VOYAGE SUMMARY SS04/2003

Title
Sources and sinks of terrigenous sediments in the southern Gulf of Carpentaria

Itinerary
Departed Cairns 0700 hrs, Friday 9 May, 2003
Arrived Darwin 0800 hrs, Tuesday 10 June, 2003

Principal Investigator
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Scientific Objectives
The southern Gulf of Carpentaria contains Australia's largest shelf province of terrigenous-dominated sedimentation. It is an area of over 100,000 km^2 where surface sediments have an average terrigenous content exceeding 50%. The adjacent coastline is characterised by prograding depositional environments (deltas and chenier plains), indicative of large sediment discharge from the hinterland to the coast throughout the Holocene. Our objective is to identify and quantify sediment sources, sinks and the Late Quaternary history of terrigenous sedimentation in the southern Gulf of Carpentaria This information is of fundamental importance for understanding the evolution of this shelf province, and for the successful management of regional river catchments and the adjacent offshore environment.

The strategy would be to conduct intensive swath bathymetry & Chirp sonar surveys and sediment coring in key selected areas: (A) inner shelf zone of low-energy, distal-deltaic sedimentation, off the Norman River; (B); inner mid-shelf zone of strong tidal currents adjacent to Mornington Island and (C) low energy Carpentaria Basin sedimentation. The sedimentary processes characterising each area are suggested by the results of wave and tide current modelling and a second aim of the study would be to validate the model predictions for this region. The total ship time requested is 27 days in the southern Gulf of Carpentaria.

Voyage Objectives
- To identify and quantify sediment sources, sinks and the Late Quaternary history of terrigenous sedimentation in the southern Gulf of Carpentaria,
- To locate and map areas on the shelf characterised by modern terrigenous deposition,
- To derive sediment budgets representative of the main depositional environments,
- To date the onset of Holocene, pro-deltaic to distal deltaic/open shelf terrigenous sediment deposition as a function of distance from the coast.

- To validate the GEOMAT sediment mobility model and its prediction of southward oriented maximum tidal current vectors adjacent to Mornington Island.

Methods used

A Reson 240 kHz swath system (model no. 8101) was hired from James Cook University, School of Earth Sciences. The system recorded data using Reson 6042 Ver. 7.2 format software. The total amount of data recorded was ~70 GB. An Applied Microsystems Ltd SV PLUS acoustic velocity profiler was used to measure the acoustic velocity range, which was from 1542 - 1546 m/s in the study area. The transducer array was mounted on a trolley through the moon pool about 30 cm below the hull. The moon pool is offset about 4 m from the vessel centre line. The motion sensor was mounted on the centre line.

A Datasonics 3.5 kHz Chirp Sub-bottom profiler, recorder model no. DSP 661/66 and tow fish model TTV170S was towed behind the ship throughout the survey. The trigger interval was 0.5 to 0.25 seconds (0.25 to 180 metres, 0.5 below 180 M) and the total amount of Chirp data recorded was ~30 GB. A EGG Sparker system was also deployed on some locations, where greater penetration was required to image the underlying sedimentary strata.

The ships Seabird SBE911 CTD was deployed along with a Seatech transmissometer, calibrated to measure suspended sediment concentration using surface and near-bed water samples. Two-litre water samples were filtered through pre-weighed 0.45 µm filter papers using a vacuum system to obtain mass concentration values. On return from the voyage, the filter papers were oven dried at 60°C and re-weighed in the lab to the nearest ±0.0001 g.

Seabed sediment samples were collected using a Smith Macintyre grab and Geoscience Australia's newly built electric vibro-corer. Sub-samples of sediment grabs were taken for laboratory analyses, including a sub-sample stored in ethanol and the collection of mini-cores where possible. Mini-cores were taken by pushing a short piece of plastic core liner by hand into the top 10 to 20 cm of the grab sample. The remainder of the grab was sieved at ~5mm and the gravel fraction was bagged and stored. Any living material was also separately recorded and packed for freezer storage.

A benthic sled built by the CSIRO and provided by Ted Wassenberg (CSIRO Marine Labs, Cleveland) was deployed at selected stations to collect a representative sample of benthic biota. On recovery, samples were sorted and packed in boxes for freezer storage for later examination.

Video footage of the seafloor was collected to characterise the seabed type and record associated benthic fauna. An underwater video camera was deployed for a minimum of three minutes at each of the stations. The video camera was built by Geoscience Australia, and comprised a digital video recorder with two, battery-powered, flood lights. The video frame was set up with a scale bar, mounted within the viewing area. The camera provided real time display of footage, enabling the winch control to maneuver the camera frame as required to view specific seabed features. Seafloor characteristics and the main biota were described on board ship and recorded in the shipboard database. Current, temperature, salinity and turbidity measurements were made using a frame designed for deployment in shelf water depths up to 300 m. The Benthic Research for Underwater sediment ConcEntrations probe (BRUCE) was constructed at Geoscience Australia. It comprises a Nortek vector acoustic current meter, Benthos optical backscatter sensor, Sequoia LISST-100 transmissometer laser particle sizer and Seabird CTD. BRUCE was deployed at location 16° 29.995 S, 139° 55.961 E in 34m water depth. Instruments were deployed at 09:45 13-May-2003 GMT. The mooring was recovered at 08:23 27-May-2003 GMT. On recovery some biofouling was apparent, however it was not in such significant abundance as to interfere with data recording.

The Nortek vector acoustic current meter (ADV #N4103) was positioned to sample at 100cm above the base of the benthic frame. The ADV was programmed to burst sample every 20 minutes for 60 s at 8 Hz, a time scale that enables turbulence to be resolved. Vector components of velocity (east, north and up) and temperature were logged internally and down-loaded on recovery.

Two Benthos optical backscatter sensors (OBS #897) were positioned at 100cm and 30 cm above the benthic frame, facing inwards from one vertical support bar. The OBS sensors were powered by, sampled at the same rate as, and logged to the ADV. OBS output is recorded in counts as an analog input to the ADV. This is converted to volts (5 V = 65535 counts) and subsequently converted to turbidity (ftu). Turbidity (ftu) = 356.7*(x + 0.002) where x is the output in Volts.

The Sequoia LISST-100 transmissometer laser particle sizer (LISST #104579) was placed 27 cm above the base of the benthic frame. The LISST was programmed to burst sample every 20 minutes for 60 s at 2 Hz. Data were down-loaded on recovery in day long segments. Transmissivity, battery voltage and volume concentration for 32 size bins were recorded. The Seabird CTD (CTD #1620) was also placed at 27cm above the base of the frame. The CTD was programmed to samples at the same rate as the LISST. Temperature and conductivity were logged to the LISST internal memory.

Two 20 cm lengths of 9 cm diameter plastic pipe were placed in the frame at 30cm and 100cm height above the base of the frame, to serve as sediment traps for the deployment.

Voyage Track

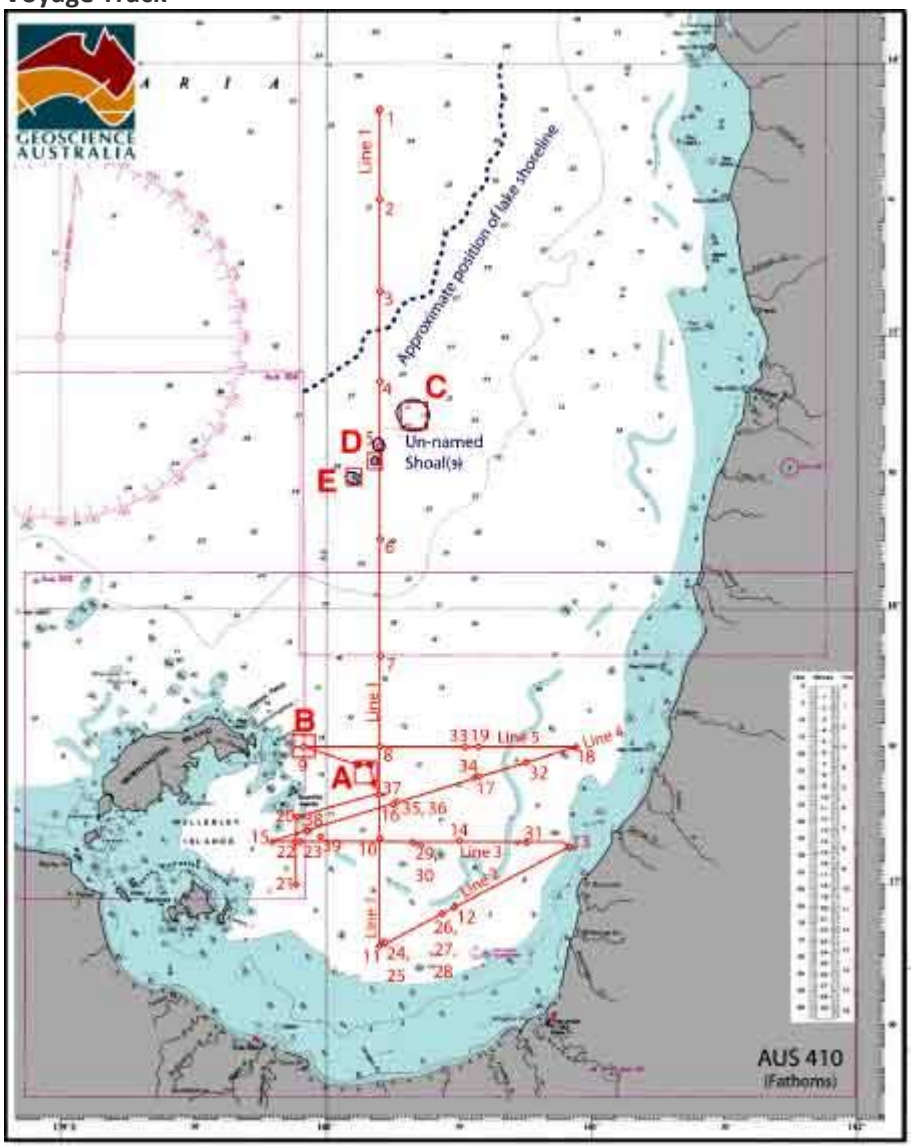

Figure 1

The RV Southern Surveyor arrived in the south-central Gulf of Capentaria and steamed southwards along a regional survey grid (Fig. 1). The regional survey lines were designed to provide a broad overview of the seafloor morphology, sediment distribution and stratigraphy and permit the identification of major sub-surface features in seismic profile records. In particular, the regional lines were placed to intercept low-stand river channels that we expected to see crossing the shelf directly seawards of the Norman River. The vessel was stopped along track at regular (~20 nautical mile) intervals to conduct a station where CTD, sediment grab sample, benthic sled and underwater video data were collected. Upon reaching station 9 (Fig. 1) a benthic current and turbidity frame (BRUCE) was deployed (see above for details of the instrument package). Station 21 was the last in this preliminary series of stations (Fig. 1). This was followed by the collection of vibrocores at sites selected from the Chirper sesimic records, at stations 22 to 39.

The regional survey lines were also used to select study sites where detailed swath mapping was carried out along closely spaced lines. The first swath survey was conducted in Area A, where the CSIRO had established 3 control sites to assess the impact of trawl operations on the seabed. The trawl boards used by prawn trawlers are known to plough the seafloor, leaving large parallel grooves on the bottom where they have been used. The CSIRO control sites included areas that have been trawled plus other pristine areas to provide a means of assessing the impacts of trawling. Our swath mapping equipment area was very flat and featureless and no trawl marks could be detected in the bathymetry or backscatter data.

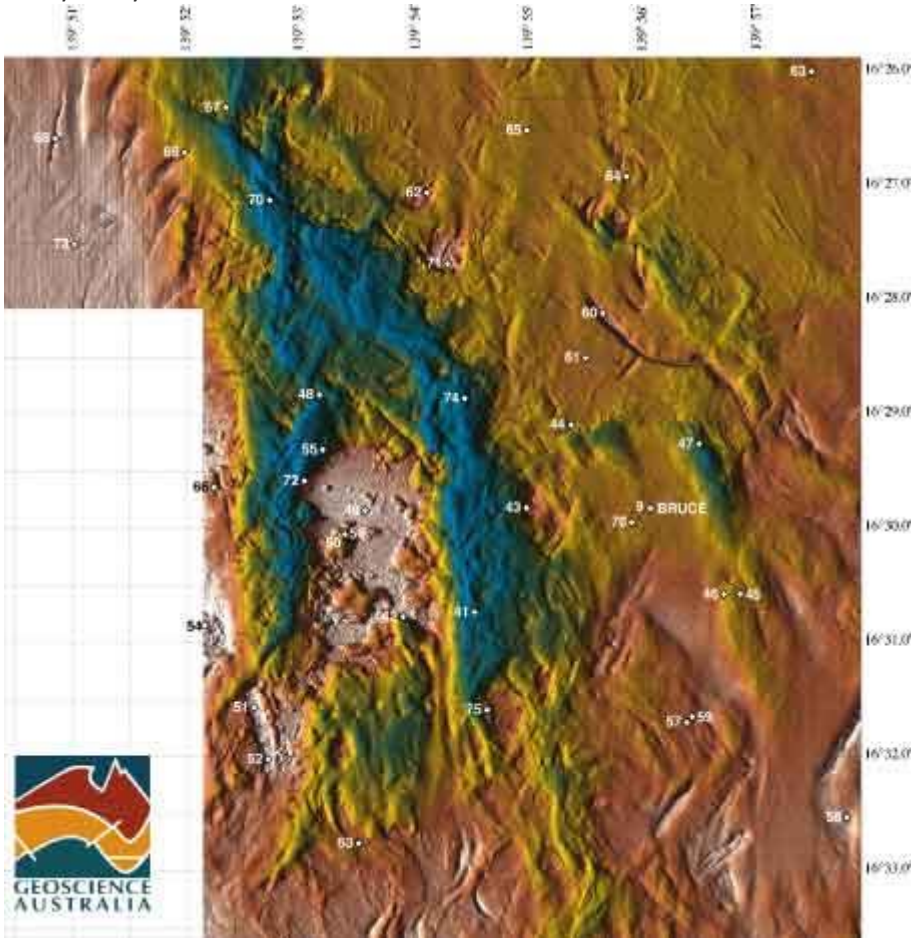

Figure 2

Swath mapping and sampling of Areas B(Fig. 2), C (Fig. 3) D and E were completed in succession. Swath surveying of Area C was interrupted while the ship called in to Weipa for refueling. Line spacing and orientation were adjusted in each area for depth and feature orientation as required. In each area mapped, a number of stations were also carried out. A list of all stations completed is given in Table 1.

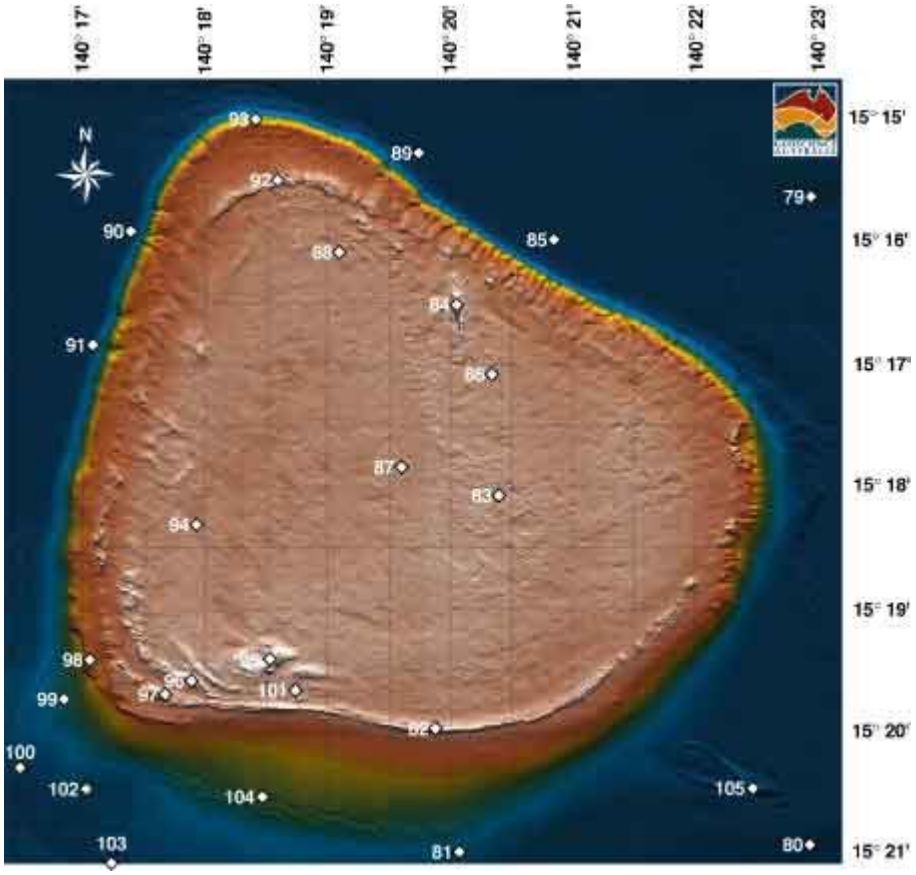

figure 4

Results

It is not known at the time of this writing (July 2003) if the data collected during our voyage will address several of the key objectives, until the data have been properly processed and analysed. The estimate of sediment transport rates (to validate existing models) using our BRUCE data and the determination of terrigenous sediment sources to the Gulf, awaits the analysis of the relevant data. The precise identification and quantification (by radiocarbon dating) of terrigenous sedimentation in the areas studied similarly awaits the analysis of core samples collected during the voyage.

Preliminary and tentative information suggests that rapid modern deposition occurs locally, indicated by anoxic (H_2S) sediments sampled at Station 12 (Fig. 1). However, preliminary indications point to much of the terrigenous component of surficial sediments in the SE Gulf being sourced from the reworking of transgressive, fluvial deltaic deposits. This relict sediment source is suggested by the thin veneer of Holocene material observed in Chirp seismic sections and by the stiff, dewatered clay encountered in several of the shorter vibrocores.

The most dramatic evidence illustrating the relict nature of the regional seafloor are shown in the shaded relief bathymetry images from Areas B and C (Figs 2 and 3). The platform located at 30m depth in Area B (position of Station 49, Fig 2) shows clear evidence of weathering, forming a distinctive pock-marked, Karst limestone bank in 30 m water depth. Weathered limestone cobbles dredged from this bank were comprised of bryozoans and molluscs. The unusual (and unexplained!) swirl patterns are similar to comet marks (also termed obstacle marks or current crescents) seen in many environments (eg. JRL Allen, 1984, Sedimentary Structures Vol 2, Elsevier, p 194) suggestive of northward sediment transport across Area B. However, given that erosion characterises much of this area, the possibility that these marks are relict or erosional (rather than depositional) features must be considered.

A major discovery of the voyage was the series of three platform reefs mapped and sampled in Areas C, D and E (Fig. 1). These are clearly reefal limestone platforms and appear to have been formed when sea level was ~30 m below its present position. The coral limestone buildups are underlain by acoustic basement features which also exhibit positive relief (Fig. 4). Repeated submergence of these reefs during sea level oscillations through the Quaternary is apparently associated with coral growth and the deposition of carbonate, as indicated by the series of 3-4 lateral ridges that can be seen along the SE margin of the atoll (Stations 96, 97 and 98 are located on the elevated ridge-tops; see Fig. 3). The fact that these reefs support live hard corals in many locations is further evidence of their origins. A live specimen of Turbinaria (plate coral) was dredged from Station 82 on the southern rim of the platform reef. Live hard corals were also seen on the video at stations 84, 87, 88, 92, 94, 95, 96 and 97 (see Fig. 3).

Preliminary plots of light transmission, salinity and temperature recorded using the ship's CTD profiler (Fig. 5) illustrate the changing oceanographic regime along a N-S transect through the Gulf. Station 1 was occupied in the deepest part of the central Gulf and illustrates the well mixed temperature and salinity conditions in the water column. Light transmission is much reduced in the lower at Stations 1 and 2 below 50 m water depth, which is probably due to local resuspension of bottom sediments. This situation was probably caused by the days preceding our voyage, when strong winds and relatively large swell waves stirred the seabed. It is interesting to note that a salinity gradient exists between stations 1 and 2 (Fig. 5). The area of reefs exhibited the highest level of light transmission (lowest turbidity) and lower salinities than other parts of the Gulf. The waters closest to the coast (Stn 24) were less saline, coldest and had the highest turbidity (Fig. 5)

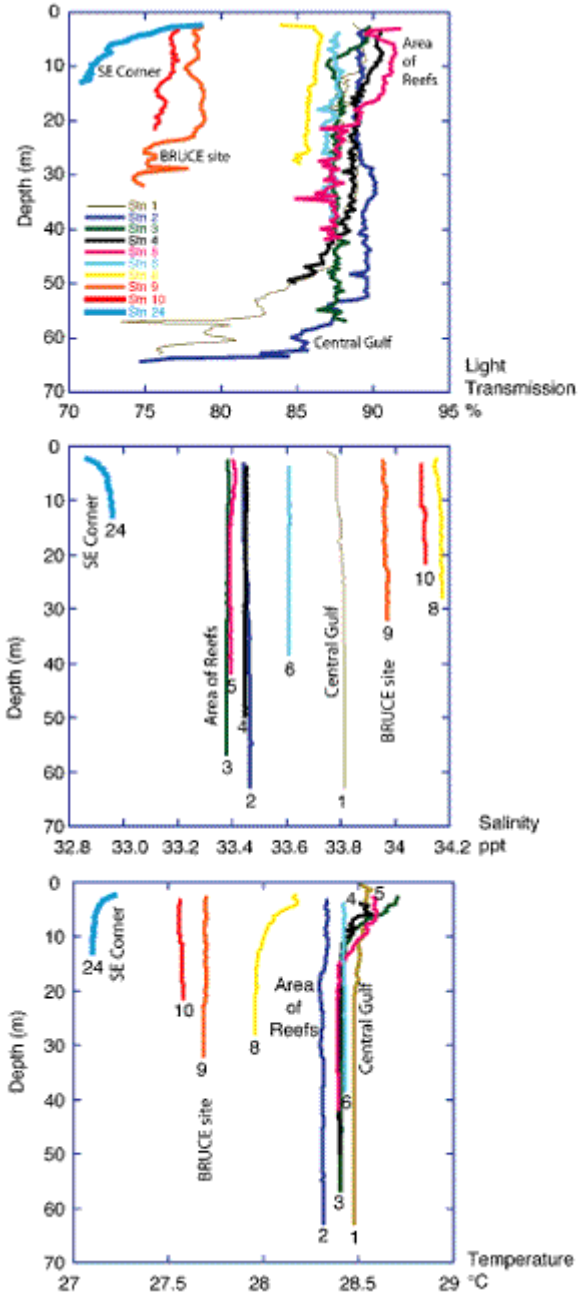

figure 5

Voyage Narrative

9-5-03 Friday Southern Surveyor sailed from Cairns Slipways at 0700 hrs, as per schedule and without incident. Scientific party were taken on a tour of the ship by the first mate John Boyes.

- 10-5-03 Transit to start of survey. A presentation of the voyage scientific plan was given by the Chief Scientist at1030 hrs. A proposed list of stations for the first phase of the voyage was delivered to the bridge.
- 11-5-03 Sunday fire drill at1030 hrs. John Stratton advised that the Boomer digital acquisition system was damaged during a power outage on the ship on the 10th. I also found out today that the EPC recorder we hired from Seismic Supply in Brisbane was faulty and was returned 2 weeks ago for repairs but was not sent back to us in time for our departure.
- 12-5-03 Arrived at the first station at 0020hrs. Station operations were CTD, camera, grab and dredge. Station 2 completed at 1000 hrs. Station 5 completed at 2350 hrs. In traversing the assumed location of the Lake Carpentaria shoreline at 55m water depth we did not see any indication of a beach or coastline depositional system in the chirp or sidescan image. The un-

named shoal appears to be a (Holocene?) sedimentary deposit as a positive relief feature was seen to overlie a horizontal reflector. This may be the new objective of the Area C survey. Much to my relief, Kevin Hooper has managed to rig up another EPC recorder from JCU so that we can print the Chirp data as we survey – this will greatly improve our ability to monitor changes in the subsurface and plan our eventual coring stations.

- 13-5-03 Deployed the current meter frame BRUCE this evening and mapped three test-trawl survey areas under investigation by the CSIRO. The seabed in the BRUCE area has some rocky features and bedforms. The CSIRO trawl areas appeared to be flat and featureless and we could see no indication of trawl marks on the seabed in our sidescan sonar images.
- 14-5-03 Continued long survey, finishing line 2 and started line 3. Encountered some muddy deltaic sediments along Line 2 and first indication of anoxic (H_2S) sediments at Station 12.
- 15-5-03 Completed Line 3 and Station 16 this evening. Sediments at station 15, SE of Mornington Island are well-sorted, fine muddy sand. The relict Norman River channel is evident in our seismic data and has been crossed on all lines so far. It is best developed on the western edge of line 3. Based on the crossing of the proposed position of Area A and its flat, uninteresting character, I have consulted with Andrew H and we decided to forgo the detailed swath survey here and to collect a set of vibrocores over a broad area instead, to compliment the seismic data. We intend to complete a swath survey of Area B as planned.
- 16-5-03 Continued swath mapping and station work. Two extra stations and a new section of swath/seismic survey were added, with the aim of arriving at the first vibrocore station in the morning. A total of ~900 line km of swath/chirp survey have been completed so far.
- 17-5-03 First vibrocore completed at 1000 and second core before lunch. Delay to first core of ~ 2hrs was caused by faulty wiring of the power cable termination. Fortunately a second back-up cable had been prepared by the science technicians otherwise a much longer delay would have occurred. By midnight 6 vibrocores up to 4.5 m in length were completed. The new GA vibrocore system, with modified deck-trolly has performed very well. It is now much safer and more reliable than the older version. I am also impressed with the performance of the GA vibrocore tower, although its legs drag on the trawl deck doors and could hang-up on them. The very calm sea conditions have continued, making our work much easier.
- 18-5-03 Eight more vibrocores collected today, along with CTD, camera, grab and dredging operations.
- 19-5-03 The 18th vibrocore was collected today at11AM, completing the sampling work for this part of the survey. Transit to area B to start swath mapping, which commenced at1400 hrs. Sighted the surface floats for BRUCE, with only yellow and two white floats showing, the rest submerged below a strong southerly tidal current.
- 20-5-03 Swath mapping of area B continues. We completed about twenty 10km lines in the first 24 hours, so are on target to complete ~100 lines in 5 days. Meanwhile, the science technicians have completed repairs to the cable for the underwater camera, which had been broken.
- 21-5-03 Swath mapping of area B continues. Today we saw the first gridded bathymetry map generated using the new data, which showed what appears to be a relict reef in about 30 m depth, with a distinctive flat top and doline Karst features (sink holes). It is surrounded by two channels up to 45 m in depth. The reef was part of what may have been a much larger reef complex that grew in the Gulf of Carpentaria when sea level was 30 m lower than present during the late Plesitocene period. If this hypothesis is correct, it could be a major finding of our voyage. Sampling of the features to prove their reefal origins has become a major goal of the sampling program.
- 22-5-03 Swath mapping of area B continues. Today we completed our 78th 10km line.
- 23-5-03 Complete E-W swath mapping lines and start N-S lines.
- 24-5-03 Complete swath mapping at 0600 hrs (1820 line km completed on voyage so far). Begin sampling program.

- 25-5-03 Sampling in area B. Strong wind from 0500 hrs onwards forced a stop of work in the morning shift. However, wind had died down by 11AM. Our 27th vibrocore and 4th rock dredge was collected today and station 61 completed. Sampling has confirmed the reef feature is a relict carbonate deposit of unknown age. Several samples of weathered and iron stained limestone (packstone/boundstone) have been recovered in dredge and grab samples. The banks appear to be comprised mainly of molluscs (pearl shell) and bryozoans. Interestingly, no living pearl shells have been recovered in any of our benthic sleds. Vibrocoring has produced mainly short core samples terminating in hard clay or sand. On one reef-top station a plug of hard lime sand was in the core cutter. Another break in the new camera cable has caused us to abandon use of the camera winch and to deploy via the main coring winch, using cable ties to attach the camera cable. This has slowed the camera deployment and removes our ability to remotely operate the winch from the video monitor station.
- 26-5-03 Sampling continues in area B. Strong wind up to 35 knots from 0500 hrs onwards again forced a stop of work in the morning shift. Wind had died down by 11AM and sea conditions abated so sampling could continue. An electrical fault in the main winch stopped the work program for 4 hours at1630 hrs. The winch paid out wire and then pulled it in without command from the winch operator. No fault could be detected but because the system is unreliable, it has been decided that henceforth the winches will be operated manually. Station 70 was completed today.
- 27-5-03 Station 75 completed this morning before strong winds forced us to stop the sampling program at 0600. It was decided to continue swath mapping the southern part of Area B. At 1600 hrs we successfully recovered the current meter frame BRUCE and began the transit to Area C.
- 28-5-03 Started long survey lines in Area C at0100 hrs and discovered that the un-named shoal is also comprised of flat-topped, reef-like features. Completed long lines at 0700 hrs and selected a 10x10 km grid for detailed swath survey. Lines were extended to 11.5 km length after it was seen the feature would extend beyond 10 km in length.
- 29-5-03 Continued swath survey of Area C completing 21 lines before breaking off the survey to head for Weipa at 1330 hrs. Based on the opaque seismic character of the reef top, it was decided to try using the Sparker system when we return, to attempt to see through to the basement structure.
- 30-5-03 Port call to Weipa. The vessel arrived offshore of the port at0700 and took aboard the pilot at 0800 hrs. Along side the jetty at 0930. The scientific party had a pleasant interlude ashore. Local fisherman informed us the unofficial name of the reefs we are mapping in Area C is “The Lost City”, presumably because the flat-tops and vertical walls of the reefs appear like submerged buildings on an echosounder. After loading 35 tonnes of fuel, ship departed Weipa at 1500 hrs and headed back to Area C.
- Continued mapping Area C on our arrival from Weipa, at0730 hrs. By midnight we had completed the 32nd line in this area.
- 1-6-03 Continued mapping Area C. On this voyage so far we have completed 2597 km of swath mapping by 1600 hrs today.
- 2-6-03 Continued mapping Area C. Saw the first print-out of Area C and spent some time with AH selecting sampling stations. We plan to start the sampling work by mid-day tomorrow. Sparker data has revealed a sub-surface reflector exhibiting positive relief under the reefal mound. Sad news today when we learned of the death of the 8 yr old niece of Chris McGuire (2nd Mate). Options are being considered to drop Chris off at a port nearby or along route.
- 3-6-03 Completed swath mapping Area C at 1900 hrs and commenced sampling.
- 4-6-03 A major discovery! Sampling of the reef top has confirmed that this is indeed a coral reef, but it is a vast living reef, with luxuriant coral growth on elevated surfaces and even within the flat reef top (relict lagoon). It is the largest continuous area of modern reef growth discovered in Australia outside of the Great Barrier Reef and Ningiloo Reef complexes.

- 5-6-03 Sampling work completed at 1700 hrs. A 4.2 m long vibrocore was collected from an area of wavy surface adjacent to the southern flank of the reef and was found to be unconsolidated muddy carbonate sand throughout. This appears to be an important sediment sink for the reef system. Commenced final phases of swath mapping at 1800 of two smaller reef features to the SW.
- 6-6-03 Completed swath mapping of two smaller reefs at 1900 hrs. Sparker data has revealed a sub-surface reflector exhibiting positive relief under both of the reefal mounds. Camera and grabs show that the smallest, SW-most reef in the group appear to have had hard corals growing on it in the recent past based on samples in the grabs, but we saw little evidence for modern corals in the video imagery. Instead there is mainly soft corals, sponges, crinoids and hydroids living here. The middle-reef supports luxuriant hard corals on its uppermost surface but mainly soft corals, sponges and hydroids elsewhere.
- 7-6-03 Completed sampling work at 0415. Transit to Gove, where we will disembark the second mate, Chris McGuire, for compassionate leave, before sailing on to Darwin. The scientific part of the voyage is now completed after 117 stations being completed, including 108 grab samples, 101 camera deployments, 62 benthic sleds, 58 CTDs, 40 vibrocores and 11 rock dredges. We have collected 3275 line km of swath and Chirp seismic data plus some 400 km of sparker data. In our voyage we have mapped about 0.01% of the Gulf of Carpentaria, which means it would take us another 830 years to map the rest.
- 8-6-03 Arrived in Gove harbour this morning at 0700 and dropped off the 2nd mate. On our way to Darwin! Packing up computers and sampling equipment.
- 9-6-03 Transit to Darwin.
- 10-6-03 Arrived in Darwin harbour at 0800. End of the voyage.

Summary

In almost every aspect, the voyage was a great success. During the voyage 117 stations were completed, including 108 grab samples, 101 camera deployments, 62 benthic sleds, 58 CTDs, 40 vibrocores and 11 rock dredges. We collected 3275 line km of swath and Chirp seismic data plus some 400 km of sparker data. The data collected revealed the occurrence of three large coral reef features that were previously not known to exist. Time lost due to equipment failure was less than 12 hours and time lost due to weather conditions was also less than 12 hours. Over a total voyage time of 33 days, this means the ship was doing useful work for 97% of the time. Apart from some problems with the main winches, there were no significant equipment failures. The data we have collected will, I believe, permit us to meet the main scientific objectives of the voyage, or at least to be well placed to design a new voyage proposal that will do so. We have made some very interesting discoveries which I believe will be useful for guiding government agencies charged with overseeing the environmental management of the region.

Personnel

Scientific Party

Dr. Peter Harris (GA) - Voyage Leader,
Dr Andrew Heap (GA) -Co-Voyage Leader
Dr. Vicki Passlow (GA) - Sedimentology, biological sampling
Mr. Ted Wassenberg (CSIRO) - Biological sampling
Mr Rick Smith (GA) - Computer support; bathymetry, water sample analysis
Mr James Daniell (GA) - Computer support; swath bathymetry
Mr Cameron Buchanan (GA) - Computer support; swath bathymetry
Mr John Stratton (GA) Technician (sediment sampling, core operation)
Mr Lyndon O'Grady (GA) Technician (sediment sampling, core operation)
Mr. Kevin Hooper (JCU) - Electronics Technician (Swath system and Chirper)
Ms. Pamela Brodie (CSIRO) - Computer Technician
Mr. Stephen Thomas (CSIRO) - Electronics Technician

Crew

Neil Cheshire	Master
John Boyes	1st Mate
Chris McGuire	2nd Mate
John Morton	Chief Engineer
Dave Jonker	1st Engineer
J. Gaffey	2nd Engineer
Mal McDougall	Bosun
Tony Hearne	IR
Graham McDougall	IR
Pat O'Neil	IR
Mathew Carden	IR
Gary Phillips	Chief Cook
Angie Zutt	2nd Cood
Dave Wilcox	Steward

On behalf of the scientific party, we would like to the CSIRO Support Personnel and Ships Crew for their support and hard work in making our voyage a success,

Dr. Peter T. Harris
Chief Scientist