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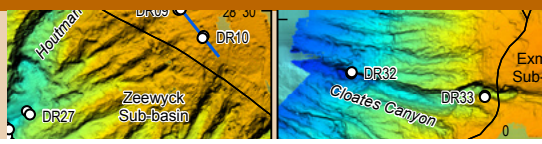
# The geology and deep marine terrains of Australia's western margin

## *Preliminary results from major marine reconnaissance survey*

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The recently completed marine reconnaissance survey of Australia's southwestern margin was the first survey to collect rock samples from this under-explored deepwater area. Significant outcomes of the survey included:

- the recovery of nearly 200 rock samples from deep to ultra-deepwater sedimentary basins.
- new evidence for the westward extension of the Exmouth and Zeewyck sub-basins
- mapping and sampling of several submarine volcanic features which provide the first evidence of recent volcanism on the western Australian margin

The sampling program conducted during the survey covered a vast area from the Perth Canyon in the south to the Exmouth Plateau in the north. Samples were obtained from deepwater areas (1000 to 5000 metres water depth) in the Perth and South Carnarvon basins. To date, hydrocarbon exploration in the area has focussed on shallow-water plays, leaving the deepwater parts of these basins under-explored and poorly understood.

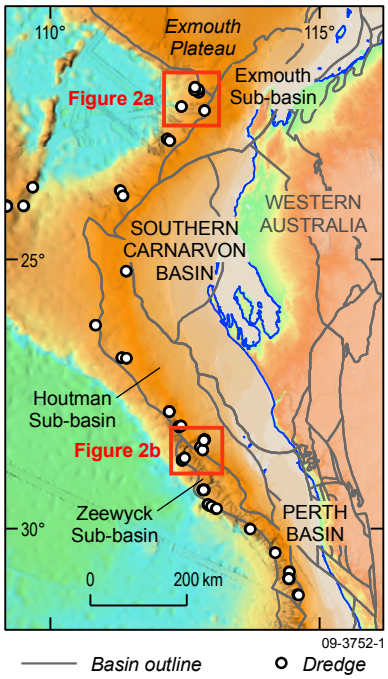



**Figure 1.** Location of dredge sites in the Perth and southern Carnarvon Basins.

"The sampling program conducted during the survey covered a vast area from the Perth Canyon in the south to the Exmouth Plateau in the north."

Of particular interest were the Zeewyck and northern Houtman sub-basins of the Perth Basin (figure 1) which had been identified as potentially prospective frontier basins (Bradshaw et al 2003). Samples collected during this survey provided the first opportunity to get insights into the age and composition of sedimentary rocks in these basins. The dredge sampling used the technique developed during the Great Australian Bight Survey in 2007 to successfully target source rock intervals and provide invaluable geological data to support the hydrocarbon prospectivity assessment (Totterdell et al 2008).

Most of the dredge sites were located in submarine canyons and scarps where steep slopes offer the best opportunity for sampling the sedimentary strata. Grab samples were taken at the base of a steep slope and provided additional information on lithologies present in the sedimentary succession above. A total of 199 rock samples were collected from 53 dredges,

13 grabs, three benthic sleds and one box core. These samples include a suite of sedimentary and volcanic rocks. Their composition and organic content will be determined by geochemical analysis whilst microfossil analysis will help resolve the age and depositional environment of the sedimentary strata.

Considerable effort went into planning the dredge locations before and during the survey. Dredge sites were selected within deeply incised canyons that exposed rocks from the synrift succession, using seismic data and seafloor bathymetry images. The Houtman Canyon, which intersects both the Zeewyck and Houtman sub-basins, and the Cape Range Canyon, to the south of the Exmouth Plateau, are the two largest canyons within the survey area (figure 2) and provided some of the best sampling targets. Dredges were deployed in different parts of these canyons to provide samples from different stratigraphic levels in the basin succession. This article highlights preliminary results from these two locations. A full description of the sampling program and the rocks collected during this survey will be published later this year in a post-survey report.

## Houtman Canyon: Zeewyck and Houtman Sub-basins

Both the Houtman and Zeewyck sub-basins are part of the 1300 kilometre long north-south trending Perth Basin (figure 1). The Houtman Sub-basin is a major Paleozoic–Mesozoic depocentre initially formed as a series of Permian to Early Triassic rift basins. In the Triassic these basins were overlain by sag deposits and in the Early Jurassic a new rifting phase led to the development of Jurassic depocentres (or areas of major sediment accumulation). The southern Houtman Sub-basin potentially hosts commercially viable Jurassic petroleum systems with gas and oil shows in the Early to Mid-Jurassic

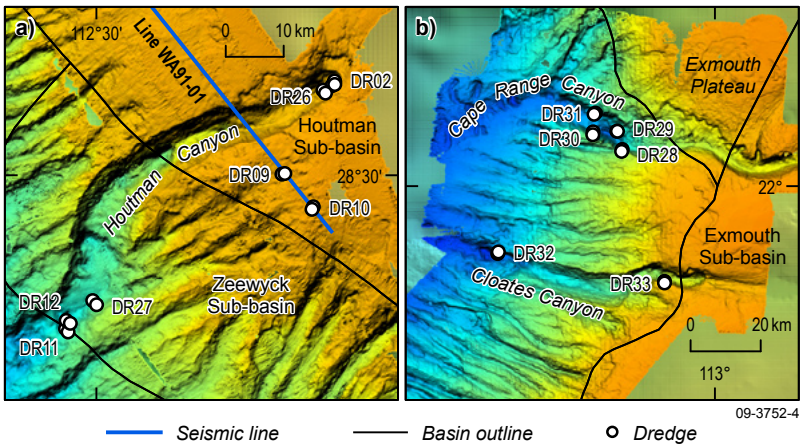



**Figure 2.** Location of dredge sites: a) the Houtman; b) the Cloates and Cape Range canyons.

Cattamarra Coal Measures. The northern Houtman Sub-basin has only a sparse coverage by regional seismic lines and little is known about its hydrocarbon prospectivity.

The Zeewyck Sub-basin is a deep-water frontier basin with no record of previous exploration. Seismic data coverage is limited to 20 regional dip lines of varying vintage and quality. The sub-basin appears to consist of a series of depocentres containing Middle Jurassic–Lower Cretaceous synrift strata overlain by Lower Cretaceous–Cainozoic postrift strata (Bradshaw et al 2003). It has the potential to be a deepwater to ultra-deepwater petroleum province with hydrocarbons possibly generated from Jurassic and Early Cretaceous source intervals. New data collected during this survey will help to develop an understanding of the geology and exploration potential of the Zeewyck Sub-basin and data-poor areas of the Houtman Sub-basin.

The Houtman Canyon is located about 400 kilometres north of the Perth Canyon and extends from the upper continental slope (600 metres water depth) down to the abyssal plain (4900 metres depth). Part of the seismic line in figure 3 intersects the Houtman Canyon, showing that both synrift and postrift sections are exposed in the canyon walls. In the upper Houtman Canyon (Houtman

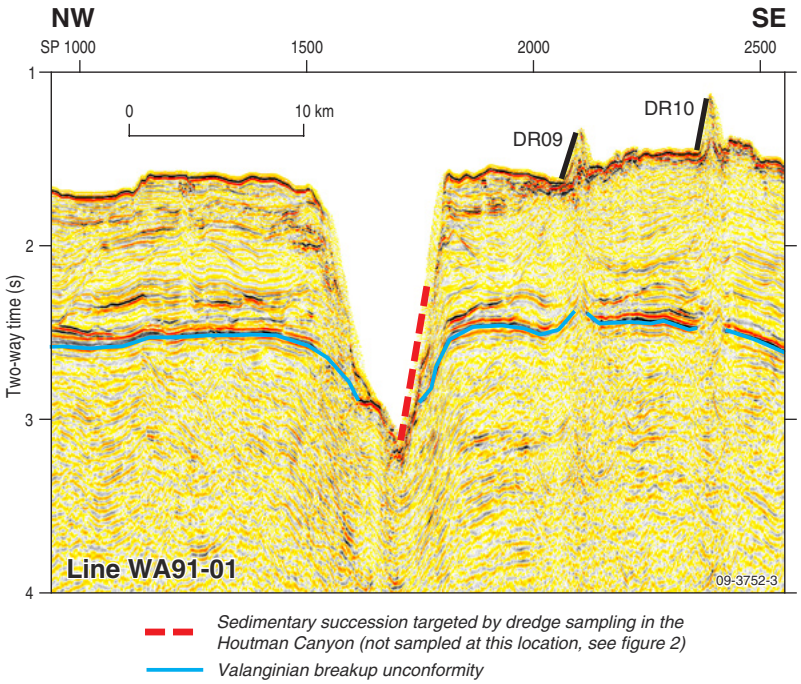



**Figure 3.** Example of a seismic line (WA91-01) intersecting the upper part of the Houtman Canyon. Location of dredge paths on the volcanic cones are shown by the black lines while the targeted part of the basin succession dredged at other locations in the canyon is shown by the red dashed line.

Sub-basin), 19 samples were obtained from three dredges in the interval from 2100 to 1700 metres water depth. Dark grey-green sandstones and claystones are the most common lithologies in this area, but siltstones, limestones and stratified siliciclastics were also recovered. Sedimentary structures recovered include planar, wavy, and ripple cross lamination. Additionally, coaly and mudstone intraclasts were observed in some of the samples.

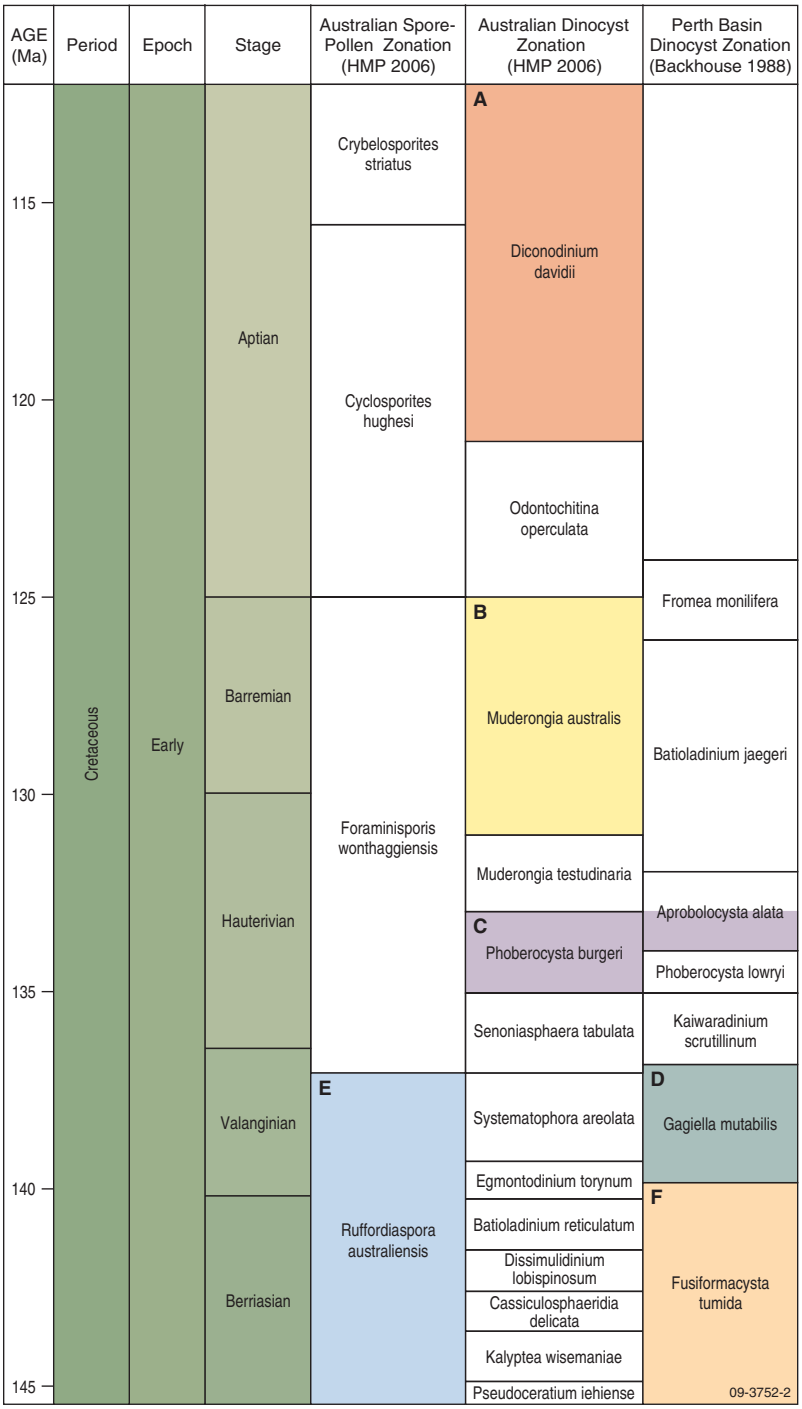
In the lower Houtman Canyon (Zeewyck Sub-basin), 18 samples were collected from three dredges in the interval between 4100 and 3800 metres water depth. This 300 metre section yielded mostly yellow-brown and grey sandstones along with claystones, limestone, basalt, chert and mixed siliciclastics. The predominant sandstones were largely unstructured although planar and trough cross bedding, normal grading and laminae were recorded from interbedded clay- and sandstone samples.

In the area surrounding the Houtman Canyon, seismic data shows several 200 to 300 metre high conical features exposed on the sea floor (figure 3). Preliminary interpretations identified two possible origins: either extrusive volcanic cones or mud diapirs (Gorter pers. comm.). Swath mapping confirmed the presence of these features and two of them near the upper Houtman Canyon were targeted for dredging (DR09 & DR10; figures 2 and 3). Three basalt samples were recovered: two vesicular basalts from the southern volcanic cone and a volcaniclastic breccia with a carbonate matrix from the northern cone. This discovery of recent volcanism in the Houtman Sub-basin is very important for understanding the basin's tectonic and thermal history.

## Cape Range Canyon: Exmouth Sub-basin

The Exmouth Sub-basin is the southernmost part of the Exmouth-Barrow-Dampier intracratonic rift system of the Carnarvon Basin. It is a major Early to Middle Jurassic depocentre containing over 12 kilometres of predominantly marine and non-marine siliciclastics. The sub-basin is a proven petroleum province hosting a number of oil and gas fields. Upper Jurassic marine shales form the principal hydrocarbon source and the Lower Cretaceous Barrow Group sandstones are the primary reservoirs in this sub-basin. However, the southern part of the Exmouth Sub-basin remains under-explored.

Cape Range Canyon (figure 2) is one of the largest canyons on the western margin of Australia. It extends for over 120 kilometres from the westernmost Exmouth Sub-basin (1800 metres water depth) to the Gascoyne abyssal plain (4800 metres depth). Cloates Canyon is a slightly smaller canyon located about 40 kilometres south of the Cape Range Canyon and occurs in similar water depths. New swath




| Sample | No. of Samples | Age | Palynological Zone | Palaeoenvironment |
|---|---|---|---|---|
| A | 2 | Late Aptian | Upper *Diconodinium davidii* dinocyst zone | Inner-middle shelf |
| B | 1 | Hauterivian - Barremian | *M. australis* - *M. testudinaria* dinocyst zone | Shallow marine/Delta front |
| C | 2 | Hauterivian | *P. burgeri* (HMP 1987) and lower *A. alata* (Backhouse 1988) dinocyst zone | Shallow marine |
| D | 1 | Valanginian | *G. mutabilis* dinocyst zone | Marginal marine |
| E | 8 | Berriasian - Valanginian | *R. australiensis* spore-pollen zone | Terrestrial |
| F | 6 | Berriasian | *F. tumida* dinocyst zone | Marginal marine |

**Figure 4.** Initial palynological results for selected samples from the Houtman Canyon (Houtman and Zeewyck sub-basins) and Cape Range and Cloates canyons (Exmouth Sub-basin).

bathymetry has shown that both canyons incise deeply into the margin, and have steep walls suitable for dredging in their lower reaches. Samples were recovered from four dredges in the Cape Range Canyon and two dredges in the Cloates Canyon. Very similar lithologies were recorded in both canyons and may be representative of the sedimentary succession lying in the interval between 4300 and 3700 metres water depth. The recovered lithologies included stratified, olive-brown to grey sandstone, dark brown to black claystone, and minor cherts and felsic igneous rocks. Some sandstone samples contain plant material and fossils indicative of shallow water deposition.

This discovery of sedimentary successions within the lower Cape Range and Cloates canyons, combined with the newly-acquired swath bathymetry images, provides strong evidence of a westward continuation of the Exmouth Sub-basin into deeper waters than previously mapped. Consequently the boundaries of the sub-basin extend at least 50 kilometres westward to the base of the continental slope.

## Initial biostratigraphic results

Dredged rock samples with suitable fine-grained lithologies, likely to preserve microfossils, were selected to analyse for their foraminiferal, nannofossil, and palynological content. Most of these samples were productive and contain well preserved microfossil assemblages. Palynological analyses of 28 high priority samples has allowed initial inferences to be made on the age, depositional environment (palaeoenvironment), and thermal maturity of the rock strata. The ages and initial palaeoenvironmental results for 20 of the productive samples from the Exmouth, Houtman, and Zeewyck sub-basins are outlined in figure 4.

These samples were all of an Early Cretaceous age (145.5 – 99.6 million years or Ma) with most being restricted to the Berriasian-Valanginian stages (145.5-133.9 Ma) corresponding to the latest stage of synrift deposition. These older samples were mostly deposited in a terrestrial, probably fluvial, environment or in marginal (restricted) marine settings. Although samples classified as marginal marine are dominated by terrestrial plant spores and pollen, they also contain a sparse, low diversity assemblage of thin-walled, dinoflagellate cysts of probable restricted marine origin (such as *Fusiformacysta tumida*).

Samples collected from the deeply incised Houtman and Cape Range canyons (figure 2) are amongst the oldest samples analysed so far and are mostly assignable to the Berriasian portion of the *F. tumida* Dinocyst zone. The colour of the palynomorphs (thermal alteration index or TAI) acts as a rough proxy for the thermal maturity of the samples. The TAI values from these samples indicate that most are thermally mature and are within or approaching the 'oil window'. Many of the Berriasian–Valanginian samples also contain copious amounts of reworked Late Permian and Early Triassic palynomorphs which, in some samples account for over half of the entire assemblage.

Younger, more open marine samples of Hauterivian to late Aptian age were collected from the Cloates Canyon (Exmouth Sub-basin) and the upper parts of unnamed canyons in the Houtman Sub-basin. These samples are dominated by marine dinoflagellate cysts with some bisaccate pollen and only sparse terrestrial plant spores which are denser and rarely transported offshore in great abundance. These samples fall within the postrift stages (following the breakup between Australia and Greater India) of the northern Perth and southern Carnarvon basin successions. The TAI values for these samples indicate they are all thermally immature for hydrocarbon generation.

## Summary

Preliminary analyses on the palynology of these rock samples suggest that both synrift and postrift successions have been sampled in these basins. When the results from more detailed analyses become available, they will provide invaluable information on the stratigraphy and petroleum prospectivity of these frontier basins.

### For more information

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