MARINE NATIONAL FACILITY

2006 program

RV *Southern Surveyor*

CSIRO

voyage summary SS04/2006

SS04/2006

Continental shelf processes between Cape Leeuwin and the Great Australian Bight during the summer

Itinerary

Departed Esperance 1600 hrs, Wednesday 12 April 2006
Arrived Fremantle 0800 hrs, Monday 1 May 2006

Principal Investigator

Prof Charitha Pattiaratchi – School of Environmental Systems Engineering,
Mailstop MO15 University of Western Australia, 35 Stirling Highway Crawley,
WA 6009 AUSTRALIA
Phone: +61 8 6488 3179   **Fax:** +61 8 9380 1015   **Email:** chari.pattiaratchi@uwa.edu.au

Scientific Objectives

- To determine the summer circulation pattern along the continental shelf between Cape Leeuwin and the Great Australian Bight, in particular, definition of the Leeuwin Current in the region and the interaction between the eastward flowing Leeuwin Current and a colder westward flowing current inshore of the Leeuwin Current, similar to the Capes and Ningaloo Currents along the west coast.
- To determine the connectivity between the Flinders Current (FC) and the Leeuwin Under Current (LUC).
- To determine the interaction of coastal currents, phytoplankton dynamics and trophic transfer in the coastal waters of southern Australia.

Voyage Objectives

After departing Esperance, Southern Surveyor will conduct 17 cross-shelf transects (Figure 1). For each transect, 10-15 CTD stations will be occupied depending on the shelf width. The transects will extend from the coast (~30 m isobath) to the 2000 m contour. As in previous voyages, stations will be located at 50m depth intervals, especially along the continental slope. In addition to the standard CTD and fluorescence, nutrient data will also be collected. At selected stations Bongo nets will be deployed to obtain zooplankton samples.

Process studies (using ADCP measurements and high resolution CTD stations) will be undertaken at a submarine canyon (located between transects K, J and I, Figure 1) to examine the fine-scale features of the effect of topography on the currents.

Voyage Track

After departing Esperance, Southern Surveyor transited to the offshore end of Transect A (off Twilight Cove, Figure 1) and conducted a cross-shelf transect. This was followed by transects B to J. Based on the data collected from transects I and J and satellite imagery, we have allowed 22 hours to undertake additional stations and ADCP transects at high resolution to capture the circulation and distribution of properties within the submarine canyon. At the conclusion, we shall complete transects K to S and return to Fremantle. The voyage track is given on Figure 1.

Results

- The summer circulation pattern along the continental shelf between Cape Leeuwin and the Great Australian Bight

The Leeuwin Current (LC) which dominates the shelf and slope circulation along Western Australia was identified clearly from the field data. The ADCP data from three selected transects indicated southward (Transect R) and eastward (Transects L and G) flow with the core (i.e. maximum flow) centered on the shelf break (Figure 3). However, strength and intensity of the current changes between each transect due the effects of topography and mesoscale processes such as eddies. The LC generally flows parallel to the coastline and follows the depth contours. At Transect R (Figure 1), the maximum surface velocity was ~0.5 m/s with an offshore eddy extending the LC offshore. After turning eastward at Cape Leeuwin, the Current accelerated along the south coast with maximum surface currents >1.0 m/s at Transects L and G (Figure 3). In the absence of westerly wind stress it is likely that the strengthening of the LC is due to the narrower continental shelf and/or strengthening of the geopotential gradient.

The Flinders Current (FC) dominated the subsurface currents and was prominent in all transects reaching maximum flows up to 0.6m/s at Transect L and 0.5 m/s at transect G (Figure 3). Part of the FC which flows westward, flows beneath the LC, imitates the Leeuwin Undercurrent (LU) which can be seen in Transect R (we define the LU undercurrent along the west coast whilst the FC is the undercurrent along the south coast). LU is smaller in strength in comparison to the FC in the south. Subsurface current in south reaches 0.6m/s. In comparison, LU along the west coast has maximum speeds of ~0.2 m/s.

The Leeuwin Current transports warmer water of tropical origin southwards and this signature is clearly evident in the cross-shore temperature distribution with the warmer water in the surface mixed layer (Figure 4). The temperature distribution in the 3 transects is very similar with the warmer water present at surface and extending off shore with decreasing thickness. Although the LC water may be identified from the higher temperature water along each transect, the temperature also decreases as the LC progresses eastward. For example, at Transect R, the maximum sea surface temperature (SST) was 20o Celsius whilst along the south coast the SST decreased to 19-18.5o Celsius (Figure 4). This decrease in temperature may be attributed to entrainment of colder onto the LC and heat loss to the atmosphere.

The salinity changes between transects when compared to the temperature distribution, are significantly different: The salinity distribution at Transect R is very different to that at Transects L and G. The main feature is the presence of a subsurface salinity maximum. Here, the surface waters consist of lower salinity water of tropical origin transported by the Leeuwin Current, whilst the higher salinity is SICW (South Indian Central Water) entrained into the LC by geostrophic inflow. The ADCP record (Figure 3) indicates the southward flowing LC extends to a maximum depth of ~300m indicating that both the surface lower salinity and sub-surface salinity maxima are part of the LC. (However, transects located further east along the lower salinity surface water, are not present with the higher salinity water located on the surface (Figure 5)).

In summary, the Leeuwin Current along the southern coast was found to be strong with maximum currents > 1 m/s. This most likely results from a strong alongshore geopotential gradient and a narrow continental shelf. The LC structure on the southern section of west coast (Transect R) consisted of a broad, weaker (max ~0.5m/s), shallow LC with lower salinity water on the surface. In contrast, the LC structure along the southern coast was narrow, stronger (> 1 m/s), deeper LC with higher salinity water at the surface. The Flinders Current (FC) was located beneath and offshore of the LC and was a prominent feature of the entire subsurface region (to depths ~800m) with maximum currents ~0.6m/s.

- Connectivity between the Flinders Current (FC) and the Leeuwin Undercurrent (LUC).

The Flinders Current (FC) – the only northern boundary current in the Southern Hemisphere – is the dominant feature along the southern coast of Australia and extends from Tasmania to Cape Leeuwin. Field data collected during the voyage indicated that the FC interacts with the Leeuwin Current (LC) at the shelf break and slope. Comparison of temperature and salinity data collected along the south and west coasts indicated the Flinders Current was the source of the subantarctic mode water (SAMW), which forms the core of the Leeuwin Undercurrent. A schematic of the relationship between the Leeuwin Current, Leeuwin Undercurrent and the Flinders Current, based on data collected during the voyage, is shown as Figure 7.

- Interaction of coastal currents, phytoplankton dynamics and trophic transfer in the coastal waters of southern Australia.

The winds during the voyage (in April 2006) were westerly and reflecting the autumn/winter conditions in the study region. Thus, wind-induced upwelling, or the westward coastal currents were not present. However, high nutrient and Chlorophyll concentrations were found at the head of the canyons (Two Peoples, Hood, Leeuwin and Perth). Those samples indicated topography driven upwelling and enhancement of primary productivity. In previous voyages on Southern Surveyor and Franklin along the west coast a notable feature was the presence of a sub-surface chlorophyll maximum; this feature was absent during the present voyage. Here, the highest fluorescence values were found on the continental shelf and offshore waters, whilst the Leeuwin Current was characterised by lower fluorescence values (see Figures 8 and 9).

Voyage Narrative

The ship departed on schedule at 1400 hrs on Wednesday 12 April from Esperance. All underway measurements: standard meteorological, thermo-salinograph (including fluorometer), shipboard ADCP, Swath Mapper and Echo-sounder were enabled when the ship departed and worked without any problems throughout the voyage. We were using the Seabird CTD, which in addition to the standard CTD sensors, included dissolved oxygen, fluorometer and PAR meter (on loan from the Australian Antarctic Division which was rated to 6000m). A 24 10L niskin bottle rosette was used for water samples and consisted of 16 bottles with the remaining bottle location taken up by the additional sensors. During the voyage, the SeaBird CTD was found be faulty (water ingress) and was replaced by the spare. Similarly the altimeter on the CTD was also found to have leaked and was replaced by a spare which was also found to be not working.

At each transect, CTD stations were located at the following depth contours: 30m, 50m, 100m, 150m, 200m, 250m, 300m, 500m and 1000m. Additional stations were completed depending on the width of the continental shelf and at deeper depths (2000m, 3000m) depending on the length of transect and in the deeper regions of the canyons. A total of 206 CTD profiles were completed. Transects B, C and D had to be truncated at the shoreward ends due to inadequate hydrographic surveys in that region.

After departing Esperance (see Figure 1), we reached transect A and completed 11 stations. After completing transects B to H, additional stations were completed in the Two Peoples and Hood Canyons before completing transects I to N. At the completion of transect N, a swath mapping exercise was undertaken with the primary objective of generating freshwater. During this time a previously unknown subsea feature was discovered and was named Mt Gabi (Figure 10). After the completion of the swath mapping, transects P and Q were completed and we headed north to the Perth canyon. Here, a transect across and along the canyon was completed, as well as completing the transect S – termed the SRFME Two Rocks transect, which had been sampled during the previous Southern Surveyor voyages. We docked in Fremantle at 0800 on 1 May 2006.

Table 1 – Daily log of completed transects and CTD stations (see Figure 1)

Date	Transect	Stations completed
12/04/2006	transit to transect A	
13/04/2006	Transect A	Stations 1-5
14/04/2006	Transects A and B	Stations 6 to 14
15/04/2006	Transects B and C	Stations 15 to 31
16/04/2006	Transect D	Stations 32 to 50
17/04/2006	Transects E and F	Stations 41 to 58
18/04/2006	Transect G	Stations 59 to 69
19/04/2006	Transect H	Stations 70 to 84
20/04/2006	Transects H and I	Stations 85 to 93
21/04/2006	Transects I and J	Stations 94 to 108
22/04/2006	Transects J and K	Stations 109 to 93
23/04/2006	Transect L	Stations 121 to 133
24/04/2006	Transects M and N	Stations 134 to 154
25/04/2006	Transect N	Stations 155 to 156*
26/04/2006	Transect P	Stations 157 to 167
27/04/2006	Transect R	Stations 168 to 177
28/04/2006	Transect S	Stations 178 to 187
29/04/2006	Transect S	Stations 188 to 204
30/04/2006	Transect S	Station 205
1/05/2006	Arrive at Fremantle	

* includes a period of swath mapping to generate freshwater – Discovery of Mount Gabi

For the duration of the voyage there were no major equipment or weather problems.

Primary Productivity

Phytoplankton investigations were undertaken by Luke Twomey, Jason Webb, Kim Brookes and Pru Bonham.

Primary productivity was measured at a total of 20 stations, which included a shelf and shelf-break station on each transect. Primary productivity was estimated using two different techniques; 1) 14C labeled sodium bicarbonate uptake, and 2) Pulse Amplitude Modulated (PAM) Fluorescence. Productivity was measured at 6 discrete depths in the euphotic zone to enable computation of depth integrated production.

Nitrogen uptake by the phytoplankton community was measured at each productivity station. Phytoplankton uptake of ammonium, nitrate and N2 gas was estimated using the stable isotope 15N method. Nitrogen uptake measurements were conducted in samples collected from the surface and the chlorophyll maximum.

Samples for stable isotope analysis of the nanoplankton and mesoplankton size fraction signatures were collected at 160 stations. Surface and chlorophyll maximum samples were collected.

Chlorophyll extractions were conducted on surface and chlorophyll maximum samples at productivity stations.

Zooplankton

Sampling for Zooplankton was undertaken using the Bongo nets but, due to problems with the starboard aft hydrographic winch, only limited samples were collected.

A total of 5 transects were samples for zooplankton. Oblique bongo tows were completed in duplicate at inshore, shelf-break and cross-shelf stations on the sampled transects. Samples were split and preserved in buffered formalin and ethanol.

Summary

This voyage was one of the first to examine in detail the physical and biological oceanography along the south coast of Western Australia, and was very successful in meeting its scientific objectives. During the voyage we had few (minimal?) problems with instrumentation. The weather was reasonable and, although we experienced high winds and swell conditions, no time was lost due to weather conditions. The presence of the swath mapper was a bonus and enabled the discovery of a previously unknown subsea feature which was named Mt Gabi (Figure 10). All of these factors, and the excellent support and cooperation of the ship's crew and Marine National Facility personnel (both on board and in Hobart) combined to produce a very successful and happy voyage.

Personnel

Scientific Contingent

Charitha Pattiaratchi	SESE/UWA	Chief Scientist/Physical Oceanography
Luke Twomey	SESE /UWA	Phytoplankton, nutrients
Mun Woo	SESE /UWA	Physical Oceanography
Florence Verspecht	SESE /UWA	Physical Oceanography, student
Fadzil Mohd Akhir	SESE /UWA	Physical Oceanography, student
Jason Webb	SESE /UWA	Phytoplankton, nutrients, student
Kim Brooks	SESE /UWA	Phytoplankton, nutrients
Pru Bonham	CMAR	Phytoplankton, nutrients
Pamela Brodie	CMAR	MNFComputing/Voyage Manager
Stephen Thomas	CMAR	MNF Electronics Support (SST)
David Terhell	CMAR	MNF Hydrochemistry Support (SST)
Mark Rayner	CMAR	MNF Hydrochemistry Support (SST)
Cameron Buchanan	GA Swath Support	

Marine Crew

Lesl Morrow	Master
Samantha Durnian	Chief Officer
Brent Middleton	2nd Officer
Jon Handicott	Chief Engineer
Dave Jonker	1st Engineer
Chris Heap	Second Engineer
Russell Williams	Bosun
Mark Jaques	IR
Joe Galvin	IR
Andrew Granger	IR
Phillip French	Greaser
Charmayne Aylett	Chief Steward
Andy Goss	Chief Cook
Jason Phillips	2nd Cook

Acknowledgements

The scientific party would like to acknowledge the professional expertise of Captain Les Morrow, and all officers and crew of RV Southern Surveyor, and thank them for their friendly help at all times. The CSIRO personnel (Pamela Brodie (Voyage Manager), Steve Thomas (Electronics Technician) and the hydrochemists, David Terhell and Mark Rayner) were thoroughly competent and co-operative. Their continual cheerfulness and skill in all situations enabled non-stop data gathering and a very high data return. Compliments are also due to the Cooks, Andy Goss and Jason Phillips for their excellent and varied menus throughout the voyage.

C Pattiaratchi
Chief Scientist

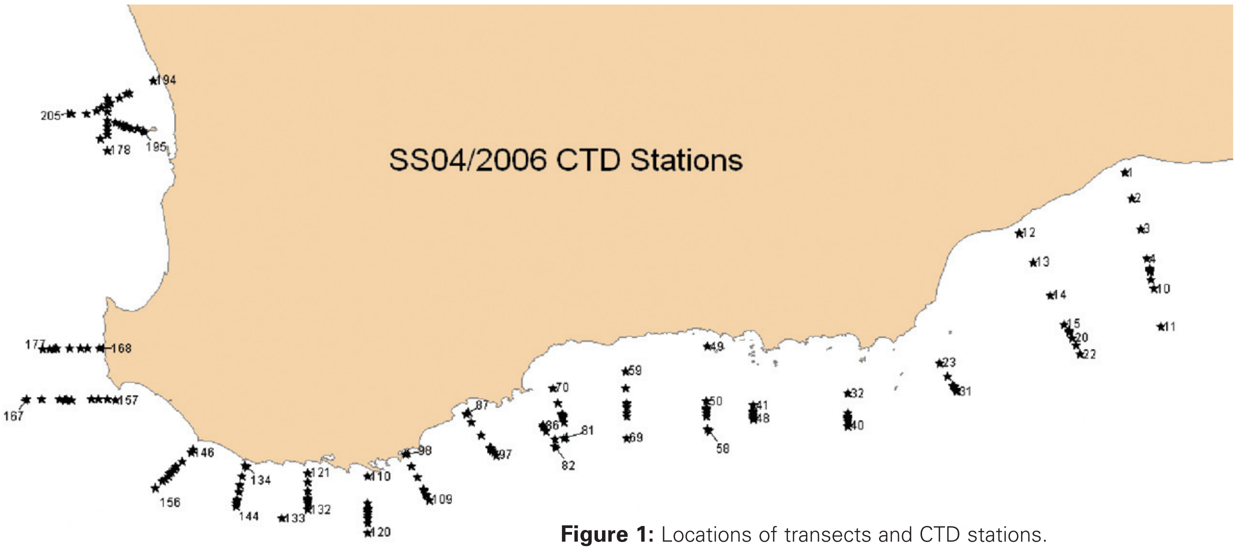

Figure 1: Locations of transects and CTD stations.

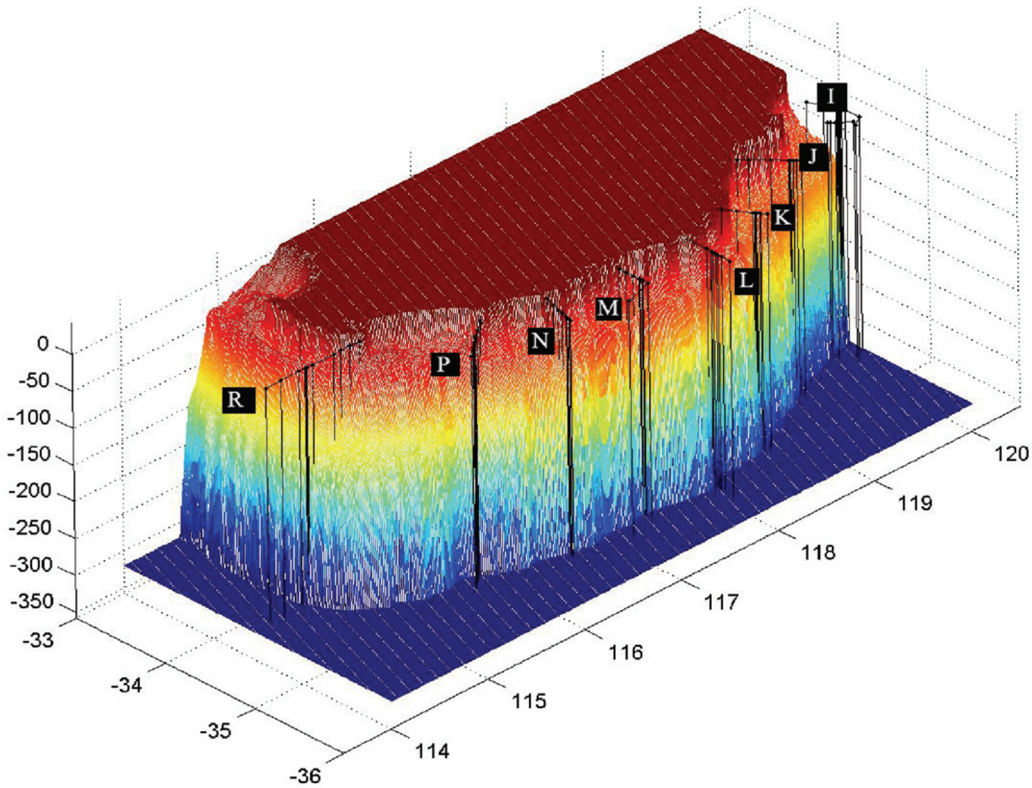

Figure 2: Location of CTD Stations from transects I to R (overlain on topography).

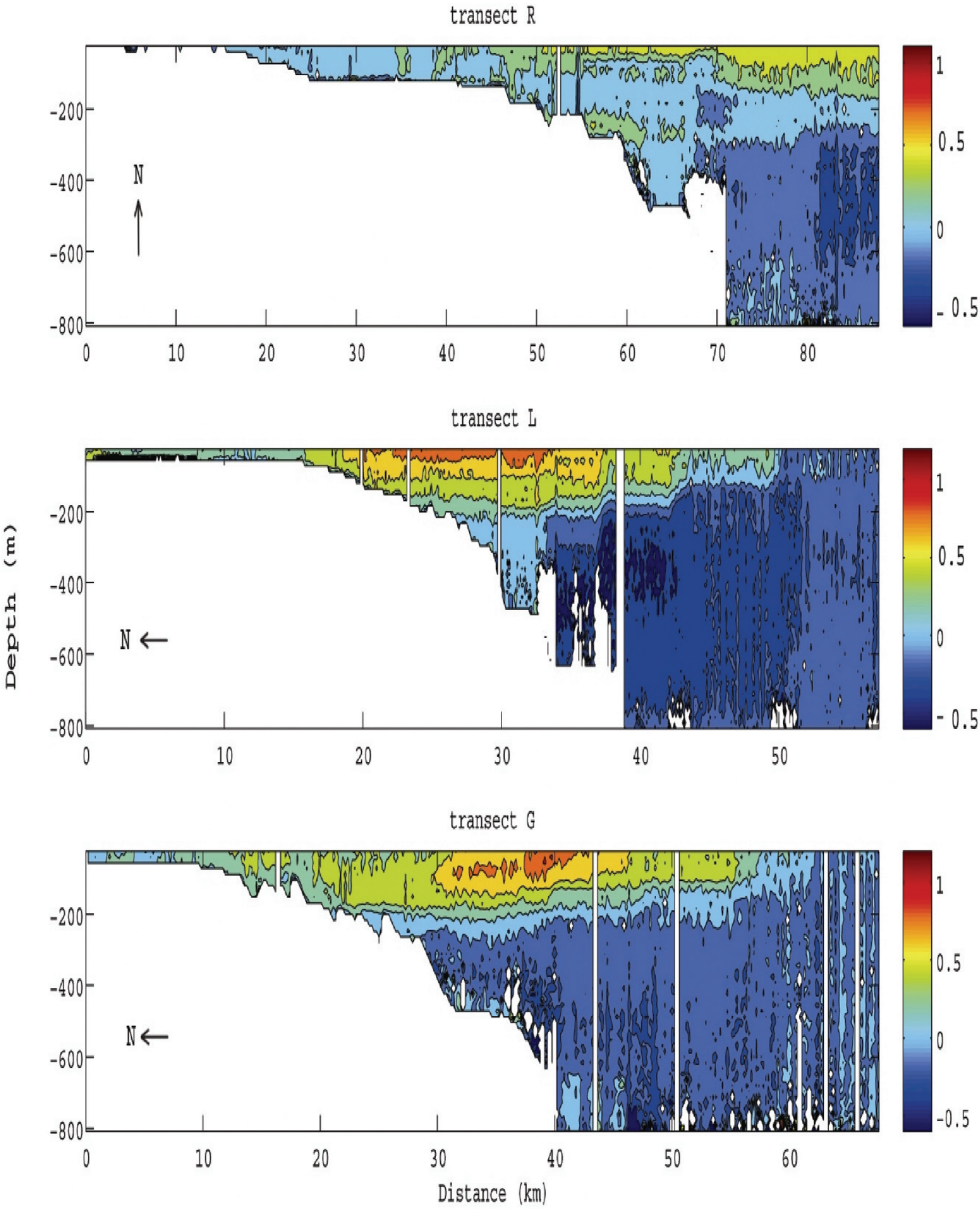

Figure 3: Velocity Distribution (ADCP) for transect R, L, and G (units are m/s)

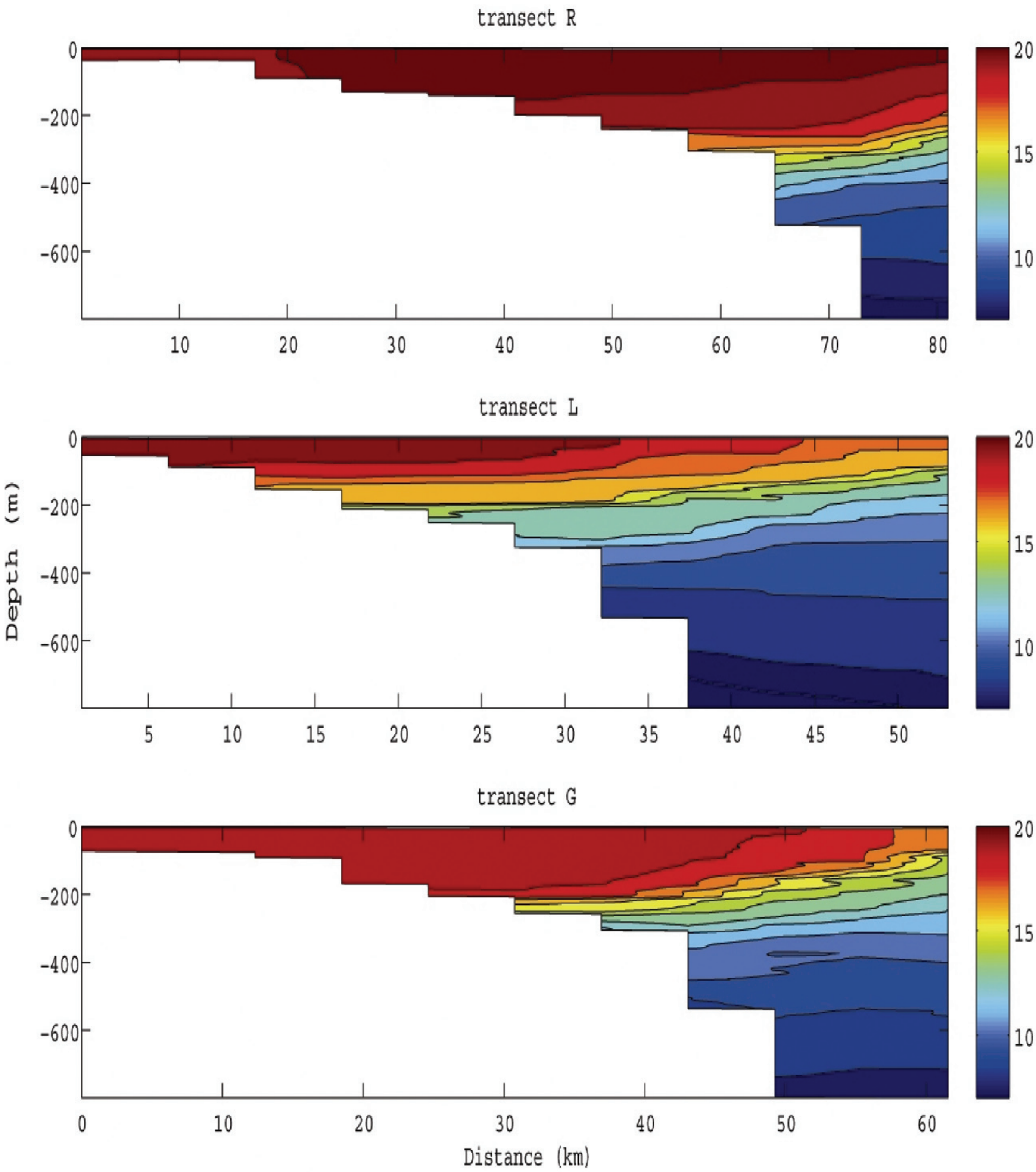

Figure 4: Temperature cross-sections for Transects R, L, and G

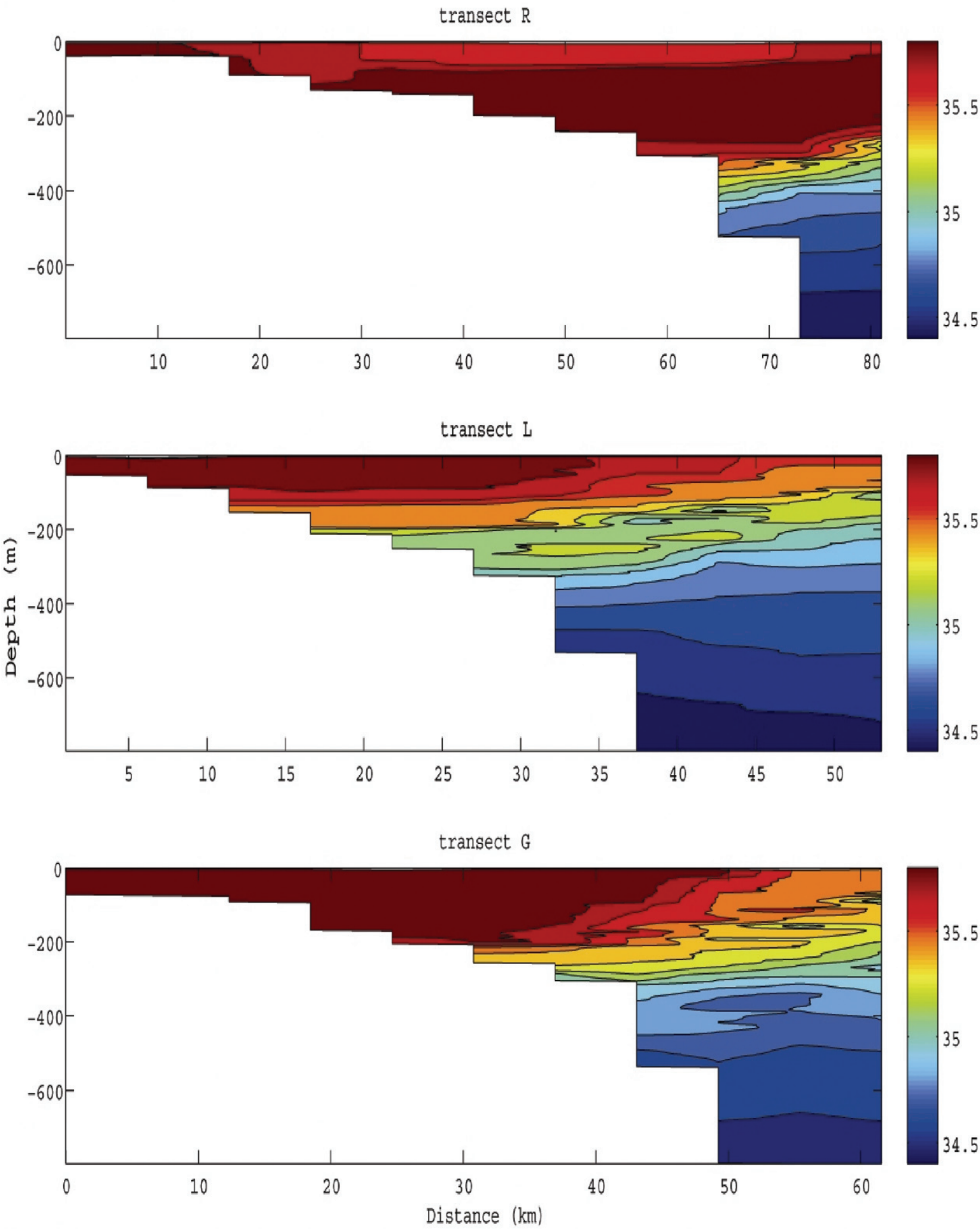

Figure 5: Salinity cross-sections for Transects R, L, and G

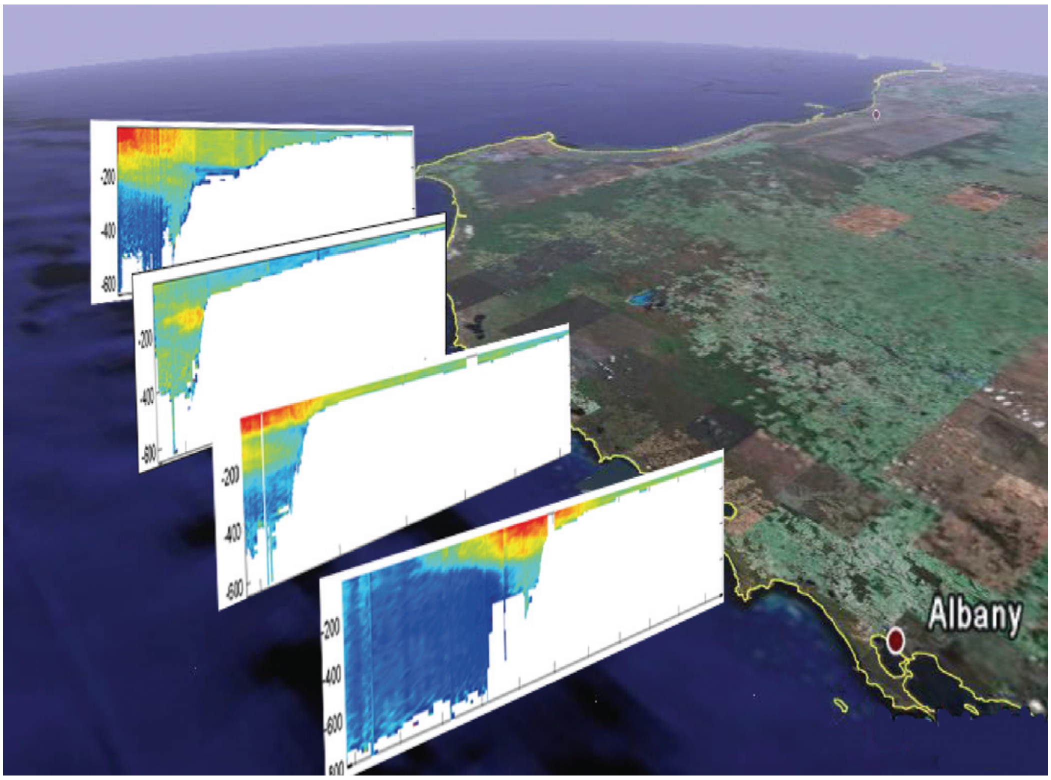

Figure 6: Velocity Distribution (ADCP) indicating that the Leeuwin Undercurrent is a continuation of the Flinders Current.

Figure 7: A schematic of the relationship between the Leeuwin Current, Leeuwin Undercurrent and the Flinders Current.

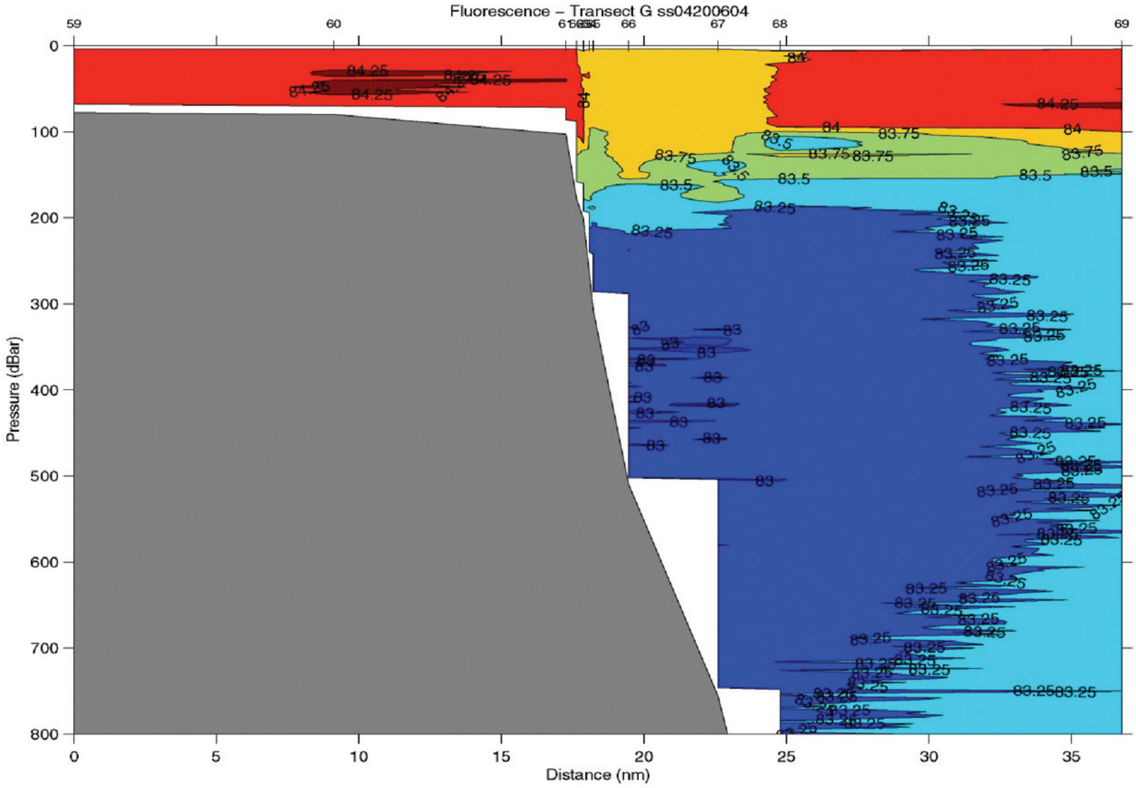

Figure 8: Fluorescence cross-section for Transect G.

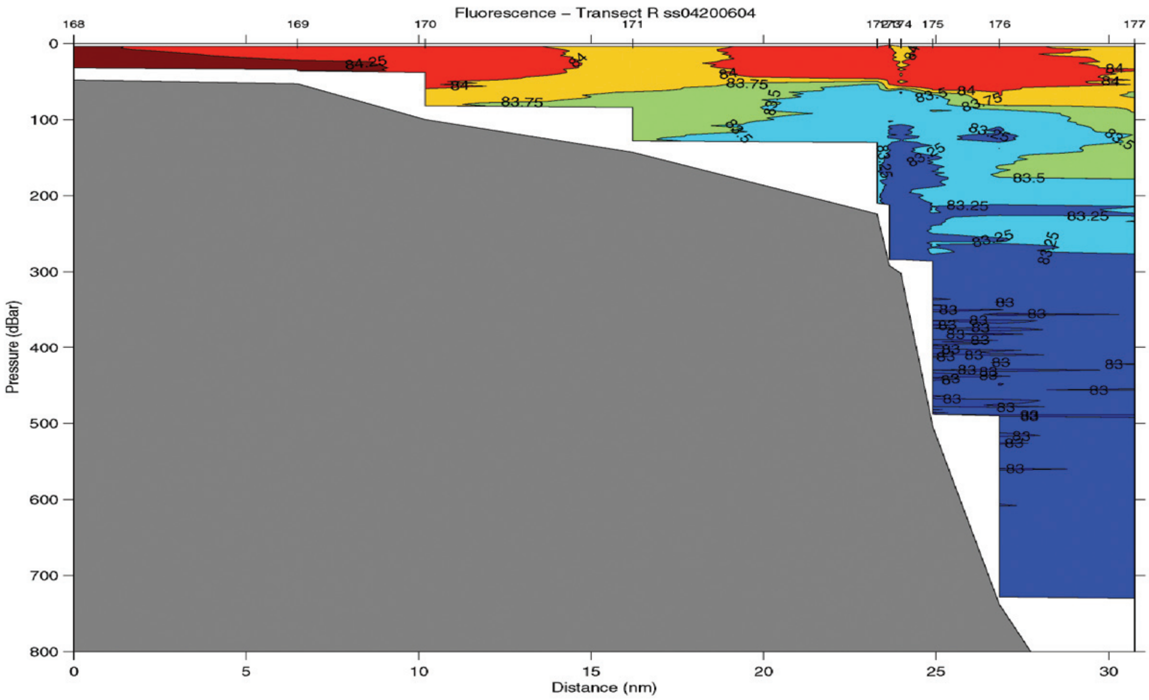

Figure 9: Fluorescence cross-section for Transect R.

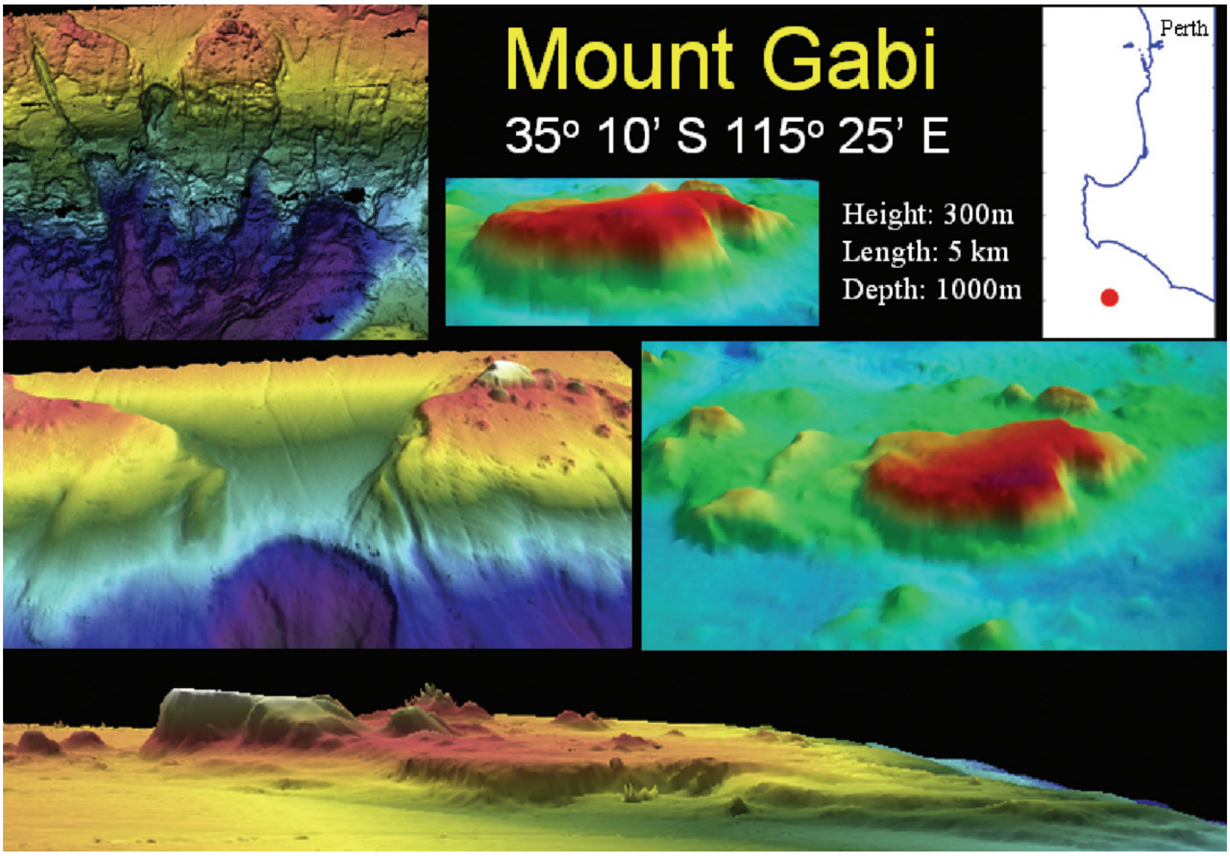

Figure 9: Images of Mount Gabi – discovered during the voyage.