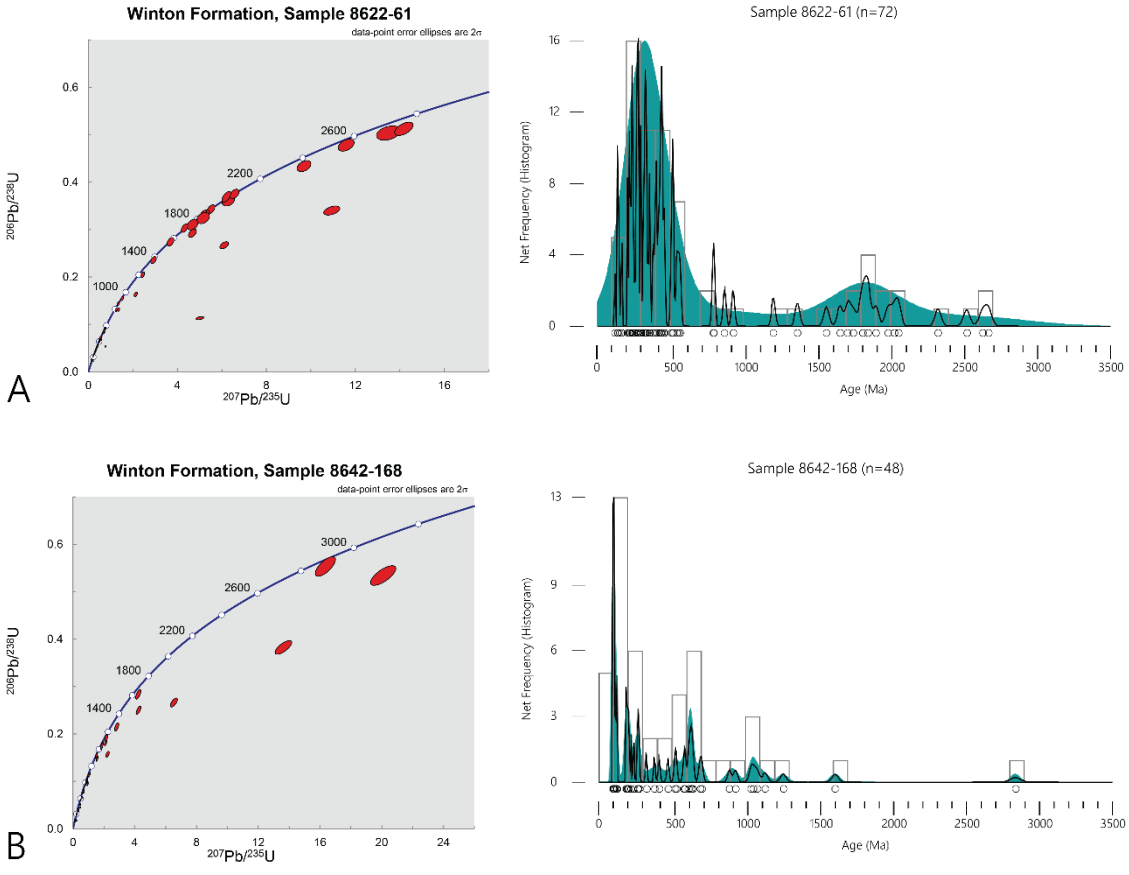



**Figure 6A&B: Uranium-lead Concordia plots showing all data for two western Eromanga basin samples from Dullingari-1 and Burely-2 drill holes with corresponding kernel density estimate (green shading, adaptive bandwidth), probability density plot (black line) and histogram (grey boxes, net frequency on Y-axis, 100 Ma bin width) using 90-110 concordant data with each datum represented by a black circle on the X-axis.**

### EROMANGA-1 (DATA FROM TUCKER ET AL. (2013))

This sample was sourced from the Winton Formation. In the sample seven discrete populations were observed (Figure 7A), the most significant population ca. 170-93 Ma zircons contained 65 (69.1%) of the <10% discordant grains. The next major population of 9 zircons (9.6%) had ages ranging from ca. 2055-1560 Ma. The remaining populations ca. 345-245, 650-500, 1030-830, 1680-1560 and 3340-3050 Ma contained 8 (8.5%), 4 (4.3%), 4 (8.3%), 2 (2.1%) and 2 (2.1%) zircons respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ grain is 93.0±1.1 Ma (Upper Cretaceous, Turonian) and is taken as the maximum depositional age.

### ISISFORD (DATA FROM TUCKER ET AL. (2013))

This sample was sourced from the Winton Formation. In the sample five discrete populations were observed (Figure 7B), the most significant population ca. 125-100 Ma zircons contained 23 (37.7%) of the <10% discordant grains. The next major population of 21 zircons (34.4%) had ages ranging from ca. 295-155 Ma. The remaining populations ca. 720-370, 1210-950 and 3260-2670 Ma contained 8 (13.1%), 5 (8.2%) and 4 (6.6%) zircons respectively. The youngest <10% discordant U238/Pb206 grain is 100.5±1.1 Ma (Upper to Lower Cretaceous, Cenomanian to Albian) and is taken as the maximum depositional age.

### LARK QUARRY CONSERVATION PARK (DATA FROM TUCKER ET AL. (2013))

This sample was sourced from the Winton Formation. In the sample five discrete populations were observed (Figure 7C), the most significant population ca 310-95 Ma zircons contained 36 (70.6%) of the <10% discordant grains. The next major population of 10 zircons (19.6%) had ages ranging from ca. 595-530 Ma. The remaining

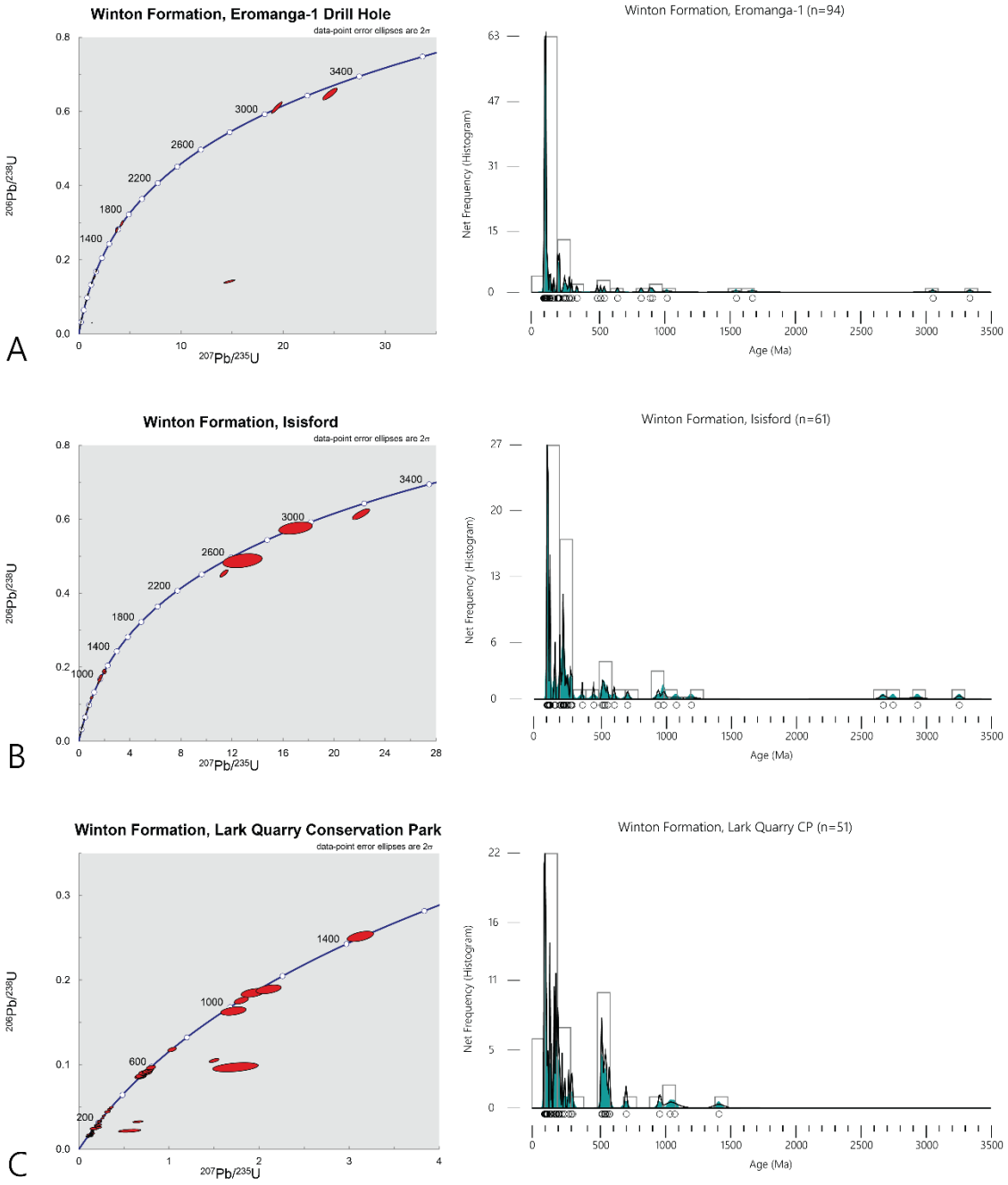
populations ca. 720, 1090-975 and 1430 Ma contained 1 (2%), 3 (5.9%) and 1 (2%) zircon(s) respectively. The youngest <10% discordant U238/Pb206 grain is 96.7±1.3 Ma (Upper Cretaceous, Cenomanian) and is taken as the maximum depositional age.

### BLADENSBURG NATIONAL PARK (DATA FROM TUCKER ET AL. (2013))

This sample was sourced from the Winton Formation. In the sample seven discrete populations were observed (Figure 7D), the most significant population ca. 280-93 Ma zircons contained 51 (66.2%) of the <10% discordant grains. The next major population of 12 zircons (15.6%) had ages ranging from ca. 720-515 Ma. The remaining populations ca. 360-340, 1120-850, 1850-1710, 2500 and 3280 Ma contained 2 (2.6%), 8 (10.4%), 2 (2.6%), 1 (1.3%) and 1 (1.3%) zircon(s) respectively. The youngest <10% discordant U238/Pb206 grain is 93.3±1.2 Ma (Upper Cretaceous, Turonian) and is taken as the maximum depositional age.

### LONGREACH-1 (DATA FROM TUCKER ET AL. (2013))

This sample was sourced from the Mackunda Formation. In the sample eight discrete populations were observed (Figure 7E), the most significant population ca. 290-100 Ma zircons contained 43 (64.2%) of the <10% discordant grains. The next major population of 15 zircons (22.4%) had ages ranging from ca. 730-340 Ma. The remaining populations ca. 890, 1210-1040, 1430, 2260, 2720-2650 and 3060 Ma contained 1 (1.5%), 3 (4.5%), 2 (3.0%), 1 (1.5%), 1 (1.5%) and 1 (1.5%) zircon(s) respectively. The youngest <10% discordant U238/Pb206 grain is 102.5±1.3 Ma (Lower Cretaceous, Albian) and is taken as the maximum depositional age.


A
Winton Formation, Eromanga-1 Drill Hole
data-point error ellipses are 2σ
$^{206}Pb/^{238}U$
$^{207}Pb/^{235}U$
3400
3000
2600
2200
1800
1400
Winton Formation, Eromanga-1 (n=94)
Net Frequency (Histogram)
Age (Ma)
B
Winton Formation, Isisford
data-point error ellipses are 2σ
3400
3000
2600
2200
1800
1400
1000
Winton Formation, Isisford (n=61)
Net Frequency (Histogram)
Age (Ma)
C
Winton Formation, Lark Quarry Conservation Park
data-point error ellipses are 2σ
1400
1000
600
200
Winton Formation, Lark Quarry CP (n=51)
Net Frequency (Histogram)
Age (Ma)

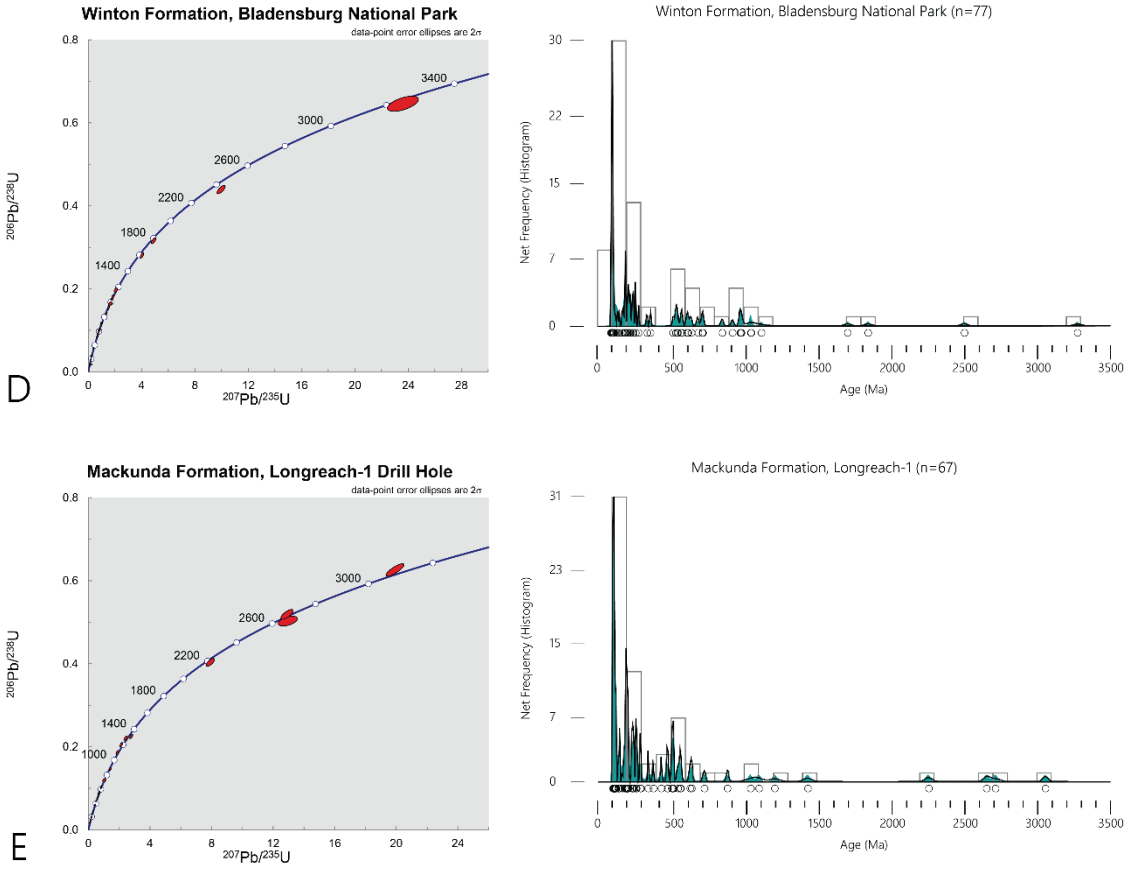



**Figure 7A-E: Uranium-lead Concordia plots showing all data for five central and eastern Eromanga basin samples with corresponding kernel density estimate (green shading, adaptive bandwidth), probability density plot (black line) and histogram (grey boxes, net frequency on Y-axis, 100 Ma bin width) using 90-110 concordant data with each datum represented by a black circle on the X-axis.**

## HUGHES-2 SAMPLE 1069106 (DATA FROM MACDONALD AND HOLFORD PERS. COMM. 2014)

This sample was sourced from the Loongana Formation of the Bight Basin, age of formation, Valanginian to Hauterivian (Hill 1991), so significantly older than the previous samples. In this dataset two discrete populations were observed (Figure 8A), the most significant population ca. 1310-1075 Ma zircons contained 55 (90.2%) of the <10% discordant grains. The other population of 6 zircons (9.8%) had ages ranging from ca. 1755-1540 Ma. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 1076.4±21.4 Ma (Mesoproterozoic, Stenian) and is taken as the maximum depositional age. This is significantly older than the depositional age of the formation.

## HUGHES-2 SAMPLE 1069111 (DATA FROM MACDONALD AND HOLFORD PERS. COMM. 2014)

This sample was also sourced from the Valanginian to Hauterivian Loongana Formation (Hill 1991). In the dataset three discrete populations were observed (Figure 8B), the most significant population ca. 1330-1025 Ma zircons contained 43 (62.3%) of the <10% discordant grains. The other major population of 25 zircons (62.3%) had ages ranging from ca. 1800-1425 Ma. The final population contained only one <10% discordant grain aged 681±12.6 Ma (Neoproterozoic, Cryogenian). This was also the youngest <10% discordant $U^{238}/Pb^{206}$ age and is taken as the maximum depositional age. This is still significantly older than the age of formation.

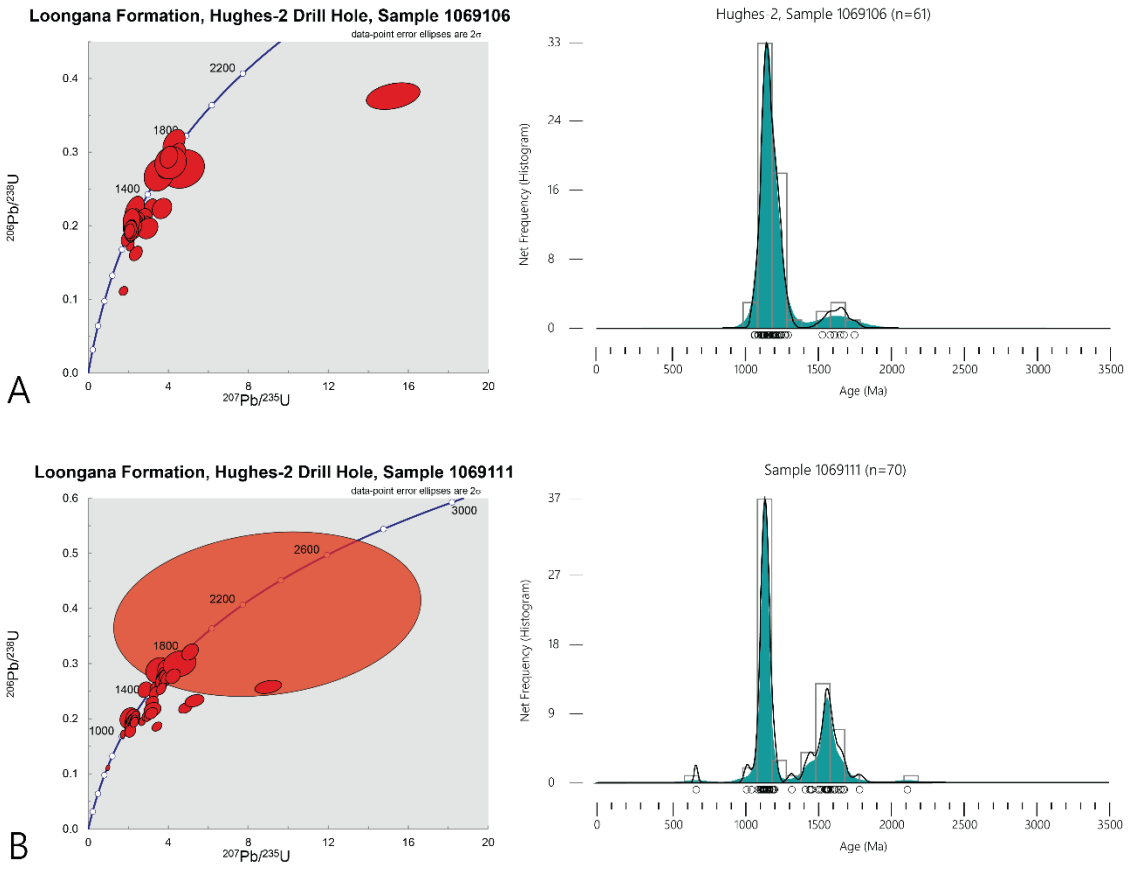



**Figure 8A&B: Uranium-lead Concordia plots showing all data for Hughes-2 drill hole samples 109106 and 1069111 with corresponding kernel density estimate (green shading, adaptive bandwidth), probability density plot (black line) and histogram (grey boxes, net frequency on Y-axis, 100 Ma bin width) using 90-110 concordant data with each datum represented by a black circle on the X-axis.**

## New U-Pb Data

### GNARLYKNOTS-1A SAMPLE 74322

Additional data were collected from Gnarlyknots-1A sample 74322 to expand the U-Pb and hafnium datasets for Gnarlyknots-1A. This particular sample was deemed most suitable for this purpose as the images were of higher quality than any other Gnarlyknots-1A sample. A further 55 U-Pb data were acquired with 53 of these being ±10% concordant (Figure 9A). These data were added to the existing U-Pb dataset (Figure 9B) from MacDonald et al. (2013b) for Gnarlykonts-1A sample 74322 (Figure 5F). This sample was sourced from the Turonian to Santonian Wigunda Formation. Using the complete dataset for sample 74322, six discrete age populations were identified (Figure 5F). The most significant population ca. 715-455 Ma zircons contained 42 (35.9%) of the <10% discordant grains. The next major population of 40 zircons (34.2%) had ages ranging from ca. 330-90 Ma. The remaining populations ca. 1220-815, 1650-1395, 2110-1795 and 2850-2495 Ma contained 20 (17.1%), 4 (3.4%), 7 (6.0%) and 4 (3.4%) zircons respectively. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 91.3±3.2 Ma (Upper Cretaceous, Turonian) and is taken as the maximum depositional age.

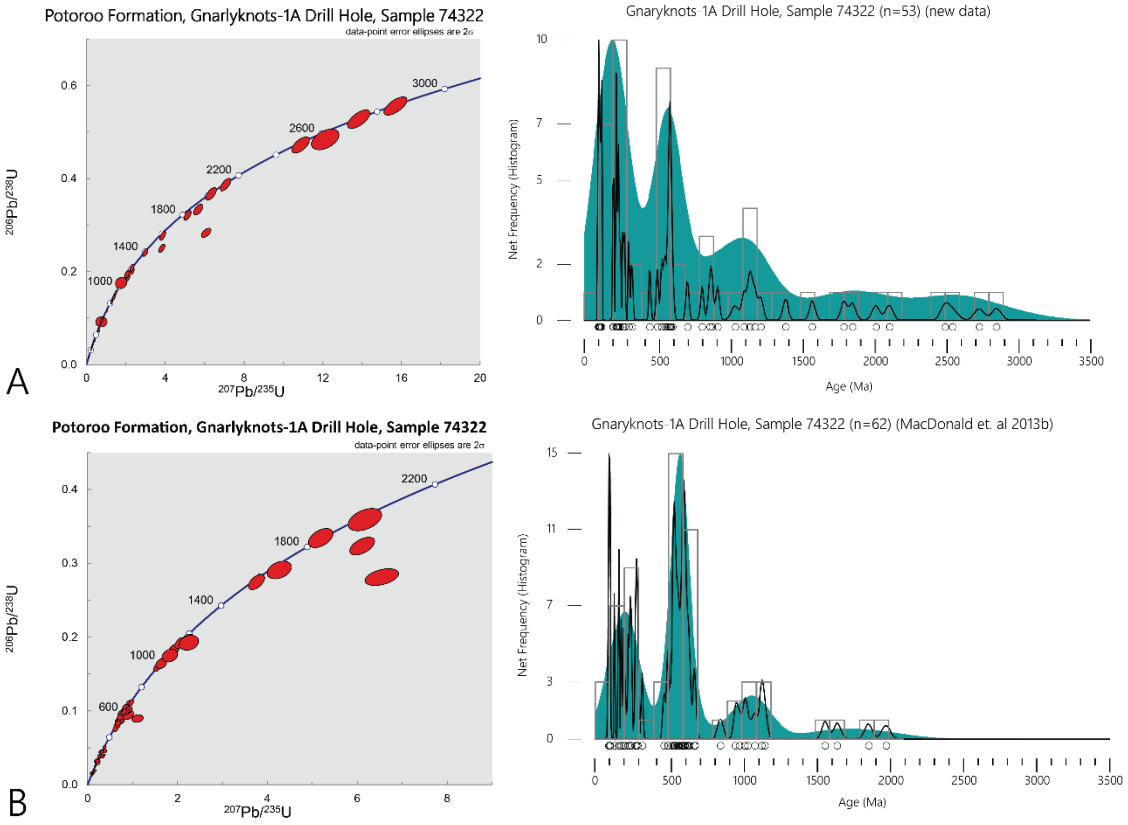



**Figure 9A&B: Uranium-lead Concordia plots showing new uranium-lead data (A) and previous data from MacDonald et al. (2013b) (B) for Gnarlyknots-1A sample 74322 with corresponding kernel density estimate (green shading, adaptive bandwidth), probability density plot (black line) and histogram (grey boxes, net frequency on Y-axis, 100 Ma bin width) using 90-110 concordant data with each datum represented by a black circle on the X-axis.**

## HUGHES-2 SAMPLE 106988

A total of 62 U-Pb data were acquired from the Hughes-2 sample 106988, with 58 of these being ±10% concordant. The youngest <10% discordant $U^{238}/Pb^{206}$ age is 1048.9±15.2 Ma (Mesoproterozoic, Stenian) and is taken as the maximum depositional age. Two distinct populations of zircons, shown in Figure 10, are present in the sample. The major population comprising 47 (81%) of ±10% concordant zircons ranges in ages ca. 1330-1040 Ma. The second population, comprising of 11 (19%) of ±10% concordant zircons ranges in ages ca. 1780-1500 Ma. These Mesoproterozoic to Paleoproterozoic zircons are significantly older than the Valanginian to Hauterivian age of the Loongana formation, (Hill 1991), from where this sample was sourced.

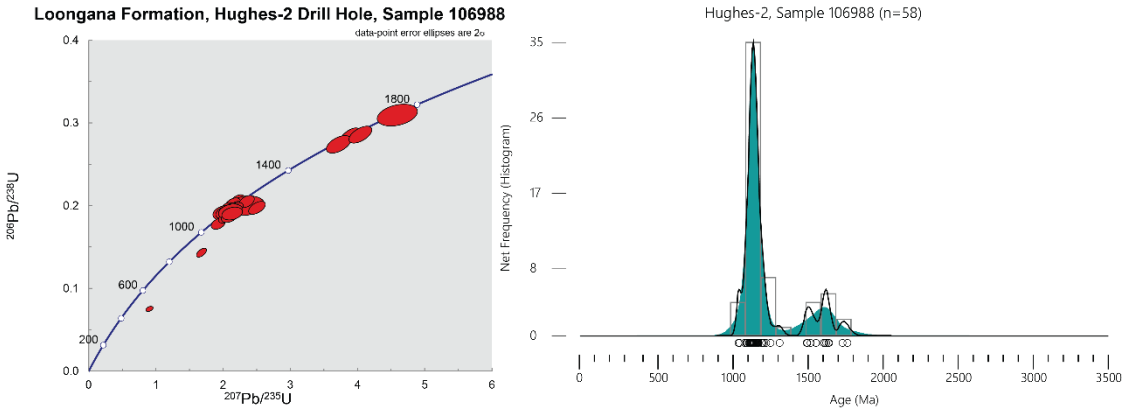



**Figure 10: Uranium-lead Concordia plots showing all data for Hughes-2 sample 106988 with corresponding kernel density estimate (green shading, adaptive bandwidth), probability density plot (black line) and histogram (grey boxes, net frequency on Y-axis, 100 Ma bin width) using 90-110 concordant data with each datum represented by a black circle on the X-axis.**

## Gnarlyknots-1A Hafnium Analyses

Corrected εHf values from Gnarlyknots-1A are given in Figure 11, isotope ratios were taken from samples 74318, 74319, 74321, 74322, 74323 and 74326. There were large variances in age corrected εHf values ranging from highly evolved (-46.4) to very juvenile (+19.9). There are distinct and diffuse populations in the dataset that correspond to the uranium-lead age populations, and in a number of cases, distinguish between similar-aged populations.

With one exception, all 3000-2300 Ma zircons show negative εHf values indicating an evolved source for those zircons. One zircon in this age, ~2859 Ma, shows a highly positive εHf value, indicating a juvenile source. There is a general trend of less negative values with increasing age in this population. Epsilon Hf values range from -19.6 to +9.1.

A second population ca. 2000-1400 Ma shows a general trend of increasingly negative values corresponding with increasing age. Epsilon Hf values range from juvenile (+7.4) to evolved (-8.4).

Late Mesoproterozoic zircons (ca. 1260-1080 Ma) show two subpopulations. One population at ca. 1100 Ma includes zircons with moderately evolved εHf values (-6.7 to

-5.0). The second coeval population is characterised by εHf values spanning zero (-1.5 to +1.9). This may indicate two different zircon sources. One zircon (~1139 Ma) has an εHf value of +11.7 indicating a highly juvenile source.

Zircons spanning the Mesoproterozoic-Neoproterozoic boundary, between ca. 1030-895 Ma, show generally positive εHf values, indicating a juvenile source; however, there are two evolved zircons. Epsilon Hf values range from -9.6 to +19.7 although most values lie between -1.8 and +9.3.

There is a large Neoproterozoic to Palaeozoic population between ca. 800-450 Ma. These involve 60 analyses and make up 40% of the analysed zircons. The older zircons in this population (ca. 800-650 Ma) span the zero εHf line, broadly between +5 and -3. After ~650 and until ~455 Ma many zircons show a vertical spread between ca. +2.1 and highly evolved values down to -17.5. There is also a smaller population ca. 570-513 Ma with highly negative (-28 to -23.3).

Silurian and Devonian zircons are absent, but Carboniferous to Lower Jurassic zircons (ca. 360-180 Ma) form two distinct εHf populations. An evolved population (εHf -13.3 to -3) occurs with ca. 360-180 Ma zircons. A second population overlapping in age (ca. 320-200 Ma), but generally younger than the previous population, has moderately juvenile εHf values range from -0.6 to +8.5 with most falling between +3 and +8.5.

A final population of Lower Jurassic to Cretaceous zircons (ca. 180-95 Ma) contains moderate to highly juvenile εHf values (+4.3 to +12.8). Within this population a tight grouping (approx. 74%) of juvenile zircons occur between ~130 Ma and ~95 Ma.

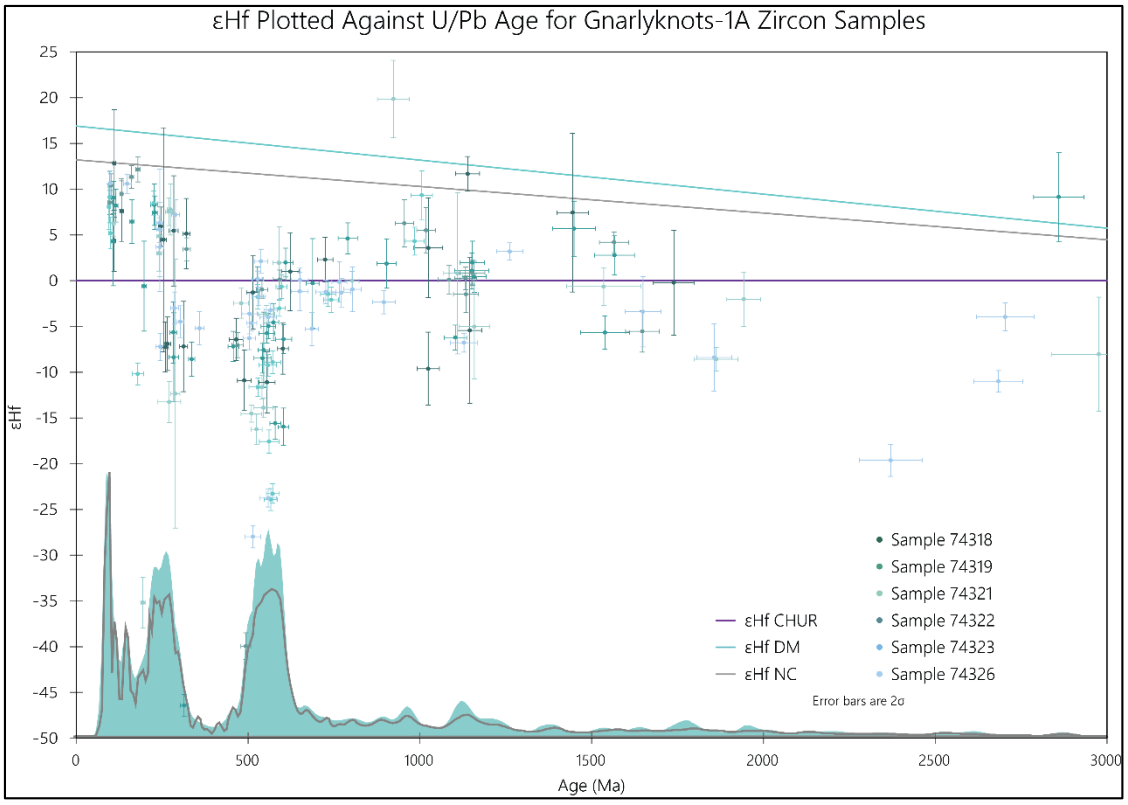



**Figure 11: Plot showing epsilon hafnium in relation to uranium-lead age of Gnarlyknots-1A zircon samples. A chondritic uniform reservoir reference line (purple) plots along (x, 0), the epsilon hafnium depleted mantle line (aqua) shows the modelled mantle epsilon hafnium values and the epsilon hafnium new crust line (grey) shows the new epsilon hafnium mantle model values as suggested by Dhuime et al. (2011). The epsilon hafnium values provide information about the material that melted to form the magma from which the zircon crystallised. Negative epsilon hafnium values indicate involvement of existing continental crust in magma genesis; conversely positive epsilon hafnium values indicate the source had experienced a prior depletion event. Data points below the chondritic uniform reservoir are considered evolved, above the depleted mantle are highly depleted and between the chondritic uniform reservoir and depleted mantle are considered juvenile. The kernel density estimate (green shaded area) and probability density plot (black solid line) are overlain for visual correlation of zircon populations.**

# DISCUSSION

## Maximum Depositional Ages

The oldest sedimentary rocks analysed were from the Lower Cretaceous Loongana Formation (ca. 139-129 Ma) in the Hughes-2 core. Two of the three Hughes-2 samples, 1069106 and 106988, had Stenian maximum depositional ages, 1076 ± 21 and 1049 ± 15 Ma respectively. The final Hughes-2 sample, 1069111 had a Cryogenian maximum depositional age of 681 ± 13 Ma. These are significantly older than any other analysed

sample maximum depositional ages, and much older than the actual depositional age. These are shown in Figure 12A.

The next oldest sample, which borders the Upper and Lower Cretaceous boundary (ca. 100-97 Ma), was the Mackunda Formation from the Longreach-1 core. The maximum depositonal age of this sample was 102.5±1.3 Ma (Figure 12B).

Samples from the stratigraphically younger and overlying (see Figure 4) Turonian to late Albian (ca 7-90 Ma) Winton Formation were the next oldest. The two western Eromanga samples had maximum depositional ages of 120.3±1.8 and 94.2±1.7 Ma. The eastern samples (Tucker et al. 2013) had maximum depositional ages of 100.5±1.1, 96.7±1.3, 93.3±1.2 and 93.0±1.1 for samples Isisford, Lark Quarry Conservation Park, Bladensburg National Park and Eromanga-1 respectively. These are shown in Figure 12B.

The youngest formations, the Wigunda and Potoroo Formations from Gnarlyknots-1A have relatively consistent depositional ages, particularly when considering their two sigma errors. There is a very slight trend of decreasing maximum depositional age with increasing depth (as shown in Figure 12D); however, this trend is not well defined and further, accurate sampling is necessary to confirm or deny this trend. The maximum depositional ages from the stratigraphically oldest sample to the youngest are 88.2±4.5, 99.3±3.1, 105.4±5.6, ±95.1±2.3, 91.3±3.2, 85±1.9, 101.6±1.7, 100.6±2.4, 98.9±2 and 103.5±4.7 Ma for Gnarlyknots-1A samples 74326, 74325, 74324, 74323, 74322, 74321, 74320, 74319, 74318 and 74317 respectively. These are shown in Figure 12C.

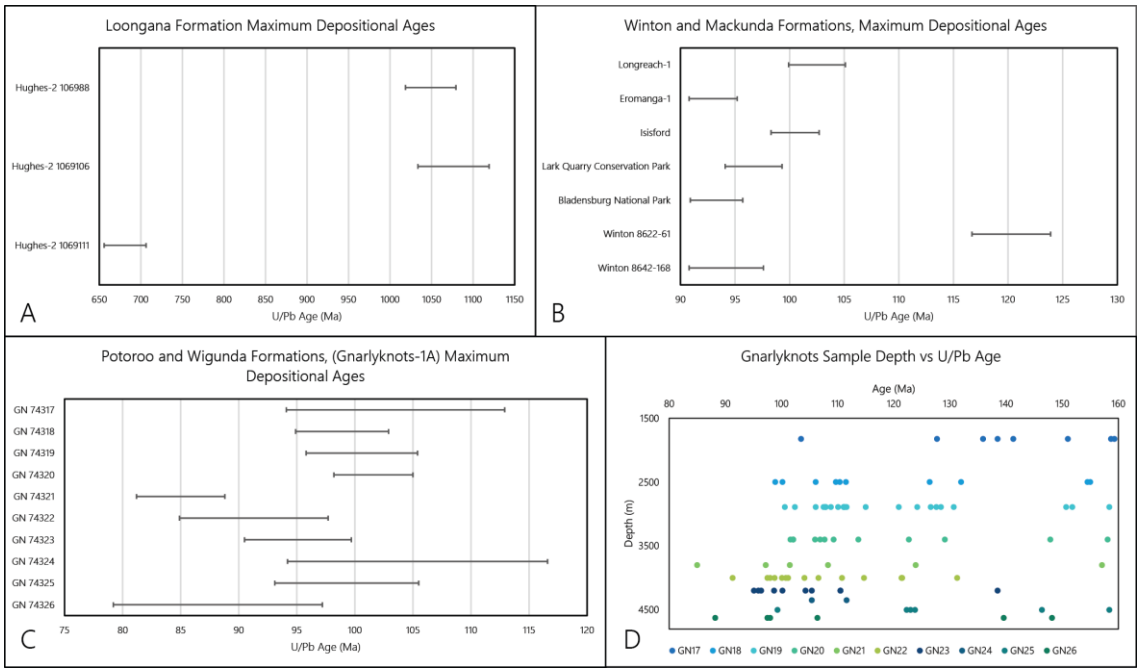



**Figure 12 A-D: Maximum depositional ages determined by the youngest near concordant $U^{238}/Pb^{206}$ age errors plotted at the 2σ level, for: (A) Mackunda Formation (Longreach-1), and Winton Formation, (B) Loongana Formation from Hughes-2 and (C) Potoroo Formation (GN 74317-74319) and Wigunda Formation (GN 74320-74326). A slight trend of decreasing age (using only <160 Ma, <10% discordant zircons) with increasing sample depth for the Gnarlyknots-1A samples is shown in (D). This suggests progressive erosion of a normally layered sedimentary succession.**

## U-Pb Age Provenance of the Cretaceous in South Australia

The detrital zircon age spectra of all three Loongana Formation samples from Hughes-2 are essentially identical (Figure 8 and Figure 10). With the exception of sample 1069111 having a small peak at ~680 Ma, two peaks are present in each sample, a major, acute peak between ~1200 and ~1100 Ma, and a second broad peak between

~1700 and ~1400 Ma. Figure 13 is a composite plot showing all near concordant data for the Loongana Formation samples.

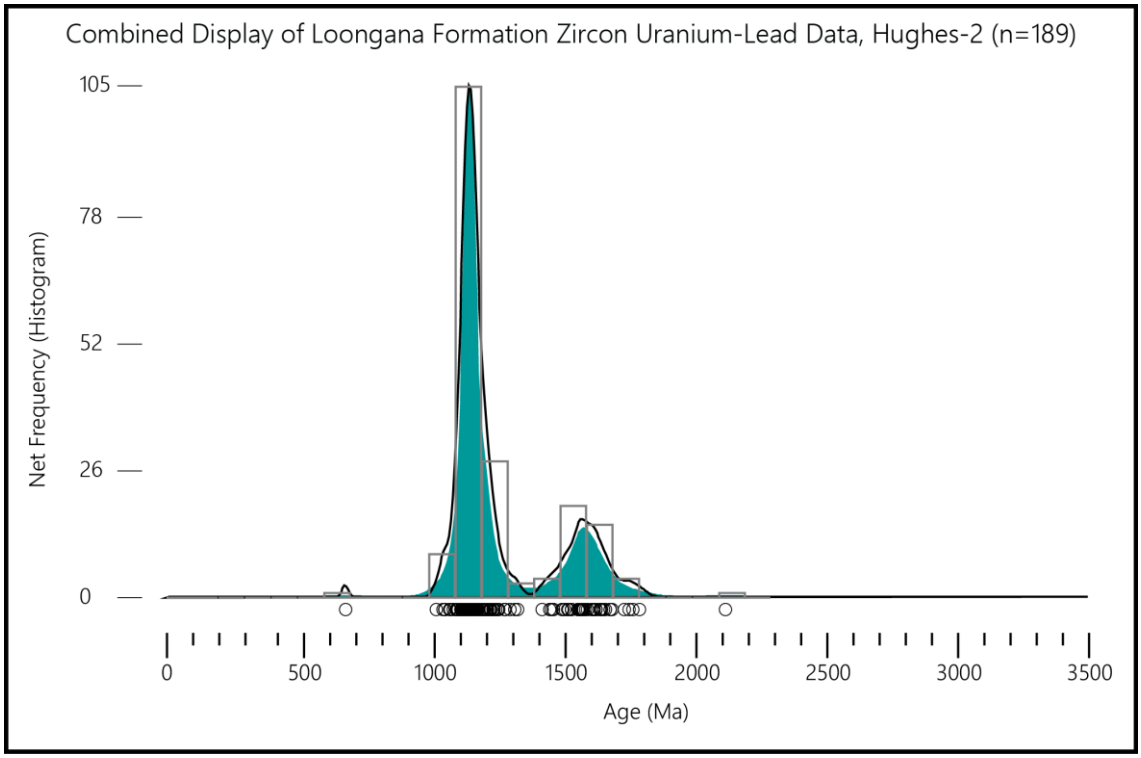



**Figure 13: Combined display of zircon uranium-lead ages for Hughes-2, Bight Basin, showing histogram (grey rectangles, net frequency shown on Y-axis, bin-width of 100), kernel density estimate (green shading, adaptive bandwidth) and probability distribution plot (black line). Each datum is represented by a black circle on the X-axis.**

The ca. 1700-1400 Ma zircons may be sourced from the Mount Painter Province. Data from Kromkhun et al. (2013) shows the same bimodal peak for igneous intrusions of the Mount Painter Province. These may also be sourced from the Musgrave Province as the ages are similar to those presented by Wade et al. (2006). Future hafnium analysis on the Hughes-2 samples will aid an accurate determination of source region. The ca. 1200-1100 Ma population is likely sourced from the Musgrave Province with an age population similar to that presented by Smithies et al. (2011).

The provenance of the Winton (and Mackunda) Formation has been recently investigated in detail by Tucker (2014) . The results obtained in this study agree with their findings. Almost all of the Winton Formation age spectra are essentially identical

and are thus collectively described with the exception of Winton 8622-61 which shows a more similar spectra to that of the Mackunda Formation presented by Tucker (2014). Figure 14 is a composite plot of all Winton Formation samples, excluding Winton 8622-61.

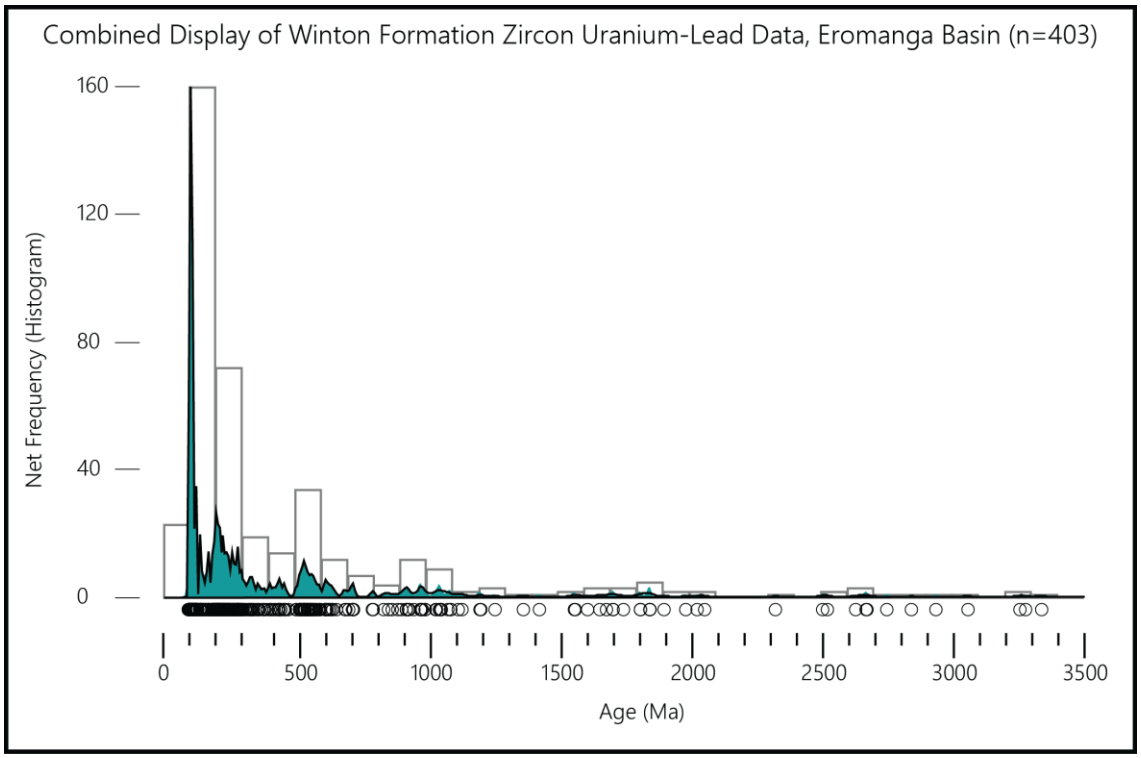



**Figure 14: Combined display of zircon uranium-lead ages for Winton Formation samples, showing histogram (grey rectangles, net frequency shown on Y-axis, bin-width of 100), kernel density estimate (green shading, adaptive bandwidth) and probability distribution plot (black line). Each datum is represented by a black circle on the X-axis**

Few Archean zircons are present, which fits with the limited Archean in NE Australia. It is plausible that these zircons are sourced from the west and southwestern Archean terranes including the Gawler Craton. The Proterozoic populations are generally small, with concentrations around ca. 2000-1500 Ma and 1200-800 Ma. These Proterozoic grains are likely to have several sources including the Musgrave Province, the Georgetown and Mount Isa Inliers. Paleozoic zircons are significantly more abundant than both Archean and Proterozoic zircons. Population density generally increases toward the Permian, with a significant peak during the Late Cambrian while Ordovician

to Silurian grains are less abundant. The Cambrian to Devonian grains are likely sourced locally from areas including the Charters Towers Province, Anakie Province and the Macrossan and Pama Igneous bodies. Carboniferous to Permian zircons become more prevalent and are plausibly sourced from the New England Fold Belt and Kennedy Igneous Province (Bryan et al. 2004). Mesozoic zircons are the most populous in the Winton Formation with Cretaceous grains being more abundant than the Triassic and Jurassic zircons. Tucker (2014) stated that there is no known source terrane within Queensland or eastern Australia for the Jurassic and Late Triassic populations; however, Li et al. (2012) demonstrated granite crystallisation ages down to ca. 217 Ma in the region. The Cretaceous zircons are interpreted to be sourced from the Whitsunday Volcanic Province (Bryan et al. 2000, Bryan et al. 2012, Tucker 2014).

Regardless of stratigraphic age and sample depth, all ten samples from Gnarlyknots-1A show no discernible differences in age spectra and can be considered similar, thus a composite plot (Figure 15) showing all concordant Gnarlyknots-1A is suitable for provenance analysis.

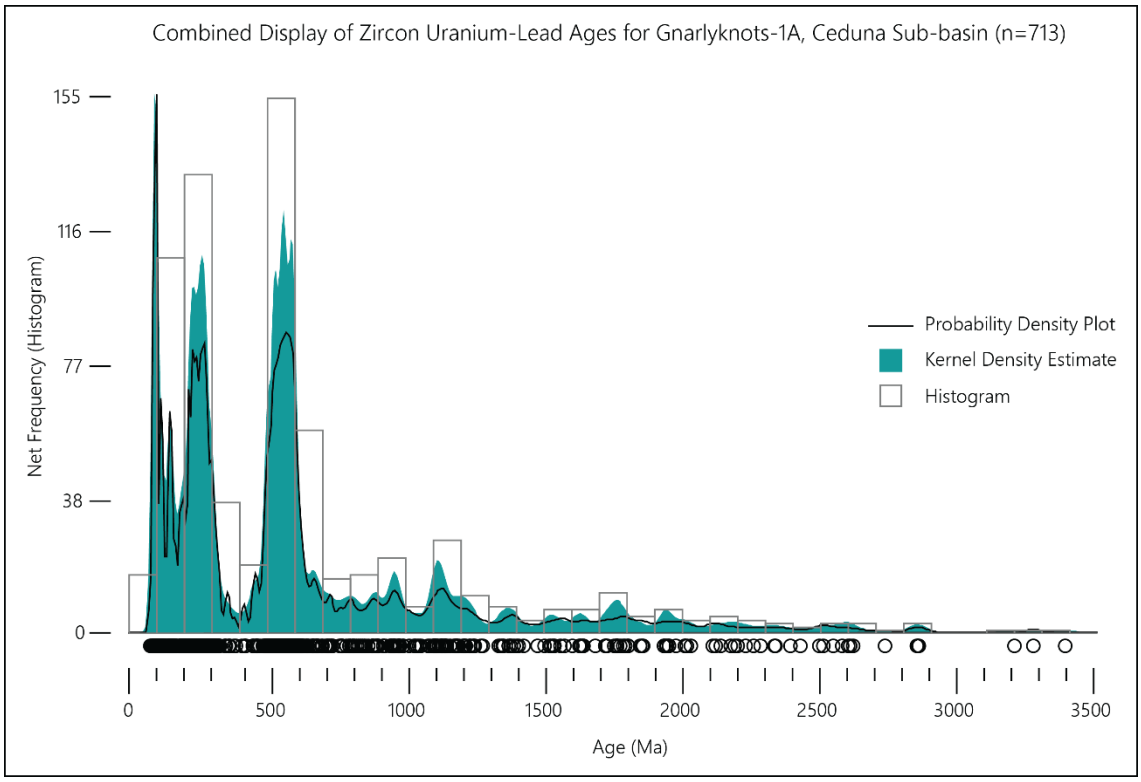



**Figure 15: Combined display of zircon uranium-lead ages for Gnarlyknots-1A, Ceduna Sub-basin, showing histogram (grey rectangles, net frequency shown on Y-axis, bin-width of 100), kernel density estimate (green shading, adaptive bandwidth) and probability distribution plot (black line). Each datum is represented by a black circle on the X-axis.**

The oldest population (>2 Ga) of zircons is plausibly sourced from the local Archean Gawler Craton. Late Paleoproterozoic to Mesoproterozoic (~1800-1000 Ma) zircons have several plausible sources including the Mount Isa Inlier, Mount Painter and Musgrave Provinces. The younger ca. 1200-1100 peak is most likely sourced from the Musgrave Province (Wade et al. 2006, Smithies et al. 2011, Kirkland et al. 2013), as is the near 1400 Ma peak. The ca. 1600-1500 Ma peak may be sourced from any or all of the, Musgrave Province, Mount Painter Province, and/or the Mount Isa Inlier, further characterisation via geochemistry is needed to distinguish between the sources. The ca. 1700 Ma and older zircons are more likely sourced from the Mount Isa Inlier, Arunta Province or Gawler Craton. The Tonian to Cryogenian (1000-635 Ma) zircons are somewhat perplexing as there is no well documented source for these zircons in Australia. As mentioned by Reid et al. (2009) there are isolated samples from around

Australia that may account for the ca. 975-950 peak; however, it still leaves a significant age period unaccounted for. It is possible that these zircons are from Antarctica as these ages have been reported in multiple studies (Veevers and Saeed 2008, Veevers and Saeed 2011, Veevers and Saeed 2013).

The large peak in the Ediacaran to Silurian is most likely from the Delamerian and/or Lachlan Orogens (Gray and Foster 2004, Reid et al. 2009). The Carboniferous-Triassic population is most likely sourced from the northern New England Orogen (Bryan et al. 2004). The Cretaceous population is the most significant. It shows the same distinct peak as the Winton Formation, thus suggesting it is originally from the Whitsunday Volcanic Province as has been suggested by numerous studies (Veevers 2000, Bryan et al. 2012, Tucker 2014). The dominant peak is ~110 Ma, this coincides with the main pulse of volcanic activity reported by Bryan et al. (1997) for the Whitsunday Volcanic Province.

### Hafnium Isoptic Constraints on the Provenance of the Ceduna Sub-Basin

In addition to U-Pb data, hafnium isoptic data was collected on Gnarlyknots-1A samples. This was collected to help aid in the determination of provenance, which can, if only using U-Pb data, be problematic as multiple (but not necessarily related) terranes can show the same zircon age spectra. The use of hafnium isotope data allows for a complimentary dataset to be used to refine or delineate source regions. It may make it possible to differentiate between terranes with similar age zircons, but have different hafnium signatures. Corrected epsilon hafnium data was presented in Figure 11 and described in detail. In addition to this, several trends occur in the dataset. Once noticeable and common trend throughout rocks from eastern Australia, is that the

population 800-450 Ma has continuous εHf values ranging from +4.6 to -39.9 indicating increasing source evolution over decreasing age.

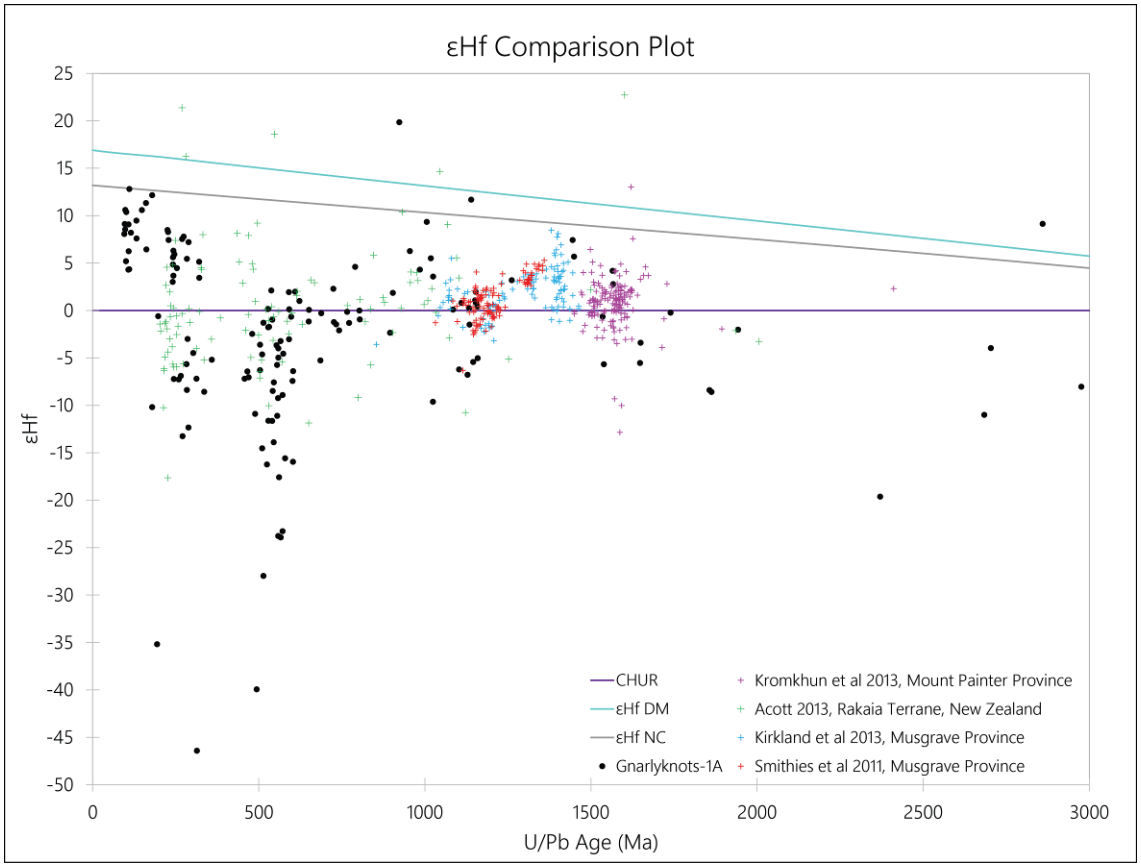



**Figure 16: Corrected εHf values for Gnarlyknots-1A, the Rakaia Terrane in New Zealand (Acott 2013), the Musgrave Province (Smithies et al. 2011, Kirkland et al. 2013) and the Mount Painter Province (Kromkhun et al. 2013).**

Figure 16 shows the corrected εHf values for several the Rakaia Terrane of New Zealand, Musgrave Province and Mount Painter Province. The similarity of the older Rakaia Terrane to the Gnarlyknots data suggests a central source for both terranes. Acott (2013) suggested several eastern Australian terranes as potential source regions for the detrital zircons in his study. The near 1500 Ma Gnarlyknots population shows a very similar to the Mount Painter Province; however, zircons of this age have been reported by previous studies (Wade et al. 2006) and should be further investigated, The ca. 1100 Ma population shows high similarity to that of the Musgrave Province. Notably both the Musgrave and Mount Painter Provinces show similar hafnium

signatures and form a near continuous dataset from ca.1600 to ca. 1100. Although the data is not shown on Figure 16, the Mount Isa Inlier (Griffin et al. 2006), the New England Orogen (Tucker 2014) and Cretaceous zircons of the Winton Formation (Tucker 2014) all coincide with hafnium signatures at ca. 1800 Ma, ca. 300-200 Ma and ca. 150-100 Ma respectively. These additional data provide further supporting evidence that the detrital zircons found in the Upper Ceduna Delta lobe are sourced from the Australian Eastern Highlands as proposed by (Veevers 2000, King and Mee 2004).

From both U-Pb age data and hafnium isotopic data it can be argued that the sediments of the Upper Ceduna Delta lobe are sourced from a multitude of terranes, and in particular many terranes from the Eastern Australian Highlands, whilst incorporating detritus from more proximal sources along its catchment path. It is thus probable that at least the Upper (and possibly Lower) Ceduna Delta lobe is the result of a continent scale "Ceduna River".

## CONCLUSIONS

This study has investigated the source of the Upper Ceduna Delta sedimentary rocks using U-Pb age and hafnium isoptic data. It has been shown that the upper lobe is sourced from the Australian Eastern Highlands, and in particular having origins in the Whitsunday Volcanic Province, most likely by a continent scale river system as originally proposed. The limitations using age only provenance was shown and the use of hafnium as a complimentary dataset has been shown to provide integral information in more accurately determining a source terrane.

**ACKNOWLEDGMENTS**

I would like to thank my supervisors, Professor Alan Collins and Dr Stijn Glorie for their support and guidance throughout the year, particularly in the final weeks of the project. I thank the Geological Survey of South Australia for financial sponsorship of the project; I hope that this work will prove useful in future.
I would also like to thank Dr Justin Payne for his help with hafnium isotope analysis Dr Simon Holford for his assistance throughout the year and Aoife McFadden from Adelaide Microscopy for training me in use of the LA-ICP-MS for U-Pb age analysis. Finally, I would like to thank both Dr Katie Howard and Dr Rosalind King for their support throughout the year.

## REFERENCES

"SHELL" 1975 Potoroo-1 Well Completion Report. pp. 147. Shell Development (Australia) Pty Ltd.

ACOTT J. C. R. 2013 New Zealand where did it come from? Provenance of the Rakaia Terrane. Honours Thesis, University of Adelaide.

ALLEY N. F., SHEARD M. J., WHITE M. R. & KRIEG G. W. 2011 The Sedimentology and Stratigraphic Significance of Cretaceous Sediments at Mt Howie, NE South Australia, *Transactions of the Royal Society of South Australia,* **135**, p. 12-25.

BRYAN S. E., CONSTANTINE A. E., STEPHENS C. J., EWART A., SCHÖN R. W. & PARIANOS J. 1997 Early Cretaceous volcano-sedimentary successions along the eastern Australian continental margin: Implications for the break-up of eastern Gondwana, *Earth and Planetary Science Letters,* **153**, p. 85-102.

BRYAN S. E., EWART A., STEPHENS C. J., PARIANOS J. & DOWNES P. J. 2000 The Whitsunday Volcanic Province, Central Queensland, Australia: lithological and stratigraphic investigations of a silicic-domininated large igenous province, *Journal of Volcanology and Geothermal Research,* **99**, p. 57-88.

BRYAN S. E., ALLEN C. M., HOLCOMBE R. J. & FIELDING C. R. 2004 U–Pb zircon geochronology of Late Devonian to Early Carboniferous extension-related silicic volcanism in the northern New England Fold Belt, *Australian Journal of Earth Sciences,* **51**, p. 645-664.

BRYAN S. E., COOK A., ALLEN C. M., SIEGEL C., PURDY D., GREENTREE J. & UYSAL T. 2012 Early-mid Cretaceous tectonic evolution of eastern Gondwana : from silicic LIP magmatism to continental rupture, *Episodes*, p. 142-152.

COTTON T. B., SCARDINGO M. F. & BOULT P. J. 2006a. Lithostratigraphy and environments of depostition. *In* Alexander E. M., Sansome A. & Cotton T. B. eds. *The petroleum geology of South Australia, Vol. 2: Eromanga Basin*. 2nd ed. *Petroleum Geology of South Australia Series*, ch. 5. South Australia: Department of Primary Industries and Resources

COTTON T. B., SCARDINGO M. F. & BOULT P. J. 2006b. Sequence stratigraphy. *In* Cotton T. B., Scardingo M. F. & Boult P. J. eds. *The petroleum geology of South Australia, Vol. 2: Eromanga Basin*. 2nd ed. *Petroleum Geology of South Australia Series*, ch. 7. South Australia: Department of Primary Industries and Resources

DHUIME B., HAWKESWORTH C. & CAWOOD P. 2011 When Continents Formed, *Science,* **331**, p. 154-155.

GRAY D. R. & FOSTER D. A. 2004 Tectonic evolution of the Lachlan Orogen, southeast Australia: Historical review, data synthesis and modern perspectives, *Australian Journal of Earth Sciences,* **51**, p. 773-817.

GRIFFIN W. L., BELOUSOVA E. A., WALTERS S. G. & O'REILLY S. Y. 2006 Archaean and Proterozoic crustal evolution in the Eastern Succession of the Mt Isa district, Australia: U – Pb and Hf-isotope studies of detrital zircons *, *Australian Journal of Earth Sciences,* **53**, p. 125-149.

HILL A. J. 1991. Revisions to the Cretaceous stratigraphic nomenclature of the Bight and Duntroon Basins, South Australia, Geological Survey of South Australia, Quarterly Geological Notes, 120, p. 2-20

HOWARD K. E., HAND M., BAROVICH K. M., REID A., WADE B. P. & BELOUSOVA E. A. 2009 Detrital zircon ages: Improving interpretation via Nd and Hf isotopic data, *Chemical Geology,* **262**, p. 277-292.

JACKSON S. E., PEARSON N. J., GRIFFIN W. L. & BELOUSOVA E. A. 2004 The application of laser ablation-inductively coupled plasma-mass spectrometry to in situ U–Pb zircon geochronology, *Chemical Geology,* **211**, p. 47-69.

KING S. J. & MEE B. C. 2004 The seismic stratigraphy and petroleum potential of the Late Cretaceous Ceduna Delta, Ceduna Sub-basin, Great Australian Bight. In Boult P. J., Johns D. R. & Lang S. C. eds. Eastern Australasian Basins Symposium II. pp. 63-73. Petroleum Exploration Society of Australia.

KIRKLAND C. L., SMITHIES R. H., WOODHOUSE A. J., HOWARD H. M., WINGATE M. T. D., BELOUSOVA E. A., CLIFF J. B., MURPHY R. C. & SPAGGIARI C. V. 2013 Constraints and deception in the isotopic record; the crustal evolution of the west Musgrave Province, central Australia, *Gondwana Research,* **23**, p. 759-781.

KRASSAY A. A. & TOTTERDELL J. M. 2003 Seismic stratigraphy of a large, Cretaceous shelf-margin delta complex, offshore southern Australia, *AAPG Bulletin,* **87**, p. 935-963.

KROMKHUN K., FODEN J., HORE S. & BAINES G. 2013 Geochronology and Hf isotopes of the bimodal mafic–felsic high heat producing igneous suite from Mt Painter Province, South Australia, *Gondwana Research,* **24**, p. 1067-1079.

LI P. F., ROSENBAUM G. & RUBATTO D. 2012 Triassic asymmetric subduction rollback in the southern New England Orogen (eastern Australia): the end of the Hunter-Bowen Orogeny, *Australian Journal of Earth Sciences,* **59**, p. 965-981.

MACDONALD J., HOLFORD S. & KING R. 2013a. Structure and Prospectivity of the Ceduna Delta—Deep-Water Fold-Thrust Belt Systems, Bight Basin, Australia. *New Understanding of the Petroleum Systems of Continental Margins of the World: 32nd Annual,* pp. 779-816. Society of Economic Paleontologists and Mineralogists

MACDONALD J. D. 2013 Origin and structure of the Ceduna delta system, offshore South Australia. PhD Thesis, University of Adelaide.

MACDONALD J. D., HOLFORD S. P., GREEN P. F., DUDDY I. R., KING R. C. & BACKÉ G. 2013b Detrital zircon data reveal the origin of Australia's largest delta system, *Journal of the Geological Society,* **170**, p. 3-6.

PAYNE J. L., PEARSON N. J., GRANT K. J. & HALVERSON G. P. 2013 Reassessment of relative oxide formation rates and molecular interferences on in situ lutetium-hafnium analysis with laser ablation MC-ICP-MS, *Journal of Analytical Atomic Spectrometry,* **28**, p. 1068-1079.

REID A. J., KORSCH R. J., HOU B. & BLACK L. P. 2009 Sources of sediment in the Eocene Garford paleovalley, South Australia, from detrital-zircon geochronology, *Australian Journal of Earth Sciences,* **56**, p. 125-137.

SLÁMA J., KOŠLER J., CONDON D. J., CROWLEY J. L., GERDES A., HANCHAR J. M., HORSTWOOD M. S. A., MORRIS G. A., NASDALA L., NORBERG N., SCHALTEGGER U., SCHOENE B., TUBRETT M. N. & WHITEHOUSE M. J. 2008 Plešovice zircon — A new natural reference material for U–Pb and Hf isotopic microanalysis, *Chemical Geology,* **249**, p. 1-35.

SMITHIES R. H., HOWARD H. M., EVINS P. M., KIRKLAND C. L., KELSEY D. E., HAND M., WINGATE M. T. D., COLLINS A. S. & BELOUSOVA E. 2011 High-Temperature Granite Magmatism, Crust-Mantle Interaction and the Mesoproterozoic Intracontinental Evolution of the Musgrave Province, Central Australia, *Journal of Petrology,* **52**, p. 931-958.

TOTTERDELL J. M., BRADSHAW B. E. & WILLCOX J. B. 2003. The petroleum geology of South Australia. Vol. 5: Great Australian Bight. *In* O'Brien G. W. O. & Hibburt J. E. eds. *Great Australian Bight,* pp. 1-57. Unpublished ed. *The petroleum geology of South Australia,* ch. 4: Structural and Tectonic Setting. South Australia: Primary Industries and Resources South Australia

TUCKER R. T., ROBERTS E. M., HU Y., KEMP A. I. S. & SALISBURY S. W. 2013 Detrital zircon age constraints for the Winton Formation, Queensland: Contextualizing Australia's Late Cretaceous dinosaur faunas, *Gondwana Research,* **24**, p. 767-779.

TUCKER R. T. 2014 Stratigraphy, sedimentation and age of the Upper Cretaceous Winton Formation, central-western Queensland, Australia: implications for regional palaeogeography, palaeoenvironments and Gondwanan palaeontology. PhD Thesis, James Cook University.

VEEVERS J. J. 2000. Billion-year earth history of Australia and neighbours in Gondwanaland. pp. 388. 2nd ed North Ryde, N.S.W.: GEMOC Press

VEEVERS J. J. & SAEED A. 2008 Gamburtsev Subglacial Mountains provenance of Permian-Triassic sandstones in the Prince Charles Mountains and offshore Prydz Bay: Integrated U-Pb and TDM ages and host-rock affinity from detrital zircons, *Gondwana Research,* **14**, p. 316-342.

VEEVERS J. J. & SAEED A. 2011 Age and composition of Antarctic bedrock reflected by detrital zircons, erratics, and recycled microfossils in the Prydz Bay-Wilkes Land-Ross Sea-Marie Byrd Land sector (70°-240°E), *Gondwana Research,* **20**, p. 710-738.

VEEVERS J. J. & SAEED A. 2013 Age and composition of Antarctic sub-glacial bedrock reflected by detrital zircons, erratics, and recycled microfossils in the Ellsworth Land–Antarctic Peninsula–Weddell Sea–Dronning Maud Land sector (240°E–0°–015°E), *Gondwana Research,* **23**, p. 296-332.

VERMEESCH P. 2012 On the visualisation of detrital age distributions, *Chemical Geology,* **312–313**, p. 190-194.

WADE B. P., BAROVICH K. M., HAND M., SCRIMGEOUR I. R. & CLOSE D. F. 2006 Evidence for Early Mesoproterozoic Arc Magmatism in the Musgrave Block, Central Australia: Implications for Proterozoic Crustal Growth and Tectonic Reconstructions of Australia, *The Journal of Geology,* **114**, p. 43-63.

WILLIS S. 2003 Gnarlyknots-1 & 1A Well Completion Report Basic Data. pp. 820. Woodside Energy Ltd.

# APPENDIX A: DETAILED METHODS

## Uranium-Lead Geochronology

U-Pb zircon geochronology was undertaken via Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). U-Pb analyses were carried out on a New Wave UP-213 laser attached to an Agilent 7500cx inductively coupled plasma mass spectrometer (ICP-MS) at Adelaide Microscopy, the University of Adelaide. Ablation was conducted in a helium atmosphere after which argon gas was added immediately to the cell to aid transport of material. A circular spot with 30-μm diameter was chosen in order to target textural domains within the grains, while maximizing signal intensity at the mass spectrometer. A laser frequency of 5 Hz and a fluence of 3-3.3 $Jcm^{-2}$ was used at the ablation site. Background measurement of 40 seconds was conducted for each analysis, after which the laser was fired for 40 seconds with the laser shutter closed, and then ablation (laser firing, shutter open) was conducted for 50 seconds. Measured isotopes were $^{204}Pb$, $^{206}Pb$, $^{207}Pb$, $^{238}U$, $^{208}Pb$ and $^{232}Th$ with dwell times of 10, 15, 30, 15, 10 and 10 milliseconds respectively. Mass $^{204}Pb$ was measured as a monitor of common lead content; however, due to the unresolvable isobaric interference of $^{204}Hg$ on $^{204}Pb$ common lead corrections were not conducted. Age calculations and corrections were completed in the GLITTER software through the use of the primary zircon standard GJ-1, TIMS normalization data $^{207}Pb/^{206}Pb$ = 608.3 Ma, $^{206}Pb/^{238}U$ = 600.7 Ma and $^{207}Pb/^{235}U$ = 602.2 Ma (Jackson et al. 2004). An overestimated uncertainty of 1% was assigned to the TIMS derived normalization age for GJ-1. Instrument drift was also corrected for in GLITTER via standard bracketing every 15-20 unknowns and application of a linear correction. Accuracy of the methodology was verified by repeat analysis of Plešovice zircon, $^{206}Pb/^{238}U$ = 337.13±0.37 (Sláma et al. 2008). The sampling procedure was as follows, three GJ-1, two Plešovice, two GJ-1, 20 or less unknown samples, two GJ-1, two Plešovice and three GJ-1. Due to the unresolvable $^{204}Hg$ on $^{204}Pb$ interference, isotope ratios are presented uncorrected for common lead, with Concordia plots generated using Isoplot 4.15.

## Hafnium Isotopic Analysis

Hf analyses were completed on zircons, with previous U-Pb ages, mounted within epoxy moulds via laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICP-MS). The Hf analyses were conducted on a Thermo-Scientific Neptune Multi-collector attached to a New Wave UP-193 Excimer laser located at a joint University of Adelaide and Commonwealth Scientific and Industrial Research Organisation (CSIRO) facility at the University of Adelaide's Waite Campus. This Excimer laser delivered a beam of UV light with a wavelength of 193 nm. For analyses a circular beam with a diameter of 50 μm, a repetition rate of 5 Hz and fluence of 7-10 J $cm^{-2}$ was chosen. A smaller 35-μm diameter was used on a few small zircons where 50 μm was not possible. For the analyses the $^{171}Yb$, $^{173}Yb$, $^{175}Lu$, $^{176}Hf$, $^{177}Hf$, $^{179}Hf$ and $^{180}Hf$ were all measured concurrently. Mudtank and Plešovice zircons were used as standard to ensure accuracy. Data processing and ratio calculations were carried out using a macro-driven Excel™ workbook, HfTRaX V3.2, written by Dr. Justin Payne. Epsilon Hf, $Hf_i$ and hafnium model ages were calculated using a modified

Excel™ workbook originally developed by the ARC National Key Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC) at Macquarie University Sydney. Hafnium methods and calculations are further described in Payne et al. (2013)

# APPENDIX B: NEW U-PB AND HF ISOTOPE DATA

**Supplementary Table 1: U-Pb data collected for Gnarlyknots-1A sample 74322**

| Analysis | Pb207/Pb206 | ± 1σ | Pb207/U235 | ± 1σ | Pb206/U238 | ± 1σ | Pb208/Th232 | ± 1σ | Rho | Concordancy | Pb207/Pb206 Age (Ma) | ± 1σ | Pb206/U238 Age (Ma) | ± 1σ | Pb207/U235 Age (Ma) | ± 1σ | Pb208/Th232 Age (Ma) | ± 1σ | Pb204 CPS | Pb206 CPS | Pb207 CPS | Pb208 CPS | Th232 CPS | U238 CPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74322_081 | 0.04821 | 0.00267 | 0.10176 | 0.00555 | 0.01531 | 0.00028 | 0.00500 | 0.00024 | 0.12123 | 100 | 109.8 | 125.76 | 98 | 1.77 | 98.4 | 5.11 | 100.9 | 4.89 | 0 | 912 | 46 | 236 | 43631 | 77871 |
| 74322_082 | 0.11576 | 0.00143 | 5.12815 | 0.07453 | 0.32142 | 0.00433 | 0.09080 | 0.00322 | 0.61317 | 102 | 1891.8 | 22.04 | 1796.6 | 21.11 | 1840.8 | 12.35 | 1756.8 | 59.61 | 2 | 102068 | 12406 | 16626 | 169634 | 416319 |
| 74322_083 | 0.04974 | 0.00162 | 0.11160 | 0.00363 | 0.01628 | 0.00025 | 0.00541 | 0.00022 | 0.23329 | 103 | 183.1 | 73.97 | 104.1 | 1.61 | 107.4 | 3.31 | 109 | 4.46 | 8 | 2157 | 112 | 561 | 96467 | 174286 |
| 74322_084 | 0.05637 | 0.00107 | 0.73263 | 0.01472 | 0.09431 | 0.00134 | 0.02830 | 0.00113 | 0.42957 | 96 | 466.2 | 41.83 | 581 | 7.91 | 558.1 | 8.63 | 564 | 22.24 | 0 | 6253 | 369 | 858 | 28273 | 87462 |
| 74322_085 | 0.06933 | 0.00095 | 1.47415 | 0.02326 | 0.15428 | 0.00211 | 0.04559 | 0.00175 | 0.57519 | 99 | 908.7 | 28.07 | 924.9 | 11.8 | 919.8 | 9.54 | 901 | 33.77 | 0 | 24529 | 1779 | 3713 | 76110 | 210369 |
| 74322_086 | 0.05125 | 0.00104 | 0.34838 | 0.00743 | 0.04933 | 0.00071 | 0.01641 | 0.00066 | 0.40757 | 98 | 252.1 | 46.01 | 310.4 | 4.36 | 303.5 | 5.6 | 329 | 13.15 | 0 | 5648 | 302 | 1457 | 83241 | 151997 |
| 74322_087 | 0.05292 | 0.00236 | 0.13092 | 0.00576 | 0.01795 | 0.00031 | 0.00625 | 0.00031 | 0.16133 | 109 | 325.3 | 98 | 114.7 | 1.99 | 124.9 | 5.17 | 126 | 6.32 | 1 | 1133 | 62 | 268 | 40340 | 84038 |
| 74322_088 | 0.06029 | 0.00137 | 0.75234 | 0.01768 | 0.09055 | 0.00136 | 0.02776 | 0.00115 | 0.37041 | 102 | 614.1 | 48.39 | 558.8 | 8.01 | 569.6 | 10.24 | 553.5 | 22.66 | 0 | 3638 | 228 | 2713 | 92097 | 53657 |
| 74322_089 | 0.15512 | 0.00225 | 6.06968 | 0.09964 | 0.28395 | 0.00405 | 0.08916 | 0.00382 | 0.56062 | 123 | 2403.1 | 24.44 | 1611.2 | 20.31 | 1985.9 | 14.31 | 1726.2 | 70.89 | 8 | 9212 | 1488 | 2129 | 22572 | 43462 |
| 74322_090 | 0.06261 | 0.00167 | 0.63145 | 0.01704 | 0.07318 | 0.00116 | 0.02183 | 0.00104 | 0.31330 | 109 | 695.1 | 56 | 455.3 | 6.99 | 497 | 10.61 | 436.5 | 20.65 | 27 | 6073 | 395 | 1313 | 57021 | 111527 |
| 74322_091 | 0.08375 | 0.00122 | 2.32230 | 0.03885 | 0.20121 | 0.00284 | 0.05088 | 0.00226 | 0.56513 | 103 | 1286.6 | 28.26 | 1181.8 | 15.22 | 1219.1 | 11.87 | 1003.2 | 43.41 | 0 | 22200 | 1932 | 10602 | 198059 | 148745 |
| 74322_092 | 0.05639 | 0.00158 | 0.34467 | 0.00977 | 0.04436 | 0.00071 | 0.01526 | 0.00082 | 0.30262 | 107 | 466.8 | 61.39 | 279.8 | 4.36 | 300.7 | 7.38 | 306.2 | 16.39 | 7 | 4490 | 262 | 516 | 32289 | 136923 |
| 74322_093 | 0.06023 | 0.00091 | 0.79887 | 0.01378 | 0.09624 | 0.00136 | 0.03045 | 0.00147 | 0.55170 | 101 | 611.8 | 32.31 | 592.4 | 8.01 | 596.2 | 7.78 | 606.2 | 28.89 | 0 | 35505 | 2217 | 2130 | 66896 | 500489 |
| 74322_094 | 0.05004 | 0.00139 | 0.24642 | 0.00699 | 0.03573 | 0.00056 | 0.01074 | 0.00054 | 0.31342 | 99 | 197 | 63.35 | 226.3 | 3.47 | 223.7 | 5.69 | 216 | 10.86 | 5 | 3526 | 182 | 1043 | 93146 | 134312 |
| 74322_095 | 0.12315 | 0.00177 | 5.66719 | 0.09500 | 0.33389 | 0.00476 | 0.09418 | 0.00557 | 0.58095 | 104 | 2002.3 | 25.32 | 1857.2 | 23.02 | 1926.4 | 14.47 | 1819.2 | 102.81 | 0 | 77855 | 9919 | 704 | 7189 | 318355 |
| 74322_096 | 0.05486 | 0.00127 | 0.26540 | 0.00642 | 0.03510 | 0.00054 | 0.01165 | 0.00040 | 0.38415 | 107 | 406.3 | 50.78 | 222.4 | 3.36 | 239 | 5.15 | 234.1 | 8.05 | 0 | 4081 | 235 | 788 | 63703 | 162029 |
| 74322_097 | 0.08193 | 0.00119 | 2.11357 | 0.03552 | 0.18714 | 0.00273 | 0.06080 | 0.00198 | 0.57978 | 104 | 1243.9 | 28.16 | 1105.9 | 14.84 | 1153.2 | 11.58 | 1192.9 | 37.72 | 31 | 68289 | 5883 | 8498 | 131700 | 509416 |
| 74322_098 | 0.06178 | 0.00097 | 0.82967 | 0.01479 | 0.09742 | 0.00142 | 0.02872 | 0.00091 | 0.54596 | 102 | 666.7 | 33.26 | 599.3 | 8.36 | 613.4 | 8.21 | 572.3 | 17.85 | 0 | 8743 | 567 | 2475 | 81308 | 125528 |
| 74322_099 | 0.05896 | 0.00950 | 0.75052 | 0.11666 | 0.09234 | 0.00446 | 0.03443 | 0.00405 | 0.03546 | 100 | 565.8 | 316.82 | 569.4 | 26.32 | 568.5 | 67.67 | 684.2 | 79.17 | 0 | 518 | 32 | 148 | 4083 | 7860 |
| 74322_100 | 0.05121 | 0.00123 | 0.26416 | 0.00662 | 0.03742 | 0.00058 | 0.01178 | 0.00041 | 0.37506 | 101 | 250.5 | 54.46 | 236.8 | 3.6 | 238 | 5.32 | 236.6 | 8.29 | 1 | 3042 | 163 | 761 | 61167 | 114150 |
| 74322_101 | 0.05035 | 0.00166 | 0.26257 | 0.00868 | 0.03784 | 0.00064 | 0.01173 | 0.00046 | 0.26105 | 99 | 211 | 74.57 | 239.4 | 3.96 | 236.7 | 6.98 | 235.6 | 9.21 | 0 | 2486 | 131 | 618 | 49990 | 92419 |
| 74322_102 | 0.05073 | 0.00175 | 0.13295 | 0.00459 | 0.01901 | 0.00032 | 0.00604 | 0.00025 | 0.24545 | 104 | 228.6 | 77.62 | 121.4 | 2.03 | 126.7 | 4.11 | 121.7 | 5.08 | 0 | 1657 | 88 | 333 | 52331 | 122827 |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74322_103 | 0.06380 | 0.00095 | 1.03168 | 0.01784 | 0.11732 | 0.00172 | 0.03507 | 0.00123 | 0.57637 | 101 | 734.9 | 31.18 | 715.1 | 9.93 | 719.8 | 8.92 | 696.6 | 23.96 | 25 | 12725 | 850 | 1932 | 52323 | 153133 |
| 74322_104 | 0.13210 | 0.00161 | 7.05382 | 0.10813 | 0.38740 | 0.00560 | 0.11207 | 0.00388 | 0.66655 | 100 | 2126.1 | 21.22 | 2110.8 | 26.01 | 2118.2 | 13.63 | 2147 | 70.54 | 0 | 62067 | 8583 | 9153 | 77662 | 226628 |
| 74322_105 | 0.20450 | 0.00249 | 15.68730 | 0.24034 | 0.55654 | 0.00806 | 0.15587 | 0.00551 | 0.66749 | 100 | 2862.4 | 19.63 | 2852.3 | 33.4 | 2857.9 | 14.62 | 2927.7 | 96.37 | 15 | 59327 | 12692 | 9044 | 55246 | 151077 |
| 74322_106 | 0.11069 | 0.00152 | 3.82243 | 0.06290 | 0.25054 | 0.00370 | 0.07836 | 0.00290 | 0.61788 | 111 | 1810.8 | 24.75 | 1441.3 | 19.06 | 1597.5 | 13.24 | 1524.9 | 54.27 | 3 | 22513 | 2605 | 3693 | 44929 | 127593 |
| 74322_107 | 0.06823 | 0.00107 | 1.27169 | 0.02297 | 0.13523 | 0.00202 | 0.04086 | 0.00155 | 0.56235 | 102 | 875.4 | 32.24 | 817.6 | 11.45 | 833.1 | 10.27 | 809.5 | 30.1 | 0 | 11859 | 845 | 2317 | 54135 | 124764 |
| 74322_108 | 0.08945 | 0.00122 | 2.97702 | 0.04904 | 0.24145 | 0.00355 | 0.06944 | 0.00263 | 0.62244 | 101 | 1413.8 | 25.79 | 1394.2 | 18.46 | 1401.8 | 12.52 | 1357 | 49.64 | 2 | 35594 | 3324 | 11102 | 152807 | 210128 |
| 74322_109 | 0.10112 | 0.00127 | 3.86792 | 0.06099 | 0.27750 | 0.00405 | 0.05690 | 0.00218 | 0.66028 | 102 | 1644.9 | 23.15 | 1578.7 | 20.41 | 1607 | 12.72 | 1118.5 | 41.76 | 12 | 109790 | 11585 | 36910 | 620838 | 565016 |
| 74322_110 | 0.07835 | 0.00119 | 2.10357 | 0.03730 | 0.19478 | 0.00292 | 0.05808 | 0.00230 | 0.58022 | 100 | 1155.8 | 29.89 | 1147.2 | 15.74 | 1150 | 12.2 | 1141 | 43.9 | 0 | 12472 | 1019 | 7115 | 117417 | 91623 |
| 74322_111 | 0.07223 | 0.00499 | 1.75283 | 0.11664 | 0.17605 | 0.00486 | 0.05644 | 0.00413 | 0.11362 | 98 | 992.5 | 134.36 | 1045.3 | 26.64 | 1028.2 | 43.02 | 1109.7 | 79.03 | 5 | 810 | 61 | 189 | 3228 | 6601 |
| 74322_112 | 0.05113 | 0.00088 | 0.30024 | 0.00583 | 0.04261 | 0.00064 | 0.01328 | 0.00056 | 0.52533 | 99 | 246.5 | 39.08 | 269 | 3.97 | 266.6 | 4.55 | 266.7 | 11.24 | 6 | 9413 | 501 | 1615 | 116836 | 317350 |
| 74322_113 | 0.04991 | 0.00384 | 0.10764 | 0.00810 | 0.01565 | 0.00038 | 0.00565 | 0.00035 | 0.09105 | 104 | 190.8 | 169.85 | 100.1 | 2.42 | 103.8 | 7.42 | 113.8 | 6.93 | 0 | 703 | 36 | 218 | 37204 | 64742 |
| 74322_114 | 0.16678 | 0.00232 | 10.86797 | 0.18335 | 0.47272 | 0.00710 | 0.13002 | 0.00567 | 0.62493 | 101 | 2525.6 | 23.17 | 2495.5 | 31.1 | 2511.9 | 15.69 | 2470.6 | 101.47 | 0 | 18919 | 3282 | 4210 | 31194 | 57707 |
| 74322_115 | 0.05711 | 0.00132 | 0.64343 | 0.01571 | 0.08173 | 0.00130 | 0.02403 | 0.00110 | 0.40545 | 100 | 495.2 | 50.62 | 506.4 | 7.78 | 504.4 | 9.7 | 480.1 | 21.79 | 0 | 3663 | 217 | 1186 | 47626 | 64757 |
| 74322_116 | 0.06913 | 0.00129 | 1.40119 | 0.02889 | 0.14703 | 0.00229 | 0.04417 | 0.00213 | 0.49743 | 101 | 902.6 | 37.93 | 884.3 | 12.88 | 889.4 | 12.22 | 873.6 | 41.3 | 3 | 16969 | 1218 | 1908 | 41728 | 167057 |
| 74322_117 | 0.06036 | 0.00090 | 0.82860 | 0.01476 | 0.09958 | 0.00151 | 0.03002 | 0.00107 | 0.60146 | 100 | 616.4 | 31.98 | 611.9 | 8.84 | 612.8 | 8.2 | 597.7 | 20.96 | 0 | 12736 | 795 | 796 | 26617 | 187151 |
| 74322_118 | 0.05077 | 0.00108 | 0.27737 | 0.00640 | 0.03962 | 0.00062 | 0.01195 | 0.00041 | 0.44972 | 99 | 230.6 | 48.6 | 250.5 | 3.87 | 248.6 | 5.08 | 240 | 8.09 | 8 | 4405 | 231 | 1864 | 157109 | 162821 |
| 74322_119 | 0.05079 | 0.00165 | 0.22158 | 0.00732 | 0.03164 | 0.00054 | 0.00981 | 0.00037 | 0.29020 | 101 | 231.3 | 73.32 | 200.8 | 3.37 | 203.2 | 6.08 | 197.3 | 7.5 | 18 | 1637 | 86 | 496 | 51160 | 75855 |
| 74322_120 | 0.04788 | 0.00371 | 0.11439 | 0.00874 | 0.01733 | 0.00038 | 0.00557 | 0.00032 | 0.09389 | 99 | 92.2 | 174.86 | 110.8 | 2.43 | 110 | 7.96 | 112.3 | 6.41 | 0 | 516 | 25 | 118 | 21662 | 43707 |
| 74322_121 | 0.04981 | 0.00295 | 0.13066 | 0.00757 | 0.01903 | 0.00042 | 0.00595 | 0.00033 | 0.13144 | 103 | 186 | 132.49 | 121.5 | 2.67 | 124.7 | 6.8 | 120 | 6.72 | 0 | 1217 | 62 | 273 | 46791 | 93952 |
| 74322_122 | 0.04803 | 0.00112 | 0.11045 | 0.00274 | 0.01668 | 0.00027 | 0.00516 | 0.00020 | 0.41547 | 100 | 100.7 | 54.14 | 106.6 | 1.69 | 106.4 | 2.5 | 104 | 3.96 | 0 | 3361 | 166 | 767 | 151972 | 296026 |
| 74322_123 | 0.18982 | 0.00257 | 13.81808 | 0.23142 | 0.52801 | 0.00813 | 0.15068 | 0.00566 | 0.64811 | 100 | 2740.6 | 22.11 | 2733 | 34.32 | 2737.3 | 15.86 | 2836.9 | 99.4 | 12 | 25581 | 5022 | 3992 | 27160 | 71235 |
| 74322_124 | 0.05782 | 0.00088 | 0.69408 | 0.01257 | 0.08707 | 0.00133 | 0.02671 | 0.00103 | 0.59586 | 99 | 522.7 | 33.3 | 538.2 | 7.87 | 535.2 | 7.54 | 532.8 | 20.2 | 0 | 16109 | 963 | 1762 | 67873 | 272234 |
| 74322_125 | 0.05876 | 0.00095 | 0.78229 | 0.01472 | 0.09657 | 0.00148 | 0.03067 | 0.00119 | 0.56792 | 99 | 558.2 | 35.13 | 594.3 | 8.72 | 586.8 | 8.39 | 610.6 | 23.26 | 14 | 12371 | 751 | 2727 | 91805 | 188675 |
| 74322_126 | 0.05297 | 0.00195 | 0.25680 | 0.00947 | 0.03516 | 0.00064 | 0.01155 | 0.00052 | 0.25029 | 104 | 327.5 | 81.4 | 222.8 | 3.96 | 232.1 | 7.65 | 232.1 | 10.41 | 0 | 1596 | 87 | 464 | 41723 | 66911 |
| 74322_127 | 0.06018 | 0.00092 | 0.81114 | 0.01478 | 0.09776 | 0.00150 | 0.03030 | 0.00124 | 0.59685 | 100 | 610.1 | 32.82 | 601.3 | 8.78 | 603.1 | 8.29 | 603.4 | 24.24 | 0 | 15234 | 947 | 2033 | 69792 | 229856 |
| 74322_128 | 0.08011 | 0.00136 | 2.30474 | 0.04476 | 0.20868 | 0.00327 | 0.06407 | 0.00265 | 0.54959 | 99 | 1199.7 | 33.09 | 1221.8 | 17.47 | 1213.7 | 13.75 | 1255.2 | 50.4 | 0 | 11070 | 916 | 4282 | 69774 | 78314 |
| 74322_129 | 0.07674 | 0.00174 | 2.06379 | 0.04959 | 0.19505 | 0.00327 | 0.05903 | 0.00262 | 0.42738 | 99 | 1114.6 | 44.59 | 1148.7 | 17.62 | 1136.9 | 16.43 | 1159.3 | 50.06 | 0 | 11124 | 882 | 3404 | 60429 | 84264 |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74322_130 | 0.06939 | 0.00119 | 1.38346 | 0.02722 | 0.14461 | 0.00226 | 0.04581 | 0.00202 | 0.54840 | 101 | 910.4 | 35.05 | 870.7 | 12.74 | 881.9 | 11.59 | 905.3 | 39.02 | 1 | 9750 | 699 | 1994 | 45796 | 99700 |
| 74322_131 | 0.05543 | 0.00245 | 0.40324 | 0.01760 | 0.05276 | 0.00105 | 0.01618 | 0.00096 | 0.20000 | 104 | 429.4 | 95.66 | 331.5 | 6.42 | 344 | 12.74 | 324.5 | 19.06 | 0 | 1365 | 78 | 238 | 15577 | 38296 |
| 74322_132 | 0.05146 | 0.00145 | 0.22768 | 0.00664 | 0.03209 | 0.00054 | 0.01080 | 0.00051 | 0.34614 | 102 | 261.5 | 63.57 | 203.6 | 3.38 | 208.3 | 5.49 | 217.1 | 10.24 | 0 | 2950 | 156 | 1060 | 104041 | 136171 |
| 74322_133 | 0.12475 | 0.00172 | 6.32188 | 0.10829 | 0.36756 | 0.00561 | 0.10940 | 0.00507 | 0.64311 | 100 | 2025.3 | 24.22 | 2017.9 | 26.46 | 2021.5 | 15.02 | 2098.4 | 92.37 | 7 | 32342 | 4168 | 6617 | 64335 | 130433 |
| 74322_134 | 0.18146 | 0.00408 | 12.12227 | 0.28490 | 0.48456 | 0.00905 | 0.13480 | 0.00787 | 0.45066 | 103 | 2666.2 | 36.8 | 2547.1 | 39.3 | 2613.9 | 22.05 | 2555.9 | 140.23 | 20 | 32353 | 6065 | 4176 | 33079 | 99055 |
| 74322_135 | 0.05810 | 0.00168 | 0.76373 | 0.02262 | 0.09535 | 0.00166 | 0.03053 | 0.00161 | 0.33376 | 98 | 532.9 | 62.03 | 587.1 | 9.75 | 576.2 | 13.02 | 607.9 | 31.56 | 0 | 5009 | 300 | 1244 | 43668 | 78007 |

**Supplementary Table 2: U-Pb data collected for Hughes-2 sample 106988**

| Analysis | Pb207/Pb206 | ± 1σ | Pb207/U235 | ± 1σ | Pb206/U238 | ± 1σ | Pb208/Th232 | ± 1σ | Rho | Concordancy | Pb207/Pb206 Age (Ma) | ± 1σ | Pb206/U238 Age (Ma) | ± 1σ | Pb207/U235 Age (Ma) | ± 1σ | Pb208/Th232 Age (Ma) | ± 1σ | Pb204 CPS | Pb206 CPS | Pb207 CPS | Pb208 CPS | Th232 CPS | U238 CPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 106988_02 | 0.0706 | 0.00349 | 2.09646 | 0.10312 | 0.21613 | 0.00538 | 0.05519 | 0.01207 | 0.243138056 | 91 | 945.9 | 98.09 | 1261.4 | 28.54 | 1147.6 | 33.81 | 1085.8 | 231.22 | 0 | 2544 | 210 | 1119 | 19965 | 18453 |
| 106988_03 | 0.07145 | 0.00416 | 1.85602 | 0.09606 | 0.18927 | 0.00431 | 0.07203 | 0.0232 | 0.081725721 | 95 | 970.4 | 114.43 | 1117.4 | 23.36 | 1065.6 | 34.15 | 1405.9 | 437.46 | 0 | 7495 | 575 | 6181 | 103588 | 50104 |
| 106988_04 | 0.09821 | 0.0031 | 3.55807 | 0.10823 | 0.26223 | 0.00458 | 0.08472 | 0.01497 | 0.220190704 | 103 | 1590.4 | 57.76 | 1501.3 | 23.41 | 1540.2 | 24.11 | 1643.7 | 278.9 | 9 | 14437 | 1559 | 3954 | 53508 | 76269 |
| 106988_05 | 0.07632 | 0.00289 | 1.88027 | 0.06569 | 0.17836 | 0.00324 | 0.0737 | 0.01481 | 0.091896709 | 102 | 1103.5 | 73.88 | 1058 | 17.7 | 1074.2 | 23.16 | 1437.2 | 278.74 | 0 | 3278 | 270 | 1499 | 25119 | 24026 |
| 106988_06 | 0.09758 | 0.00552 | 3.06008 | 0.15494 | 0.22785 | 0.00518 | 0.04144 | 0.00891 | 0.051922403 | 108 | 1578.4 | 102.22 | 1323.2 | 27.18 | 1422.8 | 38.75 | 820.7 | 172.9 | 10 | 24513 | 2576 | 3871 | 75369 | 139837 |
| 106988_07 | 0.07439 | 0.00204 | 2.02463 | 0.05433 | 0.19702 | 0.00323 | 0.07054 | 0.01048 | 0.269178929 | 97 | 1052 | 54.39 | 1159.3 | 17.39 | 1123.8 | 18.24 | 1377.7 | 197.79 | 11 | 25094 | 2027 | 8019 | 129316 | 175096 |
| 106988_08 | 0.09759 | 0.00283 | 3.91739 | 0.11276 | 0.29078 | 0.00508 | 0.07561 | 0.00897 | 0.291148536 | 98 | 1578.6 | 53.29 | 1645.4 | 25.36 | 1617.3 | 23.28 | 1473.3 | 168.53 | 8 | 13314 | 1418 | 3059 | 35619 | 65690 |
| 106988_09 | 0.07671 | 0.00204 | 2.1719 | 0.05735 | 0.20513 | 0.00339 | 0.06274 | 0.00752 | 0.301500384 | 97 | 1113.6 | 52.1 | 1202.8 | 18.13 | 1172.1 | 18.36 | 1230 | 143.07 | 10 | 5779 | 478 | 3100 | 52891 | 39299 |
| 106988_10 | 0.07639 | 0.00364 | 2.03961 | 0.09055 | 0.19426 | 0.00416 | 0.05397 | 0.00901 | 0.083633667 | 99 | 1105.2 | 92.37 | 1144.4 | 22.46 | 1128.8 | 30.25 | 1062.4 | 172.71 | 2 | 4201 | 349 | 2874 | 46789 | 28788 |
| 106988_11 | 0.09686 | 0.00206 | 3.89881 | 0.08594 | 0.29169 | 0.00455 | 0.09328 | 0.00917 | 0.402630118 | 98 | 1564.5 | 39.41 | 1649.9 | 22.73 | 1613.4 | 17.81 | 1802.5 | 169.62 | 6 | 20455 | 2139 | 3703 | 41167 | 98451 |
| 106988_12 | 0.07227 | 0.00146 | 1.76134 | 0.0378 | 0.1767 | 0.00277 | 0.05691 | 0.00487 | 0.443179872 | 98 | 993.5 | 40.57 | 1048.9 | 15.18 | 1031.3 | 13.9 | 1118.7 | 93.15 | 0 | 15888 | 1242 | 6518 | 114626 | 128627 |
| 106988_13 | 0.09115 | 0.00345 | 3.94498 | 0.15801 | 0.31627 | 0.00717 | 0.06896 | 0.01062 | 0.37753629 | 92 | 1449.7 | 70.45 | 1771.5 | 35.14 | 1623 | 32.44 | 1347.8 | 200.9 | 0 | 34639 | 3591 | 6759 | 84795 | 185927 |
| 106988_14 | 0.0795 | 0.00153 | 2.18311 | 0.04497 | 0.19909 | 0.00308 | 0.05204 | 0.00365 | 0.460143878 | 100 | 1184.6 | 37.54 | 1170.4 | 16.56 | 1175.7 | 14.34 | 1025.5 | 70.08 | 0 | 8300 | 706 | 2152 | 40760 | 59206 |
| 106988_15 | 0.08703 | 0.00274 | 2.4859 | 0.08016 | 0.20779 | 0.00422 | 0.05237 | 0.0046 | 0.352007703 | 104 | 1361.2 | 59.4 | 1217 | 22.53 | 1267.9 | 23.35 | 1031.7 | 88.27 | 38 | 4090 | 399 | 2712 | 45483 | 31728 |
| 106988_16 | 0.07442 | 0.00132 | 2.15967 | 0.04212 | 0.21046 | 0.00322 | 0.05889 | 0.00323 | 0.502432226 | 95 | 1052.8 | 35.32 | 1231.3 | 17.17 | 1168.2 | 13.54 | 1156.6 | 61.68 | 1 | 7780 | 616 | 3631 | 59987 | 52804 |
| 106988_17 | 0.09353 | 0.00297 | 2.6578 | 0.08501 | 0.20631 | 0.00415 | 0.04842 | 0.00326 | 0.325870638 | 109 | 1498.5 | 58.95 | 1209.1 | 22.19 | 1316.8 | 23.6 | 955.7 | 62.87 | 0 | 3026 | 307 | 1934 | 34195 | 22963 |
| 106988_18 | 0.07578 | 0.00116 | 2.07791 | 0.03643 | 0.19883 | 0.00295 | 0.05864 | 0.00261 | 0.563557406 | 98 | 1089.4 | 30.36 | 1169 | 15.88 | 1141.5 | 12.02 | 1151.8 | 49.89 | 16 | 12049 | 966 | 6191 | 105381 | 85928 |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 106988_19 | 0.07654 | 0.00135 | 2.11664 | 0.04108 | 0.20054 | 0.00306 | 0.05764 | 0.00231 | 0.503829519 | 98 | 1109.3 | 34.82 | 1178.2 | 16.46 | 1154.2 | 13.38 | 1132.7 | 44.05 | 1 | 5245 | 423 | 3340 | 57428 | 37156 |
| 106988_20 | 0.07587 | 0.00128 | 2.03872 | 0.03833 | 0.19493 | 0.00293 | 0.05592 | 0.00211 | 0.521553559 | 98 | 1091.6 | 33.46 | 1148 | 15.82 | 1128.5 | 12.81 | 1099.7 | 40.44 | 1 | 6823 | 541 | 3647 | 63372 | 49383 |
| 106988_21 | 0.10252 | 0.00244 | 3.71529 | 0.09332 | 0.26327 | 0.00469 | 0.05882 | 0.00403 | 0.426639057 | 105 | 1670.2 | 43.45 | 1506.6 | 23.93 | 1574.7 | 20.09 | 1155.2 | 76.95 | 36 | 28596 | 3079 | 8214 | 127242 | 167608 |
| 106988_22 | 0.07898 | 0.00099 | 2.1602 | 0.03434 | 0.19839 | 0.00295 | 0.03896 | 0.00104 | 0.669879464 | 100 | 1171.6 | 24.54 | 1166.7 | 15.88 | 1168.3 | 11.03 | 772.4 | 20.17 | 8 | 20392 | 1675 | 8752 | 213632 | 149725 |
| 106988_23 | 0.10306 | 0.00142 | 2.73651 | 0.04679 | 0.19257 | 0.00295 | 0.04489 | 0.00173 | 0.643652793 | 118 | 1679.9 | 25.32 | 1135.3 | 15.94 | 1338.4 | 12.72 | 887.6 | 33.41 | 42 | 57625 | 6142 | 18522 | 386439 | 444116 |
| 106988_24 | 0.10173 | 0.00131 | 4.0436 | 0.06479 | 0.2883 | 0.00429 | 0.07764 | 0.00217 | 0.654991497 | 101 | 1656 | 23.6 | 1633 | 21.49 | 1643 | 13.04 | 1511.3 | 40.76 | 8 | 14290 | 1512 | 5604 | 68561 | 71677 |
| 106988_25 | 0.1009 | 0.00128 | 3.72132 | 0.06006 | 0.26756 | 0.00404 | 0.0696 | 0.00213 | 0.672032877 | 103 | 1640.7 | 23.33 | 1528.4 | 20.53 | 1576 | 12.92 | 1359.9 | 40.24 | 23 | 26387 | 2765 | 4143 | 56001 | 145161 |
| 106988_26 | 0.07843 | 0.00113 | 2.02782 | 0.03487 | 0.18754 | 0.00282 | 0.05754 | 0.00169 | 0.607606909 | 102 | 1157.8 | 28.39 | 1108.1 | 15.29 | 1124.9 | 11.69 | 1130.7 | 32.23 | 25 | 10007 | 816 | 5763 | 94820 | 77036 |
| 106988_27 | 0.16385 | 0.00357 | 2.54175 | 0.05855 | 0.11251 | 0.00195 | 0.04063 | 0.00242 | 0.446206683 | 187 | 2495.8 | 36.27 | 687.3 | 11.31 | 1284.1 | 16.78 | 804.9 | 46.96 | 114 | 16128 | 2696 | 22247 | 495983 | 215613 |
| 106988_28 | 0.07798 | 0.00114 | 2.1586 | 0.03738 | 0.2008 | 0.00301 | 0.05644 | 0.00176 | 0.59876345 | 99 | 1146.4 | 28.79 | 1179.6 | 16.18 | 1167.8 | 12.02 | 1109.8 | 33.64 | 1 | 10208 | 828 | 4127 | 69444 | 73219 |
| 106988_29 | 0.07574 | 0.00101 | 2.01511 | 0.03324 | 0.19299 | 0.00288 | 0.0565 | 0.00179 | 0.64382611 | 99 | 1088.3 | 26.53 | 1137.6 | 15.58 | 1120.6 | 11.19 | 1110.9 | 34.24 | 12 | 21152 | 1667 | 9891 | 164731 | 159350 |
| 106988_30 | 0.07726 | 0.001 | 2.06558 | 0.03318 | 0.19396 | 0.00286 | 0.0514 | 0.00165 | 0.650017931 | 100 | 1127.8 | 25.47 | 1142.8 | 15.45 | 1137.5 | 10.99 | 1013.1 | 31.66 | 7 | 24405 | 1961 | 8094 | 149302 | 181322 |
| 106988_31 | 0.0794 | 0.00123 | 2.01485 | 0.03643 | 0.18411 | 0.00282 | 0.05786 | 0.00187 | 0.580528741 | 103 | 1182 | 30.3 | 1089.4 | 15.35 | 1120.5 | 12.27 | 1137 | 35.72 | 0 | 8074 | 667 | 3495 | 56863 | 63968 |
| 106988_32 | 0.08652 | 0.00202 | 0.90044 | 0.02205 | 0.0755 | 0.00128 | 0.03449 | 0.002 | 0.411885269 | 139 | 1349.9 | 44.33 | 469.2 | 7.68 | 652 | 11.78 | 685.4 | 39.02 | 13 | 11951 | 1080 | 5586 | 150247 | 235834 |
| 106988_33 | 0.0847 | 0.00131 | 1.67537 | 0.03041 | 0.14351 | 0.0022 | 0.03223 | 0.00143 | 0.58446974 | 116 | 1308.7 | 29.84 | 864.5 | 12.39 | 999.2 | 11.54 | 641.2 | 28.08 | 4 | 28063 | 2478 | 10903 | 319876 | 285954 |
| 106988_34 | 0.07771 | 0.00145 | 2.20064 | 0.04599 | 0.20539 | 0.0033 | 0.05532 | 0.00303 | 0.516314465 | 98 | 1139.5 | 36.79 | 1204.2 | 17.65 | 1181.2 | 14.59 | 1088.3 | 58.04 | 0 | 28214 | 2292 | 15169 | 254597 | 204892 |
| 106988_35 | 0.0809 | 0.00182 | 2.24564 | 0.05263 | 0.20147 | 0.00326 | 0.05789 | 0.00268 | 0.402115295 | 101 | 1218.9 | 43.51 | 1183.2 | 17.49 | 1195.4 | 16.47 | 1137.4 | 51.27 | 4 | 4125 | 347 | 2084 | 34569 | 28912 |
| 106988_36 | 0.08476 | 0.00418 | 2.33937 | 0.11107 | 0.20031 | 0.00479 | 0.05792 | 0.00373 | 0.173516882 | 104 | 1310 | 92.93 | 1177 | 25.72 | 1224.3 | 33.77 | 1138.1 | 71.21 | 9 | 1070 | 95 | 578 | 9520 | 7617 |
| 106988_37 | 0.07689 | 0.00166 | 2.13602 | 0.04915 | 0.20153 | 0.00329 | 0.05562 | 0.00209 | 0.439082867 | 98 | 1118.5 | 42.52 | 1183.5 | 17.64 | 1160.5 | 15.91 | 1094 | 40.01 | 10 | 2714 | 217 | 1061 | 17929 | 19603 |
| 106988_38 | 0.07866 | 0.00139 | 2.0881 | 0.04143 | 0.19258 | 0.00302 | 0.05365 | 0.00201 | 0.525997268 | 101 | 1163.7 | 34.72 | 1135.3 | 16.31 | 1144.9 | 13.62 | 1056.3 | 38.49 | 14 | 4801 | 392 | 1381 | 24217 | 36383 |
| 106988_39 | 0.08052 | 0.00169 | 2.13804 | 0.04787 | 0.19266 | 0.00312 | 0.05394 | 0.00214 | 0.445457826 | 102 | 1209.7 | 40.72 | 1135.8 | 16.85 | 1161.2 | 15.49 | 1061.9 | 40.99 | 9 | 3125 | 262 | 1645 | 28519 | 23498 |
| 106988_40 | 0.07553 | 0.00141 | 2.04546 | 0.04219 | 0.19649 | 0.0031 | 0.05651 | 0.00213 | 0.500668418 | 98 | 1082.6 | 36.95 | 1156.4 | 16.72 | 1130.8 | 14.07 | 1111.1 | 40.8 | 5 | 4305 | 338 | 3207 | 53296 | 32014 |
| 106988_41 | 0.07839 | 0.00135 | 2.11252 | 0.04106 | 0.19548 | 0.00305 | 0.05361 | 0.00171 | 0.535243705 | 100 | 1156.8 | 33.84 | 1151 | 16.45 | 1152.9 | 13.4 | 1055.6 | 32.73 | 0 | 4934 | 402 | 3380 | 59434 | 36868 |
| 106988_42 | 0.07945 | 0.0014 | 2.17001 | 0.04274 | 0.19813 | 0.00309 | 0.05604 | 0.00203 | 0.521936151 | 101 | 1183.3 | 34.54 | 1165.3 | 16.65 | 1171.5 | 13.69 | 1102.1 | 38.81 | 7 | 5344 | 443 | 1508 | 25479 | 39210 |
| 106988_43 | 0.07566 | 0.00118 | 2.02176 | 0.03707 | 0.1938 | 0.003 | 0.05402 | 0.00196 | 0.585875109 | 98 | 1086.2 | 31.05 | 1141.9 | 16.19 | 1122.9 | 12.46 | 1063.4 | 37.56 | 10 | 11234 | 883 | 5035 | 87877 | 85616 |
| 106988_44 | 0.07659 | 0.0012 | 2.04848 | 0.03734 | 0.19399 | 0.00298 | 0.05573 | 0.00196 | 0.576334783 | 99 | 1110.5 | 30.91 | 1143 | 16.07 | 1131.8 | 12.44 | 1096.2 | 37.57 | 0 | 7978 | 635 | 3433 | 58605 | 60183 |
| 106988_45 | 0.07745 | 0.00129 | 2.09895 | 0.03983 | 0.19654 | 0.00305 | 0.05553 | 0.00205 | 0.54926844 | 99 | 1132.9 | 32.7 | 1156.7 | 16.42 | 1148.5 | 13.05 | 1092.3 | 39.23 | 11 | 6184 | 497 | 1963 | 33656 | 46062 |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 106988_46 | 0.07647 | 0.0027 | 2.01648 | 0.06997 | 0.19152 | 0.00366 | 0.06362 | 0.00581 | 0.243230341 | 99 | 1107.3 | 69.07 | 1129.6 | 19.81 | 1121.1 | 23.55 | 1246.6 | 110.41 | 0 | 6111 | 483 | 1758 | 28594 | 45611 |
| 106988_47 | 0.09173 | 0.00166 | 2.50196 | 0.0513 | 0.19773 | 0.00319 | 0.06789 | 0.00412 | 0.533872663 | 109 | 1461.8 | 34.14 | 1163.1 | 17.15 | 1272.6 | 14.87 | 1327.7 | 77.89 | 16 | 34866 | 3306 | 3393 | 47931 | 266481 |
| 106988_48 | 0.08295 | 0.00157 | 2.34799 | 0.04657 | 0.20524 | 0.00298 | 0.06944 | 0.00396 | 0.427061823 | 102 | 1268.1 | 36.47 | 1203.4 | 15.94 | 1226.9 | 14.13 | 1357 | 74.86 | 0 | 17835 | 1552 | 3152 | 46916 | 113705 |
| 106988_49 | 0.07804 | 0.00132 | 2.11513 | 0.03996 | 0.19664 | 0.00296 | 0.05919 | 0.00195 | 0.522911257 | 100 | 1147.8 | 33.3 | 1157.3 | 15.94 | 1153.8 | 13.02 | 1162.4 | 37.16 | 0 | 7534 | 608 | 2955 | 49324 | 53937 |
| 106988_50 | 0.10758 | 0.00286 | 4.59122 | 0.12204 | 0.30976 | 0.00538 | 0.08224 | 0.00497 | 0.326489924 | 100 | 1758.8 | 47.8 | 1739.5 | 26.48 | 1747.7 | 22.16 | 1597.5 | 92.76 | 0 | 6421 | 709 | 2224 | 26691 | 28039 |
| 106988_51 | 0.07876 | 0.00155 | 2.0605 | 0.04331 | 0.18982 | 0.00293 | 0.062 | 0.00238 | 0.451172796 | 101 | 1166.1 | 38.43 | 1120.4 | 15.86 | 1135.8 | 14.37 | 1215.9 | 45.21 | 22 | 6150 | 500 | 3133 | 50824 | 45250 |
| 106988_52 | 0.09901 | 0.00127 | 3.88091 | 0.06021 | 0.28438 | 0.00403 | 0.08822 | 0.00283 | 0.629925204 | 100 | 1605.6 | 23.76 | 1613.4 | 20.22 | 1609.7 | 12.53 | 1708.9 | 52.65 | 12 | 17136 | 1748 | 6135 | 68413 | 82914 |
| 106988_53 | 0.0784 | 0.00104 | 2.02351 | 0.03191 | 0.18725 | 0.00264 | 0.06317 | 0.00224 | 0.610546285 | 102 | 1157.1 | 25.97 | 1106.5 | 14.35 | 1123.4 | 10.72 | 1238.1 | 42.61 | 0 | 26802 | 2169 | 8894 | 139147 | 196569 |
| 106988_54 | 0.07822 | 0.00127 | 2.08764 | 0.0377 | 0.19364 | 0.00281 | 0.0616 | 0.00219 | 0.52103423 | 100 | 1152.4 | 31.82 | 1141.1 | 15.17 | 1144.8 | 12.4 | 1208.3 | 41.65 | 0 | 6893 | 554 | 3432 | 54580 | 48665 |
| 106988_55 | 0.07827 | 0.00171 | 1.92538 | 0.04316 | 0.17841 | 0.00269 | 0.05605 | 0.00354 | 0.373561509 | 103 | 1153.8 | 42.69 | 1058.3 | 14.7 | 1089.9 | 14.98 | 1102.3 | 67.74 | 5 | 12522 | 1015 | 5141 | 87578 | 92585 |
| 106988_56 | 0.09827 | 0.00175 | 3.71682 | 0.07443 | 0.27447 | 0.00431 | 0.09113 | 0.00496 | 0.525454979 | 101 | 1591.6 | 32.93 | 1563.5 | 21.78 | 1575 | 16.02 | 1762.9 | 91.83 | 0 | 23716 | 2380 | 12188 | 135796 | 126188 |
| 106988_57 | 0.07641 | 0.00204 | 2.02032 | 0.05425 | 0.19184 | 0.00311 | 0.0573 | 0.00329 | 0.311342939 | 99 | 1105.7 | 52.48 | 1131.3 | 16.84 | 1122.4 | 18.24 | 1126.2 | 62.84 | 1 | 3833 | 300 | 1462 | 24317 | 26618 |
| 106988_58 | 0.08074 | 0.00152 | 2.18477 | 0.04572 | 0.19632 | 0.00311 | 0.06484 | 0.00394 | 0.504458465 | 102 | 1215.1 | 36.56 | 1155.5 | 16.78 | 1176.2 | 14.58 | 1269.9 | 74.84 | 3 | 31404 | 2601 | 9959 | 153975 | 236061 |
| 106988_59 | 0.0793 | 0.0016 | 2.03463 | 0.04365 | 0.18615 | 0.00283 | 0.05862 | 0.00248 | 0.435816122 | 102 | 1179.5 | 39.45 | 1100.5 | 15.4 | 1127.2 | 14.6 | 1151.4 | 47.35 | 7 | 3691 | 298 | 2084 | 34518 | 27229 |
| 106988_60 | 0.07927 | 0.00281 | 2.10832 | 0.07403 | 0.19297 | 0.00375 | 0.05964 | 0.00621 | 0.259388446 | 101 | 1179 | 68.58 | 1137.4 | 20.29 | 1151.5 | 24.18 | 1170.8 | 118.38 | 0 | 9991 | 821 | 3717 | 65758 | 75810 |
| 106988_61 | 0.08121 | 0.00193 | 2.09935 | 0.05278 | 0.18772 | 0.00316 | 0.05397 | 0.0045 | 0.414262195 | 104 | 1226.5 | 46.04 | 1109 | 17.17 | 1148.6 | 17.29 | 1062.4 | 86.33 | 15 | 28716 | 2396 | 10540 | 199734 | 228493 |
| 106988_62 | 0.10245 | 0.00152 | 4.0405 | 0.06955 | 0.28615 | 0.00415 | 0.08112 | 0.00364 | 0.573836489 | 101 | 1669 | 27.22 | 1622.3 | 20.8 | 1642.4 | 14.01 | 1576.5 | 68 | 0 | 13058 | 1358 | 2422 | 28943 | 63215 |
| 106988_63 | 0.081 | 0.0024 | 2.13167 | 0.06281 | 0.1908 | 0.00319 | 0.05433 | 0.00484 | 0.27384462 | 103 | 1221.5 | 57 | 1125.7 | 17.26 | 1159.1 | 20.37 | 1069.3 | 92.84 | 0 | 7397 | 606 | 2823 | 48036 | 51000 |

SUPPLEMENTARY TABLE 3: HF DATA COLLECTED FOR GNARLYKNOTS-1A, SAMPLE 74318

| Sample Number | 176Hf/177Hf | 2σ | Hf fract | 178Hf/177Hf | 2σ | 176Lu/177Hf | 2σ | 176Yb/177Hf | 2σ | U/Pb Age (Ma) | 2σ Error | $Hf_i$ | εHf | 2σ Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74318-02 | 0.282434 | 0.000042 | 0.897779 | 1.467357 | 0.000259 | 0.002067 | 0.000060 | 0.076897 | 0.000409 | 265.3 | 9.12 | 0.282424 | -6.89 | 2.92 |
| 74318-06 | 0.282801 | 0.000030 | 0.909009 | 1.467392 | 0.000384 | 0.000689 | 0.000028 | 0.024532 | 0.001420 | 246 | 7.28 | 0.282798 | 5.93 | 2.12 |
| 74318-08 | 0.281878 | 0.000057 | 0.876210 | 1.467200 | 0.000351 | 0.000652 | 0.000040 | 0.028453 | 0.002749 | 1024.3 | 32.54 | 0.281866 | -9.62 | 3.99 |
| 74318-12 | 0.282755 | 0.000175 | 0.889316 | 1.466899 | 0.001352 | 0.000712 | 0.000032 | 0.029122 | 0.001664 | 253.5 | 8.24 | 0.282752 | 4.47 | 12.25 |
| 74318-13 | 0.282394 | 0.000070 | 0.872351 | 1.467352 | 0.000480 | 0.001484 | 0.000083 | 0.055248 | 0.000567 | 312.3 | 11.58 | 0.282386 | -7.19 | 4.93 |
| 74318-17 | 0.282102 | 0.000124 | -0.899174 | 1.467844 | 0.000633 | 0.000902 | 0.000073 | 0.031424 | 0.001581 | 1444.6 | 45.66 | 0.282077 | 7.44 | 8.68 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74318-18 | 0.282769 | 0.000086 | 0.867824 | 1.467221 | 0.000493 | 0.001470 | 0.000039 | 0.058458 | 0.001916 | 283.4 | 13.1 | 0.282761 | 5.45 | 6.03 |
| 74318-19 | 0.281686 | 0.000082 | 0.852077 | 1.467279 | 0.000598 | 0.000467 | 0.000007 | 0.015274 | 0.000844 | 1739.4 | 59.72 | 0.281671 | -0.23 | 5.74 |
| 74318-20 | 0.282841 | 0.000047 | -0.808364 | 1.467286 | 0.000442 | 0.000944 | 0.000016 | 0.033927 | 0.001781 | 109.7 | 3.76 | 0.282839 | 4.35 | 3.32 |
| 74318-23 | 0.283082 | 0.000084 | -0.821824 | 1.467186 | 0.000599 | 0.001770 | 0.000063 | 0.058978 | 0.003389 | 110.4 | 4.06 | 0.283078 | 12.82 | 5.85 |
| 74318-27 | 0.281928 | 0.000114 | -0.810530 | 1.467293 | 0.000710 | 0.000982 | 0.000102 | 0.034151 | 0.003914 | 1145.2 | 35.54 | 0.281906 | -5.43 | 7.95 |
| 74318-28 | 0.282737 | 0.000055 | -0.815497 | 1.467199 | 0.000429 | 0.001308 | 0.000045 | 0.037846 | 0.001401 | 320.3 | 10.74 | 0.282729 | 5.14 | 3.84 |
| 74318-32 | 0.282179 | 0.000047 | -0.793840 | 1.467323 | 0.000464 | 0.000973 | 0.000043 | 0.030310 | 0.000344 | 488.8 | 19.66 | 0.282170 | -10.89 | 3.30 |
| 74318-33 | 0.282920 | 0.000047 | -0.826019 | 1.467171 | 0.000420 | 0.001077 | 0.000083 | 0.030876 | 0.002580 | 132 | 6.1 | 0.282917 | 7.60 | 3.30 |
| 74318-34 | 0.282316 | 0.000033 | -0.785151 | 1.467258 | 0.000327 | 0.000574 | 0.000009 | 0.022079 | 0.000122 | 465.5 | 20.52 | 0.282311 | -6.42 | 2.31 |
| 74318-37 | 0.282253 | 0.000078 | 0.878651 | 1.467461 | 0.000783 | 0.000802 | 0.000030 | 0.032836 | 0.001053 | 1024.5 | 41.9 | 0.282238 | 3.59 | 5.44 |
| 74318-39 | 0.282429 | 0.000061 | -0.927807 | 1.467270 | 0.000461 | 0.000728 | 0.000036 | 0.028871 | 0.001706 | 622.5 | 25.5 | 0.282421 | 1.00 | 4.25 |
| 74318-40 | 0.282132 | 0.000048 | -0.913327 | 1.467276 | 0.000434 | 0.000977 | 0.000034 | 0.038482 | 0.000827 | 555.3 | 22.98 | 0.282122 | -11.10 | 3.35 |
| 74318-43 | 0.282208 | 0.000040 | -0.850113 | 1.467426 | 0.000280 | 0.001015 | 0.000050 | 0.028978 | 0.001078 | 601.4 | 15.76 | 0.282196 | -7.43 | 2.78 |
| 74318-49 | 0.282424 | 0.000039 | 0.924021 | 1.467385 | 0.000274 | 0.001495 | 0.000092 | 0.050319 | 0.001905 | 259 | 8.86 | 0.282417 | -7.27 | 2.73 |
| 74318-51 | 0.282427 | 0.000057 | 0.848009 | 1.467623 | 0.000606 | 0.000249 | 0.000005 | 0.009807 | 0.000225 | 514 | 18.8 | 0.282425 | -1.29 | 4.00 |
| 74318-53 | 0.282403 | 0.000035 | 0.861183 | 1.467179 | 0.000207 | 0.000743 | 0.000043 | 0.026930 | 0.001261 | 724.2 | 22.64 | 0.282393 | 2.30 | 2.44 |
| 74318-58 | 0.282103 | 0.000027 | 0.873631 | 1.467368 | 0.000353 | 0.000467 | 0.000006 | 0.015312 | 0.000082 | 1139.2 | 34.5 | 0.282393 | 11.68 | 1.88 |

SUPPLEMENTARY TABLE 4: HF DATA COLLECTED FOR GNARLYKNOTS-1A, SAMPLE 74319

| Sample Number | 176Hf/177Hf | 2σ | Hf fract | 178Hf/177Hf | 2σ | 176Lu/177Hf | 2σ | 176Yb/177Hf | 2σ | U/Pb Age (Ma) | 2σ Error | Hfi | εHf | 2σ Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74319-02 | 0.282301 | 0.000029 | 0.875949 | 1.467441 | 0.000386 | 0.000548 | 0.000006 | 0.021515 | 0.000408 | 573.7 | 15.24 | 0.282295 | -4.56 | 2.01 |
| 74319-06 | 0.281959 | 0.000029 | 0.886396 | 1.467226 | 0.000230 | 0.000387 | 0.000004 | 0.014638 | 0.000289 | 602.9 | 16.04 | 0.281955 | -15.95 | 2.04 |
| 74319-07 | 0.282461 | 0.000020 | 0.904352 | 1.467200 | 0.000129 | 0.000392 | 0.000005 | 0.014113 | 0.000164 | 527.3 | 13.6 | 0.282458 | 0.16 | 1.37 |
| 74319-10 | 0.281987 | 0.000025 | 0.883311 | 1.467263 | 0.000210 | 0.000644 | 0.000013 | 0.025825 | 0.000239 | 579 | 15.82 | 0.281980 | -15.58 | 1.76 |
| 74319-11 | 0.282946 | 0.000026 | 0.886059 | 1.467178 | 0.000274 | 0.000616 | 0.000010 | 0.023041 | 0.000139 | 115 | 6.12 | 0.282945 | 8.21 | 1.80 |
| 74319-12 | 0.282338 | 0.000026 | 0.886882 | 1.467342 | 0.000197 | 0.000997 | 0.000015 | 0.034654 | 0.001075 | 335.6 | 9.14 | 0.282332 | -8.58 | 1.85 |
| 74319-13 | 0.281923 | 0.000019 | 0.887033 | 1.467220 | 0.000170 | 0.000540 | 0.000010 | 0.018999 | 0.000158 | 1103.1 | 32.92 | 0.281911 | -6.21 | 1.36 |
| 74319-15 | 0.281278 | 0.000017 | 0.909211 | 1.467319 | 0.000160 | 0.000244 | 0.000002 | 0.008570 | 0.000109 | 313.8 | 11.06 | 0.281276 | -46.41 | 1.22 |
| 74319-16 | 0.282233 | 0.000059 | 0.761224 | 1.467586 | 0.000527 | 0.000520 | 0.000031 | 0.015063 | 0.000699 | 545.3 | 16.48 | 0.282228 | -7.57 | 4.14 |
| 74319-17 | 0.282276 | 0.000016 | 0.890028 | 1.467224 | 0.000169 | 0.000200 | 0.000005 | 0.007532 | 0.000131 | 554.8 | 23.4 | 0.282273 | -5.74 | 1.09 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74319-20 | 0.282296 | 0.000020 | 0.899187 | 1.467284 | 0.000170 | 0.000355 | 0.000005 | 0.015544 | 0.000179 | 558.9 | 21.32 | 0.282292 | -4.97 | 1.39 |
| 74319-21 | 0.282072 | 0.000024 | 0.899275 | 1.467313 | 0.000296 | 0.000406 | 0.000004 | 0.015528 | 0.000184 | 1158.1 | 34.88 | 0.282063 | 0.42 | 1.70 |
| 74319-22 | 0.282278 | 0.000038 | 0.853838 | 1.467340 | 0.000380 | 0.000662 | 0.000031 | 0.025831 | 0.000655 | 903.4 | 28.16 | 0.282267 | 1.86 | 2.67 |
| 74319-24 | 0.281912 | 0.000030 | 0.929756 | 1.467258 | 0.000230 | 0.001519 | 0.000019 | 0.049711 | 0.000590 | 1566.5 | 58.22 | 0.281867 | 2.78 | 2.13 |
| 74319-25 | 0.282857 | 0.000026 | 0.928854 | 1.467256 | 0.000298 | 0.001296 | 0.000046 | 0.050330 | 0.001244 | 228.4 | 7.6 | 0.282852 | 7.43 | 1.83 |
| 74319-26 | 0.282365 | 0.000070 | 0.878351 | 1.467584 | 0.000385 | 0.001696 | 0.000076 | 0.069251 | 0.001475 | 687.9 | 18.46 | 0.282343 | -0.28 | 4.88 |
| 74319-35 | 0.282868 | 0.000034 | -0.874274 | 1.467337 | 0.000261 | 0.000887 | 0.000044 | 0.030816 | 0.001982 | 161.6 | 5.74 | 0.282866 | 6.44 | 2.39 |
| 74319-37 | 0.282648 | 0.000070 | -0.876816 | 1.467311 | 0.000616 | 0.001051 | 0.000050 | 0.043886 | 0.003538 | 197 | 6.78 | 0.282644 | -0.60 | 4.91 |
| 74319-40 | 0.281234 | 0.000069 | -0.872607 | 1.467649 | 0.000507 | 0.000592 | 0.000024 | 0.017960 | 0.001142 | 2859.7 | 73.2 | 0.281201 | 9.14 | 4.85 |
| 74319-41 | 0.282843 | 0.000069 | -0.858615 | 1.467601 | 0.000439 | 0.001738 | 0.000079 | 0.052542 | 0.000632 | 107.5 | 5.3 | 0.282840 | 4.31 | 4.86 |
| 74319-42 | 0.282135 | 0.000034 | -0.883686 | 1.467263 | 0.000259 | 0.001127 | 0.000023 | 0.037430 | 0.001122 | 1152.8 | 35.42 | 0.282110 | 1.97 | 2.35 |
| 74319-45 | 0.282423 | 0.000024 | -0.927479 | 1.467445 | 0.000218 | 0.000452 | 0.000040 | 0.018000 | 0.001859 | 790.1 | 28.22 | 0.282416 | 4.61 | 1.70 |
| 74319-48 | 0.282455 | 0.000048 | -0.915793 | 1.467359 | 0.000297 | 0.001310 | 0.000043 | 0.045812 | 0.002334 | 282.3 | 9.6 | 0.282448 | -5.65 | 3.34 |
| 74319-51 | 0.282304 | 0.000023 | -0.908343 | 1.467310 | 0.000197 | 0.001164 | 0.000022 | 0.041777 | 0.001303 | 457 | 15.56 | 0.282294 | -7.18 | 1.64 |
| 74319-55 | 0.282462 | 0.000023 | -0.913100 | 1.467312 | 0.000151 | 0.000415 | 0.000022 | 0.016134 | 0.000963 | 609.2 | 22.6 | 0.282457 | 1.98 | 1.58 |
| 74319-59 | 0.282228 | 0.000022 | -0.914332 | 1.467363 | 0.000307 | 0.000293 | 0.000004 | 0.011585 | 0.000471 | 603.1 | 23.86 | 0.282224 | -6.39 | 1.56 |
| 74319-65 | 0.282881 | 0.000032 | -0.917761 | 1.467425 | 0.000219 | 0.001069 | 0.000112 | 0.035358 | 0.001569 | 226.8 | 10.62 | 0.282877 | 8.29 | 2.25 |
| 74319-66 | 0.281651 | 0.000026 | -0.833370 | 1.467516 | 0.000510 | 0.000118 | 0.000004 | 0.004335 | 0.000057 | 1538.8 | 71.48 | 0.281647 | -5.66 | 1.81 |
| 74319-68 | 0.282975 | 0.000025 | 0.933812 | 1.467277 | 0.000186 | 0.000497 | 0.000041 | 0.018057 | 0.001804 | 107.8 | 5.66 | 0.282974 | 9.07 | 1.76 |
| 74319-69 | 0.282100 | 0.000028 | -0.874790 | 1.467440 | 0.000217 | 0.000621 | 0.000022 | 0.021440 | 0.001025 | 1151.3 | 49.52 | 0.282086 | 1.08 | 1.95 |
| 74319-77 | 0.282046 | 0.000043 | -0.829241 | 1.467450 | 0.000248 | 0.000762 | 0.000094 | 0.020826 | 0.003424 | 1448.8 | 62.58 | 0.282025 | 5.69 | 3.01 |
| 74319-78 | 0.282378 | 0.000069 | 0.918142 | 1.467365 | 0.000295 | 0.001412 | 0.000072 | 0.051862 | 0.005013 | 283.4 | 13.98 | 0.282370 | -8.37 | 4.85 |
| 74319-80 | 0.282208 | 0.000023 | -0.915928 | 1.467320 | 0.000279 | 0.000326 | 0.000012 | 0.012285 | 0.000676 | 541.8 | 24.56 | 0.282204 | -8.47 | 1.62 |

SUPPLEMENTARY TABLE 5: HF DATA COLLECTED FOR GNARLYKNOTS-1A, SAMPLE 74321

| Sample Number | 176Hf/177Hf | 2σ | Hf fract | 178Hf/177Hf | 2σ | 176Lu/177Hf | 2σ | 176Yb/177Hf | 2σ | U/Pb Age (Ma) | 2σ Error | Hfi | εHf | 2σ Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74321-03 | 0.282117 | 0.000018 | 0.901993 | 1.467251 | 0.000152 | 0.000078 | 0.000007 | 0.003569 | 0.000346 | 540.3 | 15.56 | 0.282116 | -11.64 | 1.29 |
| 74321-08 | 0.282895 | 0.000020 | 0.901119 | 1.467364 | 0.000189 | 0.000474 | 0.000017 | 0.015389 | 0.000254 | 108.3 | 4.92 | 0.282894 | 6.25 | 1.38 |
| 74321-10 | 0.282776 | 0.000029 | 0.879703 | 1.467444 | 0.000208 | 0.001068 | 0.000063 | 0.033376 | 0.000686 | 241.4 | 8.44 | 0.282771 | 4.86 | 2.01 |
| 74321-11 | 0.282292 | 0.000015 | 0.889741 | 1.467223 | 0.000122 | 0.000920 | 0.000009 | 0.035757 | 0.000659 | 802.7 | 20.38 | 0.282278 | -0.01 | 1.04 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74321-12 | 0.282122 | 0.000126 | 0.819083 | 1.467980 | 0.000460 | 0.000808 | 0.000032 | 0.023830 | 0.000638 | 1109.8 | 40.34 | 0.282105 | 0.81 | 8.82 |
| 74321-13 | 0.282478 | 0.000057 | 0.883443 | 1.467301 | 0.000494 | 0.000895 | 0.000021 | 0.038151 | 0.001143 | 590.5 | 18.54 | 0.282468 | 1.94 | 3.97 |
| 74321-14 | 0.281998 | 0.000023 | 0.898163 | 1.467358 | 0.000186 | 0.000157 | 0.000007 | 0.005598 | 0.000147 | 524.6 | 16.22 | 0.281996 | -16.23 | 1.64 |
| 74321-15 | 0.281533 | 0.000042 | 0.858402 | 1.466784 | 0.000888 | 0.001203 | 0.000016 | 0.045554 | 0.000598 | 1942.6 | 49.3 | 0.281488 | -2.03 | 2.97 |
| 74321-16 | 0.282723 | 0.000028 | 0.858402 | 1.467537 | 0.000224 | 0.000797 | 0.000078 | 0.026518 | 0.001449 | 240.7 | 7.64 | 0.282719 | 3.01 | 1.96 |
| 74321-22 | 0.282842 | 0.000040 | 0.899465 | 1.467313 | 0.000301 | 0.001659 | 0.000049 | 0.062085 | 0.001857 | 274 | 8.94 | 0.282833 | 7.79 | 2.80 |
| 74321-23 | 0.281673 | 0.000040 | 0.829207 | 1.467182 | 0.000522 | 0.000985 | 0.000057 | 0.028946 | 0.001540 | 193.7 | 6.52 | 0.281669 | -35.18 | 2.78 |
| 74321-25 | 0.282835 | 0.000022 | 0.915714 | 1.467274 | 0.000129 | 0.001176 | 0.000049 | 0.041245 | 0.002102 | 269.3 | 10.4 | 0.282829 | 7.54 | 1.52 |
| 74321-28 | 0.282274 | 0.000210 | 0.935404 | 1.468666 | 0.000733 | 0.003511 | 0.000266 | 0.118159 | 0.001657 | 288.3 | 12.94 | 0.282255 | -12.34 | 14.68 |
| 74321-30 | 0.282333 | 0.000013 | 0.915092 | 1.467311 | 0.000186 | 0.000034 | 0.000002 | 0.001531 | 0.000071 | 553.3 | 23.82 | 0.282333 | -3.66 | 0.94 |
| 74321-31 | 0.281818 | 0.000030 | 0.900889 | 1.467309 | 0.000186 | 0.000909 | 0.000027 | 0.032389 | 0.000279 | 1535.1 | 107.88 | 0.281791 | -0.64 | 2.07 |
| 74321-32 | 0.281384 | 0.000018 | 0.905135 | 1.467290 | 0.000148 | 0.000799 | 0.000050 | 0.031294 | 0.002435 | 1862.5 | 63.16 | 0.281356 | -8.58 | 1.27 |
| 74321-33 | 0.282421 | 0.000023 | 0.902604 | 1.467347 | 0.000170 | 0.000816 | 0.000045 | 0.032000 | 0.000930 | 480 | 21.66 | 0.282413 | -2.46 | 1.64 |
| 74321-35 | 0.281934 | 0.000082 | 0.857529 | 1.467438 | 0.000544 | 0.001108 | 0.000026 | 0.029399 | 0.000539 | 1158.7 | 43.58 | 0.281909 | -5.02 | 5.73 |
| 74321-38 | 0.282051 | 0.000015 | 0.899988 | 1.467278 | 0.000210 | 0.000094 | 0.000001 | 0.004329 | 0.000044 | 544.7 | 27.74 | 0.282050 | -13.88 | 1.08 |
| 74321-39 | 0.280680 | 0.000089 | 0.942283 | 1.468607 | 0.000782 | 0.000668 | 0.000032 | 0.021008 | 0.001112 | 2976.1 | 138.34 | 0.280642 | -8.03 | 6.23 |
| 74321-40 | 0.282055 | 0.000013 | 0.906179 | 1.467232 | 0.000199 | 0.000102 | 0.000001 | 0.004509 | 0.000029 | 509.9 | 30.3 | 0.282054 | -14.53 | 0.93 |
| 74321-42 | 0.282778 | 0.000060 | 0.871961 | 1.467467 | 0.000457 | 0.000952 | 0.000047 | 0.029291 | 0.000689 | 923 | 46.72 | 0.282762 | 19.86 | 4.22 |
| 74321-44 | 0.282245 | 0.000032 | 0.874293 | 1.467284 | 0.000278 | 0.000917 | 0.000028 | 0.032002 | 0.001576 | 270.4 | 33.16 | 0.282241 | -13.25 | 2.24 |

SUPPLEMENTARY TABLE 6: HF DATA COLLECTED FOR GNARLYKNOTS-1A, SAMPLE 74322

| Sample Number | 176Hf/177Hf | 2σ | Hf fract | 178Hf/177Hf | 2σ | 176Lu/177Hf | 2σ | 176Yb/177Hf | 2σ | U/Pb Age (Ma) | 2σ Error | Hfi | εHf | 2σ Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74322-01 | 0.282332 | 0.000036 | 0.896914 | 1.467341 | 0.000247 | 0.001876 | 0.000114 | 0.070944 | 0.002138 | 1018 | 27.12 | 0.282296 | 5.51 | 2.50 |
| 74322-02 | 0.281351 | 0.000021 | 0.922065 | 1.467360 | 0.000168 | 0.000569 | 0.000010 | 0.021371 | 0.000432 | 493.5 | 14.42 | 0.281346 | -39.94 | 1.46 |
| 74322-03 | 0.282113 | 0.000022 | 0.898463 | 1.467290 | 0.000227 | 0.000596 | 0.000005 | 0.021940 | 0.000168 | 1084.9 | 32.44 | 0.282101 | 0.10 | 1.55 |
| 74322-06 | 0.282095 | 0.000020 | 0.898803 | 1.467312 | 0.000200 | 0.000755 | 0.000007 | 0.028180 | 0.000410 | 1152.9 | 36.32 | 0.282079 | 0.86 | 1.37 |
| 74322-13 | 0.282973 | 0.000024 | 0.897319 | 1.467288 | 0.000213 | 0.000814 | 0.000030 | 0.026707 | 0.001324 | 131.3 | 4.64 | 0.282971 | 9.48 | 1.68 |
| 74322-16 | 0.282966 | 0.000019 | 0.895150 | 1.467240 | 0.000144 | 0.000496 | 0.000008 | 0.018127 | 0.000396 | 97.5 | 6.44 | 0.282965 | 8.54 | 1.31 |
| 74322-18 | 0.282417 | 0.000015 | 0.877702 | 1.467237 | 0.000257 | 0.000052 | 0.000001 | 0.002429 | 0.000056 | 591.5 | 18.06 | 0.282416 | 0.13 | 1.03 |
| 74322-20 | 0.281932 | 0.000016 | 0.887610 | 1.467289 | 0.000153 | 0.000793 | 0.000029 | 0.029069 | 0.001357 | 1565.1 | 42.5 | 0.281908 | 4.20 | 1.13 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74322-21 | 0.283008 | 0.000018 | 0.862600 | 1.467247 | 0.000172 | 0.001010 | 0.000016 | 0.033485 | 0.000195 | 160.5 | 6.4 | 0.283005 | 11.33 | 1.24 |
| 74322-26 | 0.283016 | 0.000019 | 0.912286 | 1.467293 | 0.000180 | 0.000290 | 0.000013 | 0.008897 | 0.000363 | 100.8 | 8.28 | 0.283015 | 10.38 | 1.30 |
| 74322-27 | 0.282298 | 0.000019 | 0.913777 | 1.467358 | 0.000150 | 0.000885 | 0.000026 | 0.033197 | 0.000890 | 469.3 | 16.56 | 0.282291 | -7.04 | 1.36 |
| 74322-29 | 0.282418 | 0.000014 | 0.913889 | 1.467274 | 0.000146 | 0.000052 | 0.000003 | 0.002172 | 0.000093 | 540.5 | 16.64 | 0.282417 | -0.97 | 0.95 |
| 74322-31 | 0.282038 | 0.000028 | 0.902806 | 1.467349 | 0.000230 | 0.000614 | 0.000020 | 0.021820 | 0.001109 | 1134.3 | 36.62 | 0.282025 | -1.49 | 1.99 |
| 74322-32 | 0.282096 | 0.000018 | 0.904417 | 1.467242 | 0.000159 | 0.001006 | 0.000044 | 0.037132 | 0.001386 | 1133 | 32.08 | 0.282075 | 0.26 | 1.24 |
| 74322-40 | 0.281603 | 0.000033 | 0.866871 | 1.467429 | 0.000338 | 0.000709 | 0.000004 | 0.030707 | 0.000956 | 1647.5 | 48.86 | 0.281581 | -5.53 | 2.28 |
| 74322-42 | 0.282384 | 0.000037 | 0.825370 | 1.467421 | 0.000211 | 0.001446 | 0.000113 | 0.045311 | 0.002578 | 954.8 | 26.78 | 0.282358 | 6.27 | 2.57 |
| 74322-45 | 0.282685 | 0.000018 | 0.886207 | 1.467217 | 0.000192 | 0.000688 | 0.000042 | 0.024691 | 0.001232 | 320.8 | 11.36 | 0.282681 | 3.45 | 1.25 |
| 74322-50 | 0.283020 | 0.000019 | 0.899535 | 1.467255 | 0.000170 | 0.001008 | 0.000036 | 0.029498 | 0.000957 | 179.1 | 6.02 | 0.283016 | 12.16 | 1.36 |

SUPPLEMENTARY TABLE 7: HF DATA COLLECTED FOR GNARLYKNOTS-1A, SAMPLE 74323

| Sample Number | 176Hf/177Hf | 2σ | Hf fract | 178Hf/177Hf | 2σ | 176Lu/177Hf | 2σ | 176Yb/177Hf | 2σ | U/Pb Age (Ma) | 2σ Error | Hfi | εHf | 2σ Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74323-07 | 0.282430 | 0.000038 | 0.929782 | 1.467203 | 0.000144 | 0.000931 | 0.000032 | 0.034361 | 0.001148 | 1005.5 | 31.2 | 0.282413 | 9.34 | 2.65 |
| 74323-08 | 0.282871 | 0.000025 | 0.925638 | 1.467316 | 0.000155 | 0.001051 | 0.000016 | 0.040081 | 0.000256 | 100.2 | 6.2 | 0.282869 | 5.20 | 1.72 |
| 74323-09 | 0.281754 | 0.000017 | 0.922809 | 1.467248 | 0.000149 | 0.000128 | 0.000000 | 0.005280 | 0.000036 | 566.1 | 18.9 | 0.281753 | -23.92 | 1.20 |
| 74323-10 | 0.281769 | 0.000015 | 0.929398 | 1.467267 | 0.000155 | 0.000120 | 0.000000 | 0.004897 | 0.000038 | 571.4 | 18.0 | 0.281768 | -23.26 | 1.07 |
| 74323-11 | 0.282886 | 0.000019 | 0.922150 | 1.467221 | 0.000147 | 0.000551 | 0.000015 | 0.019603 | 0.000723 | 225.2 | 10.1 | 0.282883 | 8.48 | 1.31 |
| 74323-12 | 0.282302 | 0.000022 | 0.925129 | 1.467257 | 0.000186 | 0.000973 | 0.000025 | 0.036387 | 0.001186 | 984.7 | 27.2 | 0.282284 | 4.31 | 1.52 |
| 74323-13 | 0.282175 | 0.000017 | 0.931566 | 1.467304 | 0.000194 | 0.000236 | 0.000004 | 0.009878 | 0.000244 | 557.8 | 25.4 | 0.282173 | -9.24 | 1.19 |
| 74323-14 | 0.282176 | 0.000017 | 0.939542 | 1.467312 | 0.000212 | 0.000254 | 0.000002 | 0.010690 | 0.000047 | 571.4 | 23.3 | 0.282173 | -8.91 | 1.22 |
| 74323-15 | 0.282386 | 0.000017 | 0.930070 | 1.467247 | 0.000212 | 0.000438 | 0.000003 | 0.016815 | 0.000098 | 178.9 | 16.6 | 0.282385 | -10.19 | 1.21 |
| 74323-19 | 0.282274 | 0.000020 | 0.940520 | 1.467239 | 0.000158 | 0.001135 | 0.000059 | 0.043380 | 0.002120 | 741.9 | 21.8 | 0.282258 | -2.09 | 1.39 |
| 74323-20 | 0.282292 | 0.000019 | 0.954907 | 1.467240 | 0.000172 | 0.000746 | 0.000005 | 0.028806 | 0.000274 | 732.7 | 21.8 | 0.282282 | -1.46 | 1.36 |
| 74323-22 | 0.282396 | 0.000018 | 0.939874 | 1.467284 | 0.000174 | 0.000492 | 0.000006 | 0.020412 | 0.000216 | 597.4 | 16.1 | 0.282390 | -0.66 | 1.29 |
| 74323-30 | 0.282988 | 0.000040 | 0.932629 | 1.467142 | 0.000138 | 0.003087 | 0.000025 | 0.106831 | 0.001648 | 96.4 | 2.9 | 0.282983 | 9.13 | 2.81 |
| 74323-31 | 0.282957 | 0.000036 | 0.941798 | 1.467167 | 0.000173 | 0.001627 | 0.000012 | 0.056666 | 0.000235 | 95.1 | 4.6 | 0.282954 | 8.08 | 2.50 |
| 74323-40 | 0.281941 | 0.000018 | 0.931887 | 1.467213 | 0.000117 | 0.000512 | 0.000006 | 0.019464 | 0.000362 | 561.0 | 28.5 | 0.281935 | -17.57 | 1.27 |
| 74323-41 | 0.282125 | 0.000015 | 0.928601 | 1.467231 | 0.000159 | 0.000130 | 0.000003 | 0.005634 | 0.000113 | 528.7 | 26.2 | 0.282124 | -11.62 | 1.02 |
| 74323-63 | 0.282410 | 0.000019 | 0.909117 | 1.467247 | 0.000147 | 0.000721 | 0.000001 | 0.029415 | 0.000210 | 528.1 | 15.3 | 0.282402 | -1.77 | 1.36 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74323-64 | 0.282328 | 0.000012 | 0.908228 | 1.467201 | 0.000163 | 0.000051 | 0.000000 | 0.002545 | 0.000042 | 591.1 | 16.9 | 0.282327 | -3.02 | 0.87 |

SUPPLEMENTARY TABLE 8: HF DATA COLLECTED FOR GNARLYKNOTS-1A, SAMPLE 74326

| Sample Number | 176Hf/177Hf | 2σ | Hf fract | 178Hf/177Hf | 2σ | 176Lu/177Hf | 2σ | 176Yb/177Hf | 2σ | U/Pb Age (Ma) | 2σ Error | Hfi | εHf | 2σ Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74326-01 | 0.282079 | 0.000014 | 1.135225 | 1.467291 | 0.000178 | 0.000134 | 0.000001 | 0.004333 | 0.000059 | 1261.2 | 38.16 | 0.282075 | 3.19 | 0.95 |
| 74326-02 | 0.280795 | 0.000017 | 1.117271 | 1.467394 | 0.000218 | 0.000853 | 0.000025 | 0.029819 | 0.000807 | 2684 | 70.72 | 0.280751 | -10.99 | 1.19 |
| 74326-03 | 0.282994 | 0.000015 | 1.121588 | 1.467181 | 0.000123 | 0.000800 | 0.000025 | 0.026683 | 0.001176 | 148.2 | 11.34 | 0.282991 | 10.59 | 1.06 |
| 74326-04 | 0.280963 | 0.000022 | 1.112096 | 1.467331 | 0.000285 | 0.000522 | 0.000017 | 0.019172 | 0.001066 | 2703.6 | 83.8 | 0.280936 | -3.97 | 1.53 |
| 74326-08 | 0.282811 | 0.000023 | 1.117669 | 1.467185 | 0.000309 | 0.000748 | 0.000030 | 0.028824 | 0.001342 | 288.7 | 11.5 | 0.282807 | 7.21 | 1.61 |
| 74326-12 | 0.282461 | 0.000013 | 1.135316 | 1.467195 | 0.000169 | 0.000409 | 0.000001 | 0.015919 | 0.000201 | 528 | 16.82 | 0.282457 | 0.18 | 0.88 |
| 74326-14 | 0.282335 | 0.000013 | 1.138561 | 1.467242 | 0.000139 | 0.000209 | 0.000046 | 0.007813 | 0.001663 | 510.3 | 15.12 | 0.282333 | -4.63 | 0.88 |
| 74326-16 | 0.281885 | 0.000015 | 1.127952 | 1.467313 | 0.000136 | 0.000269 | 0.000002 | 0.009787 | 0.000134 | 1128.3 | 38.88 | 0.281879 | -6.77 | 1.03 |
| 74326-19 | 0.282298 | 0.000018 | 1.140682 | 1.467313 | 0.000156 | 0.000443 | 0.000003 | 0.016411 | 0.000219 | 726.2 | 28.66 | 0.282292 | -1.22 | 1.28 |
| 74326-22 | 0.281674 | 0.000017 | 1.126622 | 1.467226 | 0.000204 | 0.000251 | 0.000003 | 0.009512 | 0.000168 | 513.9 | 22.18 | 0.281671 | -27.97 | 1.22 |
| 74326-24 | 0.282348 | 0.000030 | 1.101726 | 1.467323 | 0.000214 | 0.000439 | 0.000051 | 0.013927 | 0.001214 | 650.2 | 25.02 | 0.282342 | -1.16 | 2.09 |
| 74326-25 | 0.282161 | 0.000018 | 1.133673 | 1.467242 | 0.000177 | 0.000444 | 0.000061 | 0.017471 | 0.002519 | 895 | 32.92 | 0.282153 | -2.34 | 1.28 |
| 74326-26 | 0.282321 | 0.000011 | 1.134009 | 1.467223 | 0.000198 | 0.000046 | 0.000001 | 0.002167 | 0.000046 | 558.8 | 24.42 | 0.282320 | -3.99 | 0.77 |
| 74326-31 | 0.283025 | 0.000020 | 1.141671 | 1.467299 | 0.000193 | 0.000816 | 0.000028 | 0.024894 | 0.001017 | 98 | 4.74 | 0.283023 | 10.60 | 1.41 |
| 74326-34 | 0.282423 | 0.000026 | 1.136478 | 1.467302 | 0.000150 | 0.001555 | 0.000018 | 0.059029 | 0.000489 | 358.5 | 12.78 | 0.282413 | -5.20 | 1.81 |
| 74326-38 | 0.282476 | 0.000025 | 1.131562 | 1.467238 | 0.000177 | 0.001273 | 0.000020 | 0.045205 | 0.001224 | 302.6 | 11.34 | 0.282468 | -4.48 | 1.73 |
| 74326-41 | 0.282795 | 0.000021 | 1.115211 | 1.467256 | 0.000137 | 0.000715 | 0.000022 | 0.023437 | 0.000936 | 241.5 | 8.36 | 0.282792 | 5.61 | 1.46 |
| 74326-42 | 0.282338 | 0.000011 | 1.145011 | 1.467246 | 0.000117 | 0.000027 | 0.000002 | 0.001200 | 0.000086 | 565.5 | 19.54 | 0.282338 | -3.21 | 0.74 |
| 74326-43 | 0.282818 | 0.000084 | 1.046049 | 1.467243 | 0.000318 | 0.001694 | 0.000075 | 0.044654 | 0.001507 | 242.7 | 8.5 | 0.282811 | 6.30 | 5.87 |
| 74326-44 | 0.282378 | 0.000020 | 1.135928 | 1.467259 | 0.000153 | 0.000178 | 0.000010 | 0.007010 | 0.000497 | 651.1 | 24.48 | 0.282376 | 0.06 | 1.38 |
| 74326-45 | 0.282290 | 0.000018 | 1.126072 | 1.467368 | 0.000302 | 0.000030 | 0.000002 | 0.001408 | 0.000071 | 503.7 | 17.98 | 0.282290 | -6.29 | 1.25 |
| 74326-46 | 0.282273 | 0.000022 | 1.121694 | 1.467257 | 0.000207 | 0.000822 | 0.000064 | 0.028373 | 0.001501 | 771.7 | 28.02 | 0.282261 | -1.30 | 1.56 |
| 74326-50 | 0.282510 | 0.000019 | 1.116452 | 1.467315 | 0.000255 | 0.000379 | 0.000031 | 0.013613 | 0.001180 | 537.5 | 19.5 | 0.282506 | 2.12 | 1.33 |
| 74326-51 | 0.280724 | 0.000025 | 1.101397 | 1.467250 | 0.000279 | 0.000225 | 0.000008 | 0.007927 | 0.000188 | 2370.3 | 91.62 | 0.280714 | -19.63 | 1.76 |
| 74326-53 | 0.281766 | 0.000014 | 1.127142 | 1.467277 | 0.000126 | 0.000416 | 0.000012 | 0.015929 | 0.000424 | 558.4 | 23.38 | 0.281762 | -23.77 | 0.97 |
| 74326-55 | 0.282403 | 0.000014 | 1.129301 | 1.467280 | 0.000177 | 0.000110 | 0.000022 | 0.003775 | 0.000656 | 530.9 | 19.64 | 0.282402 | -1.73 | 1.01 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74326-57 | 0.282366 | 0.000032 | 1.069338 | 1.467203 | 0.000603 | 0.000047 | 0.000005 | 0.001754 | 0.000118 | 503.9 | 22.22 | 0.282366 | -3.61 | 2.21 |
| 74326-60 | 0.282532 | 0.000025 | 1.108738 | 1.467244 | 0.000124 | 0.002011 | 0.000066 | 0.074911 | 0.001722 | 285.8 | 11.24 | 0.282521 | -2.99 | 1.75 |
| 74326-61 | 0.281680 | 0.000055 | 1.045607 | 1.467322 | 0.000412 | 0.001303 | 0.000063 | 0.036228 | 0.001182 | 1649.4 | 52.18 | 0.281640 | -3.39 | 3.85 |
| 74326-66 | 0.282212 | 0.000026 | 1.138020 | 1.467184 | 0.000208 | 0.000591 | 0.000067 | 0.024845 | 0.002965 | 685.4 | 19.8 | 0.282204 | -5.27 | 1.80 |
| 74326-71 | 0.282741 | 0.000070 | 1.101544 | 1.467138 | 0.000319 | 0.001086 | 0.000034 | 0.038287 | 0.000083 | 242.8 | 10.66 | 0.282736 | 3.68 | 4.87 |
| 74326-72 | 0.282304 | 0.000032 | 1.076299 | 1.467359 | 0.000336 | 0.000433 | 0.000034 | 0.016254 | 0.001573 | 765.7 | 21.94 | 0.282298 | -0.14 | 2.21 |
| 74326-77 | 0.281398 | 0.000052 | 1.071156 | 1.467291 | 0.000407 | 0.000948 | 0.000102 | 0.034428 | 0.002638 | 1856.7 | 50.22 | 0.281365 | -8.39 | 3.67 |
| 74326-78 | 0.282434 | 0.000021 | 1.140219 | 1.467216 | 0.000130 | 0.001334 | 0.000026 | 0.050635 | 0.001282 | 244.1 | 12 | 0.282428 | -7.22 | 1.48 |
| 74326-79 | 0.282261 | 0.000035 | 1.116642 | 1.467169 | 0.000431 | 0.000692 | 0.000020 | 0.030204 | 0.000442 | 803.9 | 24.9 | 0.282251 | -0.94 | 2.43 |