Northern Depths of the Great Barrier Reef

30-day Post Cruise Report

Ship name: Falkor
Cruise Dates - Day Departed: 09/30/2020 **Day Returned**: 11/17/2020
Cruise Number: FK200930
Departure Port: Brisbane, Australia **Arrival Port**: Brisbane, Australia
Mid-Cruise Port Call (if any): Cairns, Australia
Participating Organizations, Institutions, Foundations, Government Agencies, etc. James Cook University www.jcu.edu.au
Queensland University of Technology https://www.qut.edu.au/
University of Queensland https://www.uq.edu.au/
The University of Sydney https://www.sydney.edu.au/
Geoscience Australia http://www.ga.gov.au/
Queensland Museum https://www.qm.qld.gov.au/
Museum of Tropical Queensland https://mtq.qm.qld.gov.au/
CSIRO https://www.csiro.au/
Biopixel https://biopixel.tv/
Coral Sea Foundation http://www.coralseafoundation.net/
Parks Australia https://parksaustralia.gov.au/
JAMSTEC http://www.jamstec.go.jp/e/
University of Grenada https://www.ugr.es/en/
Funding Sources
Nil funding sources identified or required at this stage.

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Geographical area(s) where the science occurred and why working in this location was important or impactful:
The project focused on the offshore Cape York Peninsula area through geophysical mapping of the shelf edge and upper continental slope adjacent to the shelf barrier reefs, and around the seven detached reefs lying north of Cape Weymouth, including within the large Wreck Bay that lies close to these detached reefs. The voyage was split into three legs. Brisbane, in southern Queensland, was the start and end port. Cairns, in north Queensland, was the crew changeover port between Legs 1-2 and Legs 2-3.

The offshore Cape York Peninsula area was selected as the focus of Leg 2 because the upper slope and shelf edge may preserve a record of submerged (or drowned) reefs that now represent a key habitat for modern mesophotic reef communities. The continental slope in the offshore Cape York area is heavily incised with submarine canyons, as the far northern Great Barrier Reef (GBR) is the oldest section of the GBR. Around the detached reefs is a deep platform or ledge upon which these reefs have grown, but which is poorly mapped.

The Leg 1 transit northward from Brisbane to Cairns was an opportunity to complete the mapping of the newly-discovered 'Swain slide'. This ~20 km long underwater landslide near the Swain Reefs had only been partly mapped during previous expeditions, and so completing the full mapping of the slide debris field provided understanding of the full spatial limits of the slide area. Mapping the slide was important to reveal the natural hazards that have shaped the GBR reef edge in the geological past.

The Leg 3 transit from Cairns to Brisbane provided an opportunity to map a long (~70 km) section of the Swain Reefs shelf edge and upper slope that had no previous multibeam data. The location was important because we did not know where the edge of the GBR was in this large and very remote Swain reefs area, i.e. the shallow reefs had been mapped through aerial lidar surveys but not where the shelf edge lay to seaward of these shallow reefs.

Leg 3 was also an opportunity to map around the steeper flanks of the Coral Sea Marine Park's Saumarez, Frederick, Kenn, Wreck and Cato Reefs. These coral reefs grow upon the remains of extinct volcanoes: the Tasmantid Seamounts. Mapping around the steeper flanks can help reveal the interface between the deeper basaltic base and the limestone cap. Visits to several islands at these reefs was also conducted to provide visual records of their present condition for Parks Australia marine managers.

Cruise Objectives:
Conduct multibeam surveying of the shelf edge and continental slope offshore of the Cape York

Peninsula area, with the aim to 'fill the gaps' between the lidar bathymetry data over the shelf edge barrier reefs, with any existing multibeam data coverage along the lower slope. This broad-scale mapping aimed to prove the existence of any submerged reefs extending farther north of the Ribbon Reefs, and also to reveal the full inventory of canyons and their character to provide a complete coverage of their morphological variability from head to foot.

Conduct multibeam surveying of the steeper flanks of the seven detached reefs and their surrounding deeper ledge, and including within the indented bays such as Wreck Bay. The mapping aimed to prove the existence of any possible fossil fringing reefs and/or wave-cut caves that might indicate Last Glacial Maximum (LGM) lowstand, similar to the LGM lowstand-generated features found on the adjacent shelf edge farther south of Cape York.

Impact of the Research:
16,664 square kilometers of seafloor mapped with high-resolution multibeam depth data.

New map data along the offshore Cape York Peninsula region, for the continental slope opposite Cape Melville to as far north as the Great Detached Reef, a distance of ~300 km.

Complex seafloor revealed, including submarine canyons, submerged reefs, underwater landslides, vertical walled 'plunge pools', debris blocks broken off sides of reefs.

ROV vision over undersea landslide area, mesophotic coral habitats, deep plunge pool environments, contrasting shelf-connected and slope-confined canyons, submerged reefs.

No evidence of mass bleaching in the corals observed within the mesophotic zone to ~50 m.

Wide variety of mesophotic reef habitats, with very different ecological communities between steeper gradient upper flanks compared to more gentle gradient slopes.

Better understanding of the depth trends and habitat preferences of the deeper coldwater coral communities and shallower mesophotic coral ecosystems of the far northern GBR.

Relevance to managers and the local communities
This project addresses knowledge gaps for the Great Barrier Reef Marine Park Authority (GBRMPA) in terms of mapping and characterising a poorly known frontier area of the GBR Marine Park.

The new multibeam data have been added to the national bathymetry archive managed by Geoscience Australia, and made available to the public through the AusSeabed Marine Data Portal.

The vision data collected during island visits to the Coral Sea Marine Park islands at Kenn, Wreck and Cato Reefs have been provided to the Parks Australia marine managers.

The ROV vision data are preserved as YouTube links, allowing public access to the video imagery collected during these dives. This vision is invaluable for educational, social and mainstream media platforms.

Summary of Operations and Data Collection
see below

Did you collect Measurements or Samples, including biological specimens? Yes
Is there any suspected or confirmed new species discovered during the cruise? Maybe
Black coral
Likely collected at least one new species belonging to the family Cladopathidae,
One species belonging to the family schizopathidae
One species belonging to the family aphanipathidae.
Range expansions from at least five species to Australia coming from this expedition.

Zooxanellate coral
Possible range extension to the Coral Sea of a new species of Leptoseris coral, currently known from only a single specimen from 80 m depth in Pohnpei, Micronesia.

Sharks
Sighting of the rare short-tail catshark Parmaturus bigus, extending the known depth of this species down to 881 m and represents a 1200 km northward range extension.

Molluscs
Chambered nautilus observed in one ROV dive, with several dives showing empty shells of nautilus, indicating this cephalopod animal is found in the far northern Great Barrier Reef.
First in situ sighting of a rams horn squid Spirula spirula, confirming swimming/orientation behaviour.

Did you deploy and/or recover any Moorings, Bottom Mounted Gear, or Drifting Systems? Yes
Equipment Used: No
Total number of CTD casts completed during the cruise: 1
Total number of AUV dives completed during the cruise: 0
Total number of ROV dives completed during the cruise: 10
Total number of ROV samples collected during the cruise: 158 samples

Total number of Unmanned Aerial Vehicle (UAV) or other vehicle deployments during the cruise: 0
Total amount (TBs) of data collected during the cruise: 16.7

Other interesting things about the cruise
One ~500 m tall detached reef was discovered, bring the total number of detached reefs in the Cape York area to eight. This is the first new detached reef to be discovered and mapped in over 100 years. This significant reef feature will need to be given a name.

Numerous (>100) drowned reefs were discovered as mostly ~40-50 m tall pinnacles on the upper continental slope offshore of Cape York. One prominent drowned reef was mapped offshore of Tydeman Reef with ~300 m elevation.

Non-marine, sedimentary rock is exposed at the deeper (>1000 m) parts of the continental slope offshore of Cape York Peninsula. This rock is presumed to be ancient continental crust, having subsided several km deep over long geological time and now exposed at the seafloor.

A broad ledge up to 20 km wide projects out from under the Great Barrier Reef from depths ~200-900 m. The eight detached reefs have grown to the current sea level from this broad ledge. The ledge composition is calcium carbonate (limestone) pointing to a Miocene/late Pliocene age of deposition.

The ledge is incised with what appears to be ancient river channels resulting in several ‘plunge pools’ at their seaward limits. These plunge pools drop 200-300 m vertically. The evidence of paleo-river channels and plunge pools point to a time of sub-aerial exposure to freshwater, allowing incising and weathering of the limestone surface.

Daily diary of FK200930

Wednesday 30 September 2020

Wind 8 kn from 070°. Sea state 2. Nil swell.

0900 in position 27.441266°S 153.067820°E alongside wharf in Brisbane Port.

At 1000, *Falkor* left its berth position and headed out of the Brisbane River for the start of voyage "Northern depths of the Great Barrier Reef" FK200930. At 1100, the ship entered Moreton Bay for the ~ 3-hour pilotage through the bay. By 1600, *Falkor* had completed the pilotage and headed east across the Fraser shelf towards the deeper shelf edge, with the aim to commence a northerly transect adjacent to the previous FK200802 ship track into Brisbane. Both the EM702 and EM302 multibeam systems were turned on to acquire new multibeam mapping data along the Fraser shelf edge and upper slope.

Thursday 01 October 2020

Wind 9 kn from 055°. Sea state 4. Low swell.

0900 in position 24.528000°S 153.827000°E in vicinity of Fraser Island.

Through the night, *Falkor* continued mapping the upper slope in depths around 150 m, directly landward and adjacent to the previously collected multibeam data. Around 0700 opposite Fraser Island, the ship left the upper slope and commenced a northeast transect across the ~3500 m deep Fraser Canyon towards the planned ROV dive site near the southeast corner of the Great Barrier Reef Marine Park. At 1200, the ship stopped ~100 km northeast of Fraser Island to conduct ROV dive #393, a midwater dive with audio commentary by Dr Dhugal Lindsay from JAMSTEC. The dive continued to 1212 m depth, and then ROV SuBastian was recovered at 1700. By 1800, *Falkor* had recommenced multibeam surveying across the smaller feeder canyons into the main Fraser Canyon, and then returned to the northward planned ship track.

Friday 02 October 2020

Wind 11 kn from 115°. Sea state 4. Low swell.

0900 in position 22.854567°S 153.015187°E in vicinity of Swain Reefs.

Overnight, *Falkor* continued the northward ship track towards the Swain Reefs, crossing the Capricorn Channel and south Marion Plateau at ~400 m, then crossing onto the broad terrace that extends around the Swain Reefs. *Falkor* arrived off the southeast corner of the Swain Reefs

at 1100 and then tracked north, adjacent to existing multibeam data over the 'Swain pinnacles', a cluster of many small pinnacles lying around 100 m depth. Through the afternoon, the ship continued north along the eastern edge of the Swain Reefs then passed through the 5 km wide gap between the Swain Reefs and Elusive Reef. At 2000, the ship commenced a systematic survey over the Swain slide – a 20 km wide undersea landslide, only partly mapped by the R/V *Investigator* in October 2019.

Saturday 03 October 2020

Wind 19 kn from 100°. Sea state 4. Low-moderate swell.

0900 in position 21.018744°S 152.679009°E in vicinity of Swain slide.

The ship continued on the systematic survey over the Swain slide through the night, however, stronger southeasterly winds reduced surveying speed to ~3 hours for just two passes across the slide boundaries. Slide boundaries are generally about 7.5 nm wide, slowly narrowing towards the scarp face at the Swain Reefs. The seafloor morphology is very rough within the slide debris field, with larger intact blocks lying scattered within the main debris material. Through the most of the day, *Falkor* continued the systematic survey of the slide debris field, completing the final data gap against the previous multibeam data at 1430. The ship then headed north across the debris field to a predetermined ROV transect site in ~300 m. However, the East Australian Current (EAC) velocity was too strong (~1.5 kn) to launch ROV SuBastian. The ship instead completed filling small gaps in the multibeam data until 1730, and then commenced the long transit along the face of the Swain Reefs towards the next destination at the Bowl slide.

Sunday 04 October 2020

Wind 22 kn from 115°. Sea state 4-5. Low-moderate swell.

0900 in position 19.876760°S 150.591134°E in vicinity of Swain Reefs.

Falkor continued mapping along the Swain Reef shelf edge overnight in ~200 m, with no obvious seafloor features detected. From around 0500, the seafloor shallowed to ~100 m and more small pinnacles were revealed on the seafloor. At 0930, the ship arrived at the Hydrographers Passage area, previously surveyed in 2007, and continued in a northwest direction towards the Bowl slide area on the central GBR margin. Through the afternoon and evening, the ship continued edge mapping previous upper slope multibeam data in depths around 100 m. The seafloor occasionally showed isolated boulders scattered over a relatively

flat surrounding surface. Weather from the southeast made for easy sailing along the GBR upper slope towards the Bowl slide area.

Monday 05 October 2020

Wind 19 kn from 100°. Sea state 4. Low swell.

0900 in position 18.386986°S 147.670867°E in vicinity of Bowl slide.

Falkor continued mapping along the GBR shelf edge and upper slope through the night, occasionally revealing the ~10 m high cliff that is the shelf break around 100 m depth. Large boulders at times were observed to seaward of the shelf break on the upper slope. Around 0200, the ship crossed another well-mapped, small underwater landslide, called the Viper slide, where previous geoscience research has taken place. At 0800, the ship was in position at the Bowl slide, a large underwater landslide, for ROV dive #394. This was planned as a mesophotic dive to a maximum depth of 237 m, intended to cross the upper scarp face then into the shelf break region searching for mesophotic corals. The ship did a live audio cross with Jeremy Horowitz and Tom Bridge based in Townsville, and concluded the dive at 1600. *Falkor* then commenced a transit westerly along the shelf break around 100 m, mapping the large embayment between the GBR shelf and Myrmidon Reef, which is a detached reef growing on the deeper Burdekin River paleo-delta that extends out from the GBR shelf. Around 2200, the ship passed the Palm Passage entrance and continued northward towards the Noggin canyon closer to Cairns in the northern GBR.

Tuesday 06 October 2020

Wind 15 kn from 105°. Sea state 4. Low swell.

0900 in position 16.836573°S 146.496636°E in vicinity of Noggin canyon.

Falkor continued mapping along the GBR shelf edge and upper slope through the night, heading northwards from Myrmidon Reef. This shelf edge mapping was important to help delineate the abrupt change in slope between the relatively flat GBR shelf into the gentle gradient of the continental slope. Around 0900, the ship arrived at the Noggin canyon site, previously visited during FK200802, but could not dive with the ROV due to strong ocean currents. Currents were sub-1 kn and so ROV dive #395 commenced at 1000 to 970 m depth, with the aim to conduct a transect across the canyon axis then up the canyon sidewalls. The dive proved the canyon axis and sidewalls were quite muddy with no obvious exposed rock or strata observed, hence all associated benthic life were infaunal or muddy deposit feeders. The dive concluded at 1400 and

then the ship commenced mapping some large unmapped areas within the Queensland Trough in depths ~1400 m.

Wednesday 07 October 2020

Wind 17 kn from 115°. Sea state 4. Low swell.

0900 in position 16.802578°S 146.089342°E approaching Cairns port limits.

Through the morning, *Falkor* continued to map the Queensland Trough, and then made way towards the GBR shelf, entering Grafton Passage at 0730. The ship stationed off Cairns port and Leg 2 participants joined, while others left the ship. *Falkor* then got underway, heading back out through Grafton Passage, and bound for the far northern GBR and offshore Cape York area. Through the afternoon, *Falkor* mapped the upper slope, edge matching previously collected multibeam data from FK200802 Leg 2 along the front of the Ribbon Reefs.

Thursday 08 October 2020

Wind 19 kn from 150°. Sea state 4-5. Moderate swell.

0900 in position 14.614135°S 145.653227°E in vicinity of Yonge Reef.

Wind and swell increased throughout the night as the ship mapped along the Ribbon Reefs upper slope. A short east-west line was made opposite Ribbon Reef No. 10 for engineering purposes, which allowed for collecting additional multibeam data in the Queensland Trough. By 0800, *Falkor* was back mapping on the upper slope in front of Ribbon Reef No. 10, and then continued the transit northwesterly towards the Cape York region. The ship passed Two Mile Entrance with the shallow reefs on the GBR shelf becoming exposed at low tide. At 1700, *Falkor* arrived offshore of Cape Melville, the start of the main Cape York survey area and commenced upper slope mapping within the Clack canyons area. This is a very large unmapped, and therefore unknown, area of the offshore Cape York region, and so our first mapping pass revealed a dramatic seascape of multiple canyons incising the slope.

Friday 09 October 2020

Wind 16 kn from 120°. Sea state 4-5. Low-moderate swell.

0900 in position 13.921808°S 144.484227°E in vicinity of Tydeman Reef.

Overnight, *Falkor* continued mapping this large Clack canyons (south) area lying offshore of Princess Charlotte Bay in Cape York. The mapping lines, over 70 km long, slowly revealed a

seascape comprised of multiple canyons and smaller gullies draining towards larger trunk canyons. Backscatter imagery showed high reflectance pixels, likely indicating coarse sediments, focused within the axes of the larger canyons. With daylight, the ship focused efforts in closer towards Tydeman Reef and the other shallow barrier reefs at the shelf edge. A broad ridge extended out from Tydeman Reef into the Osprey Embayment area, which was capped with a strange peak rising to a depth of 350 m, located about 5 km from the shelf edge. Informally, we called this the Tydeman Knoll. The ship continued mapping easterly close to the shelf edge, then doubled back around 1800 to continue mapping within deeper waters through the night.

Saturday 10 October 2020

Wind 19 kn from 120°. Sea state 4. Low swell.

0900 in position 13.886375°S 144.419261°E in vicinity of Rodda canyon.

Falkor continued mapping within the Clack canyons (south) area, focusing on the deeper >1500 m waters during nighttime, while mapping closer to the shallow reefs during the daytime. The canyons draining the Princess Charlotte Bay region are the most spectacular of canyon systems anywhere along the GBR margin - incredibly steep, deep and diverse in morphology. The strange looking Tydeman Knoll about 5 km out from the GBR shelf edge rises from ~700 to 350 m depth. At 0930, we conducted ROV dive #396 in the Rodda canyon, so named because this large canyon drains between Rodda and Willson reefs. This is a shelf-connected canyon with an ancient river channel directly joining to the head of this canyon. The maximum depth was 1785 m, then did a transect up the northern sidewall of the canyon to a crest around 1370 m. A highlight was seeing a large amount of land-based vegetation, e.g. coconuts, mangrove seeds and even seagrass blades in the axis of the canyon. The ROV recovered onboard at 1630. *Falkor* then commenced mapping again along the continental slope filling in data gaps overnight.

Sunday 11 October 2020

Wind 23 kn from 115°. Sea state 4-5. Low-moderate swell.

0900 in position 13.777029°S 144.306999°E in vicinity of Sand Bank No 5 Reef.

Falkor continued mapping over the data gaps throughout the Clack canyons (south) area overnight, then running a long east-west transect over deeper waters >2000 m within the adjacent Osprey Embayment. At 1000, *Falkor* started heading southeast along the GBR upper slope closer to the shallow reefs, conducting mapping from Sand Bank No. 5 Reef towards Rodda Reef. The aim was to map a terrace feature that extends out from the shelf break. A

cluster of possibly drowned reefs some 200-300 m in length, were discovered on the upper slope in depths 380 m. At 1200, the ship mapped over the head of the canyon between Rodda and Wilson reefs, which directly connected to an ancient river channel on the GBR shelf. This river channel would have fed freshwater directly to the head of the canyon when sea levels were about 100 m lower during the last Ice Age, about 20,000 years ago. The ship then headed easterly to commence deep >2000 m mapping in the Osprey Embayment area through the night.

Monday 12 October 2020

Wind 22 kn from 110°. Sea state 4-5. Low swell.

0900 in position 13.912771°S 144.506306°E in vicinity of Tydeman Knoll.

Overnight, *Falkor* continued mapping the deeper >2000 m waters adjacent to this Clack canyons (south) site. The ship then positioned for ROV dive #397 at the Tydeman Knoll, an unusual seamount-like feature discovered on the broad ridge extending out from Tydeman Reef. The knoll is about 1.4 km long, about half km wide and ~300 m high. The backscatter showed very high reflectance compared to the surrounding broad ridge. The dive commenced at 0900 to a maximum depth of 549 m and traversed across the eastern face looking for clues as to its geological origins and any associated marine life. The knoll itself was covered in a dark brown thick crust and quite hard, overlying a less resistant limestone substrate, leaving pits and caves in its surface. Large cod had taken up residence around the summit in 340 m. We recovered ROV SuBastian at 1530 and commenced multibeam mapping northward towards the Clack canyons (north) area, with the aim to commence a long southeastly deep >2000 m mapping transect in the night.

Tuesday 13 October 2020

Wind 22 kn from 125°. Sea state 5. Moderate swell.

0900 in position 13.709360°S 144.838823°E in Osprey Embayment.

With stronger winds in the Cape York region, *Falkor* commenced mapping a large data gap area over the Queensland Trough, about 170 km long by 10 km wide. Thus, about 24 hours were required to map the 1700 sq km. When completed, the new map data revealed the lower reaches of the canyons that lie offshore of Lizard Island. At 1000, the ship was 60 km northwest of Cape Melville in depths 2500 m deep, within the Osprey Embayment, tracking southwest and parallel to the GBR margin. By 2200, the ship was opposite the northern Ribbon Reefs and then

turned around to commence the long transit back towards the Cape York region, edge mapping against existing multibeam data.

Wednesday 14 October 2020

Wind 20 kn from 125°. Sea state 4. Low-Moderate swell.

0900 in position 13.504196°S 144.676402°E in Osprey Embayment.

Falkor continued edge mapping existing multibeam data along the large data gap within the Osprey Embayment and Queensland Trough. The weather eased to make the northwestern run back towards Cape York much better conditions for everyone onboard. At 1300, we commenced a southward pass along the upper slope adjacent to Creech Reef and the nearby reefs. The prominent ledge on the upper slope, observed in earlier mapping, was also found along this stretch of the reef. The ledge was near continuous around the 450 m depth, lying above a steeper gradient slope within the heads of canyons at about 700 m depth. Several closer passes to the shallower reefs found the steep wall rising to the sea surface had a base depth at ~200 m. At 1800, the ship headed offshore away from the upper slope towards the deeper Osprey Embayment for mapping overnight.

Thursday 15 October 2020

Wind 23 kn from 125°. Sea state 4. Low swell.

0900 in position 13.518197°S 144.102591°E in vicinity of Noddy Reef canyon.

After an overnight mapping transect in depths greater than 2000 m, the ship approached Noddy Reef for ROV dive #398 within a very prominent bowl that is the head of a canyon draining this section of the GBR margin. The site was selected as it is reef-blocked canyon (i.e. a reef lies at the head of the canyon). ROV SuBastian had previously dived within a shelf-connected canyon (i.e. head of canyon is directly connected to the shelf through an inter-reef passage), and so having a contrasting site was important for comparisons between biota found in each type of canyon. The maximum depth was 824 m, with a climb up a steep wall to a ledge at 500 m. The steep wall was found to be a very hard rock and resistant to erosion. We then crossed the ledge above 500 m and then up vertical limestone wall into the mesphotic zone at ~100 m. The ROV was recovered at 1700 and we commenced mapping within the Tijou canyons survey area.

Friday 16 October 2020

Wind 21 kn from 115°. Sea state 4-5. Low swell.

0900 in position 13.356451°S 143.979235°E in vicinity of Sand Bank No. 8 Reef.

Through the night, *Falkor* continued mapping the Tijou canyons survey area. Then, as daylight arrived, we commenced mapping northward along the shallower upper slope to just seaward of the Tijou Reefs in the shallower depths. We completed the northern transit along Tijou Reef at 1230, then turned around and started edge mapping southward against our previous multibeam data. Throughout the evening, the ship continued mapping the deeper >1000 m slope, filling in data gaps to reveal a similarly complex canyon system.

Saturday 17 October 2020

Wind 21 kn from 115°. Sea state 4-5. Low swell.

0900 in position 12.800382°S 143.831274°E in vicinity of Log Reef (South).

Around 0200, *Falkor* had completed mapping the Tijou canyons survey area, and then commenced a mapping transit northward along the Bligh canyons survey area, about one nautical mile offshore of the shallower coral reefs. We continued a northward transit through the morning, mapping around the Southern Small Detached Reef, then at 0800 headed southward closer to the shallow reefs. At 1230, *Falkor* reached Tijou Reef then turned around again and commenced mapping northward along the Bligh canyons survey area, filling in data gaps through the afternoon and into the evening.

Sunday 18 October 2020

Wind 18 kn from 125°. Sea state 4. Low swell.

0900 in position 12.535431°S 143.860730°E in vicinity of Southern Small Detached Reef.

Falkor continued mapping the continental slope between Tijou Reef and Bligh Reef. The ship then headed to the Small Detached Reefs survey area. The detached reefs of the far northern GBR are strange, extending several km out from the GBR shelf. These detached reefs rise up from a broad, relatively flat ledge that extends at a depth 400-600 m out from under the GBR shelf. The surface of this ledge has numerous pinnacles and even broad snaking 'river' channels, which in places lead to remarkable circular 'plunge pools' with vertical walls over 300 m high, as if the remains of ancient waterfalls. If we are looking at the remains of waterfall-carved landscape, then the 400-600 m ledge are the remains of a once exposed Australian landscape, now subsided over deep geological time. ROV dive #399 commenced at 0900 with a maximum

depth of 1108 m within the base of the ‘plunge pool’. Many sponges, squid and fish were seen, with samples of rock taken for later analysis. ROV SuBastian was recovered at 1630 and then the ship commenced reef edge mapping.

Monday 19 October 2020

Wind 15 kn from 110°. Sea state 4. Low swell.

0900 in position 12.320923°S 143.892582°E in vicinity of Southern Small Detached Reef.

The morning was spent mapping the Small Detached Reefs survey area, building upon the mapping efforts over the previous day across this prominent 400-600 m deep ledge. Submarine canyons lie to seawards of this hard rock ledge, eroding into the softer sediments of the main continental slope. With daylight, *Falkor* commenced mapping the shallower shelf edge in depths ~60 to 200 m, working northwards around Mantis Reef and towards the prominent Wreck Bay. At 1030, *Falkor* entered Wreck Bay for the first time, mapping in a clockwise direction around the shallower reef edge. The first lap around the inside Wreck Bay was completed at 1300, revealing a similar flat, broad ledge ~400-700 m deep, with gullies coalescing towards the centre.

Tuesday 20 October 2020

Wind 9 kn from 120°. Sea state 3. Low swell.

0900 in position 12.099041°S 143.948698°E in vicinity of Wishbone Reef.

Falkor continued mapping inside of Wreck Bay overnight, completing the work by daybreak. The bay is about 20 km long by 15 km wide, and is bowl-shaped with two distinct channels cut into the surface. These channels drain into a spectacular 'plunge pool' dropping to 1100 m with vertical sides 300 m high, similar to the plunge pool we dived on during ROV dive #399. Then lying below this upper plunge pool is another deeper plunge pool, with a near-vertical cliff from 1200 to 2000 m - a truly incredible seascape lying offshore of Cape York. At 0900, the ROV dive #400 commenced up the steep reef wall at Wishbone Reef, which forms the northern boundary of Wreck Bay. Happy birthday to ROV SuBastian on this 400th dive since the first dive in 2016! The maximum depth was 507 m with a transect across some ~60 m high pinnacles, looking for evidence these are drowned reefs, and then climbed up the steep reef wall into the mesophotic zone. SuBastian was recovered at 1630 and the ship headed south past the entrance to Wreck Bay towards the Northern Small Detached Reef survey area, to map as much as possible in

daylight. Throughout the remaining evening, *Falkor* continued to map around these detached reefs.

Wednesday 21 October 2020

Wind 10 kn from 110°. Sea state 3. Low swell.

0900 in position 12.363141°S 143.901765°E in vicinity of Northern Small Detached Reef.

Falkor continued mapping near the Northern Small Detached Reef, by mapping gaps in the previous multibeam data. At 1000, *Falkor* discovered and mapped a newly discovered detached reef lying 2.5 km northeast of Northern Small Detached Reef. This new reef rises about 500 m in vertical height above the surrounding broad ledge. The reef is blade-like in plan view, with the shoaled part of the reef (that part of reef shallower than 70 m depth) about 300 m long by 50 m wide. The shoal depth measured was 41.6 m, so with predicted tides of 1.6 m (Raine Island at 1000), results in a shoal depth of 40.0 m (vertical datum LAT). This new reef is not a danger to navigation, but it is still significant that one can still discover such tall reefs (~500 m high) in the far northern GBR. This new discovery points to the remoteness of the area and rarity of opportunities to map with modern technologies in these deeper waters. Looking at old charts from the late 1800s, which first mapped these detached reefs, the discovery is the first new detached reef to be mapped in the Great Barrier Reef in over 120 years. The ship then commenced mapping northward, following the shelf edge inside the bay surrounding Yule Detached Reef. At 1900, the ship completed the shallower mapping adjacent to Great Detached Reef and commenced the transit north towards the Torres Strait for refueling.

Thursday 22 October 2020

Wind 12 kn from 120°. Sea state 3. Low swell.

0900 in position 10.091747°S 144.051876°E in vicinity of Murray Islands, Torres Strait.

Through the early morning, *Falkor* continued to map the shelf edge and upper slope of the far northern Great Barrier Reef on the transit towards the Torres Strait. At 0900, the volcanic Murray Islands were within view as the ship mapped northward. The multibeam data were the first ever collected along the far northern GBR this close to the shallow barrier reefs, providing an insight into the edge of the reef, which has only ever been mapped previously using airborne lidar bathymetry. At 1500, *Falkor* completed the northern transit along the GBR shelf edge, successfully revealing the continental slope bounding the reef. The ship then headed northeast across the Gulf of Papua towards the merchant vessel traffic corridor into Torres Strait. At 2330,

all multibeam systems were turned off as the ship entered Great North East Channel for passage through Torres Strait.

Friday 23 October 2020

Wind 13 kn from 115°. Sea state 3. Nil swell.

0900 in position 10.206966°S 142.932450°E in Great North East Channel, Torres Strait.

Falkor continued southwest down the Great North East Channel overnight. All multibeam systems were turned off, as the channel is shallow and well surveyed. At 0500, the Pilot was taken onboard for the transit into Horn Island. We rounded Thursday Island and berthed at Horn Island at 1700. Fueling at Horn Island was successful and the ship departed at 2100 for transit back towards the Great North East Channel.

Saturday 24 October 2020

Wind 11 kn from 110°. Sea state 3. Nil swell.

0900 in position 09.371000°S 143.650666°E in Great North East Channel, Torres Strait.

Through the morning, *Falkor* transited northeast through the Great North East Channel, passing Stephens Island at 0800. On exiting the deep-water channel at the entrance to Torres Strait at 1140, both the EM302 and EM710 multibeam systems were turned back on as the ship headed towards the previously mapped track at the far northern limits of the Great Barrier Reef. At 1500, *Falkor* re-joined the previous track at the far northern limit of the Great Barrier Reef and then continued the track southward, edge mapping the previous multibeam data back towards the detached reefs.

Sunday 25 October 2020

Wind 9 kn from 145°. Sea state 2. Nil swell.

0900 in position 11.751253°S 144.105222°E in Great Detached Reef.

Overnight, *Falkor* continued edge mapping the previously collected map data along the far northern GBR shelf edge and upper slope. At 0600, the ship arrived at Saunders Reef, the northern-most detached reef, and passed the eastern side of Raine Island Reef. At 0830, the ship mapped the steeper flanks of Great Detached Reef. From 1000, *Falkor* commenced mapping Yule Detached Reef in a clockwise direction. The first circuit was completed at 1230, for another wider circuit around Yule Detached Reef. Weather conditions were calm and

perfect for close shallow reef edge mapping. At 1600, *Falkor* had completed a circuit of Woody Reef, a smaller detached reef lying north of Yule Detached Reef.

Monday 26 October 2020

Wind 7 kn from 120°. Sea state 2. Nil swell.

0900 in position 12.401896°S 143.854743°E in vicinity of Northern Small Detached Reef.

With excellent weather offshore of Cape York, *Falkor* had completed mapping about half of the Yule Detached Reef survey area. This is a similar sized bay compared to Wreck Bay just to the south. At 0500, the ship departed the Yule Detached Reef survey area to transit to the newly discovered ~500 m tall reef, about 2.5 km north of Northern Small Detached Reef. ROV dive #401 was commenced at 0900 with a maximum depth of 578 m. The dive revealed a hard limestone substrate with much mobile marine life around the base of the reef, increasing in sessile benthos coverage as we ascended. The summit was covered in reef fish and had at least four large sharks circling. Shallow corals, sponges and algae were prolific at the top of the reef. The dive confirmed the newly discovered reef was a significant reef coral habitat at shallower depths. The ROV was recovered by 1700, and then the ship commenced mapping northward towards the Yule Detached Reef survey area.

Tuesday 27 October 2020

Wind 8 kn from 145°. Sea state 2. Low swell.

0900 in position 12.129181°S 143.974720°E in vicinity of Wreck Bay.

Overnight, *Falkor* completed mapping the Yule Detached Reef survey area, and mapping the waters deeper than 1000 m to seaward of Wreck Bay. At 0900, the ship arrived at the 'plunge pool' at the entrance to Wreck Bay for ROV dive # 402. Maximum depth was 2071 m, initially as a slow midwater descent with Dhugal Lindsay narrating to describe the midwater plankton species. At the seafloor, huge blocks of sedimentary rock lay scattered about, broken from the steeper cliffs above. Samples found these rocks to be non-marine mudstone and sandstone, thought to be outcrops of ancient continental rock, having subsided over long geological time and now exposed at these deeper depths. ROV SuBastian was recovered at 1730, then the ship commenced multibeam mapping to seaward of the Great Detached Reef survey area.

Wednesday 28 October 2020

Wind 12 kn from 125°. Sea state 3. Low swell.

0900 in position 12.531287°S 143.983370°E in vicinity of the Small Detached Reefs.

We completed the mapping along the Cape York Peninsular, as far north as the Great Detached Reef survey area, then at 0600 commenced our transit return to Cairns for the Leg 2/Leg 3 crew-changeover. The mapping continued through the transit back to Cairns, along the deeper parts of the previously mapped data coverage in an effort to fill in any data gaps. At 1300, the ship was 12 km east of the tip of Tijou Reef mapping southwards over along the foot of the continental slope. Through the evening, *Falkor* continued mapping over previously collected data gaps along the lower continental slope in depths >2000 m.

Thursday 29 October 2020

Wind 08 kn from 150°. Sea state 3. Low swell.

0900 in position 14.631951°S 146.030877°E in the northern Queensland Trough.

Falkor mapped the lower continental slope through the night, then at daybreak headed east into the Coral Sea Marine Park across the Queensland Trough in depths greater than 2000 m. At 1200, the ship commenced a westerly transit back towards the Great Barrier Reef margin. By 1330, the ship had returned to upper slope opposite Ribbon Reef No. 10, then headed southward mapping along the upper slope in depths ~600 m. Weather conditions were excellent as the ship continued towards Cairns.

Friday 30 October 2020

Wind 08 kn from 150°. Sea state 3. Nil swell.

0900 in position 16.928250°S 146.780216°E at Cairns wharf.

At 0300, *Falkor* entered Grafton Passage opposite Cairns to commence the transit into Cairns Port. The Pilot boarded at 0730 and by 0800, the ship had berthed at the main Cairns Wharf. The Leg 2 science team participants left the ship at 0930, while others joined for Leg 3. The remainder of the day was spent reprovisioning and refuelling, and the ship's crew changeovers.

Saturday 31 October 2020

Wind 08 kn from 150°. Sea state 2. Nil swell.

0900 in position 16.928250°S 146.780216°E at Cairns wharf.

With the ship alongside Cairns Wharf, preparations were made for sailing through the day. At 1530, emergency drills were conducted onboard, and then at 1800 *Falkor* departed Cairns for

the transit out of Grafton Passage. At 2130, the ship had exited Grafton Passage then headed southward along the upper slope towards the Swain Reefs. Both the EM710 and EM302 multibeam sonars were started and mapping recommenced.

Sunday 01 November 2020

Wind 03 kn from 090°. Sea state 2. Low swell.

0900 in position 17.948313°S 146.932616°E in vicinity of Barnett Patches reef.

Falkor continued mapping the upper continental slope southward from Cairns through the night. By daybreak, weather conditions were very flat and mapping commenced closer to the shelf break in depths ~150 m. At 0900, the ship was opposite the outer-shelf Barnett Patches reef. At 1300, *Falkor* traversed the entrance to Palm Passage, then at 1400 conducting a clockwise transit around Myrmidon Reef with depths around 220 m. From around 1500 to 1800, *Falkor* transited across the upper part of the Swain slide, close to where ROV dive #394 was previously located.

Monday 02 November 2020

Wind 11 kn from 110°. Sea state 3. Low swell.

0900 in position 19.340496°S 149.617573°E in vicinity of Joist Reef.

Falkor continued to make good progress through the night towards the Swain Reefs. At 0900, the vessel was near Joist Reef on the upper continental slope, conducting edge mapping against previous multibeam data. Depths were about 150 m. At 1100, *Falkor* stopped to conduct a stationary sound velocity (SV) profile in ~180 m water depth. With the SV profiling completed at 1230, *Falkor* continued mapping the upper slope towards Hydrographers Passage. At 1330, *Falkor* transited across the entrance to Hydrographers Passage in depths ~120 m. Through the evening, the ship headed southeast across the north Marion Plateau towards the Swain Reefs. Numerous small pinnacles were observed in depths ~130 m.

Tuesday 03 November 2020

Wind 21 kn from 130°. Sea state 4. Low-moderate swell.

0900 in position 20.823511°S 151.995198°E in vicinity of the Swain Reefs.

In the early morning, *Falkor* commenced the systematic survey of the Swain ‘embayment’ – a broad bay on the shelf edge and upper slope of the Swain Reefs. The origin of this embayment

is unknown, and the mapping may reveal why there is a distinct change from a low gradient, but deeper shelf edge to the west, compared to a shallower but much steeper shelf edge to the east. By 0900, the ship had completed the first pass in depths ~270 m. As stronger winds developed throughout the day, effort was made to stay in relatively deep water. The second east to west pass was completed at 1330. The third west to east pass was completed at 2100, before reversing course to head west in depths ~270 m.

Wednesday 04 November 2020

Wind 14 kn from 130°. Sea state 4. Low swell.

0900 in position 20.767853°S 151.428547°E in vicinity of the Swain Reefs.

Through the early morning, *Falkor* continued westerly across the deeper waters of the Swain 'embayment'. With daybreak and easing windy conditions, the ship headed towards the reef to commence mapping closer to the shoals revealed by the lidar survey of the area. Progress was slowed to around 5-6 kn due to the unknown nature of the seafloor. Numerous small pinnacles were found to lie seawards of the shoals. At 1100, the ship was close to the southern-most part of the embayment. The seafloor here remained consistent at 60-70 m. At 1530, the ship completed the close to reef mapping, then looped back to edge map from east to west. The shelf break became far more obvious with a step revealed at ~110-140 m. Another step appeared higher up on the shelf edge at ~80-90 m. At 1820, the ship had completed this edge mapping close to the shelf edge, then reversed and conducted two more passes in depths ~200 m through the evening.

Thursday 05 November 2020

Wind 05 kn from 330°. Sea state 2. Low swell.

0900 in position 20.813045°S 151.491985°E in vicinity of the Swain Reefs.

Falkor continued mapping the deeper offshore areas in depths ~200 m through the night, then at daybreak transited closer to the shelf edge in depths ~100 m. By midday, the vessel had completed a shallow pass from east to west, then reversed course to map the shelf break itself at 100-120 m depth. Towards the evening, the ship broke off from the survey ground and headed north away from the GBR for engineering purposes.

Friday 06 November 2020

Wind 07 kn from 310°. Sea state 2. Low swell.

0900 in position 20.899002°S 151.725517°E in vicinity of the Swain Reefs.

Falkor continued to map the Swain 'embayment' revealing the shelf break at around 115 m. However, another ledge appeared below this at ~150 m, then dropping to ~175 m. This deeper ledge is unlikely to be the Pleistocene shelf break, which is typically between 90-120 m along the entire GBR margin, and so must be older than Pleistocene in age. From 1100 to 1400, the ship did a long pass across the embayment at ~150 m to delineate the limits of this deeper ledge. At 1400, *Falkor* commenced a shallow ~60 m survey on the shelf edge in depths ~60 m at the far western area of the embayment, to reveal the lagoon-style seafloor. This shallow mapping work continued until nightfall, and then the ship transited into deeper waters ~250 m and continued mapping the remaining gaps through the night.

Saturday 07 November 2020

Wind 11 kn from 120°. Sea state 3. Low swell.

0900 in position 20.801203°S 151.521727°E in vicinity of the Swain Reefs.

Through the early morning and then for most of the daytime, *Falkor* worked on completing the mapping of the larger Swain 'embayment' area in depths around 200-250 m. By 1600, the ship had completed this area and commenced transit east towards the wedge-shaped data gap between the Swain embayment and the previously mapped Swain slide.

Sunday 08 November 2020

Wind 21 kn from 115°. Sea state 4. Low-moderate swell.

0900 in position 20.958931°S 152.392081°E in vicinity of the Swain Reefs.

The wedge-shaped data gap between the Swain embayment and the previously mapped Swain slide was completed at 0830, then *Falkor* continued easterly following the upper slope towards the Swain slide. By 1200, the ship had passed through the Swain slide scarp and then transited between the 5 km wide gap between the Swain Reefs and Elusive Reef. The ship continued to map the upper slope in depths ~65 m, then at 1230 headed east towards Saumarez Reefs. At 1500, the ship crossed from the Great Barrier Reef Marine Park and into the Coral Sea Marine Park. At 1828, *Falkor* arrived at the northwest corner of Saumarez Reefs and commenced a clockwise loop mapping along the steeper upper flanks of this 38 km wide reef.

Monday 09 November 2020

Wind 22 kn from 125°. Sea state 4-5. Moderate swell.

0900 in position 21.118488°S 154.168184°E in vicinity of Frederick Reef.

Overnight, *Falkor* completed the clockwise mapping loop around Saumarez Reefs, and then headed towards Frederick Reef. Depths were generally deeper than ~2000 m and relatively flat. At 1000, the ship arrived on the southwest corner of Frederick Reef and conducted a CTD dip to test the sensors in deeper waters. The CTD dip was completed at 1200, and then the ship carefully made way into the western lagoon area of Frederick Reef. Weather conditions proved too rough, so the island visit at Frederick Reef was canceled. At 1300, the ship commenced a clockwise mapping transit around the steeper flanks of Frederick Reef. Poor weather conditions made mapping operations challenging while heading into the wind. At 1730, the ship once again tried mapping down the windward, eastern side of the reef due to the poor quality of the data form the previous lap. At 1841, *Falkor* had completed its final pass of Frederick Reef and commenced the transit easterly towards the Kenn Reefs.

Tuesday 10 November 2020

Wind 18 kn from 125°. Sea state 4. Moderate swell.

0900 in position 21.205689°S 155.624366°E in vicinity of Kenn Reefs.

Strong winds continued to make mapping operations challenging. Overnight, *Falkor* worked easterly towards the Kenn Reefs. The ship approached the northern flanks of Kenn Reefs in the early morning and commenced a systematic survey of the deeper waters surrounding the reef. With daybreak, mapping continued down the western side. Then at 1000, the ship carefully transited across the lagoon towards the southwest sand cay. At 1019, the ship arrived close to the sand cay to assess wind and swell conditions; however, the swell was too strong. At 1040, the ship exited the lagoon and recommenced counter-clockwise mapping of the steeper flank around Kenn Reefs. At 1300, the ship had passed the eastern extremity of Kenn Reefs in depths ~400 m and then headed north. Through the night, the ship mapped the eastern flanks of the Kenn Reefs.

Wednesday 11 November 2020

Wind 16 kn from 125°. Sea state 4. Moderate swell.

0900 in position 21.275284°S 155.625095°E in vicinity of Kenn Reefs.

Through the morning, *Falkor* mapped the eastern and southern steeper flanks of the Kenn Reefs, then repositioned to the southwest corner at 0730 to commence a transit onto the

lagoon in order to drop off the boat team. At 0800, the small boat team departed the ship to commence a photographic survey of the southwest sand cay. The ship departed the lagoon and started mapping the shallower flanks on the west side of Kenn Reefs. At 1100, the ship made its way again into the lagoon to recover the boat team from the southwest cay. On recovery, *Falkor* headed to the northern side of Kenn Reefs where a broad, deep plateau extended northward of the reef. Mapping continued through the night along the western edge of this deeper bank in depths ~1500-3000 m.

Thursday 12 November 2020

Wind 14 kn from 120°. Sea state 3. Low-moderate swell.

0900 in position 20.924996°S 155.658621°E in vicinity of Kenn Reefs.

Through the early morning, *Falkor* mapped the western side of the deeper bank extending northward of Kenn Reefs. Multibeam backscatter imagery showed high reflectance pixels, likely revealing the hard, rough volcanic rocks exposed at the seafloor on this bank. At 1030, the ship left the Kenn Reefs, and commenced transit southwards towards the Wreck Reefs. Mapping continued through the day over a relatively flat seafloor in depths around 3000 m. At 1630, the ship stopped northeast of the Wreck Reefs to conduct a deep CTD dip. The CTD dip concluded at 1800. The ship continued to Wreck Reefs, arriving at 2100 and then mapping around the steeper reef flanks.

Friday 13 November 2020

Wind 13 kn from 050°. Sea state 3. Low swell.

0900 in position 22.153841°S 155.302983°E in vicinity of Wreck Reefs.

Falkor mapped around the steep upper flanks of the Wreck Reefs, then transited close to Bird Cay to drop off the boat team for their visual surveys of the cays and islands. The ship then continued mapping the upper steep flanks around Wreck Reefs while waiting for the boat crew to return. Good weather conditions allowed high quality mapping data in these shallower waters, with the vessel doing several laps around Wreck Reefs. The boat team was recovered at 1500, and then the ship departed the Wreck Reefs area heading southward towards Cato Reef.

Saturday 14 November 2020

Wind 06 kn from 325°. Sea state 2. Low swell.

0900 in position 23.149284°S 155.513713°E in vicinity of Cato Reef.

Falkor mapped towards Cato Reef through the morning and conducted a series of laps around the reefs steeper flanks. At 0800, the small boat team departed the ship for Cato Island – the largest island of the Coral Sea Marine Park, to conduct photographic surveys of the bird and turtle nesting. Through the day, the ship continued mapping around the steeper flanks of the island, then at 1300 the ship remained on station, awaiting the arrival of the small boat team onboard. The small boat team was recovered at 1500, and the ship departed Cato Reef, heading westerly back towards the Great Barrier Reef. *Falkor* passed over the Cato Trough at 2000, and continued to head west across the deeper flanks of the South Marion Plateau.

Sunday 15 November 2020

Wind 10 kn from 340°. Sea state 2. Low swell.

0900 in position 23.916100°S 153.847323°E in the vicinity of the Fraser Canyon.

Falkor mapped westerly through the morning then arrived at the head of the Fraser Canyon – a large ~100 km long canyon that drains sediments from both the Great Barrier Reef shelf and the South Marion Plateau. The ship commenced north-south mapping lines, filling in gaps until 1000, then headed west to map the smaller feeder gullies into the canyon. Good weather conditions allowed efficient surveying in ~1700 m depths across the slope feeding into the main Fraser Canyon axis. Several narrow gullies were revealed draining west-east across the slope. The mapping of the area continued through the night, filling in data gaps to reveal the large network of gullies feeding into the Fraser Canyon.

Monday 16 November 2020

Wind 06 kn from 055°. Sea state 2. Low swell.

0900 in position 24.675721°S 153.837909°E in the vicinity of the Fraser Canyon.

Falkor continued west-east systematic mapping through the morning, then at 0630 broke off all systematic mapping of this Fraser Canyon to commence the final transit back towards Brisbane. Through the morning, the ship mapped the middle continental slope, heavily incised with canyons, around 3000 m depth. By 1400, *Falkor* had worked upslope onto the relatively smooth upper slope east of Fraser Island, then continued edge mapping the previous Leg 1 multibeam data in depths around 250 m.

Tuesday 17 November 2020

Wind 09 kn from 340°. Sea state 2. Nil swell.

0900 in position 27.443581°S 153.076226°E alongside wharf in Brisbane Port.

At 0100, *Falkor* completed edge mapping the upper slope along the Fraser shelf, then headed west across the shallow shelf towards the pilot boarding ground north of Stradbroke Island. The Pilot boarded at 0500 and the ship commenced pilotage across Moreton Bay. The ship berthed at 0900 in Brisbane Port and concluded the voyage FK200930 “Northern depths of the Great Barrier Reef”.