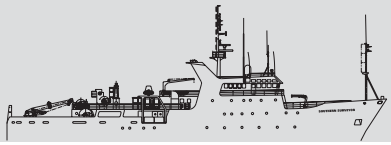

MARINE
NATIONAL FACILITY

2005 program

RV *Southern Surveyor*

CSIRO

voyage summary SS09/2005

SS09/2005

Nature and origin of the Naturaliste Plateau and Diamantina Zone: a key to understanding the assembly and breakup history of eastern Gondwana.

Itinerary

Departed Fremantle 1600hrs Friday 21 October 2005.
Arrived Fremantle 0900hrs Saturday 12 November 2005, 4 days ahead of schedule.

Principal Investigator

Prof Anthony J Crawford
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Scientific Objectives

The main scientific goals of this voyage were to dredge basement rocks:

- To investigate the nature and origin of the Naturaliste Plateau (NP) through determining the composition and age of the basement on the steep, southern and northern flanks of the plateau.
- To establish the nature and extent of the continent-ocean transition zone to the south of the Naturaliste Plateau, by analysing the basement rocks from the continent-ocean transition zone between the southern margin of the NP and the Diamantina Zone (DZ).

Analyses of samples from the Naturaliste Plateau region will help to resolve uncertainties with oceanic vs continental origin of the plateau itself and of the basement provinces lying to the south of it. This improved understanding of crustal origin will help to refine plate tectonic reconstructions in the region. Key outcomes could include:

1. Sampling of the unique complex zone lying to the south of the Naturaliste Plateau (including the Diamantina Zone) will help constrain composition of basement rocks in areas of undefined crustal origin.
2. Crustal basement rocks on the Naturaliste Plateau will enable comparison with those of the immediately adjacent onshore Pinjarra Orogen (aka Kuunga Suture) and with rocks in northeastern India that are interpreted to have formed adjacent to the Naturaliste Plateau prior to breakup of this margin between 155 and 130Ma.
3. Volcanic rocks dredged from the Naturaliste Plateau will be valuable in (i) identifying the eastern extent of the immense Kerguelen mantle plume, via comparisons with the ~110-135 Ma Bunbury Basalts, Rajmahal Traps (India), Antarctic lamprophyres, and basalts on the Kerguelen Plateau and Broken Ridge proper, and also in (ii) evaluating the source and origin of the component responsible for the Indian Ocean suboceanic mantle "HIMU" radiogenic isotopic signatures compared to the Pacific and Atlantic oceanic mantle reservoirs.

Voyage Objectives

We dredged steep scarps around the margins of the Naturaliste Plateau to sample the basement rocks needed to address our primary objectives. We commenced at the eastern end of the southern margin scarp, and steamed in a clockwise direction, and sequentially swath mapped segments approx. 100km long to identify optimal dredgable scarps and to understand the local bathymetric/structural context. We then dredged these target scarps before moving to the next segment. Only swath mapping along the broad western and northern margins of the plateau allowed us to identify suitable scarps for dredging, although we note a 1972 dredge by R/V Eltanin on the northern margin did sample conglomerate. Apart from swath mapping and dredging, no other scientific data acquisition or sampling was planned.

Voyage Track

A map showing the voyage track is appended as Fig. 1. As planned, we commenced on the southeastern margin of the plateau, and swathed abroad part of this margin with the Simrad EM300 system prior to dredging. As requested by Geoscience Australia, we swath mapped (with sub-bottom profiler Simrad TOPAS (Topographic Parametric Sonar) PS 18 active) an area in the southern Mentelle Basin (eastern part of the Naturaliste Plateau) directly below a remotely sensed oil slick. No site suitable for dredging in this rectangle was identified.

Subsequent swathing and dredging proceeded to the western end of the steep southern margin. We then carried out a swath path clockwise around the western and northwestern margins of the plateau, essentially seeking steep slopes judged to be dredgable. Unfortunately, these slopes were almost uniformly low, non-reflective, sedimented slopes offering few optimal dredge targets. We then swath mapped the seamount immediately off the northwest of the Naturaliste Plateau in detail, demonstrating that it is a fault-bound, isolated block. Three dredges were carried out on this feature. From there, we swathed a transect directly east into the northwestern 'bulge' of the plateau, where a series of en echelon, interpreted pull-apart basins and a contiguous interpreted rift basin were defined and mapped out, and several dredges undertaken. A final long line directly east was swathed towards several dredge sites at the heads of Busselton and Geographe Canyons, just southwest of Fremantle. These were dredge prior to a final transit line direct into Fremantle.

Results

The swath mapping of the southern margin of the Naturaliste Plateau defined a magnificent series of steep cliffs arrayed along 350+km. In places the cliffs stand almost 1000m above the adjacent seafloor. Some 21 dredges were attempted along this margin, 11 of which yielded useful rocks. On the margins of the plateau itself, every dredge yielded abundant highly vesicular and often autobrecciated basaltic lavas with very shallow water aspect. These varied from exceptionally weathered, to relatively fresh, often the smaller Mn-coated cobbles being fresher than the larger blocks. At least 4 of these dredges also carried common cobbles of fine- to medium-grained dolerite, most significantly weathered. Four dredges also contained crystalline basement rocks, including a coarse-grained plagioclase-phyric diorite or leucogabbro in DR7, a very fresh diorite in DR11, a cobble of granitoid rock in DR18, and an array of fresh intermediate and felsic gneisses in DR21.

No dredge sites were obvious along the smooth western margin of the plateau, but the seamount NW of the plateau was thoroughly swathed, and interpreted as a fault block separated from the plateau itself, rather than a intraplate volcanic edifice. Several dredges on this feature showed that it consisted of the same fragmental and vesicular lavas as those already dredged extensively along the southern scarps.

In our transit east and northeastward to dredge the northern scarp where USNS Eltanin dredged volcanic conglomerate 33 years ago, we swathed over a significant basement depression in the northwestern bulge of the plateau. This was carefully swathed out, and shown to be a well-defined series of en echelon, interpreted trans-tensional pull-apart basins and a contiguous interpreted rift basins formed, perhaps dating from the extensional event that led to the separation of India from this margin ~130 million years ago. Dredging of one of the transverse ridges delineating two en echelon basins yielded only Mn nodules, but the TOPAS sub-bottom profiler defined faults and slumps that will allow a more comprehensive evaluation of this basin.

Finally, two dredges in the area just south of the Eltanin dredge site (which lay in ~4500m water depth) yielded weathered volcanic rocks identical to those sampled along the southern margin. We then traversed to the east to carry out 4 dredges on behalf of Geoscience Australia; these were scheduled in voyage SS 05/08, but were not completed then due to bad weather. The first dredge station DRGA-1, yielded rounded boulders of soft pale grey and orange mudstone. The second dredge, at station DRGA-2, was snagged, and shear pin failure led to no recovery. Redredging at this same location saw a second dredge return empty, and a third dredge attempt yield a single 30kg boulder of fine-grained meta-sandstone.

Our dredging proved that the Naturaliste Plateau undoubtedly has continental crustal basement as far west as the southwestern extremity of the plateau. Dating of the crystallization age and metamorphic age of these crustal rocks will

provide excellent constraints on the origin of the basement, and its correlations with the adjacent Pinjarra Orogen rocks, or rocks now further afield in Antactica or southeastern India. Dredging also provided an exceptional sample set of presumably Mesozoic volcanics associated either with the Kerguelen plume or breakup of Australia and India. Detailed geochronological (40Ar/39Ar), geochemical and isotopic studies of these lavas will enable assessment of the extent of the Kerguelen plume and its role in modifying the geochemical and isotopic nature of the Indian Ocean mantle domain. Petrophysical characterisation of both the volcanics and the older basement has commenced, and a database of density and magnetic susceptibility is being created. These results will be used to improve existing geophysical models for the basement-cover relationships on the main Naturalister Plateau, as well as on the conjugate margin with Bruce Rise off Antarctica.

It became clear in our dredging operations that the volcanic rocks noted above extended to as deep as our dredge wire allowed us to sample (4000m), and that rocks associated with the Australia – Antarctic breakup (100 Ma) lay to the south, in much deeper water. Unfortunately sampling this crust was impossible with the current wire length of 4500m (although we were recommended to leave significant wire on the roller, so that 4200m was the "working length"), so we were unable to address the thematic objective related to the Diamantina Zone and ultra-slow spreading in early Australia – Antarctic breakup.

Voyage Narrative

We were very lucky to have mainly fine weather through a large part of voyage SS09/2005. Certainly the sea conditions did not affect our swathing and dredging operations, although in one or two places, prevailing wind and sea conditions required us to choose alternative dredge sites rather than the optimal sites originally chosen.

The swath mapping system worked well throughout the voyage, actually performing better than expectations by providing excellent imagery of seafloor deeper than 4000m, despite significant ship-generated noise. A communication error interpreted to be a hardware problem, for which the ship does not carry a spare, did not affect data acquisition or quality, but should be addressed. The TOPAS provided reasonable data for water depths to about 3000m, and very good images for depths <1500m. It was useless, however, in water depths >~3000m. Simultaneous use of the TOPAS and EM300 systems interfered with and degraded EM300 data, and therefore TOPAS was not operated continuously during the voyage.

By far our biggest constraint was the available wire length on the dredge spools (4200m). Although we managed to retrieve rocks fairly consistently at depths from 3000-3600m, the inability to sample rocks in water depths up to 4500m, even if it had proven possible to add ~400m of 'sacrificial wire' to the 4200m

of wire on the dredge spools, proved fatal to our hopes to sample crust passing into the Diamantina Zone. However, until our dredging program on this voyage, it could not be known at what depth the Naturaliste Plateau crust 'finished', or passed into the transitional crust of the northern Diamantina Zone.

Early in the voyage, we lost two dredges in successive dredging operations at the eastern end of the southern scarp. It was suspected that weaknesses in the chain above the dredge may have led to the total dredge loss. It appears that the shear-pin choice (strength evaluation) provided by CSIRO was appropriate for the water depths dredged, although the second dredge at GA Station 2 had a 9-tonne shear pin failure when no tension >7 tonnes was recorded.

Long sections of the western and northern margin of the Naturaliste Plateau were found to be very gentle broad slopes that offered very poor prospects as dredge targets. Thus approximately 12-14 planned dredges were omitted from our schedule, enabling us to do some infill swathing and 4 extra dredges for Geoscience Australia at the heads of several nearer-shore submarine canyons. Even with this extra activity, the voyage terminated 4 days earlier than scheduled in Fremantle.

Summary

A successful ARC grant based on this research voyage proposed three major objectives, namely, (i) the age, nature and correlations of the basement to the Naturaliste Plateau, (ii) the composition, extent and implications of Mesozoic magmas related to the Kerguelen plume, and (iii) the nature of the continent-ocean transition and crust generated during ultra-slow spreading between Australia and Antarctica.

The voyage has provided excellent material to thoroughly evaluate points (i) and (ii) above, but we were unable to dredge deep enough to samples rocks pertinent to point (iii). The swath imagery of the precipitous southern margin of the Naturaliste Plateau will be publishable in the popular press, and the discovery of the trans-tensional basin on the northern Naturaliste Plateau will allow a useful evaluation of rifting models associated with India – Australia breakup. On this basis, I consider the voyage to have been particularly successful. Rocks sampled were slabbed in half, with one set going to UTasmania, and the other to Geological Survey of Western Australia.

The ship operations, including dredging and swath mapping, were carried out in a most professional and effective manner, with outstanding cooperation between the scientific and ship crew.

Personnel List

Scientific Contingent

Prof Anthony Crawford	Chief Scientist, UTas (petrology, geochem, tectonics)
Prof Mike Coffin	UTokyo (geophysics)
Dr Nick Direen	UAdelaide (geophysics)
Dr Caroline Forbes	Geol. Surv. WA (SHRIMP geochronology)
Mr Bence Paul	PhD student UMelbourne (radiogenic isotopes)
Mr Ben Cohen	PhD student UQueensland (Ar/Ar dating)
Ms Lesja Mitrovic	PhD student UAdelaide (geophysics)
Mr Galen Pettigrew	student UTasmania
Mr Cameron Hamilton	student UTasmania
Mr Cameron Buchanan	GA swath processing
Mr Bob Beattie	CSIRO – Voyage manager & computer systems
Mr Steve Thomas	CSIRO – Electronics & computer support

Marine Crew

Mr Ian Taylor	Master
Mr Arthur Staron	First Officer
Mr Marcus Kongras	2nd Officer
Mr Roger Thomas	Chief Engineer
Mr John Elfstrom	First Engineer
Mr Chris Heap	Electrical Engineer
Mr Tony Van Rooy	Boatswain
Mr Peter Williams	Chief Steward
Mr Andrew Goss	Chief Cook
Mr Jason Phillips	2nd Cook
Mr Les Webster	IR
Mr Steve Salter	IR
Mr Russell Williams	IR
Mr Phil French	IR

Acknowledgements

Research voyage SS09/05 was blessed with good weather and sea conditions, outstanding cooperation between the ship crew and the scientific crew, and excellent scientific outcomes. I thank the ship crew, one and all, for their wonderful support, professionalism and enjoyable company. It has been my pleasure and good fortune to carry out to research voyages with RV Southern Surveyor under command of Capt. Ian Taylor – his professionalism, competence, can-do approach, and very friendly manner contributed substantially to the success of this voyage. Ian and the ship crew could not have made the job of the scientific crew any easier.

The scientific crew proved to be a diligent, reliable, capable and fun group to work with at all times. I thank Mike Coffin and Nick Direen for wise counsel and broad-ranging, entertaining discussions, and Caroline Forbes for her energy, commitment and resounding infectious laugh. PhD students Bence Paul, Ben Cohen and Lesja Mitrovic, and undergraduate students Galen Pettigrew and Cameron Hamilton (aka 'pin bitch') did a fantastic job, whether it was sawing rocks, monitoring the EM3000, or controlling the TOPAS, and considerably facilitated my job as chief scientist. They can be very proud of their efforts.

Swath mapping king Cameron Buchanan provided exceptional expertise and support,and great company, throughout the voyage, and contributed in a major way to the success of the mission. CSIRO's Bob Beattie and Steve Thomas were at all times very pleasant, capable and effective as Voyage Manager/IT expert and Electronics support, respectively. Such outstanding technical support for complex shipboard systems and associated software is vital to the scientific success of national facility programs.

Last but not least, the 'background' support with voyage planning and logistics provided by CSIRO Marine Division's Don McKenzie, Lee Panton and Ron Plaschke has been much appreciated, and contributed in a significant way to the success of this mission.

Prof AJ Crawford
Chief Scientist SS09/2005

Some SS09/2005 Voyage Statistics

Track length in line km 6760.9km

No of soundings 38,088,222

No of edits..... 2,663,480

Total hours surveying 498.9hrs

Sq km swath mapped ..... 17,496km^2

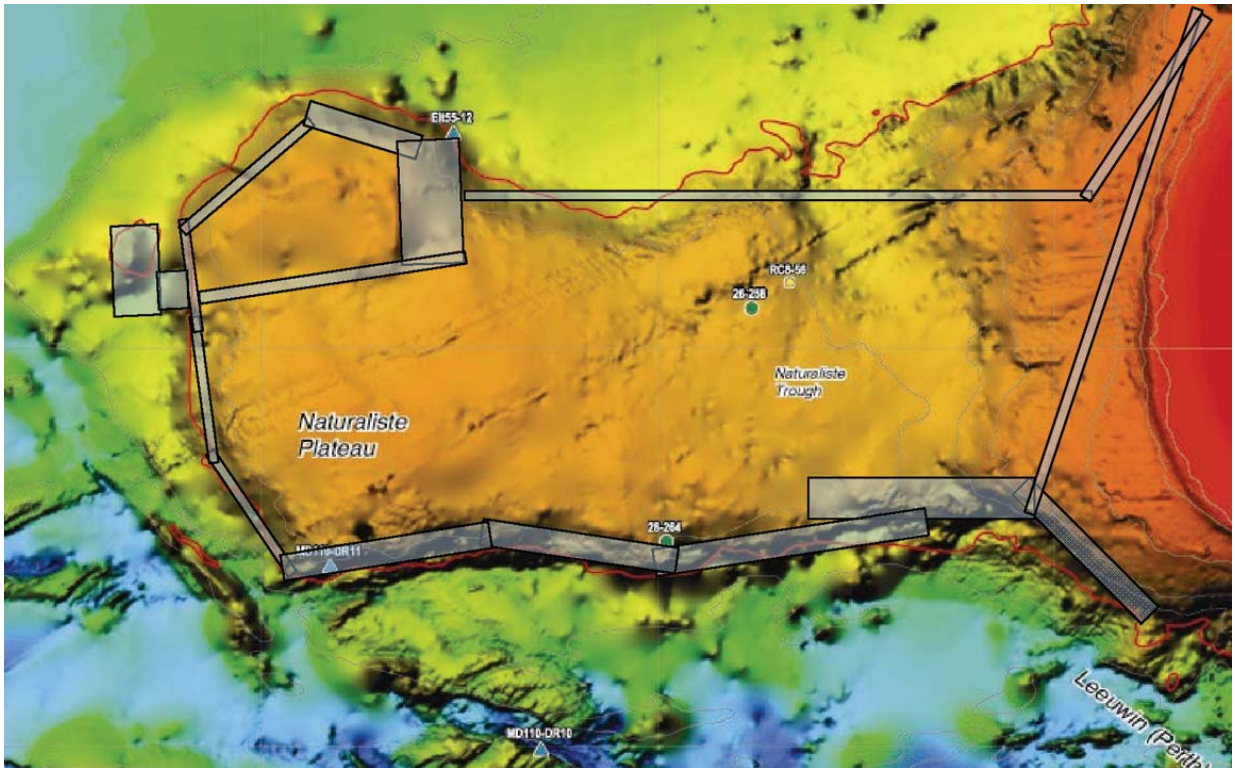

Figure 1: Ship track clockwise from Fremantle and back showing swath areas covered during voyage SS09/2005

Voyage #	Dredge station # (fn)	(dn)	Calendar	Vessel	Institution(s)	32.59.462	Locality	Navigation	Start Lat	Start Long	End Lat	End Long	Mean Lat	Mean Long	Depth Start	Depth End	Position Comm.	Subsamples to:	Total WT/VOL	Dredge haul description
Example																				
SS09/05	SS09/05-1	DR1	23 10 2005	Southern Surveyor	U. Tasmania	Crawford	S end ofNW-trending Leeuwin Escarpment	DGPS	35.16.216	114.29.694	36.15.412	114.29.091	35.15.814	114.29.350	3432m	2788m	Ship positions	UTAS, GSWA, GA	10 kg	Bldrs & cbls soft olive sst and granule conglomerate
SS09/05	SS09/05-2	DR2	23 10 2005	Southern Surveyor	U. Tasmania	Crawford	Same scarp as DR1, several km further southeast	DGPS	35.17.837	114.32.271	35.17.319	114.32.108			3131	2472	Ship positions	UTAS, GSWA, GA	10 kg	weakly metamorphosed slate/phyllite
SS09/05	SS09/05-3	DR3	24 10 2005	Southern Surveyor	U. Tasmania	Crawford	Seamount at NW end of Leeuwin Escarpment	DGPS	34.46.188	113.38.696	34.45.983	113.39.114			3851	3690	Ship positions	UTAS, GSWA, GA	20kg	Cobbles of metaseds and volcanics plus several white muddy limestone cobbles
SS09/05	SS09/05-4	DR4	26 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste	DGPS	34.53.097	113.03.540	34.52.858	113.02.132			4098	3342			EMPTY	
SS09/05	SS09/05-5	DR5	26 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		34.53.305	113.00.595	34.52.714	113.01.054			4225	3640			EMPTY	
SS09/05	SS09/05-6	DR6	27 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		34.55.037	112.51.469	34.54.785	112.50.691			4250	3500			EMPTY	
SS09/05	SS09/05-7	DR7	27 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		34.54.128	112.56.331	34.52.181	112.56.543			3710	3200		UTAS, GSWA, GA	100+kg	Altered vesicular mafic lavas
SS09/05	SS09/05-8	DR8	27 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		34.55.817	112.49.175	34.55.090	112.47.854			3800	3000			LOST DREDGE	
SS09/05	SS09/05-9	DR9	27 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		34.56.011	112.49.561	34.55.225	112.48.322			4260	3400			LOST DREDGE	
SS09/05	SS09/05-10	DR10	28 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.02.136	112.14.242	35.02.150	112.12.691			3752	3072		UTAS, GSWA, GA	half tonne	Coarse qtz-poor felsic intrusive (altered) and abundant altered mafic lavas and lava bx
SS09/05	SS09/05-11	DR11	31 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.06.348	111.58.961	35.05.816	111.58.978			3600	3180		UTAS, GSWA, GA	half tonne	Angular blocks granodiorite, altered mafic lavas and lava bx
SS09/05	SS09/05-12	DR12	31 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.03.518	111.43.412	35.02.359	111.43.504			3700	3250		UTAS, GSWA, GA	half tonne	Altered mafic voclancis
SS09/05	SS09/05-13	DR13	31 10 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.02.093	111.36.189	35.00.444	111.36.842			3800	3130		UTAS, GSWA, GA	half tonne	Altered volcanics
SS09/05	SS09/05-14	DR14	01 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.03.339	110.56.307	35.02.777	110.55.626			4000	3300			Empty	
SS09/05	SS09/05-15	DR15	01 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste	Repeat DR14	35.03.175	110.55.414	35.02.964	110.54.904			4000	3300			Empty	
SS09/05	SS09/05-16	DR16	02 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.03.553	110.52.553	35.03.464	110.52.725			4140	3120		UTAS, GSWA, GA	200kg	Weathered and altered mafic voclancis
SS09/05	SS09/05-17	DR17	03 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.02.688	110.28.537	35.02.388	110.25.605			3890	3200			Empty	
SS09/05	SS09/05-18	DR18	03 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.03.035	110.24.800	35.02.584	110.25.143			3900	3100		UTAS	Few in pipe dredge	Gneiss. Granite fragments, <1 kg total
SS09/05	SS09/05-19	DR19	03 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.03.970	110.23.169	35.03.393	110.22.077			3860	3250			Empty	
SS09/05	SS09/05-20	DR20	03 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.05.657	110.19.447	35.05.449	110.18.357			3850	3325		UTAS, GSWA, GA	5kg	
SS09/05	SS09/05-21	DR21	04 11 2005	Southern Surveyor	U. Tasmania	Crawford	South facing scarp, southern margin Naturaliste		35.02.753	110.24.954	35.02.457	110.24.988			3900	3100		UTAS	5kg in pipe dredge	
SS09/05	SS09/05-22	DR22	06 11 2005	Southern Surveyor	U. Tasmania	Crawford	East facing scarp of seamount fault block NS corner NP		33.33.959	109.22.996	33.33.862	109.21.355			3930	3440		UTAS, GSWA, GA	10kg	
SS09/05	SS09/05-23	DR23	07 11 2005	Southern Surveyor	U. Tasmania	Crawford	East facing scarp of seamount fault block NS corner NP		33.30.746	109.23.344	33.30.864	109.22.413			3830	3430		UTAS	1 rock V weathered	Weathered mafic lava
SS09/05	SS09/05-24	DR24	07 11 2005	Southern Surveyor	U. Tasmania	Crawford	East facing scarp of seamount fault block NS corner NP		33.29.251	109.18.153	33.29.093	109.17.820			3825	3620			Empty	
SS09/05	SS09/05-25	DR25	07 11 2005	Southern Surveyor	U. Tasmania	Crawford	Linear ridge 100m high on E side seamount fault bock		33.33.990	109.21.734	33.33.777	109.20.852			3545	3450			Empty	
SS09/05	6SS09/05-26	DR26	08 11 2005	Southern Surveyor	U. Tasmania	Crawford	Ridge 100m high in pull apart basin, NW Nat Plateau		33.26.232	110.52.083	33.27.189	110.51.306			2800	2650		UTAS	Mn nodules only	
SS09/05	SS09/05-27	DR27	09 11 2005	Southern Surveyor	U. Tasmania	Crawford	South of Eltanain dredge site, NE margin of bulge on NP		32.59.580	110.57.435	33.01.167	110.56.503			3425	3240		UTAS, GSWA, GA	50kg weathered volcanics	Weathered and altered mafic voclancis
SS09/05	SS09/05-28	DR28	09 11 2005	Southern Surveyor	U. Tasmania	Crawford	South of Eltanain dredge site, NE margin of bulge on NP		32.55.130	110.53.810	32.56.019	110.53.747			3400	3200		UTAS	Mn nodules	
SS09/05	SS09/05 GA1	DRGA-1A	11 11 2005	Southern Surveyor	U. Tasmania	Crawford	Head of Geographe canyon		32.49.626	114.12.996	32.49.405	114.13.171			1400	1500		UTAS GA	100kg round rocks & ooze	Soft white and orange mudstones
SS09/05	SS09/05 GA1	DRGA-2	11 11 2005	Southern Surveyor	U. Tasmania	Crawford	Head of Geographe canyon		32.46.243	114.09.343	32.46.167	114.10.997			2188	1580				
SS09/05	SS09/05 GA1	DRGA-2A	11 11 2005	Southern Surveyor	U. Tasmania	Crawford	Head of Geographe canyon		32.46.247	114.09.176	32.46.240	114.09.435			2200	1600		UTAS GA	1 rock & ooze	
SS09/05	SS09/05 GA1	DRGA-2B	11 11 2005	Southern Surveyor	U. Tasmania	Crawford	Head of Geographe canyon		32.46.250	114.09.315	32.46.076	114.09.799			2240	1780		UTAS GA	1 big rock & ooze	Metasediment (sst)