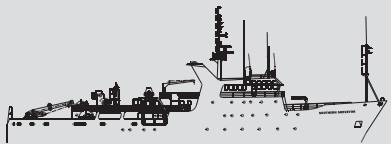

MARINE
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2006 program

RV *Southern Surveyor*

CSIRO

voyage summary SS06/2006

SS06/2006

Central North West Shelf Seepage: identifying potential natural hydrocarbon seeps and petroleum prospectivity, Offshore Canning and Roebuck Basins.

Itinerary

Departed Geraldton 1200 hrs, Monday 29 May, 2006
Arrived Port Hedland 1510 hrs, Thursday 22 June, 2006

Principal Investigator

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Scientific Objectives

- Identify, characterise and sample sites of natural hydrocarbon seepage.
- Improve the understanding of the petroleum prospectivity of the Offshore Canning and Roebuck Basins.

Natural hydrocarbon seepage can provide evidence for an active petroleum system within the subsurface. Sites of hydrocarbon seepage can also support highly diverse ecosystems due to nutrients, biogeochemical cycles and changes in sediment substrate; they may thus be associated with palaeo- or modern reefal buildups.

Voyage Objectives

Areas of potential hydrocarbon seepage have been identified from existing regional seismic, bathymetry, echo-sounder and remote sensing (SAR – synthetic aperture radar data). A number of prioritised areas were surveyed and mapped using multi-beam swath bathymetry, 12 & 120 kHz echo-sounder, 120 kHz side-scan sonar, 1.5 kHz sub-bottom profiler and near-surface water fluorometer (generally via the vessel's seawater intake system). This data provided information on bathymetry, nature of the seafloor, sediment types, sub-seabed stratigraphy and faulting, and potential evidence for shallow gas. This data was then used to select specific sampling sites. These sampling sites were chosen to reflect a range of areas of suspected natural hydrocarbon seepage for geochemical and sedimentological sampling (CTDs, grabs, gravity cores, vibro cores, dredges and seafloor video-camera footage).

Voyage Track

Figure 1 shows the voyage track and 18 areas surveyed. In addition to the pre-survey prioritised areas of potential seepage (Areas 1-11), 7 additional potential seepage areas (Areas 3A, 9A and Areas X1 to X5) were also surveyed and sampled. This was possible since sampling deployment/processing was generally significantly quicker than anticipated and scheduled in the original voyage plan.

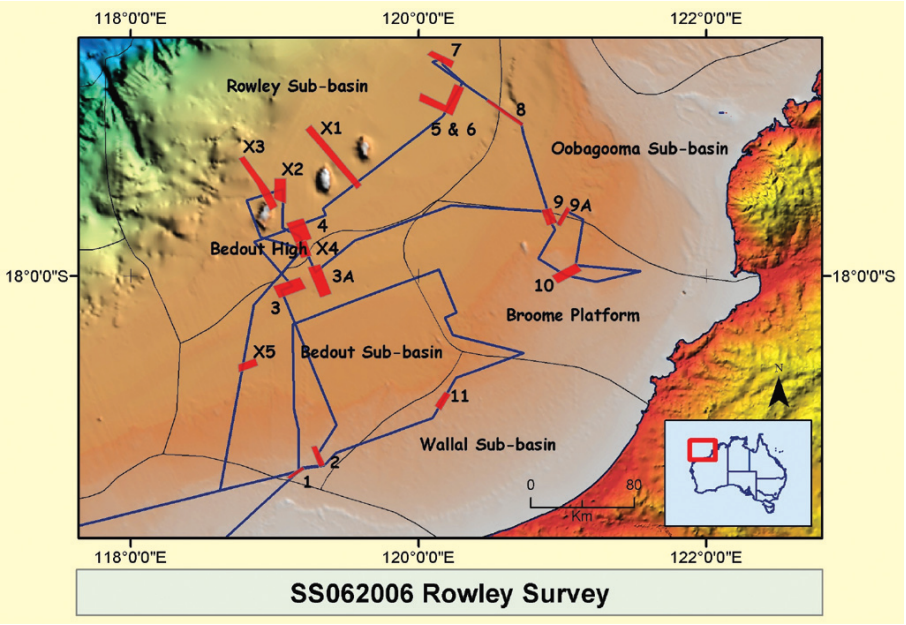

Figure 1: Voyage track and surveyed Areas 1-11 and X1 to X5.

Results

18 potential hydrocarbon seepage sites were surveyed and mapped on a 300-1500 m line spacing (Figure 1), and all survey data was integrated to select and optimise sampling sites. Grab, gravity core (4-6 m recovery), vibro-core (up to 4.7m recovery) and dredge samples were collected for follow-up sedimentological, head-space gas and geochemical analysis, together with CTD water column profiles and water samples for suspended sediment analysis. Seafloor video-camera footage was also obtained for most areas. A summary of all data acquired during the survey is presented in Table 1.

Two oceanographic moorings, an ADCP and GA's 'BRUCE' instrumented frame (which includes a Vector Velocimeter, a LISST-100 Particle size recorder, a Conductivity and Temperature sensor, and a Turbidity Sensor), were deployed in Area 1.

Additional SAR satellite scenes of the region were also acquired during the survey period.

Identified features of interest and/or potential seepage origin include:

- shallow and near-seabed amplitude anomalies (Areas 3, 3A, 4, 5, 7, 9, X1, X5)
- shallow faults (Areas 4, 5, 6 and 7)
- erosional escarpments and sink holes (Areas 8, X4)
- extensive ~60 m thick, low-relief pelagic depositional mound (Areas 3, 3A)
- mega-dunes (4-6 m relief) and dunes (1-2 m relief) (Area 1, 4, 5, 6, 9, 11 and X1)
- plume-like water column features on echo-sounders (Areas 2, 3, 9, 9A, 10, 11)
- pockmark fields and hardgrounds on side-scan sonar images (Area 9)
- active fluid plumes from pockmark fields on seabed video-camera (Area 9)

Highlights include an active extensive transtensional fault zone aligned with and immediately inboard of the Rowley Shoals reefs (Mermaid Fault Zone; Areas 4, 5 and 6), and a field of oolitic mega-dunes pierced by clusters of small, crater-shaped, pockmarks approx 1-2 m diameter and 30 cm deep (Area 9; Figure 2). These pockmarks range from clean ooid sands, to pocks with scattered nodular cemented concretions, to pocks with near complete 'armour' of nodular concretions (Figure 3), to fully cemented nodular hardgrounds with abundant encrusting benthos. Video-camera footage indicates that fish are clearly attracted to these pockmarks. Active venting of cloudy fluids was also observed from the pockmark field on video camera, but there was no evidence of gas-bubbles within the plumes. Follow-up geochemical analyses of concretions dredged from the pockmark field (Figure 4) will help shed light on the origin of the vented fluids (eg. basinal or meteoric groundwater, and any evidence of thermogenic hydrocarbons).

Poor weather conditions (20-35 knots wind, 2-3 m seas) hampered sampling operations at times, and piston coring proved to be impractical and ineffective with present configuration. Deployment of a towed sea-surface skimmer was limited to 1 transit between Areas 3A and X2 due to rough seas; elsewhere fluorometer analysis of near surface waters was conducted via the ship's continuous saltwater intake system. Minor downtime of the side-scan sonar (and in some cases the deepwater camera) was experienced due to episodic failure of the high voltage side-scan/camera armoured electrical cable. Utilisation of a side-scan fish depressor proved largely ineffective in all water depths. Mechanical problems with the vessel's gear box resulted in early termination of the survey 41 hours ahead of schedule, and prevented acquisition of a planned ~12 additional lines of data in Area 1, and supplementary gravity cores above the Phoenix-1, 2 gas accumulations (Area X5).

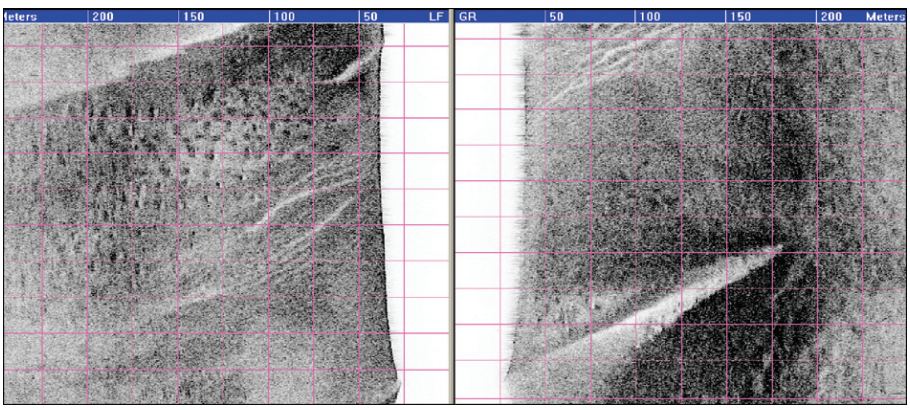

Figure 2: Side-scan sonar image of oolitic mega-dune pierced by cluster of pockmarks.

Figure 3: Pockmark lined with nodular concretions (108 m water depth).

Figure 4: Tube-shaped and nodular concretion dredged from pockmark fields, Area 9.

Voyage Narrative

Transit to survey Area: 28-31 May 2006
Multi-beam swath bathymetry was acquired during the transit from Geraldton to the survey area. Multi-beam swath, sub-bottom profiler and fluorometer data were acquired across an area of previously identified pockmarks offshore Cape Range (22° 6.514′ S, 113° 37.110′ E as identified on Survey SS07/2005; within Acreage Release Areas W05-19, southern Exmouth Sub-basin). The pockmarks lie at 790 m water depth, and appear to be localized where a poorly defined substrate horizon imaged on the sub-bottom profile sub-crops to the seabed. No evidence of fluid escape was detected on the echo-sounders. 22-27 kt winds, 1.5-2 m sea.

Area 1 (Lambert Shelf SAR anomalies): 1 June 2006
Commenced recording of sub-bottom profile data 22:20 Julian Day (JD) 151 on approach to Area 1, and commenced survey of Area 1 at 01:47 JD 152. 5 lines of swath, sub-bottom profile, side-scan and fluorometer data acquired in Area 1. Possible water column plume observed on 12 and 120 kHz echo-sounder prior to arrival at Area 1. High quality sub-bottom profile and side-scan data recorded, with abundant ~2-5m wavelength mega-ripples imaged on side-scan. Side-scan towfish electronics failed during Line 4 and towfish retrieved for repairs.

Station 01 (51-58 m water depth): CTD, Grab, ADCP and BRUCE instrumented oceanographic moorings successfully deployed.

No evidence of seepage within Area 1, and no obvious association of swathed bathymetric features with previously recorded SAR anomalies. 26 kt wind, 2 m sea.

Transit Area 1 to Area 2: 1 June 2006
Swath, sub-bottom profile and fluorometer data acquired on transit to Area 2 (side-scan towfish electronics still under repair).

Area 2 (Edge of Bedout Sub-basin SAR anomalies): 1-2 June 2006
12 lines of swath, sub-bottom profile and fluorometer data acquired in Area 2 along and parallel to seismic line JN87-09 (side-scan towfish electronics still under repair).

Station 02 (50 m): CTD, Grab and Gravity Core successfully deployed.
Station 03 (68 m): Grab successfully deployed.
Station 04 (68 m): Dredge successfully deployed.

Gravely carbonate sand and indurated substrate unsuited to coring, but successful grab and dredge sampling. No evidence of seepage within Area 2, and no obvious association of swathed bathymetric features with recorded SAR anomalies. 22 – 26 kt wind, 2-2.5 m sea.

Transit Area 2 to Area 3: 2 June 2006
Swath, sub-bottom profile and fluorometer data acquired on transit to Area 3 along seismic lines JN87-11 (side-scan towfish electronics still under repair).

Area 3 (Bedout High): 2-4 June 2006
14 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area 3 orthogonal to seismic lines JN87-11, GA120-01.

Station 05 (127-131 m): CTD, Grab, 2 Gravity Cores and Camera successfully deployed. Piston core deployment attempted, but very limited success due to problems with setting and release of trigger devise.
Station 06 (158-160 m): Grab, 3 Gravity cores and camera successfully deployed.
Station 07 (150 m): Grab and 2 Gravity cores successfully deployed.
Station 08 (129 m): Grab and Gravity core successfully deployed.
Station 09 (130 m): Camera successfully deployed during period of ship's engineering repairs.

Excellent sub-bottom data (~up to 100 ms penetration) obtained across Pliocene-Recent Pteropod mound that overlies deep seismic HRDZ's. Good correlation of shallow amplitude anomalies on sub-bottom profile (10-30 ms below seabed) with deep HRDZ's and water column activity (?pelagic Pteropod) imaged on 12 and 120 kHz echo sounders. Minor humps of humics and hydrocarbon wavelengths also recorded on fluorometer (via ship's water intake) in this area. Generally uniformly bland seabed imaged on side-scan sonar, but local well defined highly reflective patches (?hardgrounds). Gravity cores achieved good recovery (4.5-5.1 m with 6m barrel) of sandy muds for headspace gas and geochemical samples. Minor delays due to jammed cable in grab winch feed, and water in engine room. Winds eased from 22-8 kt, sea eased from 2.5-1 m.

Transit from Area 3 to Area 4: 4 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Area 4 along seismic lines GA120-01, JN87-08.

Area 4 (southern Mermaid Fault Zone): 4-5 June 2006
9 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area 4 along and parallel to seismic line JN87-13.

Station 10 (333 m): CTD, Grab, 3 Gravity cores and Camera successfully deployed.
Station 11 (338 m): Grab successfully deployed.
Station 12 (338 m): Grab and Dredge successfully deployed.

Micro-wavy sea bottom observed and mapped on deep seismic data represents extensive mega-dune field, not pockmarks. Somewhat surprised to find active dunes in ~340 m water outboard of muddy sediments. Active transtensional/transpressional microfaults imaged on sub-bottom profile to within 15 msec of seabed. Moderately good recovery of gravity cores at these sites (4.5-5m). Sampling of sand sheet above shallow faults limited to grabs and pipe dredge – gravity cores nil recovery. Sand sheet up to 6m thick and characterised by mega-dunes 3-4m high. 18 kt wind, 1.5-2 m sea.

Transit from Area 4 to Area X1: 5 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Area X1 along seismic lines JN87-8, JN87-15, GA95-13.

Area X1 (Miocene patch reef): 5-6 June 2006
2 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area X1 parallel to seismic line DC98-222.

Station 13 (466 m): Grab successfully deployed.

Additional (previously unplanned) transit to deeper water (hopefully muddier) site west of Mermaid Reef identified prominent shallow amplitude anomaly (~6 msec below seabed) on excellent quality sub-bottom profile data directly above lateral extent of fault related Miocene patch reef identified at 980 msec on seismic line DC98-222. Shallow amplitude anomaly has minor negative polarity and low frequency anomaly, consistent with gas-sand. Prepared for 8m gravity core deployment, but coring abandoned due to recovery of firm well sorted sand in grab sample. 16 kt wind, 1.5 m sea.

Transit from Area X1 to Area 5: 6 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Area 5 along seismic lines GA95-13, JN87-06, 6A, BR02-009.

Area 5 (SAR anomaly, northern Mermaid Fault Zone): 6-7 June 2006

8 lines of swath, sub-bottom profile and fluorometer data, and 6 lines of side-scan sonar data acquired in Area 5 parallel to seismic line BR02-032.

Station 14 (448 m): CTD, Grab and Gravity core successfully deployed.
Station 15 (436 m): Grab, 3 Gravity cores and Camera successfully deployed.
Station 16 (434 m): Grab and 2 Gravity cores successfully deployed.
Station 17 (440 m, revisit of station 14): 2 Gravity cores successfully deployed.

Sub-bottom profile data indicates series of anastomosing strike slip faults to within 10 msec of seabed, with shallow amplitude anomalies in crestal pop-ups. Side-scan indicates seabed covered with small scale linear dunes which are continuous across the fault zone but abruptly die out to NW along the outboard margin of the fault zone. Grab samples return relatively well sorted fine carbonate sand with delicate skeletal shells. Successful deployment of 2m gravity core recovered nearly 2m of firm clayey mud! Second grab deployment again retrieved moderately well sorted fine carbonate sand. Courageous deployment of 6m gravity core recovered 5.7m of firm clayey mud! Even more courageous deployment of 8m gravity core recovered 5.7 m of firm clayey mud. Ideal sediment for geochemical sampling. It appears that a relatively thick clayey mud unit (homogeneous on sub-bottom profile) is covered by a veneer of relatively well sorted mega-rippled sand (starved ripples?) which is blown away by the impact of the gravity core.

Deployment of 8m gravity core has proved difficult due to restricted length of back deck, and compounded by fairly rough seas. 16-20 kt wind, 1.5-2.5 m sea.

Transit from Area 5 to Area 6: 7 June 2006

Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on short transit to adjacent Area 6 along seismic line BR02-009

Area 6 (northern Mermaid Fault Zone): 7-8 June 2006
6 lines of swath, sub-bottom profile and fluorometer data, and 5 lines of side-scan sonar data acquired in Area 6 parallel to seismic line BR02-009, and along orthogonal line BR02-029.

Station 18 (440 m): Grab and 2 Gravity cores successfully deployed.
Station 19 (440 m): Grab, 3 Gravity cores and Camera successfully deployed.

Sub-bottom profile data indicates a network of strike slip faults to within 10 msec of seabed, with some faults active to seabed. Side-scan sonar indicates linear to wavy low relief mega-ripples, which pass to irregular rectilinear ?ripples/ridges and conjugate linear network of shallow depressions that define fault intercepts of the seabed. No amplitude anomalies associated with these shallow faults. Again grab samples recovered very slightly muddy fine carbonate sand, whereas gravity cores recovered 5.4-6.0 m of relatively soft clayey mudstone with scattered fossils. Many core sections coated with a thin outer annulus of sand (1-3 mm thick) that has been flushed upwards between the core barrel and the PVC core liner. Camera deployments indicate rippled sands, with minor biota. Hence previous interpretation of a thick homogeneous mud unit overlain by thin mega-rippled and rippled sand sheet confirmed.

Consistent 5+m core recoveries have resulted in shortage of disrupters and tins for headspace gas samples. Hence have abandoned duplicate samples for all core sections except the deepest section at the base of the core. Similarly, headspace gas sampling of shallow upper 2m core sections has also been abandoned to conserve disrupters/tins. Relatively rough sea states prevent deployment of 8 m gravity cores, as well as the sea-surface skimmer for the fluorometer. 20 kt wind, 2-2.5 m sea.

Transit from Area 6 to Area 7: 8 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Area 7 along seismic lines BR02-009, JN88-02, JN88-05, JN88-02.

Area 7 (Late Miocene buried reef): 8-9 June 2006
7 lines of swath, sub-bottom profile and fluorometer data, and 6 lines of side-scan sonar data acquired in Area 7 parallel and orthogonal to seismic line BR02-025.

Rough and choppy seas causing boat to shudder and poor quality swath and sub-bottom profile data.

Station 20 (475 m): CDT, Grab and 3 Gravity cores successfully deployed.
Station 21 (463 m) : Grab and 2 Gravity cores successfully deployed.

Sub-bottom profile indicates minor faulting to 15 msec sub-sea bottom above outboard (and to lesser extent inboard) margin of Miocene Reef, with minor amplitude brightenings above reef. Thin veneer of rippled sands overlies clayey mud. Consistent recovery of 5-5.6 m gravity cores with 6m barrel. Continuing strong winds and rough sea states prevent deployment of 8 m gravity cores, as well as the sea surface skimmer for the fluorometer. 20-25 kt wind, 2-2.5 m sea.

Transit from Area 7 to Area 8: 9 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Area 8 along seismic lines JN88-05, BR02-009, JN88-05.

Area 8 (Seabed scarp and Miocene impact crater): 9 June 2006
1 line of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in transit across Area 8 along seismic line JN88-05. Prominent seabed scarp identified on regional seismic confirmed on swath and sub-bottom profile data.

No features of interest to warrant sampling. 20-25 kt wind, 2-2.5 m sea.

Transit from Area 8 to Area 9: 9 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit from intersection of seismic lines JN88-05 & JN88-12 to Area 9 via intersection of seismic lines JN88-3 & JN88-20.

Area 9 (Broome Platform/Oobagooma Sub-basin SAR anomaly): 9-10 June 2006
5 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area 9.

Station 22 (105 m): Grab successfully deployed; tow-fish/camera cable damaged during attempted Camera deployment.

Side-scan data shows mega-dunes and several well define sub-circular pockmark fields 150x150m, with individual pocks approx 5 m diameter. Some pocks fields are very recent and penetrate 4-5m mega-dunes, other pock fields partially covered and buried by migration of these dunes. Pock fields show progressive transition to initially patchy hard areas and finally coalesced hard ground patches. Pock fields are associated with numerous diffuse sub-vertical water column events on 12 and 120 kHz echo sounders. No obvious features on sub-bottom profile beneath pock fields.

Grab sample successful (gravely sand), but deployment of all equipment from back deck is not possible in present rough sea state – further sampling postponed to later date. Side-scan/Camera cable is being repaired, but out of action for next 18-24 hours. 30-35 kt wind, 2.5 m sea.

Transit from Area 9 to Area 10: 10 June 2006

Swath, sub-bottom profile and fluorometer data acquired on transit to Area 10 via seismic lines JN88-22A, through SAR anomaly ausnw_33b-001, JN88-01 and previously identified (Franklin 05/2000) echo-sounder water column events in Area 10 and to east of Area 10 (side-scan towfish electronics still under repair).

Area 10 (Broome Platform): 10-12 June 2006

5 lines of swath, sub-bottom profile and fluorometer data acquired in Area 10 prior to repair of side-scan sonar cable. Additional 13 lines (Lines 6 to 18) of swath, sub-bottom profile, fluorometer and side-scan sonar data acquired in Area 10 after repair of side-scan cable.

Station 23 (57-60 m): CTD, Grab, Dredge and Camera successfully deployed.

Several vertical to near vertical water column events identified on 12 and 120 kHz echo-sounders, some of which also occur on side-scan sonar in basal part of water column. Sub-bottom profile indicates hard substrate, with little penetration, and no obvious features associated with water column events. Most water column events

observed during low tide phase, but others observed near high tide. Strong winds and rough sea states have prevented all sampling from back deck during 36 hour period.

Re-survey of numerous side-scan and echo-sounder water column features observed in Area 10 during low tide, together with camera deployment and sampling (grab, gravity core and dredge), suggests that water column features are most likely biological, not seepage. Excellent camera video footage of benthic biota. 30-35 kt wind abating to 15-20 kt in afternoons, 2.5 m sea abating to 2 m.

Return transit from Area 10 to Area 9A and 9: 12 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on return transit to Area 9A, 9.

Area 9A, 9 (Broome /Oobagooma SAR anomaly ctd): 12-13 June 2006
Have returned to pockmark fields observed in Area 9 to re-survey and sample at low tide during afternoon when winds ease. 3 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area 9A.

Additional 7 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data (Line 6-12) acquired in Area 9.

Station 24 (108 m): Grab, Dredge and Camera successfully deployed.
Station 25 (103-110 m): CTD, Grab and Dredge successfully deployed.
Station 26 (108-113 m): Grab and 2 Dredges successfully deployed.

Re-sampling of pock fields at Area 9 during favourable weather and low tide has been highly successful. Excellent camera footage shows pock fields developed in mega-dunes and ripples, and scattered pock 'craters' approx 1m diameter and 30 cm deep. Pock field varies from clean pocked sands, to sands with scattered nodular concretions within pocks, to pocks with near complete 'armour' of nodular concretions, to fully cemented nodular hardground. Concretions and hardgrounds encrusted by various biota. Active venting of cloudy fluids observed from some pocks (no evident gas bubbles), and small fish obviously attracted to these venting fluids.

Grab samples recovered ooid sand with common skeletal fragments. Dredge samples recovered abundant nodular concretions and blocks 5-60 cm, with irregular hollow tubes 2-4 cm diameter and up to 30 cm long. Nodules comprise cemented ooid sands (ooid-skeletal grainstone), with abundant encrusting/boring biota. Numerous examples of smooth fine straight tubules 4mm diameter and up to 10cm long – interpreted as shrimp tubes (live shrimp of appropriate size recovered from one such tubule). Significant improvement in weather has enabled sampling and put smiles back on faces. 30 kt wind abating to 15-20 kt in afternoon, 2-2.5 m sea.

Transit from Area 9 to Area 3A: 13 June 2006
Swath, sub-bottom profile and fluorometer data acquired on transit to Area 3A via seismic line JN88-10.

Area 3A (Bedout High east): 13-15 June 2006
Returned to Bedout High region to extend coverage of data and undertake additional sampling.

15 lines of swath, sub-bottom profile and fluorometer data, and 14 lines of side-scan sonar data acquired in Area 3A parallel and orthogonal to seismic line JN87-13C.

Station 27 (147 m): CDT, Grab and 3 Gravity cores successfully deployed.
Station 28 (143 m): Grab and 2 Gravity cores successfully deployed.
Station 29(171-173 m): Grab, 3 Gravity cores and Camera successfully deployed.
Station 30 (165 m): Grab and 2 Gravity cores successfully deployed.
Station 31 (140 m): Grab and 2 Gravity cores successfully deployed.
Station 32 (156 m): Grab and 2 Gravity cores successfully deployed.
Station 33 (166-174 m): Grab and Gravity core successfully deployed.
Station 34 (191 m): Grab and Gravity core successfully deployed.

Sampling stations sited on shallow amplitudes events imaged on sub-bottom profile. Very good data, with up to 100 msec stratigraphic record with at least 4 depositional sequences evident. Moderate-very good recovery of soft Pteropod sandy mud gravity cores (4.5-6.2 m), moderately strong H2S smell. Observation of prominent sea surface slick attributed to tidal currents and wind. 12-6 kt wind, 1 m to calm sea.

Transit from Area 3A to Area X2: 15 June 2006
Deployed catamaran sea surface skimmer for fluorometer on transit to Area X2 along seismic line JN87-13C to Area 4 and then NW and then N to Area X2.

Swath, sub-bottom profile and fluorometer data acquired on transit to Area X2 (side-scan sonar not deployed due to deployment of catamaran sea surface skimmer). Large circular seabed "hole" imaged on outer beam of swath data during transit – 250 m wide, 12 m deep. Origin uncertain - possible karst sink hole formed during Miocene lowstand, or large pock hole? Feature not captured on sub-bottom profile. Feature will be further investigated on return transit.

Area X2 (Miocene patch reef): 16 June 2006
12 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area X2 centered on intersection of seismic lines JN87-13C, JN87-04 & DC98-220. Near surface water for fluorometer analysis was acquired via the vessel's seawater intake system.

Station 35 (390 m): CTD, Grab, 3 Gravity cores and Camera successfully deployed.
Station 36 (384 m): Grab and 2 Gravity cores successfully deployed.

Survey and sampling of all deepwater areas now completed, and preparing vibro-core for shallower water sandy substrate deployments. 5 kt wind, calm sea.

Transit from Area X2 to Area X3: 17 June 2006
Swath, sub-bottom profile and fluorometer data acquired on transit to Area X3 along seismic line JN87-04. Side-scan sonar towfish progressively deployed during short transit.

Area X3 (SAR anomaly RSW1-26 to north of Imperieuse Reef): 17 June 2006
2 lines of swath, sub-bottom profile and fluorometer data, and 1 line of side-scan sonar data, acquired in Area X3 through SAR anomaly RSW1_26.

Station 37 (668 m): CDT, Grab and Gravity core successfully deployed.
Station 38 (505 m): Grab and 2 Gravity cores successfully deployed.
Wind 5 kt, calm sea.

Transit from Area X3 to Area X4: 17 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Area X4 via seismic lines JN87-04, JN87-11.

Area X4 (Seabed 'hole' and scarp, flank of Bedout High): 17-18 June 2006
6 lines of swath, sub-bottom profile and fluorometer data, and 2 lines of side-scan sonar data, acquired in Area X4.

Station 39 (290 m): Grab, Gravity core and Camera successfully deployed.
Station 40 (277-300 m): Grab and Gravity core successfully deployed.
Station 41 (284 m): Grab and Gravity core successfully deployed.

Further investigation of previously circular seabed "hole" indicates that it forms a 'blind' hollow/sinkhole at the head of a much larger linear narrow blind depression approx 2 km long, 250m wide and 30m deep. Camera video and sampling shows benched/bedded drop-off, large blocks and boulders of debris shed from steep rim, and weathered calcareous mudstone fragments scattered within sandy muddy substrate. No evidence of any fluid escape. Hollows occur at outer edge of eroded topography, and inboard of sandy-mud wedge that also contains weathered mudstone fragments. Most feasible explanation is that the blind hollows represent karst sink holes formed during Miocene lowstand, and onlapped by lowstand wedge. 11 kt wind, 1 m sea.

Transit from Area X4 to Area X5: 18 June 2006
Swath, sub-bottom profile and fluorometer data acquired on transit to Area X5 along seismic lines GA110-06. Side-scan towfish electronics failed during transit.

Area X5 (Phoenix-1, 2 gas accumulations): 18-19 June 2006
7 lines of swath, sub-bottom profile and fluorometer data, and 2 incomplete lines (Lines 4, 5) of side-scan sonar data, acquired in Area X4 parallel to seismic line JN87-16. Side-scan towfish electronics failed during survey of Area X5.

Station 42 (140 m): Grab and 2 Vibro cores successfully deployed.
Station 43 (140 m): Grab and Vibro core successfully deployed.

Survey of Pheonix-1,2 gas accumulation area revealed very prominent discontinuous amplitude anomalies ~65 msec sub-seabed. High amplitude features also exhibit prominent instantaneous amplitude and low frequency anomalies, but no polarity anomaly. No unusual features evident on side-scan sonar. Grab samples recovered very sandy-gravelly mud to muddy gravely sand. Vibro-cores recovered 4.2-4.7m very pale clayey mud overlain by thin muddy gravely sand veneer as per grab sample.

Transit from Area X5 to Area 11: 19 June 2006
Swath, sub-bottom profile and fluorometer data acquired on transit to Area 11, via seismic line GA110-06, water column event previously imaged on echo-sounders on approach to Area 1, Area 1, and seismic lines JN87-24A, GA120-12. Side-scan towfish electronics repaired during first part of transit. Re-investigation of previously imaged water column event failed to locate features worthy of further study.

Area 11 (Broome Platform – flatspot within apparent Callovian closure): 20 June 2006
14 lines of swath, sub-bottom profile, side-scan sonar and fluorometer data acquired in Area 11 parallel to seismic line GA120-12.

Station 44 (76-85 m): Grab, 2 Vibro cores and Camera successfully deployed.
Station 45 (74 m): CTD, Grab, Vibro core successfully deployed.
Station 46 (78-80 m): Grab, Vibro core and Dredge successfully deployed.

Survey of Area 11 identified discontinuous, lozenge-shaped, high relief dunes (up to 8m), with little penetration of substrate by sub-bottom profile (max 20 msec). Dunes very similar morphology to those identified in Area 9, and sub-circular more reflective patches between dune tips commonly show feint irregular texture reminiscent of pockmarks in Area 9, but no clear evidence of pockmarks.

Video camera shows rippled and bioturbated sands with common attached soft coral, sponges and other biota. Grab sample recovered gravely sand with abundant shell /coral fragments. Vibro-core resulted in poor recoveries <1m, not suitable for headspace gas analyses. Sands appear to be relatively thin veneer across hard substrate. 15 kt wind, 1.5 m sea.

Transit from Area 11 to Lagrange-1 well and Area 1: 20-22 June 2006
Swath, sub-bottom profile, side-scan sonar and fluorometer data acquired on transit to Lagrange-1.

Transect undertaken along seismic line JN87-22A to southern margin of Broome Platform, SAR anomaly RSW1-24, seismic lines JN87-18A, JN87-19 & JN87-14 through Lagrange-1. Side-scan electronics failed (15:34 UTC 20 June) due to water seepage into cable, but cable still ok for camera (lower voltage) deployments. Cable will require new mechanical and electrical connections for future side-scan use – repairs would take bulk of remaining available survey period to fix, so decided to defer repairs and be able to use camera if required.

Survey (swath and sub-bottom profile) temporarily interrupted at 02:15 UTC 21 June (10:15 WA local time) for 1 hour to shut down main engine and investigate oil leak from gear box. Significant oil leak from gear box due to blown seal. Transect resumed and remaining survey program revised and cut short in order to retrieve deployed moorings BRUCE and ADCP at Area 1 at first light Thursday 22 June, and then return directly to port. Anticipate arriving at Port Hedland 1400 22 June, 42 hours prior to original voyage plan. Fortunately all but one priority survey activity (detailed swath mapping at Area 1 to investigate hypothesis that SAR slicks in this area may be due to accelerated tidal flow across bathymetric features) have been completed, so that impact of mechanical problem on science program is relatively minor.

Area 1: 22 June 2006
Completed transect to Area 1 and retrieved deployed moorings BRUCE and ADCP at first light.

Departed Survey region 7:00 to return to port.
Tied up at Port Hedland Wharf 15:10.

Summary

The survey proved highly successful both in terms of the quality of data acquired and sediment samples recovered, and the higher than expected number of potential seepage site surveyed (total 18). Active seepage of fluids of unknown composition has been identified from a pockmark field at the junction of the Oobagooma Sub-basin and Broome Platform (Area 9), and possible evidence of shallow gas is indicated by amplitude anomalies (brightenings) on the sub-bottom profile data in many of the surveyed areas.

The volume and quality of data obtained from a geological, sedimentological, geochemical and biological perspective was outstanding. This data will be analysed and placed within a spatial context to identify and characterize any sites of natural hydrocarbon seepage, and to enhance the understanding of the petroleum prospectivity of the region and its benthic habitats.

Digital data acquired during this survey can be made available upon request, at cost of transfer. For further information contact: ausgeodata@ga.gov.au. Information on samples collected during the survey will be available from Geoscience Australia's online Marine Sediment Database (MARS); see http://www.ga.gov.au/oracle/mars/ .

Personnel

Scientific Participants

John Kennard	GA	Chief Scientist/Shift leader
Andrew Jones	GA	Scientist/Shift Leader
George Bernardel	GA	Scientist/geophysics
Anne Fleming	GA	Scientist/geophysics
Cameron Mitchell	GA	Scientist/swath processing
Karen Earl	GA	Scientist
Alison Hancock	GA	Scientist/databases
Michele Spinoccia	GA	Swath supervisor/processing
Matthew Carey	GA	Science technician
Ray DeGraaf	GA	Mechanical technician
Craig Wintle	GA	Mechanical technician
Franz Villagran	GA	Electronic technician
Ian Atkinson	GA	Electronic technician
Stephen Thomas	CMAR National Facility	Voyage Manager, Electronics, SST
Hiski Kippo	CMAR National Facility	Computing, System Support Tech

Marine Crew

Ian Taylor	Master
Nick Whalan	Chief Officer
Rob Ferries	2nd Officer
Roger Thomas	Chief Engineer
Rob Cave	1st Engineer
Seamus Elder	2nd Engineer
Tony Hearne	Bosun
George Cook	IR
Mark Robinson	IR
Karl Cooke	IR
Robert Stephens	Greaser
Bob Cumming	Chief Steward
Andy Goss	Chief Cook
Jason Phillips	2nd Cook

John Kennard
Chief Scientist
July 2006

Table 1: Summary of data and samples acquired during Survey SS06/2006

Echo-sounder	~6,100 km		32 Gigabytes
Swath	6,078 km		17.3 Gigabytes
Sub-bottom profile	4,135 line km		46 Gigabytes
Side-scan sonar	~4,000 line km		202 Gigabytes
Fluorometer	389 hours		2.84 Gigabytes
ADCP	20.6 days		45.5 Megabytes
BRUCE mooring:			
LISST	20.6 days		9 Megabytes
Vector	20.6 days		244 Megabytes
Sampling Stations	46		
CTDs	12		
Grabs	43		
Gravity Cores	57		
Vibro-cores	7		
Piston cores	1		
Dredges	8		
Cameras	12	332 Minutes	74 Gigabytes