Flooding, Faults and Fractures

Hello Chair Justice Pepper, and Panel.

Thank you for this opportunity to present at this hearing today.

I have reviewed the draft Final Report and have found that it creates more questions than it answers.

Of the 120 recommendations made in the report. There are some I wholeheartedly support (such as the reversal of onus of proof) and others to which I take great exception (such as refusing landholders the right to veto). Many recommendations are on the right track, but don't go far enough, as they only apply to production not exploration. Yet the risks from exploratory fracking are equal to or greater than a production well.

The 115 risks identified in the report are a significant concern. Reducing or mitigating risks is not the same as eliminating them or making fracking safe. Defining low risk as people losing their access to water for 2 weeks is unacceptable and misleading. Just ask anyone reliant on bore water, how losing access to it for 2 weeks will affect them. Territorians have clearly and repeatedly stated that any risk to water is too great and will not be tolerated.

Many Territorians have been expressing to me their overwhelming disappointment over not having their staunch opposition to fracking recognised in the draft Final Report or Coffey's Social Impact Assessment. So many people have voiced their discontent and disillusionment with the Inquiry due to this. They feel as if they have been ignored and have expressed their reluctance to continue any participation in these final stages of the Inquiry, viewing it as a waste of their time.

There are many more issues I would like to raise. I will focus however, on the topics of flooding and fractures.

To propose that fracking will only take place in the dry season is misleading, as equipment and partially prepared sites will be exposed in the wet season and vulnerable to failure as a result.

Faults and fractures

A new report[2] released last month (January 2018) attempted to map the faults in the Beetaloo Basin (see Maps 14 & 15). As you can see many faults are shown. Though this map is far from complete. In fact, Origin discovered a fault when drilling the Amungee NW1H well (as is shown in Figure 6.5 on page 81 of the draft report).

Geologically there is no such thing as solid rock. The subsurface is a maze of fractured and faulted material.

In conventional rock strata above gas or oil reservoirs the material has developed an impermeablity that can be observed and trusted to remain as the gas or oil is extracted. In some cases, the reservoir requires water injection to replace what's extracted to maintain the integrity of the reservoir and aid the extraction. In most cases the observed sealing quality of the layer above the reservoir remains intact and the issues are only around the well engineering.

Hence the focus in advice given to you by the engineers has been all about how good the well engineering is.

This completely misses the point, and a sceptic might say intentionally so.

The proposed fracking process is entirely different to conventional gas. In fracking there is no proof of impermeability of overlaying strata. Impermeability cannot be observed.

Trusting that impermeability exists is just not an acceptable position.

Faults and fractures are to be expected as the norm above the shale layers proposed for fracking. All and every geologist will attest to this. It is for this very reason that you cannot get a guarantee from the fracking companies as to

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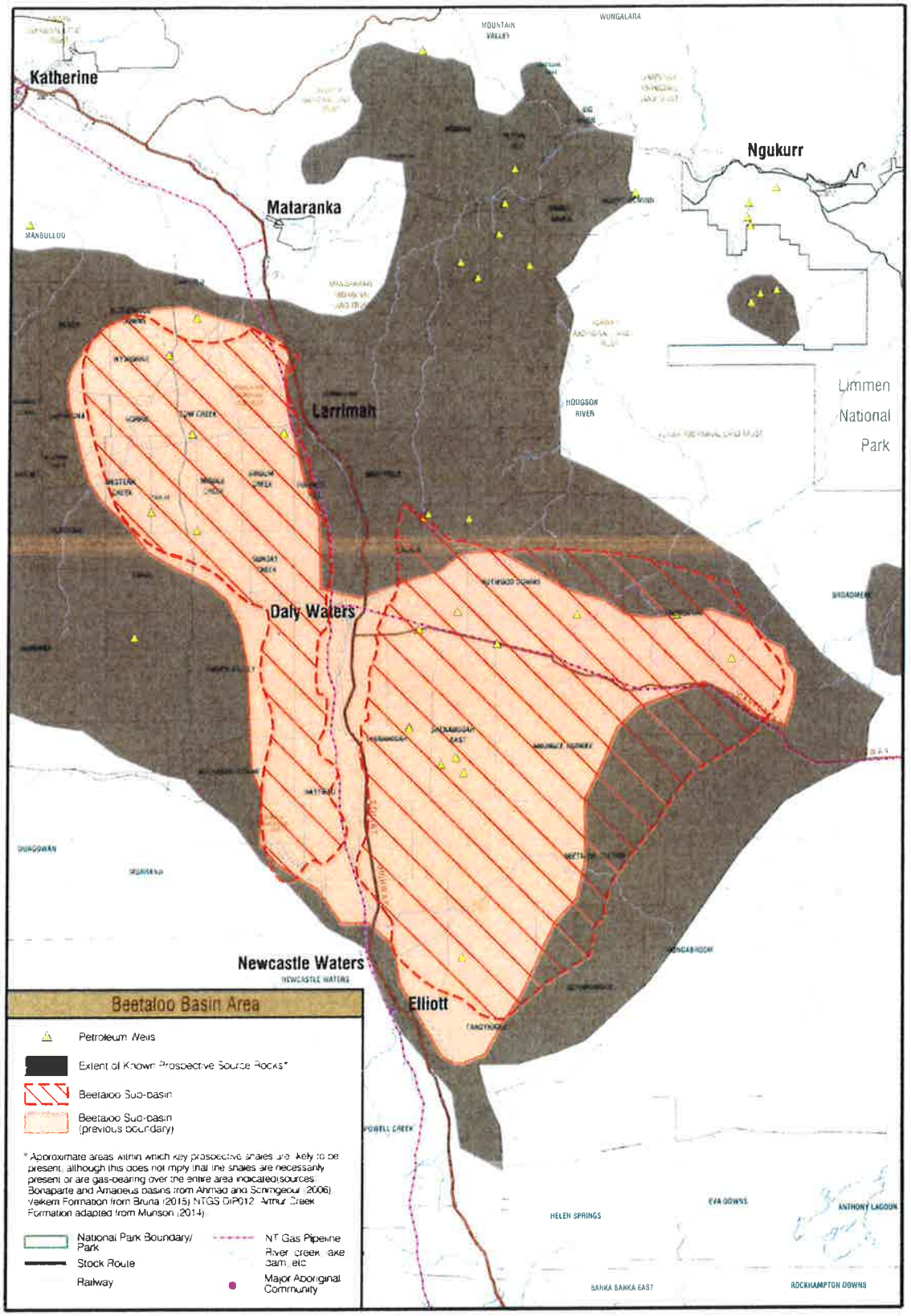
[2] 'Spatial and temporal variation in detrital zircon age provenance of the hydrocarbon-bearing upper Roper Group, Beetaloo Sub-basin, Northern Territory, Australia' (2017) http://www.sciencedirect.com/science/article/pii/S0301926817303613#b0125

map 1

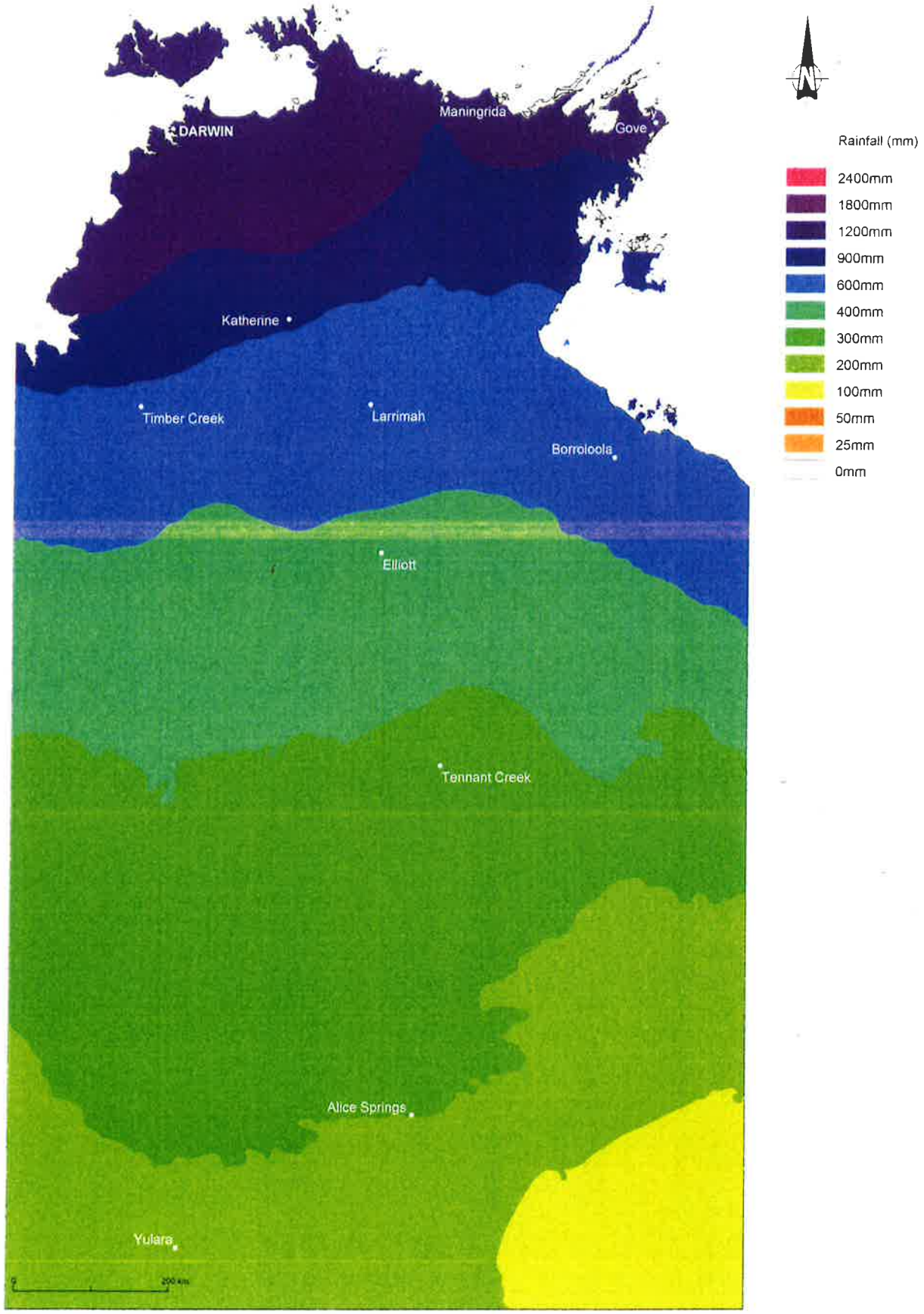
Figure 6.4: Newly defined and previous boundaries of the Beetaloo Sub-basin: Source DPIR.[17]



17 DPIR submission 479.

Map 2.

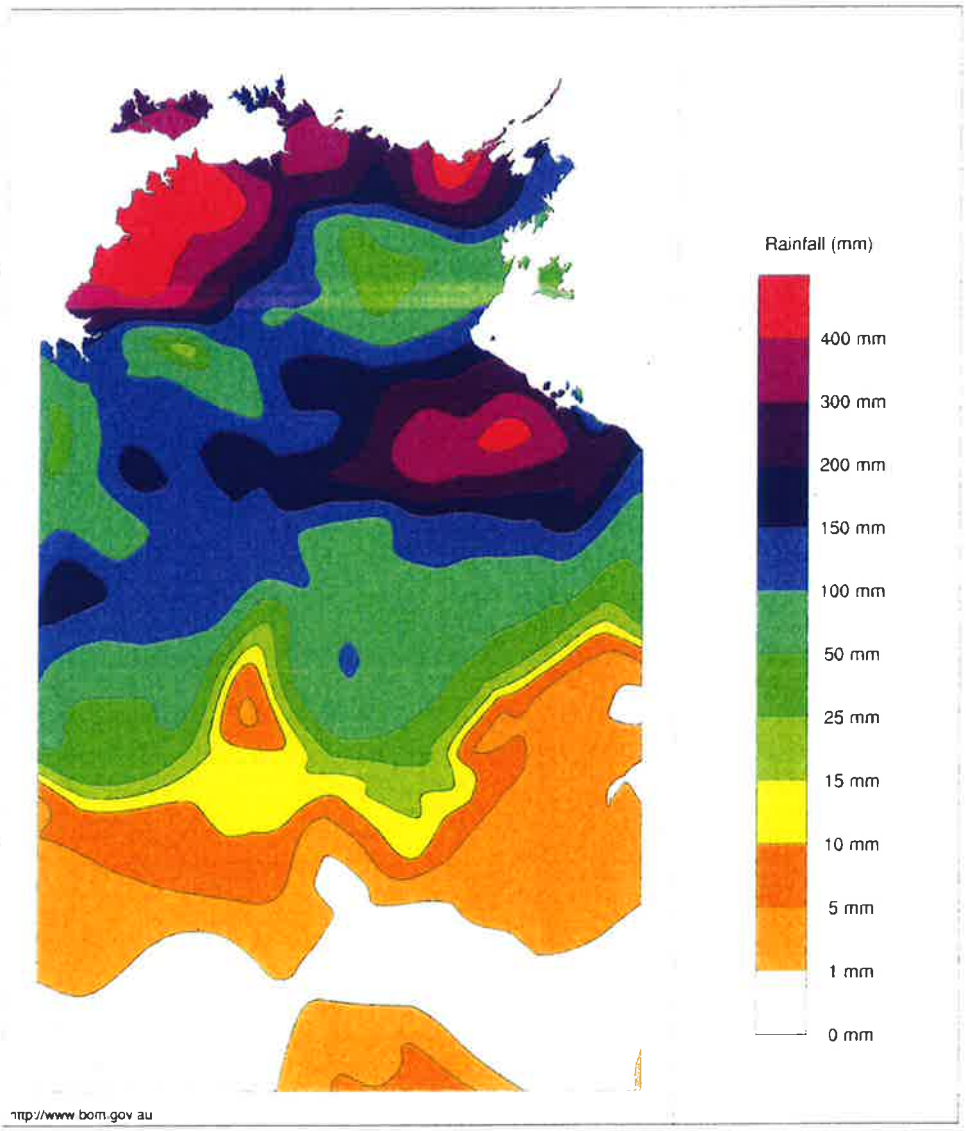
Figure 7.1: Average annual rainfall in the Northern Territory over the period 1960-1990. Source: BOM.



Map 3.

Northern Territory Rainfall Totals (mm) Week Ending 30th January 2018

Australian Bureau of Meteorology



http://www.bom.gov.au

Issued: 30/01/2018

Map 4.

EWN Alerts - Northern Territory

17:36 Jan 24 NT Severe Thunderstorm Warning: Heavy Rain, Mataranka, Ngukurr, Larrimah, Mallapunyah, Mcarthur River, Daly Waters

Details:

NT Severe Thunderstorm Warning: Heavy Rain

For people in Carpentaria and parts of Daly, Arnhem and Gregory districts.

Issued at 5:34 pm Wednesday, 24 January 2018.

MONSOON TROUGH GENERATING HEAVY RAINFALL ACROSS THE BASE OF THE TOP END.

Weather Situation: Heavy rainfall with thunderstorms is currently occuring in the Carpentaria District along the monsoon trough. Further heavy falls are possible with thunderstorms developing near a tropical low located southwest of Katherine.

Severe thunderstorms are likely to produce heavy rainfall that may lead to flash flooding in the warning area over the next several hours. Locations which may be affected include Mataranka, Ngukurr, Larrimah, Mallapunyah, McArthur River and Daly Waters.

93.8mm has been recorded in the last hour as of 5:30pm CST at McArthur River Mine

The Northern Territory Emergency Service advises that people should:
* slow down and turn your headlights on
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* secure loose outside objects
* ensure pets and animals are safe
* avoid remaining in the open when storms threaten
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

map 5

EWN Alerts - Northern Territory

11:47 Jan 23 NT Severe Weather Warning: Heavy Rain. Borroloola, Mataranka, Ngukurr and Wollogorang

Details:

NT Severe Weather Warning: Heavy Rain

For people in Carpentaria and parts of Tiwi and Arnhem districts.

Issued at 11:14 am Tuesday, 23 January 2018.

HEAVY RAIN AND ABNORMALLY HIGH TIDES DUE TO A MONSOON LOW NEAR THE BASE OF THE TOP END.

Weather Situation: The monsoon trough is located near the base of the Top End. A weak tyropical low embedded within the monsoon trough is expected to remain slow moving over the next few days. Associated vigorous monsoonal flow is causing heavy rainfall and combined with a high tide, is generating abnormally high tides over the northern and eastern areas of the Top End.

HEAVY RAIN which may lead to FLASH FLOODING is possible over the Carpentaria District.
Locations which may be affected include Borroloola, Mataranka, Ngukurr and Wollogorang.

ABNORMALLY HIGH TIDES which may cause sea water flooding of low lying areas is possible along the north coast and Gulf of Carpentaria coast.

Locations which may be affected include Nhulunbuy, Maningrida, Murganella and Birany Birany.

The immediate threat of FLASH FLOODING from HEAVY RAINFALL has eased along the north coast and Barkly District, but the situation will continue to be monitored and further warnings will be issued if neccessary.

Another 211mm was recorded at Bing Bong Port, 137mm at Centre Island and 126mm at Borroloola in the 24 hours to 9 am, 23 January.

The Northern Territory Emergency Service advises that people should:
* secure loose outside objects and seek shelter when conditions deteriorate
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* stay away from flooded drains, rivers, streams and waterways
* ensure pets and animals are safe
* be prepared in case of power outages, have an emergency kit with a radio, torch, spare batteries and first aid kit
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

map 6

EWN Alerts - Northern Territory

13:12 Jan 23 NT Flood Watch: North West, Bonaparte and Carpentaria Coastal Rivers

Details:

NT Flood Watch: North West, Bonaparte and Carpentaria Coastal Rivers

Issued at 12:55 pm CST on Tuesday 23 January 2018

Flood Watch Number: 2

Monsoonal conditions expected to bring flooding to Carpentaria Coastal Rivers and Western Top End.

The monsoon trough lies near the base of the Top End. A tropical low is embedded within the trough which is expected to remain slow-moving near the base of the Top End over the next few days.

Catchments in the Carpentaria Coastal Rivers are quite wet following widespread rainfall totals of 100 - 150 mm throughout the area over the past week. Some coastal areas have received over 400 mm over the past three days. Whilst conditions have been dry in the Bonaparte Coastal Rivers, recent monsoonal conditions have brought rainfall totals of 200 - 250 mm to many parts of the North West Coastal Rivers and rivers are rising in response.

Daily rainfall totals of 40-80mm are expected over the Carpentaria Coastal Rivers, with isolated falls exceeding 100mm near the coast. These conditions are likely to continue for the next few days. Widespread daily rainfall totals of 50-100mm, with up to 120mm near the coast are expected to develop over the southern parts of the North West Coastal Rivers from Wednesday and extend south to the Bonaparte Coastal Rivers on Thursday.

River rises have already been seen throughout the North West and Carpentaria Coastal Rivers with road conditions likely to be affected. Some roads may have become impassable and some communities isolated. Over the next three days river levels are expected to rise in northern parts of the Bonaparte Coastal Rivers which is likely to affect road conditions in these areas as well.

Catchments likely to be affected include:
Victoria River below Kalkarindji

Fitzmaurice River

Tiwi Islands

Finniss River

Lower Daly River

Daly River above Douglas River

Moyle River

Waterhouse River

Roper River

Towns River

Limmen Bight River

Flooding is no longer expected in the following catchments: McArthur River

See www.bom.gov.au/australia/warnings to view all of the Bureau's current warning products.

More information on the Flood Watch Service and maps of Flood Watch areas are available at www.bom.gov.au/water/floods/FloodWarningServices.shtml
Flood Safety Advice:

The Northern Territory Emergency Service advises that people should:

* Stay away from flooded drains, rivers, streams and waterways.
* Prepare for flooding and move away while safe to do so.
* Don't drive into floodwaters.

For emergency help in floods, storms and cyclones call 132 500.

Emergency information is available at www.securent.nt.gov.au

The latest road conditions are available at www.roadreport.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support

map 7

EWN Alerts - Northern Territory

11:47 Jan 23 NT Severe Weather Warning: Heavy Rain. Borroloola, Mataranka, Ngukurr and Wollogorang

Details:

NT Severe Weather Warning: Heavy Rain

For people in Carpentaria and parts of Tiwi and Arnhem districts.

Issued at 11:14 am Tuesday, 23 January 2018.

HEAVY RAIN AND ABNORMALLY HIGH TIDES DUE TO A MONSOON LOW NEAR THE BASE OF THE TOP END.

Weather Situation: The monsoon trough is located near the base of the Top End. A weak tyropical low embedded within the monsoon trough is expected to remain slow moving over the next few days. Associated vigorous monsoonal flow is causing heavy rainfall and combined with a high tide, is generating abnormally high tides over the northern and eastern areas of the Top End.

HEAVY RAIN which may lead to FLASH FLOODING is possible over the Carpentaria District.
Locations which may be affected include Borroloola, Mataranka, Ngukurr and Wollogorang.

ABNORMALLY HIGH TIDES which may cause sea water flooding of low lying areas is possible along the north coast and Gulf of Carpentaria coast.

Locations which may be affected include Nhulunbuy, Maningrida, Murganella and Birany Birany.

The immediate threat of FLASH FLOODING from HEAVY RAINFALL has eased along the north coast and Barkly District, but the situation will continue to be monitored and further warnings will be issued if neccessary.

Another 211mm was recorded at Bing Bong Port, 137mm at Centre Island and 126mm at Borroloola in the 24 hours to 9 am, 23 January.

The Northern Territory Emergency Service advises that people should:
* secure loose outside objects and seek shelter when conditions deteriorate
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* stay away from flooded drains, rivers, streams and waterways
* ensure pets and animals are safe
* be prepared in case of power outages, have an emergency kit with a radio, torch, spare batteries and first aid kit
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

map 8

EWN Alerts - Northern Territory

13:00 Jan 22 NT Flood Watch: Waterhouse River, Roper River, Towns River, Limmen Bight River, Mcarthur River

Details:

NT Flood Watch: Waterhouse River, Roper River, Towns River, Limmen Bight River, Mcarthur River

Issued at 12:53 pm CST on Monday 22 January 2018

Flood Watch Number: 1

Monsoonal conditions expected to bring flooding to Carpentaria Coastal Rivers.

The monsoon trough lies near the base of the Top End. A tropical low has developed within the trough over the Carpentaria Coastal Rivers, which is expected to remain slow-moving near the base of the Top End over the next few days.

Catchments in the Carpentaria Coastal Rivers are quite wet following widespread rainfall totals of 50 - 100 mm throughout the area over the past week. Some coastal areas have received over 400 mm over the same period.

Daily rainfall totals of 40-80mm are expected over the Carpentaria Coastal Rivers, with isolated falls exceeding 100mm, and up to 200mm near the coast. These conditions are likely to continue for the next few days.

Strong river rises can be expected throughout the Carpentaria Coastal Rivers with road conditions likely to be affected. Some roads may become impassable and some communities can expect to become isolated.

Catchments likely to be affected include:

Waterhouse River
Roper River
Towns River
Limmen Bight River
McArthur River

See www.bom.gov.au/australia/warnings to view all of the Bureau's current warning products.

More information on the Flood Watch Service and maps of Flood Watch areas are available at www.bom.gov.au/water/floods/floodWarningServices.shtml.

Flood Safety Advice:
The Northern Territory Emergency Service advises that people should:

* Stay away from flooded drains, rivers, streams and waterways.
* Prepare for flooding and move away while safe to do so.
* Don't drive into floodwaters.

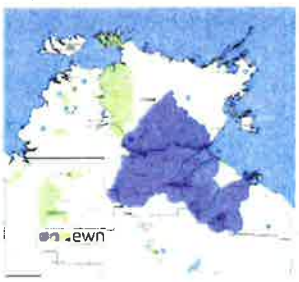
For emergency help in floods, storms and cyclones call 132 500.

Emergency information is available at www.securent.nt.gov.au.

The latest road conditions are available at www.roadreport.nt.gov.au.

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/



Map 9

EWN Alerts - Northern Territory

22:53 Jan 06 NT Severe Weather Warning: Heavy Rain & Damaging Winds. Daly, Tiwi, Arnhem, Carpentaria, Gregory, Parts of Barkly Districts

Details:

NT Severe Weather Warning: Heavy Rain & Damaging Winds

For people in Daly, Tiwi, Arnhem, Carpentaria, Gregory and parts of Barkly districts.

Issued at 10:53 pm Saturday, 6 January 2018.
HEAVY RAIN AND DAMAGING GUSTS OVER THE TOP END AND GREGORY DISTRICT DUE TO A WEAK TROPICAL LOW IN THE TIMOR SEA.

Weather Situation: A weak low [1005 hPa] in the monsoon trough lies just south of the Tiwi Islands and is expected to move slowly southwest away from the Northern Territory. The low is causing an increase in shower and storm activity over the Top End. Storms over the Top End and Carpentaria District will be slow-moving, bringing possible heavy falls tonight and on Sunday. Storms futher south over the Gregory and northwest Barkly Districts may bring damaging wind gusts on Sunday afternoon and evening.

HEAVY RAIN which may lead to FLASH FLOODING is possible tonight over the northern and eastern Daly, Tiwi, Arnhem and Carpentaria Districts, extending into the southwest Daly
District and northern Gregory District on Sunday
Locations which may be affected include Darwin, Katherine, Nhulunbuy, Palmerston, Jabiru, Maningrida, Wadeye, Wurrumiyanga, Nauiyu and Borroloola.

DAMAGING WINDS with peak gusts of around 90 km/h with thunderstorms are possible over the Gregory and far northwest Barkly Districts on Sunday afternoon and evening.

Locations which may be affected include Lajamanu, Kalkarindji, Timber Creek, Daguragu, Newry and Top Springs.

The Northern Territory Emergency Service advises that people should:
* secure loose outside objects and seek shelter when conditions deteriorate
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* stay away from flooded drains, rivers, streams and waterways
* ensure pets and animals are safe
* be prepared in case of power outages, have an emergency kit with a radio, torch, spare batteries and first aid kit
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

Map 10

EWN Alerts - Northern Territory

17:05 Jan 06 NT Severe Weather Warning: Damaging Winds & Heavy Rain, Lajamanu, Kalkarindji, Timber Creek

Details:

NT Severe Weather Warning: Damaging Winds & Heavy Rain

for DAMAGING WINDS and HEAVY RAINFALL
For people in Daly, Tiwi, Arnhem, Carpentaria, Gregory and parts of Barkly districts.

Issued at 4:53 pm Saturday, 6 January 2018.
HEAVY RAIN AND DAMAGING GUSTS OVER THE TOP END AND GREGORY DISTRICT DUE TO A WEAK TROPICAL LOW IN THE TIMOR SEA

Weather Situation: A weak low [1004 hPa] in the monsoon trough lies just south of the Tiwi Islands and is expected to move slowly southwest away from the Northern Territory. The low is causing an increase in shower and storm activity over the Top End. Storms over the Top End and Carpentaria District will be slow-moving, bringing possible heavy falls tonight and on Sunday. Storms futher south over the Gregory and northwest Barkly Districts may bring damaging wind gusts tonight.

HEAVY RAIN which may lead to FLASH FLOODING is possible tonight over the northern and eastern Daly, Tiwi, Arnhem and Carpentaria Districts, extending into the southwest Daly District on Sunday.

Locations which may be affected include Darwin, Katherine, Nhulunbuy, Borroloola, Jabiru, Maningrida, Wadeye, Wurrumiyanga and Nauiyu.
DAMAGING WINDS with peak gusts of around 90 km/h with thunderstorms are possible over the Gregory and far northwest Barkly Districts this evening.

Locations which may be affected include Lajamanu, Kalkarindji, Timber Creek and Top Springs.

The Northern Territory Emergency Service advises that people should:
* secure loose outside objects and seek shelter when conditions deteriorate
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* stay away from flooded drains, rivers, streams and waterways
* ensure pets and animals are safe
* be prepared in case of power outages, have an emergency kit with a radio, torch, spare batteries and first aid kit
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

Map 11

EWN Alerts - Northern Territory

11:04 Jan 06 NT Severe Weather Warning: Damaging Winds & Heavy Rain. Daly, Tiwi, Arnhem, Carpentaria, Gregory

Details:

NT Severe Weather Warning: Damaging Winds & Heavy Rain

For people in Daly, Tiwi, Arnhem, Carpentaria and Gregory districts.

Issued at 11:03 am Saturday, 6 January 2018.
HEAVY RAIN AND DAMAGING GUSTS OVER THE TOP END DUE TO A WEAK TROPICAL LOW IN THE TIMOR SEA.

Weather Situation: A weak low [1006 hPa] in the monsoon trough lies just west of the Tiwi Islands and is expected to move slowly southwest away from the Northern Territory. The low is causing an increase in shower and storm activity over the Top End. Storms over the Top End and Carpentaria District will be slow-moving, bringing possible heavy falls. Storms futher south over the Gregory and southwest Daly District may bring damaging wind gusts.

HEAVY RAIN which may lead to FLASH FLOODING is possible today and on Sunday over the Daly, Tiwi, Arnhem, Carpentaria and northest Gregory Districts.
Locations which may be affected include Darwin, Katherine, Nhulunbuy, Palmerston, Jabiru, Maningrida, Wurrumiyanga, Nauiyu and Borroloola.

DAMAGING WINDS with peak gusts of around 90 km/h with thunderstorms are likely over the southwestern Daly and northern Gregory Districts this afternoon and evening.
Locations which may be affected include Wadeye, Kalkarindji, Timber Creek, Daguragu, Palumpa and Peppimenarti.

The Northern Territory Emergency Service advises that people should:
* secure loose outside objects and seek shelter when conditions deteriorate
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* stay away from flooded drains, rivers, streams and waterways
* ensure pets and animals are safe
* be prepared in case of power outages, have an emergency kit with a radio, torch, spare batteries and first aid kit
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

map 12

EWN Alerts - Northern Territory

14:39 Nov 21 NT Severe Thunderstorm Warning: Damaging Winds. Daly Waters and Dorisvale

Details:

NT Severe Thunderstorm Warning: Damaging Winds

For people in parts of Daly, Carpentaria and Gregory districts.

Issued at 2:38 pm Tuesday, 21 November 2017.

Severe thunderstorms are likely to produce damaging winds in the warning area over the next several hours. Locations which may be affected include Daly Waters and Dorisvale.

The Northern Territory Emergency Service advises that people should:
* secure loose outside objects
* ensure pets and animals are safe
* avoid remaining in the open when storms threaten
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

Map 13

EWN Alerts - Northern Territory

20:28 Nov 11 NT Severe Thunderstorm Warning: Heavy Rain. Elliott and Top Springs

Details:

NT Severe Thunderstorm Warning: Heavy Rain

For people in parts of Carpentaria, Gregory and Barkly districts.

Issued at 8:23 pm Saturday, 11 November 2017.

An active area of thunderstorms have become slow moving across central parts of the Territory.

Severe thunderstorms are likely to produce heavy rainfall that may lead to flash flooding in the warning area over the next several hours. Locations which may be affected include Elliott and Top Springs.

The Northern Territory Emergency Service advises that people should:
* slow down and turn your headlights on
* create your own sandbags if there is flooding, by using pillow cases or shopping bags filled with sand and place them around doorways to protect your home
* secure loose outside objects
* ensure pets and animals are safe
* avoid remaining in the open when storms threaten
* pull over if it is raining heavily and you cannot see, park with your hazard lights on until the rain clears
* avoid driving into water of unknown depth and current
* for emergency help in floods, storms and cyclones, contact the NTES on 132 500. For more safety tips visit www.securent.nt.gov.au

Alert Source: Bureau of Meteorology

Early Warning Network:
http://www.ewn.com.au
Council Resident Options & EWN Support:
http://www.ewn.com.au/support/

map 14

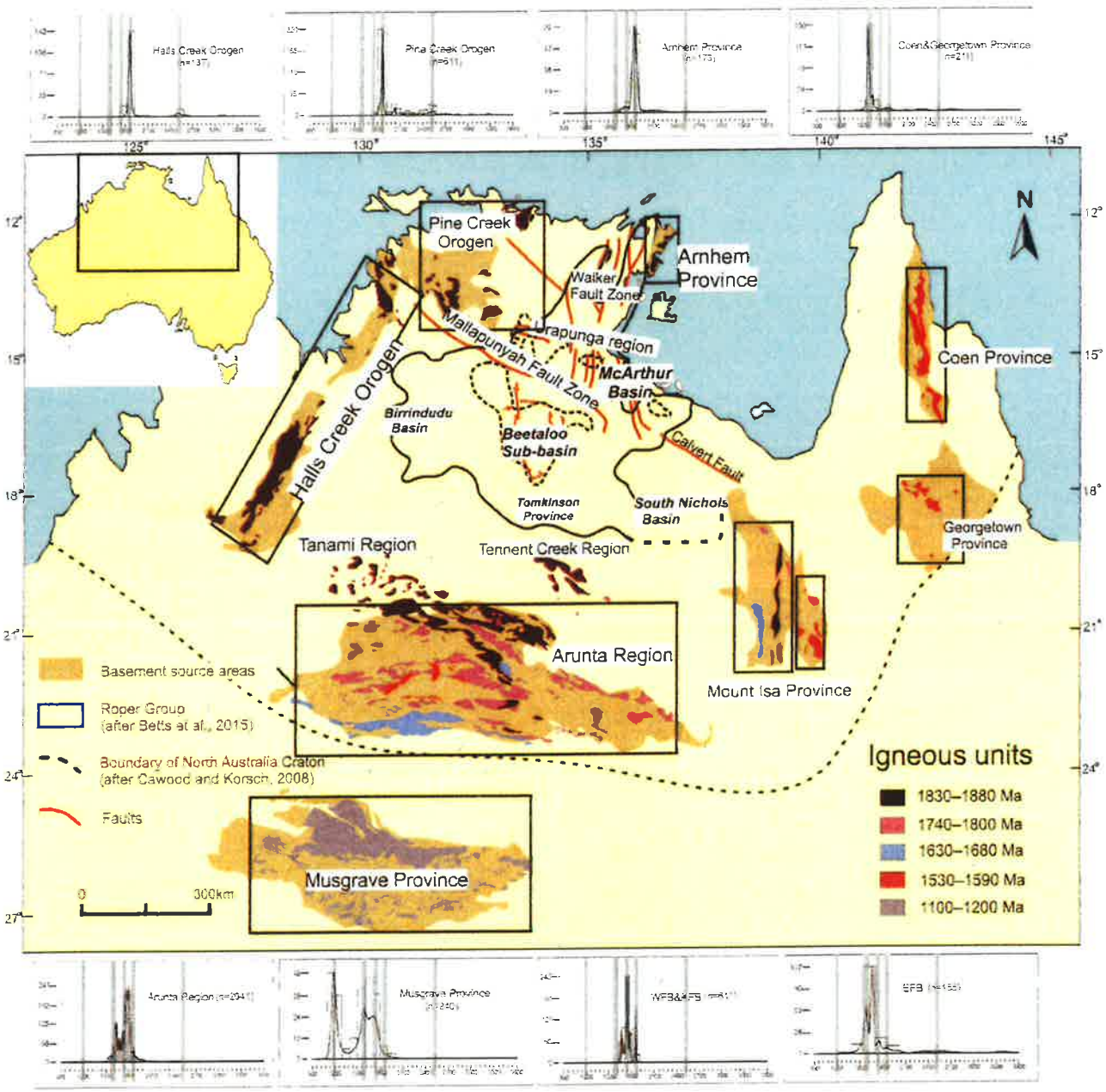


Fig. 9. Distribution of igneous units and kernel density estimation (KDE) plots for potential source areas.

restricted or partly restricted by land or by chains of islands while retaining some connection with the open sea (Munson, 2016; Munson et al., 2016). This model, to some extent, is consistent with the palaeography suggested by the results of this work, which shows that the Roper Group, at least from ca. 1450 Ma to 1320 Ma, was restricted by multiple sources to the south, east, and possibly west, whereas how far the basin extended in the open sea direction remains unknown (Fig. 10A).

6. Conclusions

New detrital zircon data presented in this research provides constraints on the age, provenance and tectonic geography of the hydrocarbon-bearing upper Roper Group (Maiwok Subgroup). Coupled techniques of Multidimensional Scaling (MDS) and Kernel Distribution Estimate (KDE) enable a detailed spatial and temporal provenance analysis of the Beetaloo Sub-basin. This improves our understanding of the palaeotectonic geography and evolution history of the North Australia Craton through the late Mesoproterozoic and into the early Neoproterozoic. The main conclusions and suggestions of this research are:

1) The maximum depositional age of the Bessie Creek Sandstone is constrained at 1386 ± 13 Ma. The Velkerri Formation and overlying Moroak Sandstone are now constrained to being deposited between 1349 Ma and 1320 Ma, based on the youngest detrital zircon grains and assuming that the 1324 ± 4 Ma age for Derim Derim Dolerite is representative of the age of the sills in the Beetaloo Sub-basin. The maximum depositional age of the Kyalla Formation is constrained to 1313 ± 47 Ma by the youngest detrital zircon (taken from drill core Jamison-1). The maximum depositional age of the two ungrouped formations, the lower and upper Jamison sandstones, are constrained to 1092 ± 16 Ma and 959 ± 18 Ma, respectively.

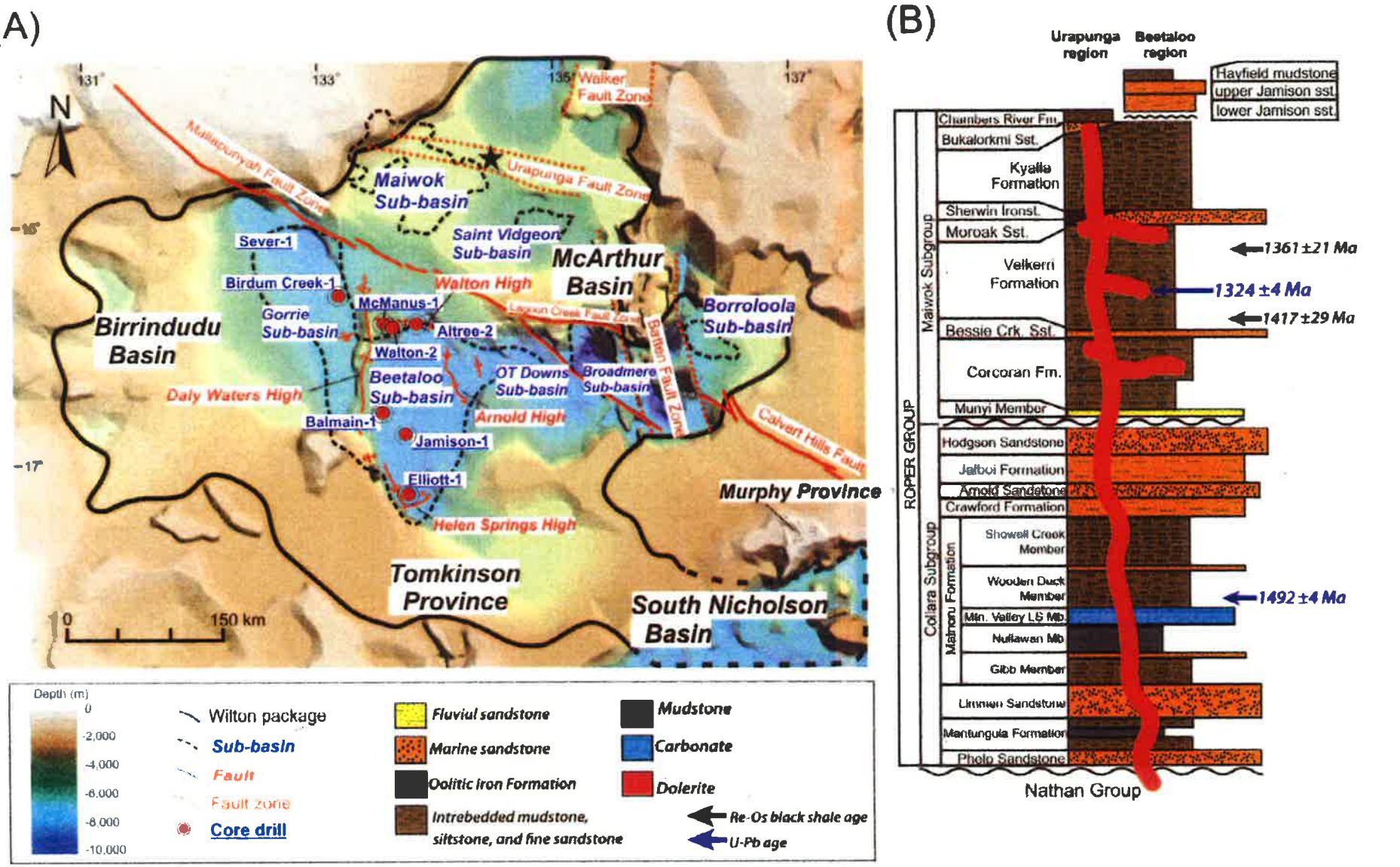


Fig. 1. (A) Extent of Wilton package based on Proterozoic SEEBASE™ basement surface, showing the locations of drillholes and major structural highs. SEEBASE™ image after De Vries et al. (2006); black star represents outcrop samples from Urapunga region from Munson et al. (2016). (B) Stratigraphic column of upper Roper Group modified after Cox et al. (2016).

map 15