

Figure 4.37. Composition of bulk carbonate content in geomorphic features of the NNMR: a) bank/shoal; b) deep/hole/valley; c) basin; d) canyon; e) ridge; f) apron/fan; and g) terrace.

5. Geomorphology and Sedimentology of Bioregions

5.1 INTRODUCTION

Samples with quantitative textural and compositional data represent all eight bioregions in the NWMR (Fig. 5.1; Table 5.1). New data significantly improve sample densities in seven of the eight bioregions and provide the first sediment data for the Central Western Shelf Transition in the NWMR.

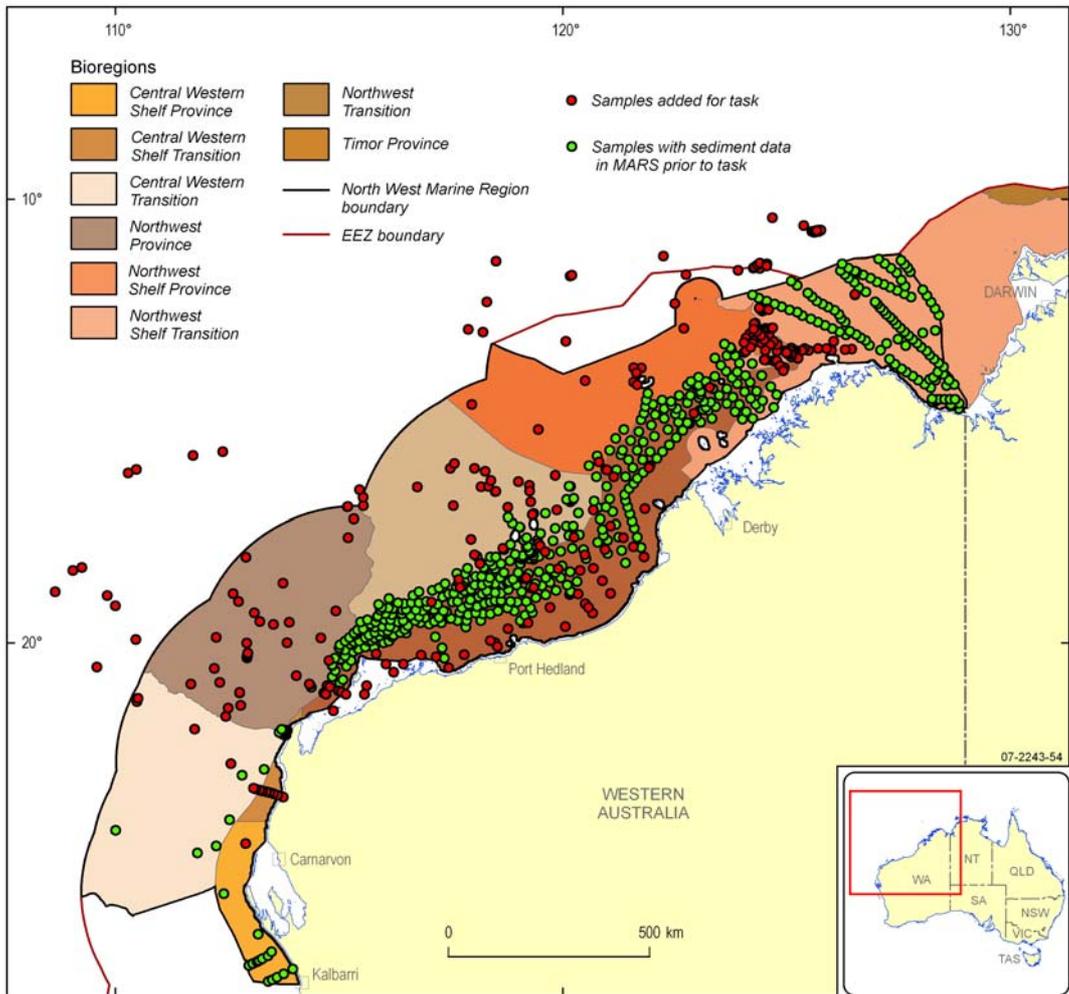
A total of 693 samples (72%) occur in the four shelf bioregions which comprise <37% of the NWMR area. A total of 275 samples (28%) occur in the four offshore bioregions which comprise 64% of NWMR area. The remaining 17 (1%) samples occur in the area of the NWMR not allocated to any bioregion. Data added from the current study 120 samples in shelf bioregions and 115 samples in offshore bioregions.

Average sample densities attain >1:2,550 km² in four Shelf and two offshore bioregions (Table 5.1). Elsewhere in the NWMR average sample densities are lower. The Northwest Province (NWP) covers 178,700 km² or 17% of the NWMR and contains 58 samples; this results in an average sample density of <1:3,100 km². The Central Western Transition (CWT) covers 162,900 km² or 15% of the NWMR and contains 15 samples, resulting in a sample density of <1:10,850 km² (Table 5.1).

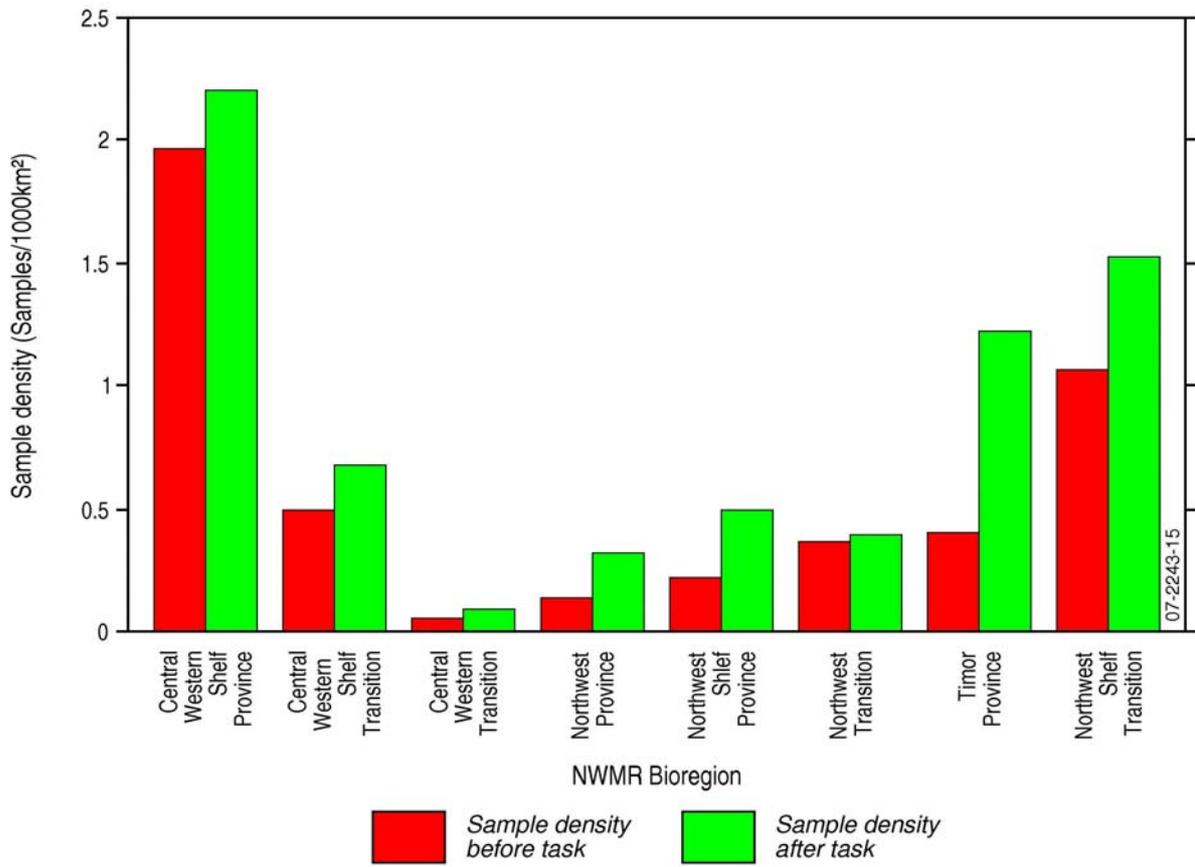
Geomorphology and bathymetry of each bioregion is described from quantitative data (Chapter 4). Where sample coverage is adequate, the sedimentology of geomorphic features judged to be significant within each bioregion is described. The Central Western Shelf Province (CWSP), Central Western Shelf Transition (CWST) and much of the Northwest Shelf province (NWSP) are characterised by simple geomorphology and data coverage is adequate to describe the sedimentology of most features. Where bioregions are characterised by complex geomorphology, particularly the Northwest Shelf Transition (NWST), data coverage is insufficient to describe the sedimentology of all the geomorphic features. Where available, information from previous studies (Chapter 3) and from the planning region scale analysis (Chapter 4) are used to characterise seabed sediments in features without sufficient sample coverage for analysis at bioregion scales. This information is included in the summary and discussion of results in Chapter 6.

Shelf and offshore bioregions can be distinguished from one another based on sediment texture and composition and the spatial distribution of these properties relative to other physical data sets such as bathymetry and geomorphology. Changes in sedimentology are most clearly observed by an increase in mud content and decrease in carbonate of sediment within offshore bioregions compared to shelf bioregions (Fig. 5.2 & 5.3). 79% (a total of 417 samples) of samples in shelf bioregions contain >80% carbonate content compared to 60% (154 samples) in the offshore bioregions. Similarly, 21% (225 samples) of samples in offshore bioregions contain >80% mud content compared to only 3% (14 samples) of samples in shelf bioregions. Changes in the sedimentology of shelf and offshore bioregions are attributed to decreasing energy levels and sediment transport mechanisms with distance offshore as described in section 3.

Differences between the texture of sediments in shelf bioregions are difficult to quantify as CWST and CWSP contain only nine and 13 samples, respectively. However, data from the NWST indicate that the sediments in this bioregion differ significantly in texture and composition from those in other shelf bioregions, with mud and gravel fractions regularly attaining >20% and bulk carbonate contents <20% locally. The NWST can be distinguished from all other bioregions by high mud content of sediments across the entire shelf. The NWST and CWSP are characterised by highly variable carbonate contents (standard deviation 22%). The NWSP is distinguished from the other bioregions by consistently high carbonate contents (>80%).



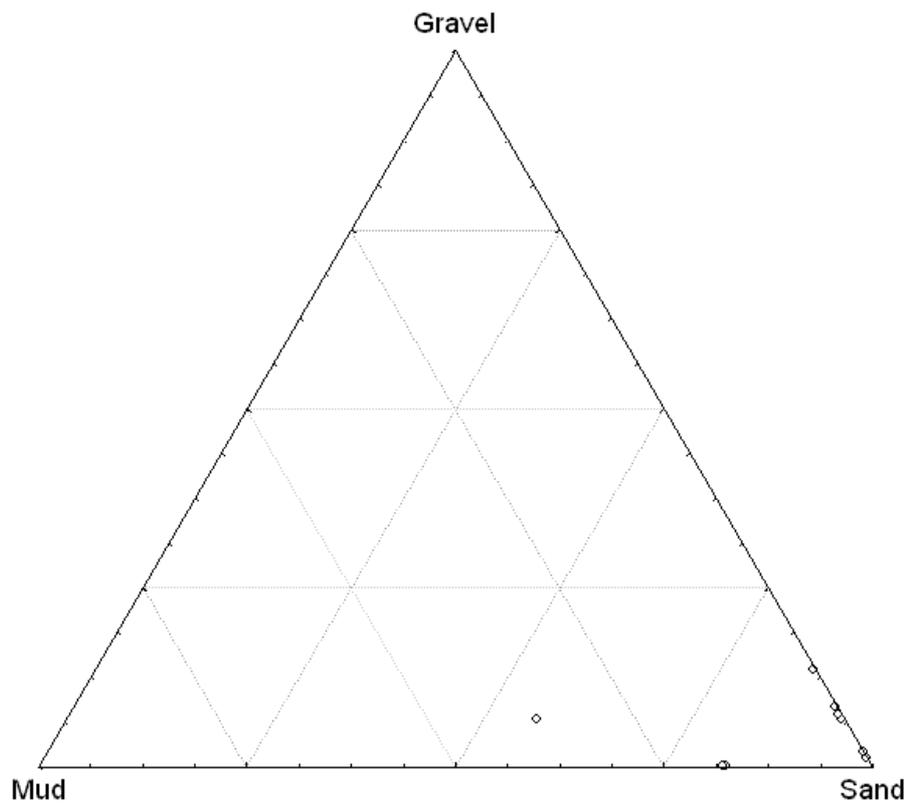
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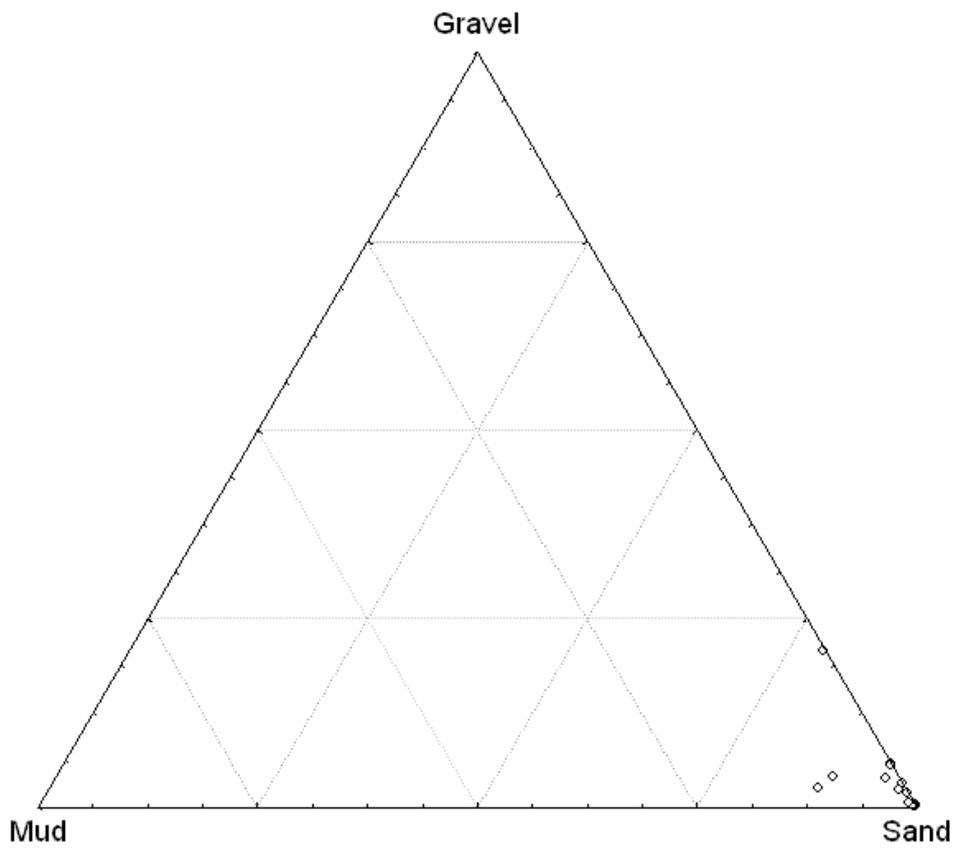
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Figure 5.1. a) Sample coverage of bioregions within the NWMR; and b) sample density of each bioregion before and after the task.

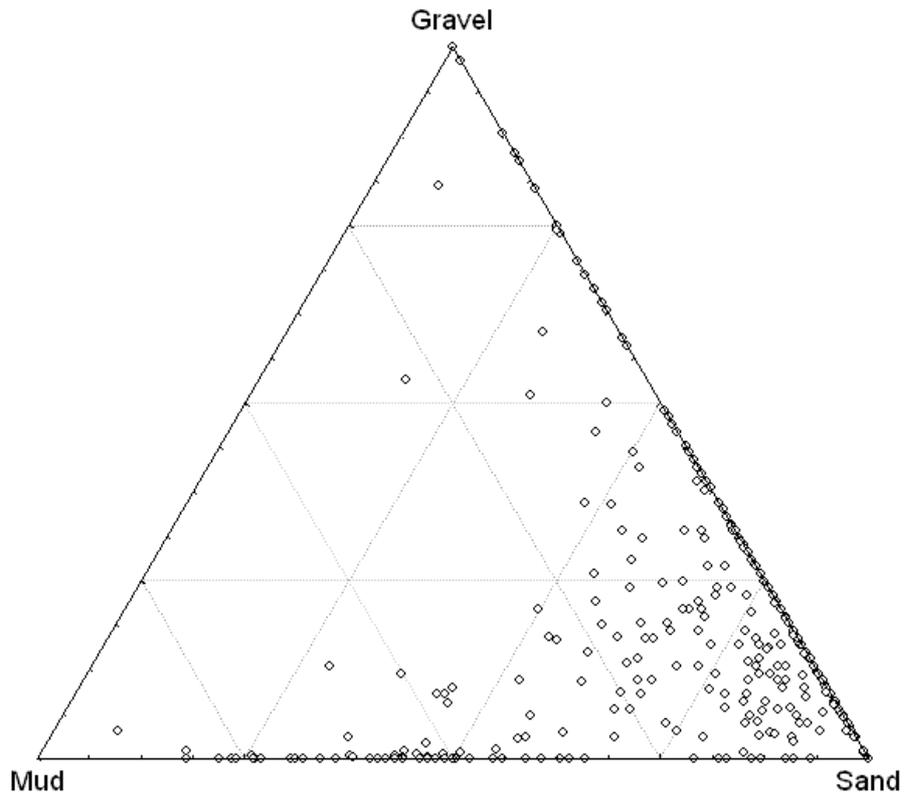
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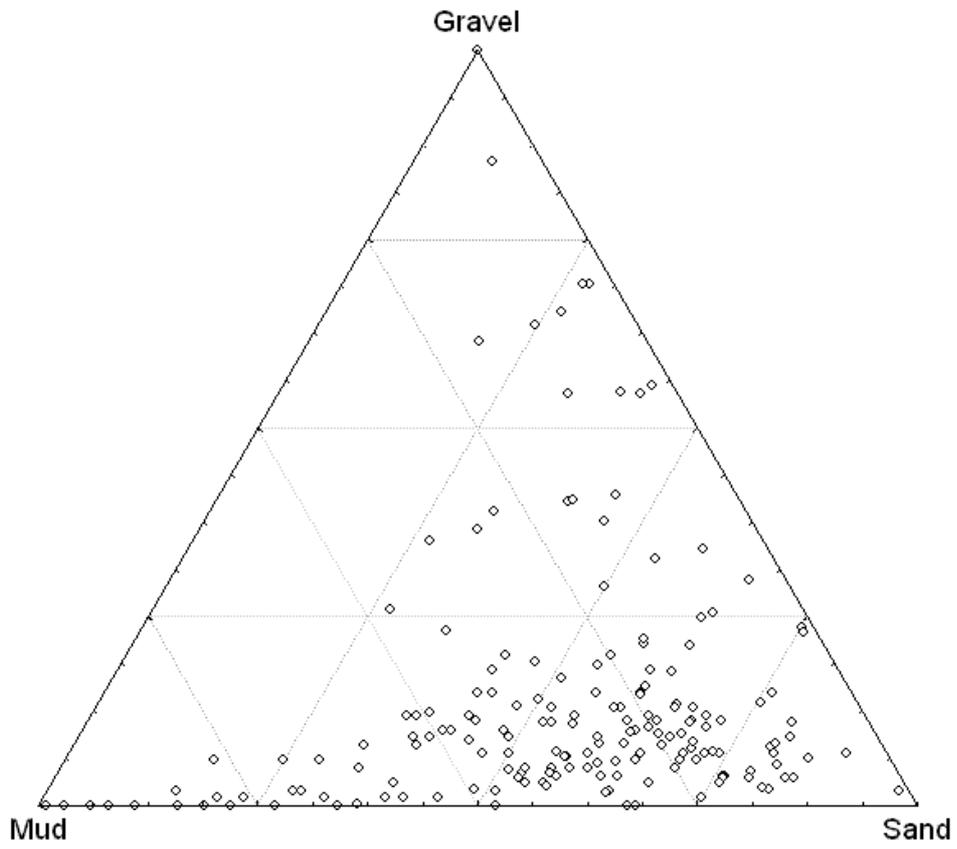
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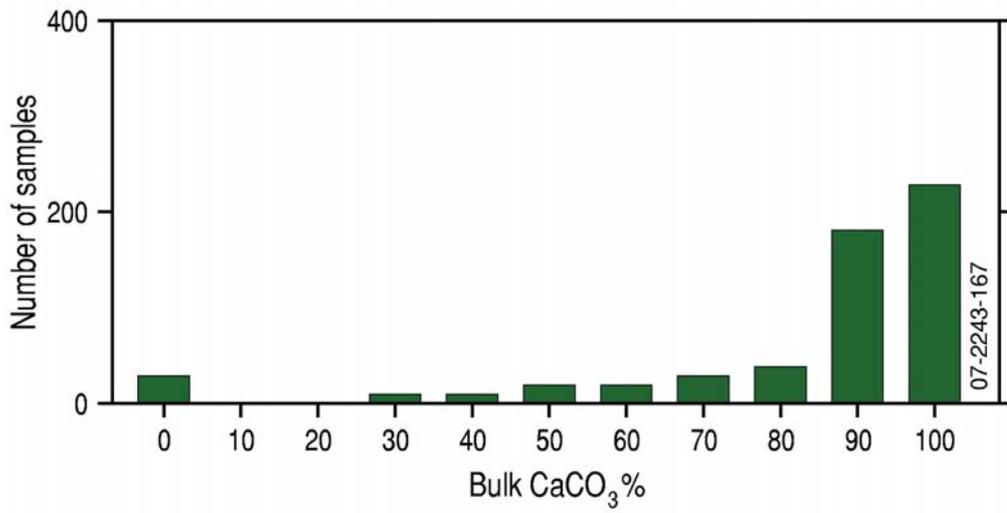
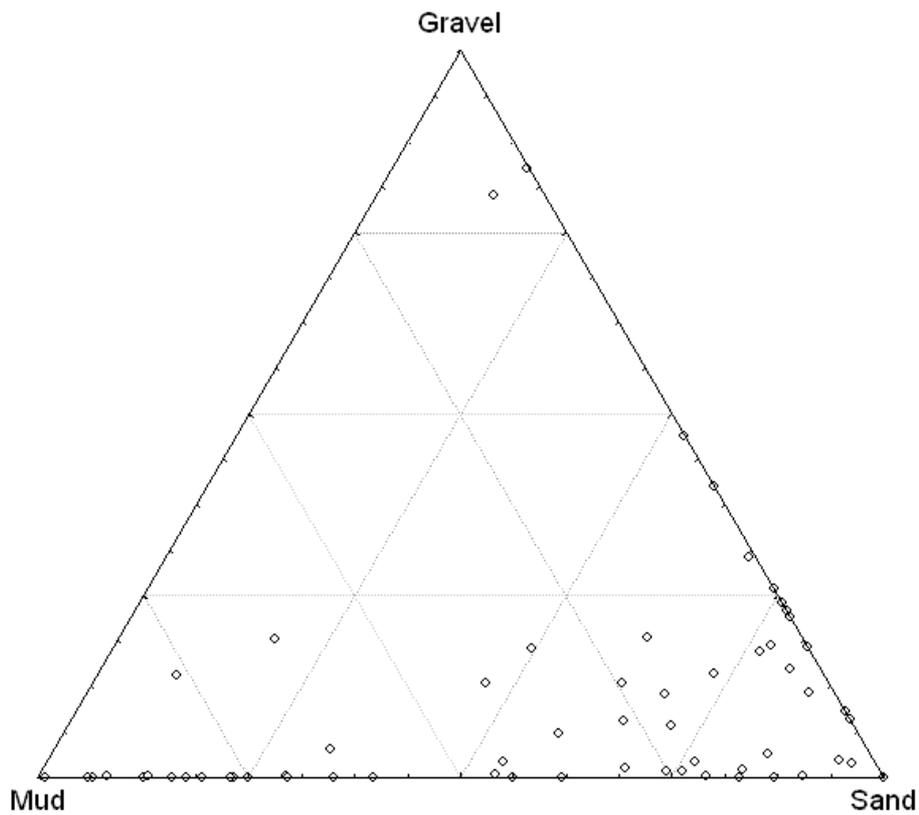
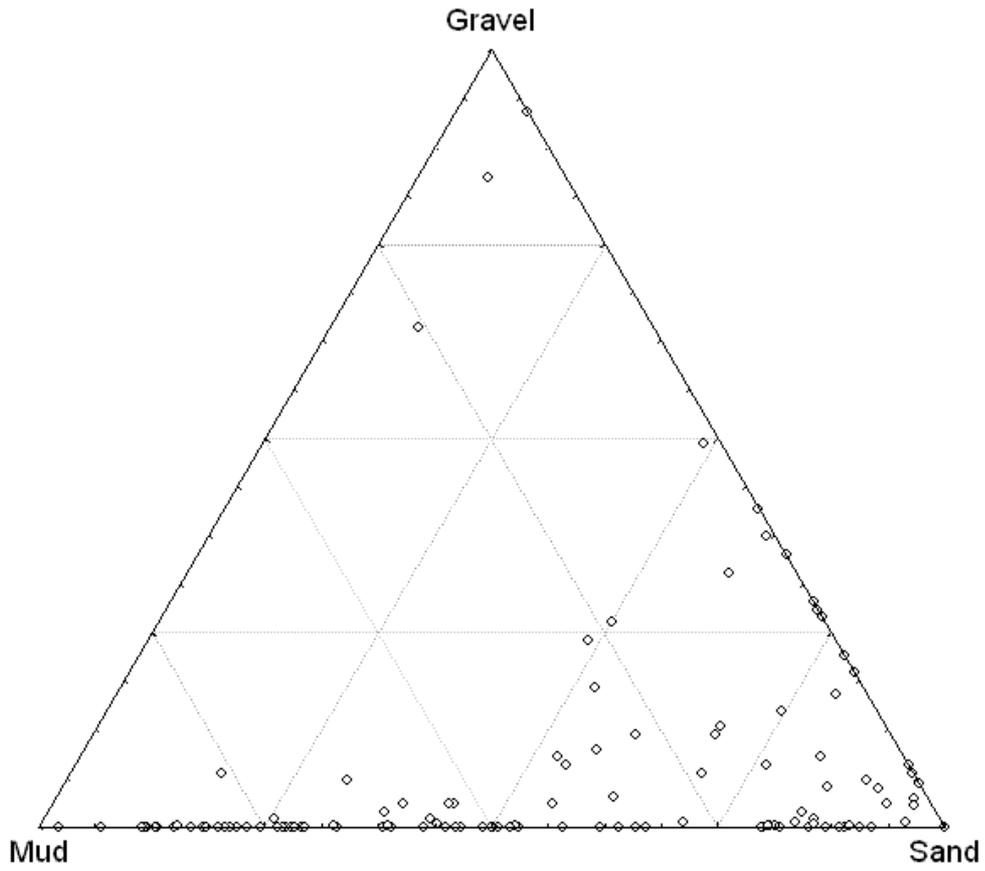


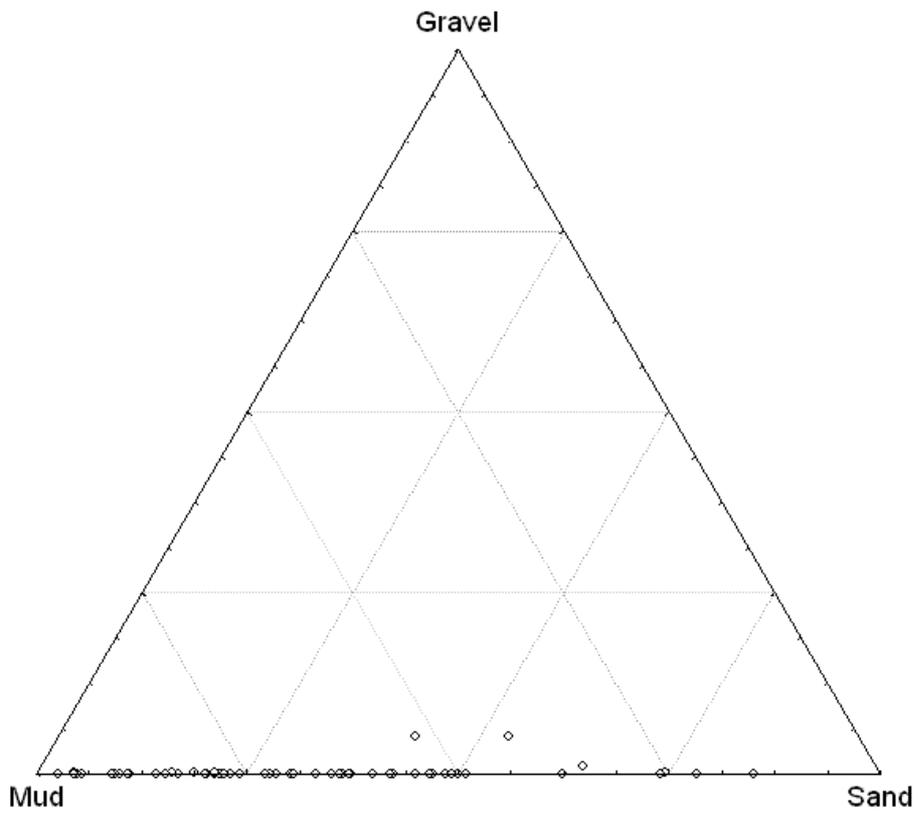
Figure 5.2. Textural composition (mud:sand:gravel ratio) of sediments in the shelf bioregions of the NWMR; a) Northwest Shelf Transition, b) Northwest Shelf Province, c) Central Western Shelf Transition, d) Central Western Shelf Province, and e) Carbonate content of all the above shelf bioregion sediments in the NWMR.

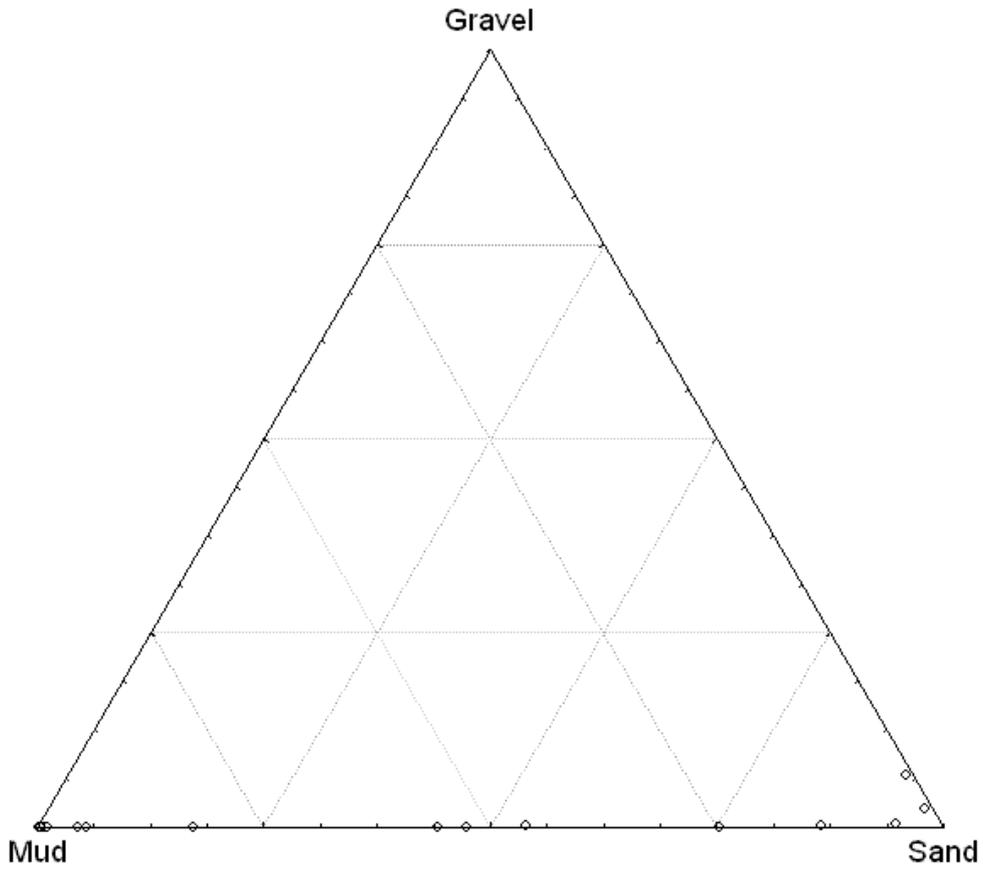
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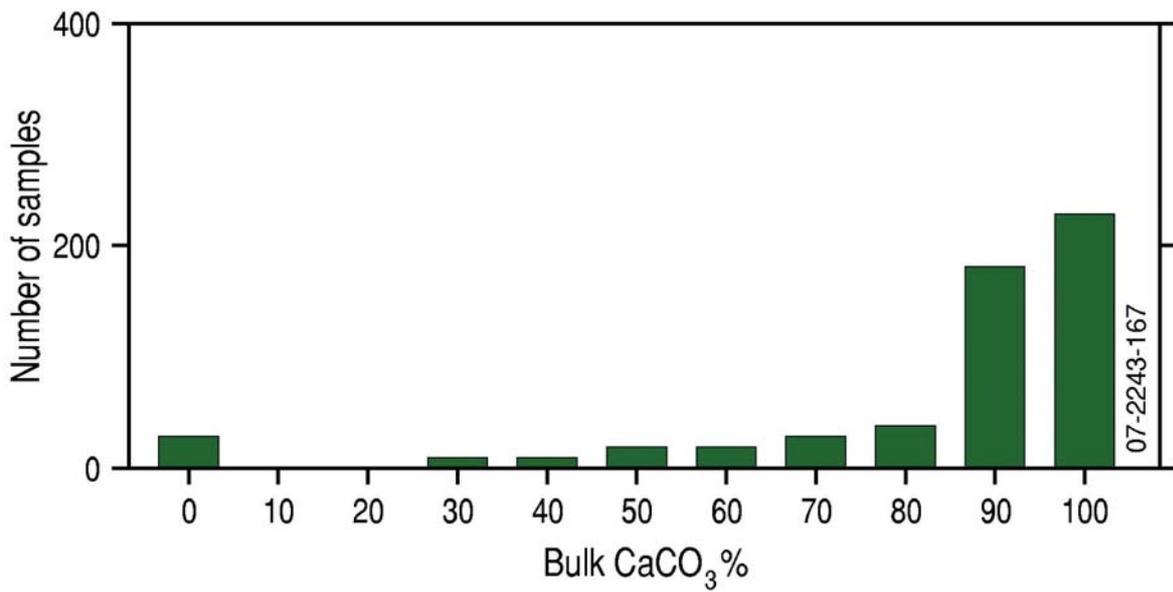


b)
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Figure 5.3. a) Textural composition (mud:sand:gravel ratio) of sediments in the offshore bioregions of the NWMR; a) Central Western Transition, b) Timor Province, c) Northwest Transition, d) Northwest Province, and e) Carbonate content of all the above offshore bioregion sediments in the NWMR.

Table 5.1. Description of change in sample coverage of the NWMR area of bioregions with task

Bioregion	No. sample points (no. added for task)*	% NWMR Area	Average sample density (km ²)
Northwest Shelf Transition	208 (62)	13	1:650
Northwest Shelf Province	463 (51)	20	1:450
Central Western Shelf Transition	9 (6)	<1	1:800
Central Western Shelf Province	13 (1)	3	1:2,550
Central Western Transition	15 (6)	15	1:10,850
Timor Province	77 (42)	15	1:2,000
Northwest Transition	125 (34)	17	1:1,450
Northwest Province	58 (33)	17	1:3,100

*The task that was set by the MOU between DEWHA and GA.

5.2. CENTRAL WESTERN SHELF TRANSITION (CWST)

5.2.1. Geomorphology and bathymetry

The Central Western Shelf Transition (CWST) covers a total area of 7,340 km², all of which occurs in the NWMR (Fig 5.1). This bioregion represents <1% of the total area of the NWMR (Table 5.1). The CWST is located on the continental shelf from north of Carnarvon to the tip of the North West Cape (Fig. 5.4a). It is bounded to the north by the Northwest Shelf Province and to south by the Central Western Shelf Province. The Central Western Transition and Northwest Province lie off the shelf adjacent to the CWST.

The CWST is located almost entirely on the seabed (unassigned). The shelf area included in the bioregion varies in width from approximately 25 km in the south to less than 1 km in places along the western edge of the Northwest Cape. Water depths vary from 0 to approximately 80 m near the shelf break in the south of the bioregion (Fig 5.5a). Approximately 460 km² (15%) occurs in water depths <10 m and has been excluded from this study. More than 55% of the remaining area of the bioregion (~15,000 km²) occurs in depths between 50 and 80 m (Fig 5.5b).

CWST is dominated by shelf (unassigned). Canyons and terraces are the only geomorphic features identified in this bioregion, and these cover ~1,140 km² (~15.55%) of the bioregion (Table 5.2). Canyons occur on the northern extent of the CWST, and terraces occur running in bands (~10 km in width) parallel to the shore.

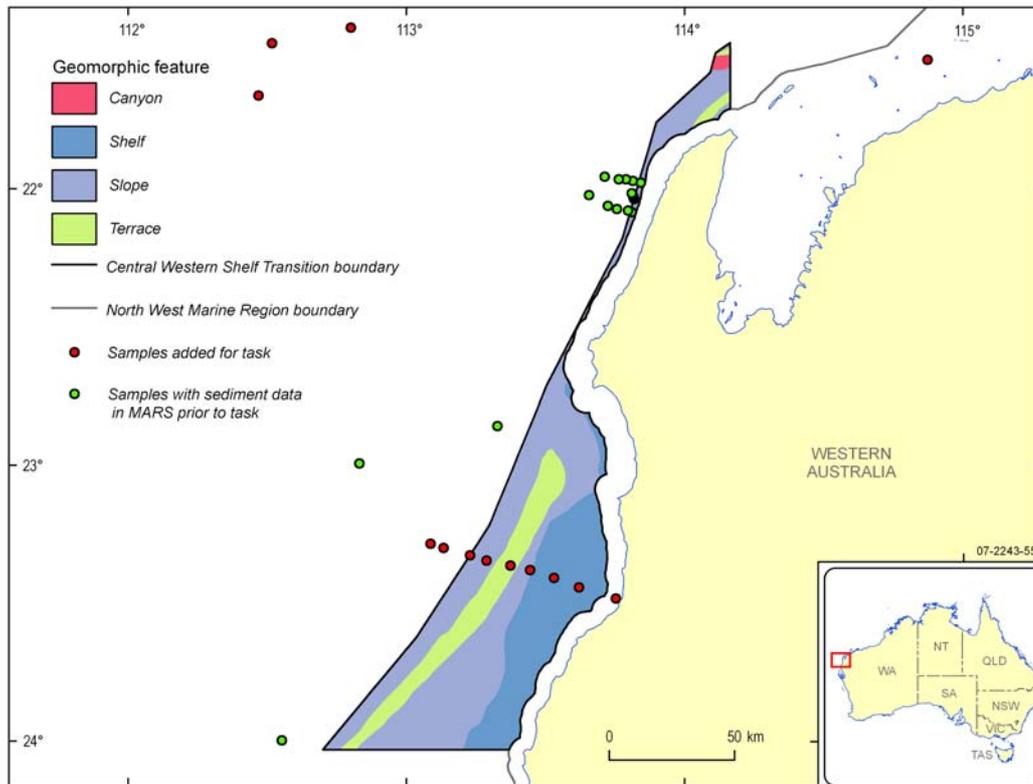
Areas of unassigned shelf are both identified as significant features characterising the Central Western Shelf Transition. Due to the complex shape of the coast and current patterns in this region (Section 3.1.2), the sedimentology of the shelf in the CWST may differ from that of shelf areas elsewhere in the NWMR.

5.2.2. Sample Coverage

The CWST is represented by nine data points (Figs. 5.4a & 5.5a). Six of these occur in a cross-shelf transect south of the bioregion. The remaining samples occur in a line parallel to the shore

towards the north of the bioregion. Samples provide coverage of the mid-range of water depths present on the shelf, occurring at depths between 50 and 250 m. Assays from these samples may not provide a good representation of the range of sediments occurring on the shelf due to small sample numbers. Despite targeted sample acquisition, only six samples were collected from reefs in the CWST; sedimentology of reefs is discussed in Chapters 3 and 6.

a)



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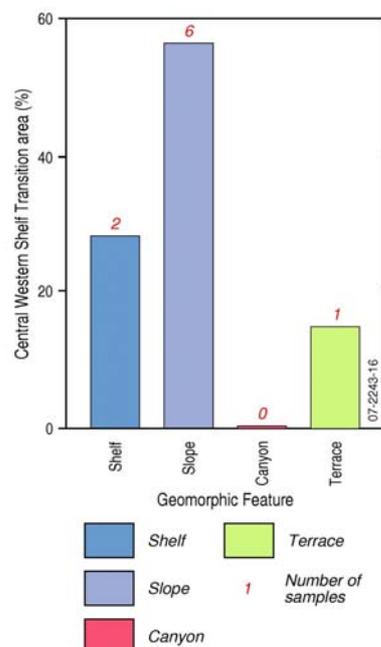
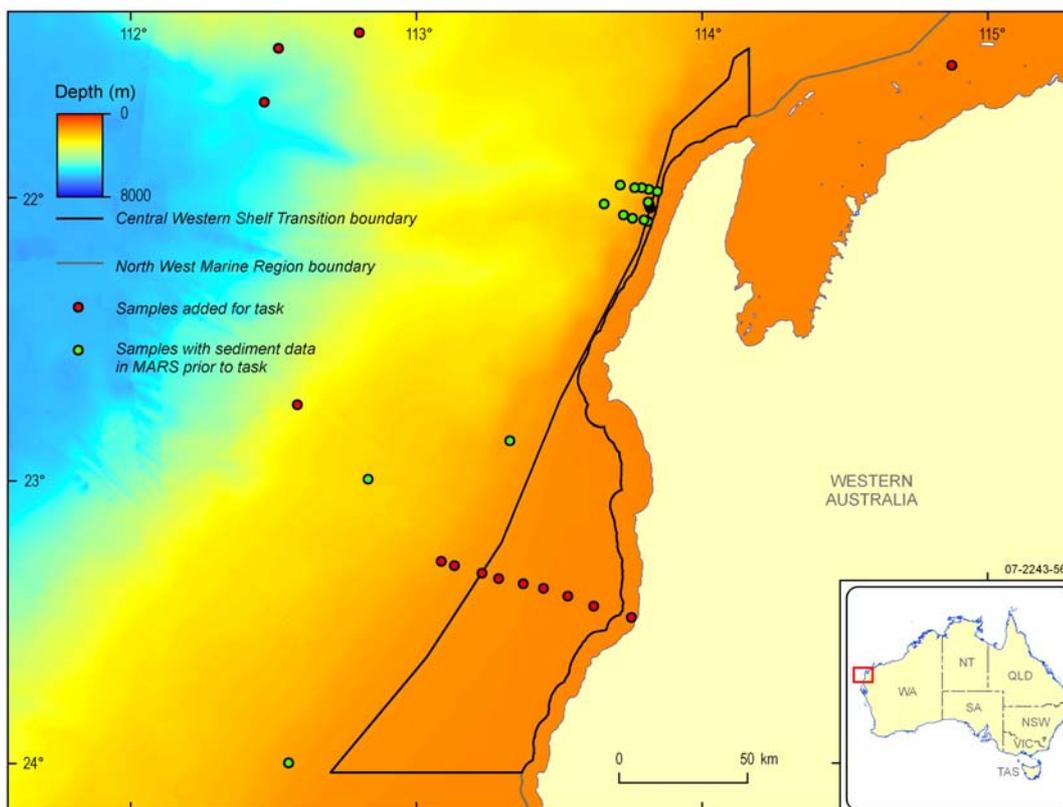


Figure 5.4. a) Geomorphology of the Central Western Shelf Transition (CWST) with location of samples; and b) Percentage area of each geomorphic feature within the CWST with number of corresponding sediment samples.



a)
b)

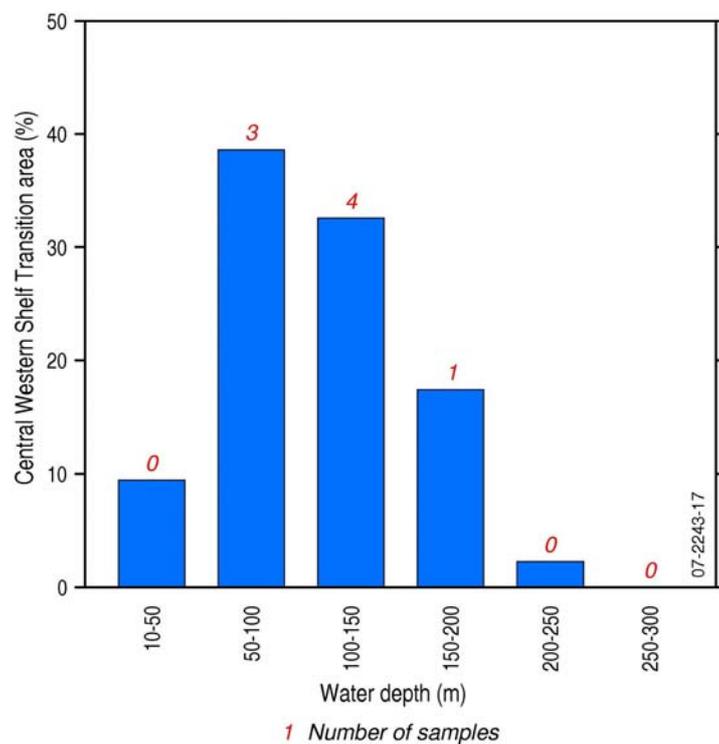


Figure 5.5. a) Bathymetry of the Central Western Shelf Transition (CWST) with location of samples; and b) Percentage area of bathymetry class within the CWST with number of corresponding sediment samples.

Table 5.2. Details of the geomorphology of the Central Western Shelf Transition.

Feature	% of bioregion area covered	% of NWMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
<i>Geomorphic Feature</i>			
Unassigned shelf and slope	84.44	-	-
Canyon	0.50	0.34	0.03
Terrace	15.05	0.49	0.19

Table 5.3. Distribution of water depths covered by the geomorphology in the Central Western Shelf Transition.

Feature	Depth Range (m)	Mean Depth (m)
<i>Geomorphic Province</i>		
Unassigned shelf and slope	35 - 210	105
<i>Geomorphic Feature</i>		
Canyon	180 - 210	195
Terrace	45 - 240	125

5.2.3. Sedimentology of the Central Western Shelf Transition

A total of nine samples were collected from the CWST, two from the shelf (unassigned), six from the slope (unassigned) and one from the terrace (Figs. 5.4a & 5.4b). Texture and composition of the sediments on the shelf are homogenous with the sand fraction comprising 98-99%, gravel <3%, and mud <1%. Bulk carbonate content and carbonate sand content attain 96%, and carbonate gravel attains 95%.

A total of six samples were obtained from the slope (unassigned). Assays indicate that this feature is characterised by relatively homogenous sediments dominated by sand, ranging between 82 and 93% with one sample containing 56% (Fig. 5.6). Mud is the next most abundant fraction with contents ranging between <1 and 18%, attaining 37% in one sample. Gravel attains up to 8% in all samples apart from one, which attains 14%. Bulk carbonate content ranges between 73 and 94% in all samples, carbonate sand ranges from 76 to 93%, and carbonate gravel ranges between 80 and 100% (Fig. 5.7). Carbonate mud attains up to 74% in three samples.

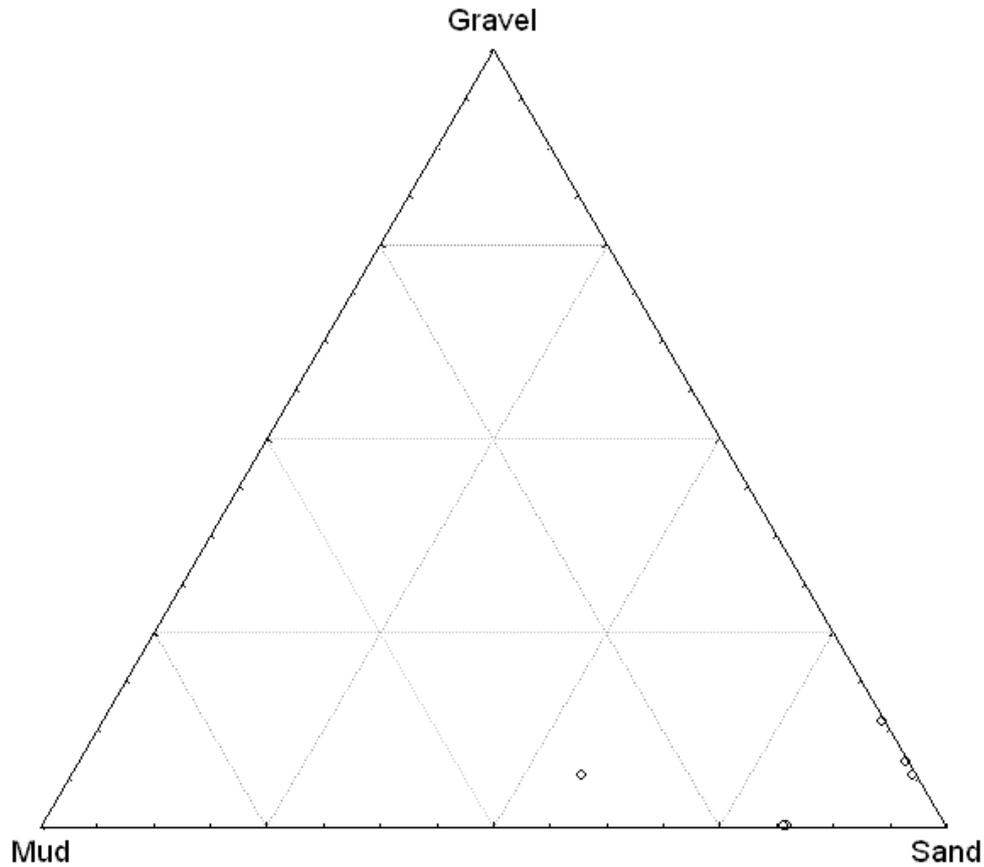


Figure 5.6. Textural composition (mud:sand:gravel ratio) of slope sediments within the CWST.

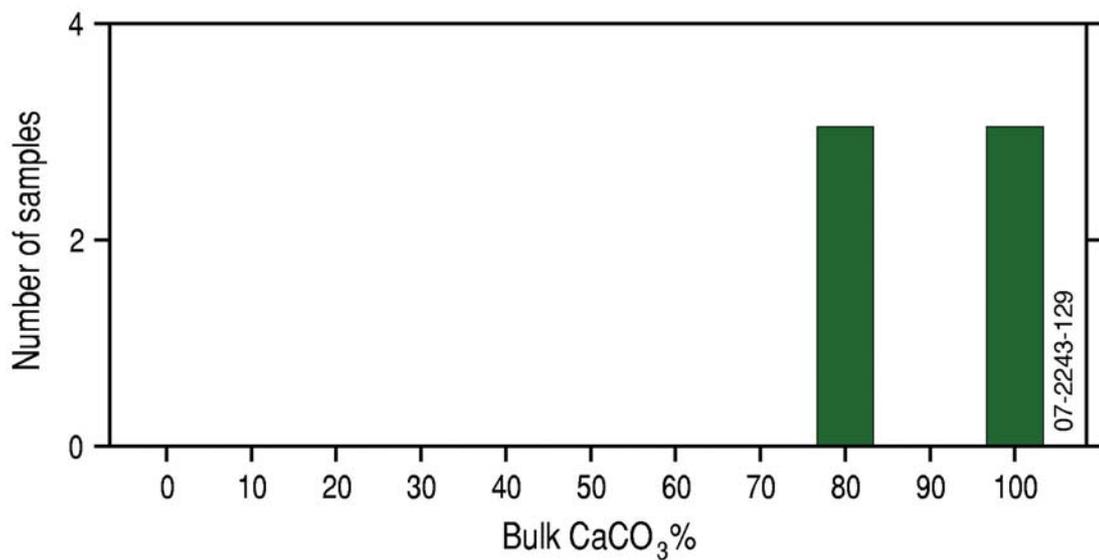


Figure 5.7. Carbonate content of slope sediments within the CWST.

5.3. CENTRAL WESTERN SHELF PROVINCE (CWSP)

5.3.1 Geomorphology and bathymetry

The Central Western Shelf Province (CWSP) covers a total area of 33,000 km², all of which is situated in the NWMR (Fig. 5.1). This bioregion represents 3% of the total area of the NWMR

(Table 5.1). The CWSP is located on the shelf offshore between Kalbarri and Coal Bay (Fig. 5.8a). The Bioregion lies on the southern boundary of the NWMR and is bounded to the north by the CWST and to south by the Southwest Shelf Transition (not included in the NWMR).

The CWSP is located on the shelf and upper slope (Table 5.4; Fig. 5.8a). The shelf varies in width from <20 km in the north to approximately 125 km in the vicinity of Shark Bay. Water depths range from 0 to approximately 100 m near the shelf break and in deeps/holes/valleys in the south of the bioregion (Fig 5.9a). Almost half of the area of the bioregion lies in depths between 50 and 100 m, and less than 2% lies in depths of >100 m. (Fig. 5.9b). Approximately 10,000 km² (>30%) occurs in water depths of <10 m and has been excluded from this study.

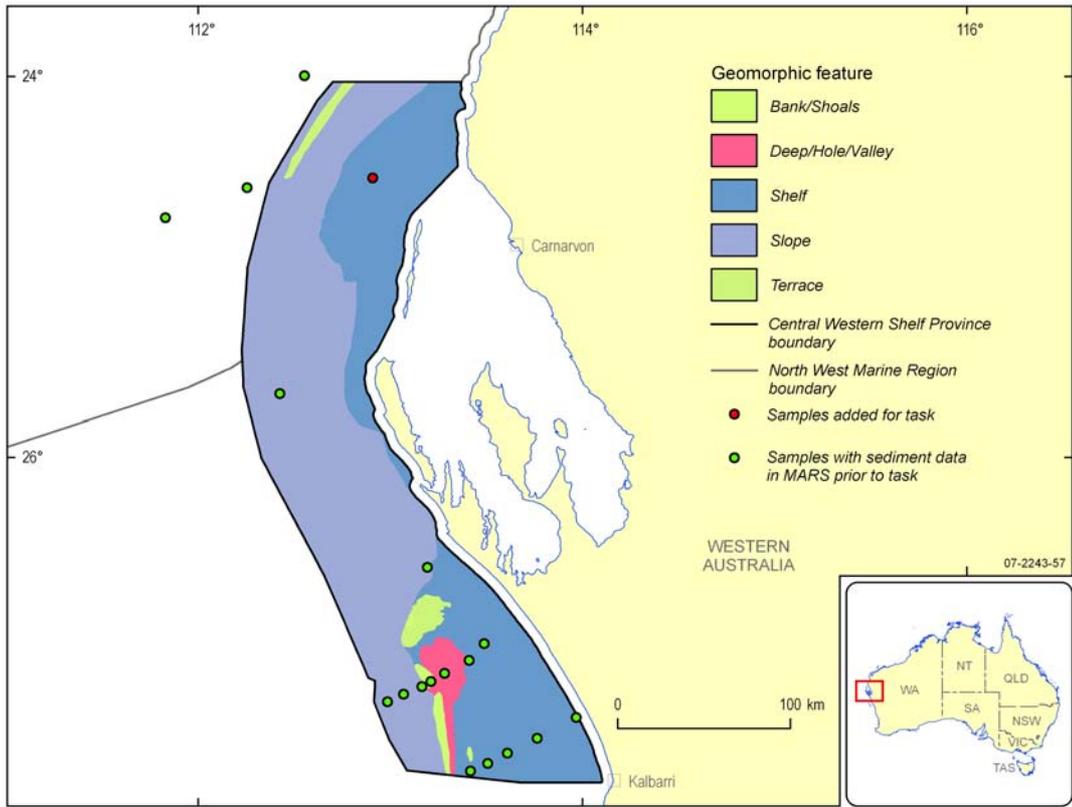
The CWSP is dominated by unassigned shelf and slope (30,000 km², 94% CWSP area). Small areas of deeps/holes/valleys (780 km², 2% CWSP area), terraces (710 km², 1%) and banks/shoals (330 km², 1%) are located within the shelf (Table 5.4).

Three significant geomorphic features are identified in the CWSP: Unassigned shelf and slope cover the majority of the bioregion. Banks/shoals in the CWSP form the second largest of three major occurrences of these features and lie at significantly lower latitudes than other banks/shoals in the NWMR.

5.3.2. Sample coverage

The CWSP is represented by 13 sample points (Fig. 5.8a). All but two of the total data points occur in two transects across the shelf and slope in the south of the bioregion in water depths ranging from 60 to >100 m. Data coverage is sparse to the north of Shark Bay with only one sample collected from this area.

Average sample density across the bioregion is approximately 1:2,550 km². Samples attain sufficient coverage to describe the sediment distribution on the shelf (unassigned) and slope (unassigned) only; other features contain <3 data points. Only two samples were collected from banks/shoals, and one sample was collected from deeps/holes/valleys. One sample was added to the shelf in the CWST during this study. No samples collected from tidal sand wave/sandbanks and banks/shoals were available for procurement. Sedimentology for these features is discussed in Chapter 3, 4 and 6. This sample distribution means that results for the shelf represent only the area offshore northwest of Kalbarri. The results best represent sediments occurring in shallow water, with approximately 50% of data points occurring in <40 m water depth (Fig 5.9a & 5.9b).



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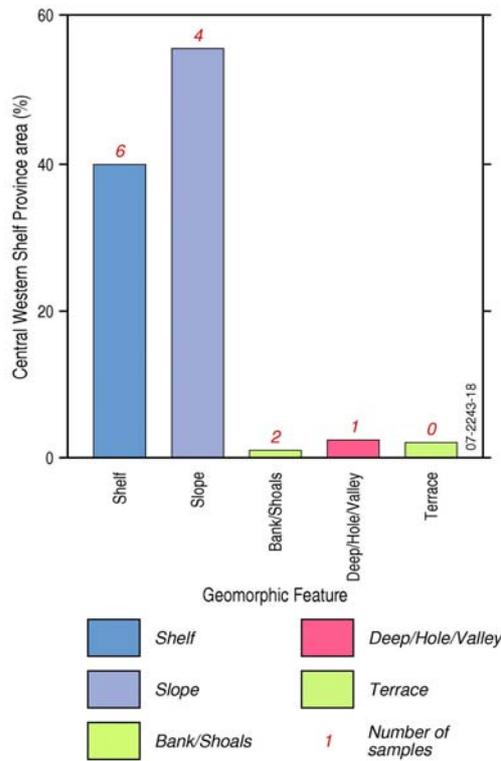
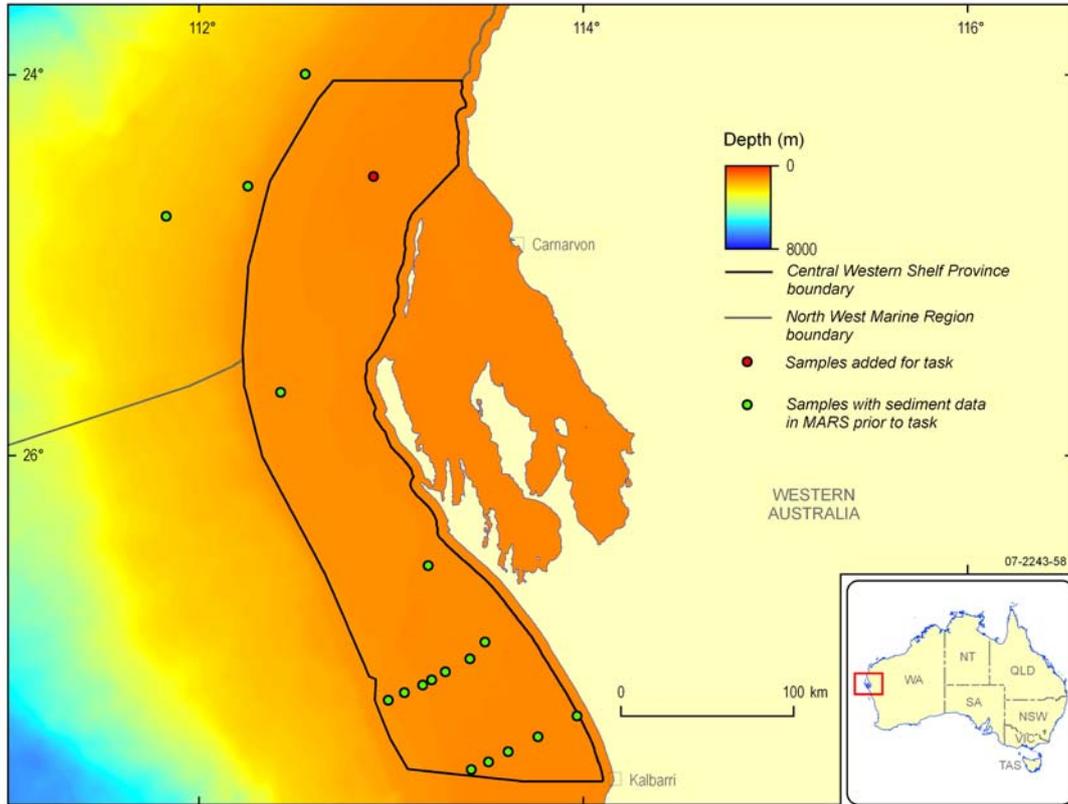


Figure 5.8. a) Geomorphology of the Central Western Shelf Province (CWSP) with location of sediment samples; and b) Percentage area of each geomorphic feature within the CWSP with number of corresponding sediment samples.



a)
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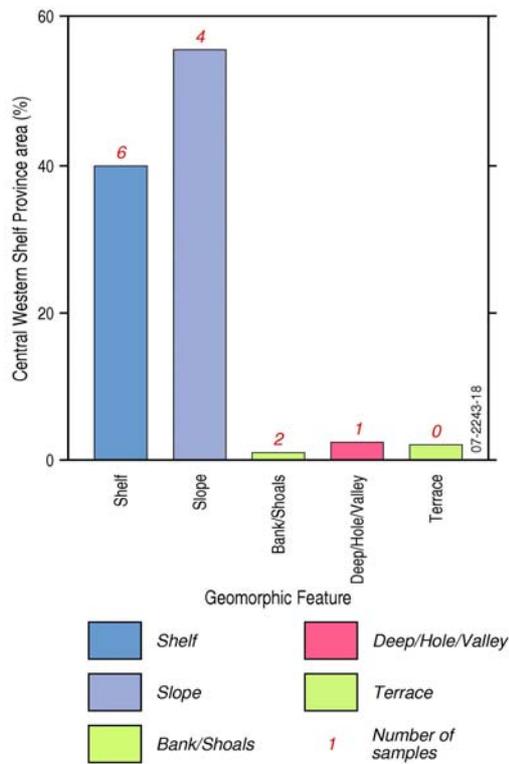


Figure 5.9. a) Bathymetry of the Central Western Shelf Province (CWSP) with location of sediment samples; and b) Percentage area of each bathymetry class within the CWSP with number of corresponding sediment samples.

Table 5.4. Details of the geomorphology of the Central Western Shelf Province.

Feature	% of bioregion area covered	% of NWMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
<i>Geomorphic Feature</i>			
Unassigned shelf and slope	94.51	-	-
Bank/Shoals	0.99	1.12	0.65
Deep/Hole/Valley	2.37	0.84	0.47
Terrace	2.14	0.31	0.12

Table 5.5. Distribution of water depths covered by the geomorphology in the Central Western Shelf Province.

Feature	Depth Range (m)	Mean Depth (m)
<i>Geomorphic Province</i>		
Unassigned shelf and slope	35 – 235	105
<i>Geomorphic Feature</i>		
Bank/Shoals	45 – 110	85
Deep/Hole/Valley	75 – 105	100
Terrace	50 – 175	120

5.3.3. Sedimentology of the Central Western Shelf Province

A total of 13 grain size and 15 carbonate assays are available for the CWSP in water depths of >10 m. All but one of these occurs on the shelf south of Shark Bay. Sediment texture in this area is relatively homogeneous. Sand is the dominant size fraction in all samples with contents ranging from 79 to 100% (Fig 5.10). Sand content exceeds 96% in seven out of 13 samples. Gravel comprises <5% in 10 out of 13 samples, and <1% in four samples. Mud comprises <1% in all but two samples, which attain up to 10%.

To the south of Shark Bay, carbonate content comprises >75%, and >89% to the north (Fig. 5.11). Carbonate content exceeds 80% in 14 samples (93%). Carbonate assays from the area of Shark Bay located at water depths <10 m show that similar variability is occurs across the embayment.

5.3.4. Sedimentology of Significant Geomorphic Features

5.3.4.1. Dirk Hartog Shelf

A total of six samples were obtained from the Dirk Hartog Shelf. Assays indicate that this feature is characterised by relatively homogeneous sediments dominated by carbonate sands. Sand is the dominant fraction with contents generally ranging between 94 and 100% (Fig. 5.10a). Gravel is the next most abundant fraction with contents attaining <6%. Mud content attains

<1%. Bulk carbonate content ranges from 78 to 95% (Fig. 5.11a). Carbonate sand ranges between 93 and 95%, and carbonate gravel ranges from 75 to 100% in five samples.

5.3.4.2 Slope (*unassigned*)

A total of four samples were obtained from the slope (*unassigned*). Assays indicate that this feature is characterised by relatively homogenous sediments dominated by sand with contents ranging from 87 to 94% (Fig. 5.10b). Gravel is the next most dominant fraction with contents ranging between <1 and 6%. Mud content attains 7% in four samples. Bulk carbonate content ranges from 85 to 94%, carbonate sand ranges between 90 to 95% in four samples, and carbonate gravel ranges between 95 and 100% (Fig. 5.11b).

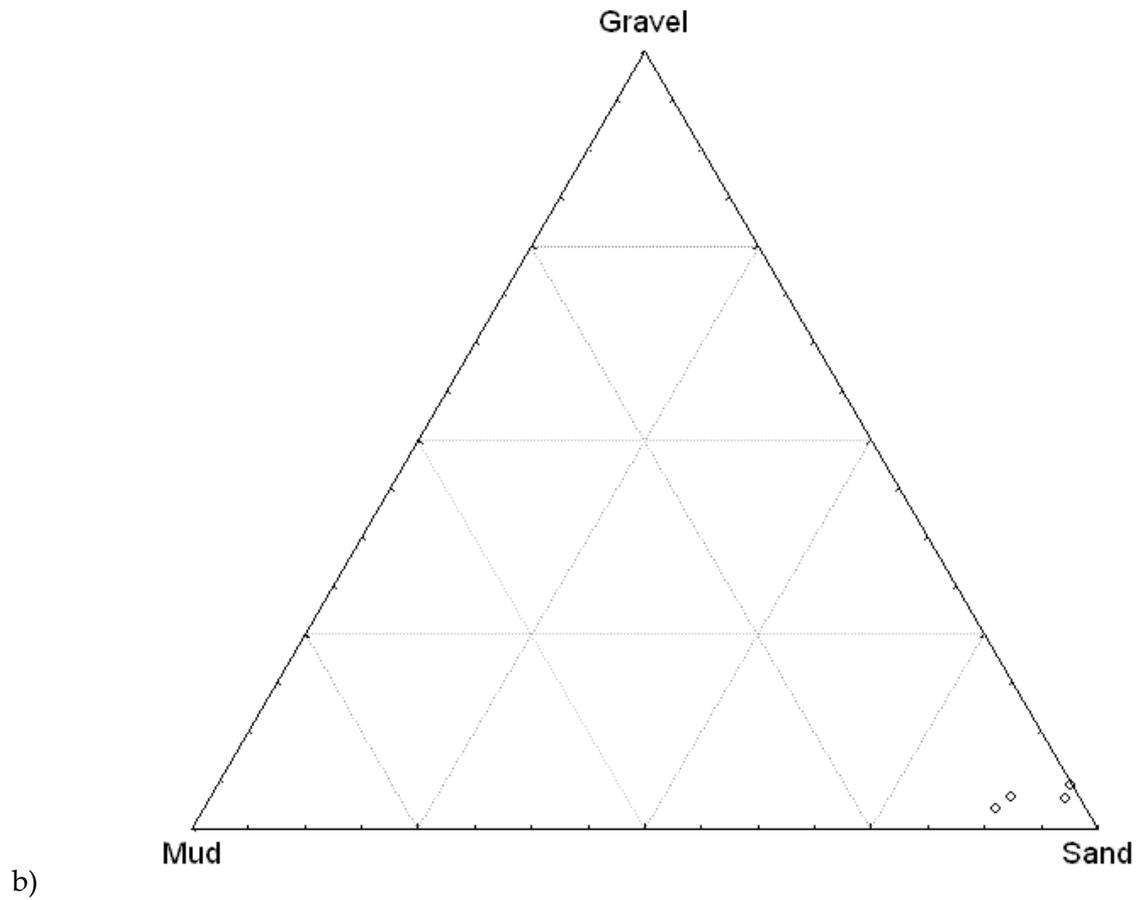
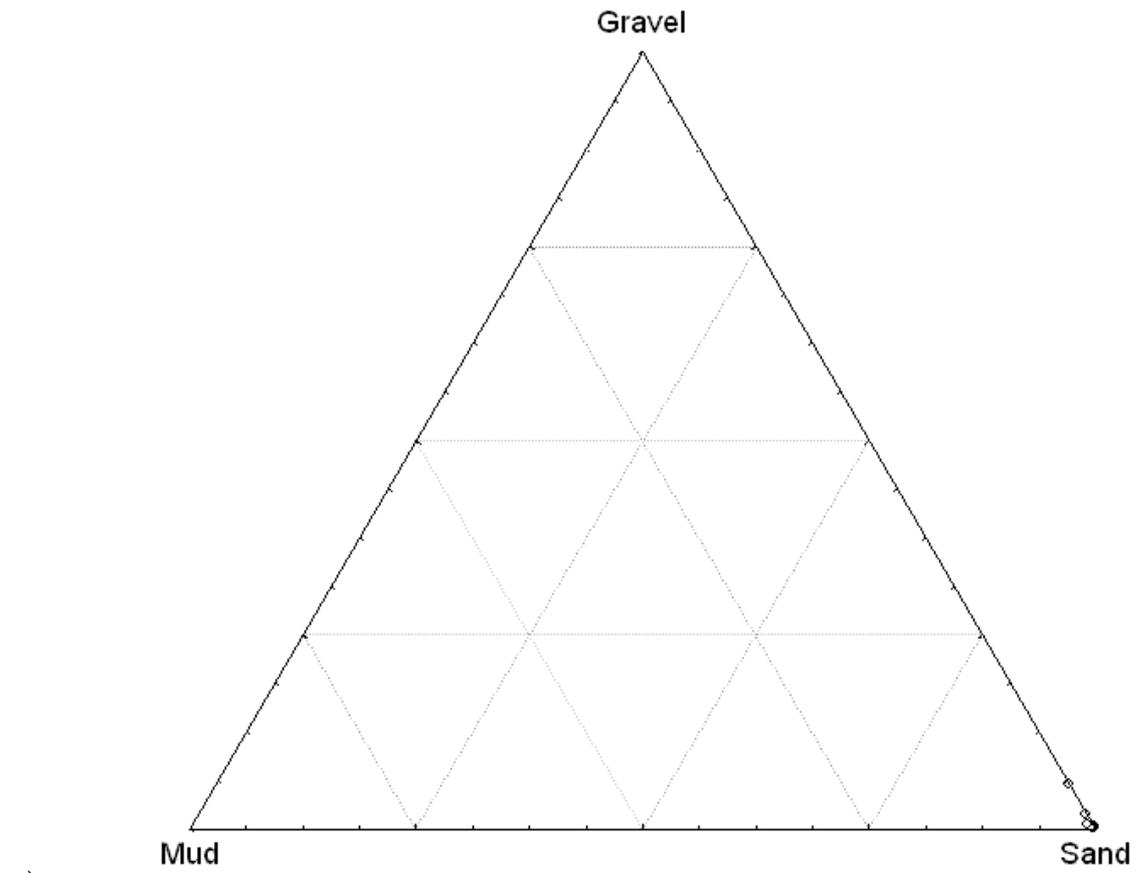


Figure 5.10. Textural composition (mud:sand:gravel ratio) of a) shelf and b) slope sediments within the CWSP.

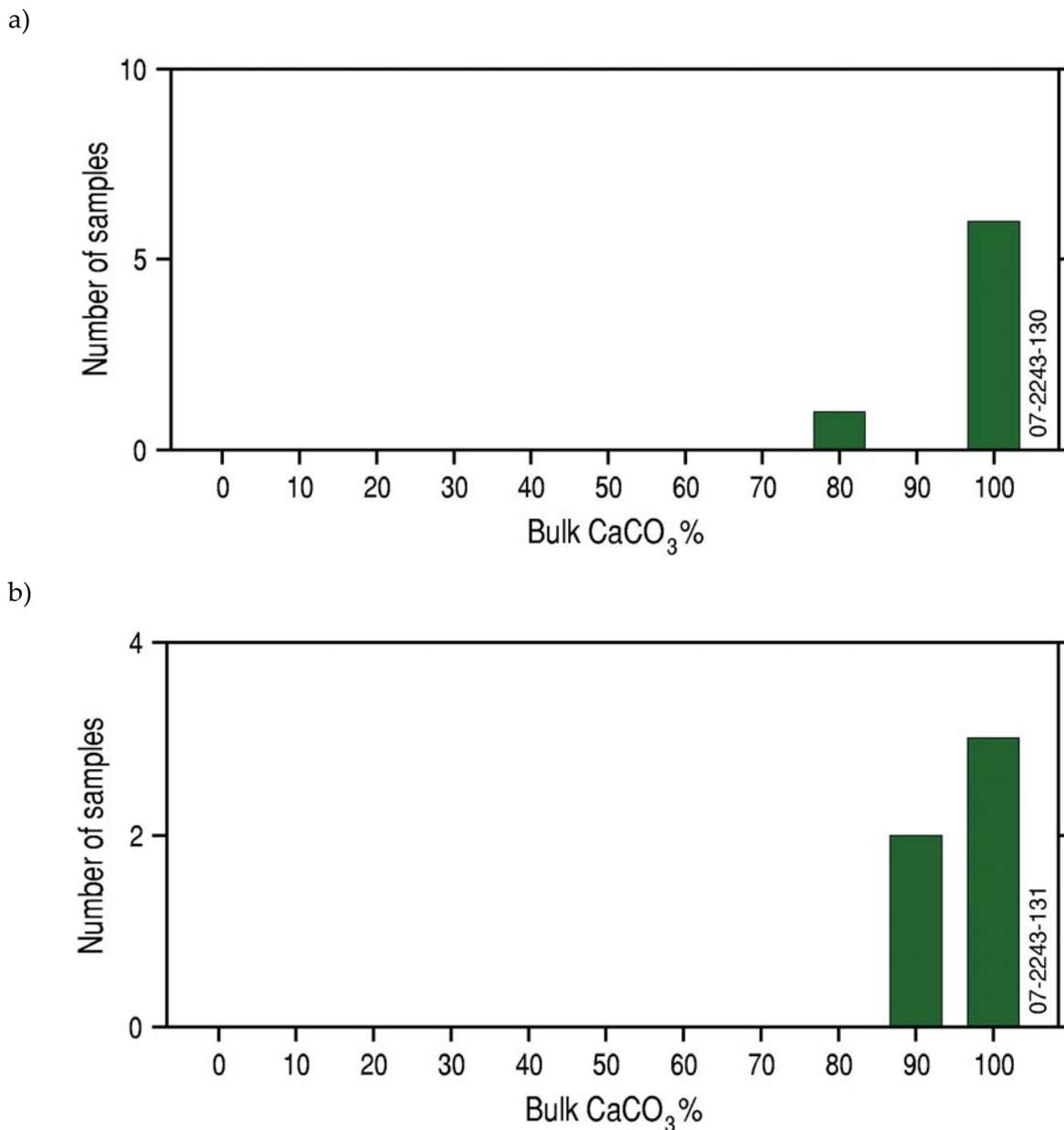


Figure 5.11. Carbonate content of sediments within the CWSP on a) shelf and b) slope.

5.4. NORTHWEST SHELF PROVINCE (NWSP)

5.4.1. Geomorphology and bathymetry

The Northwest Shelf Province (NWSP) covers a total area of 209,740 km², all of which is situated in the NWMR (Fig 5.1). This bioregion represents 20% of the total area of the NWMR (Table 5.1). The NWSP is located on the shelf between the North West Cape and Cape Bougainville. Between the southernmost point and Cape Leveque, the bioregion covers the entire width of the shelf. North of Cape Leveque, the bioregion extends from the shelf break to 80 km of the coast. In this area it is separated from the coast and bounded to the north by the Northwest Shelf Transition. The western boundary of the Northwest Shelf Province coincides with the Timor Province in the north and Northwest Transition and Northwest Province in the south.

The NWSP is located predominantly on the shelf and includes a section of the upper slope (Fig. 5.12a). The shelf is narrow in the south, approximately 50 km adjacent to Exmouth Gulf, and widens to >250 km north of Cape Leveque. Water depths vary from 0 to approximately 200 m along the shelf break and within the deeps/holes/valleys to the south of the bioregion. More than 45% of the bioregion lies in depths between 50 and 100 m (Fig. 5.13b).

Unassigned shelf and slope in the NWSP cover 122,990 km² (59% of the area of the NWSP). Terraces cover 45,570 km², (22% of the area of the NWSP) and deep/hole valleys 26,040 km², (12%). Plateaus cover 9,740 km², (5%), banks/shoals 2,310 km², (1%), and pinnacles 200 km², (0.1%) of the bioregions (Table 5.6).

Six significant geomorphic features are identified for the NWSP. The Rowley Shelf covers 47% of the bioregion and forms >70% of the area of the shelf in the NWMR. Banks/shoals in the NWSP display significant differences in morphology and dimensions from those in adjacent bioregions; they are therefore likely to be characterised by different sedimentology. Deeps/holes/valleys cover a significant area of the bioregion (26,040 km²) and occur in two separate locations, each displaying morphology that distinguishes them from deeps/holes/valleys elsewhere in the NWMR. The Leveque Rise (a large plateau) is one of only two plateaus in the NWMR located on the shelf and extending into water depths as shallow as 100 m. Terraces located in water depths <200 m in the NWSP are unique to the northern NWMR; individual terraces cover larger areas and display morphology that differs from terraces occurring at these water depths in other shelf bioregions (Table 5.7). These form part of a suite of mid-shelf terraces that extend into the adjacent NWST and Timor Province Bioregions. However, the sedimentology in these features is best described in the NWSP as both the majority of the area of these features and best sample coverage occurs there.

Pinnacles occur in the south of the bioregion. These features cover a minor area of the NWSP (<1%) but form approximately 29% of the total area of this feature in the NWMR, with >70% of the pinnacles in the NWMR occurring outside of the NWST.

5.4.2. Sample Coverage

The Northwest Shelf Province is represented by 463 samples (Fig. 5.12a & b; Table 5.1). The majority of the samples occur on the mid-to outer-shelf, with more than 200 (>40%) samples located >60 km from the coast and 211 (46%) in water depths of >50 m. Average sample density across the bioregion is 1:450 km². Samples achieve sufficient coverage to describe the sedimentology in five of the six significant geomorphic features identified for this bioregion. A total of 178 samples were collected from the area of the Rowley Shelf; this gives an average density of 1:560 km² in this feature.

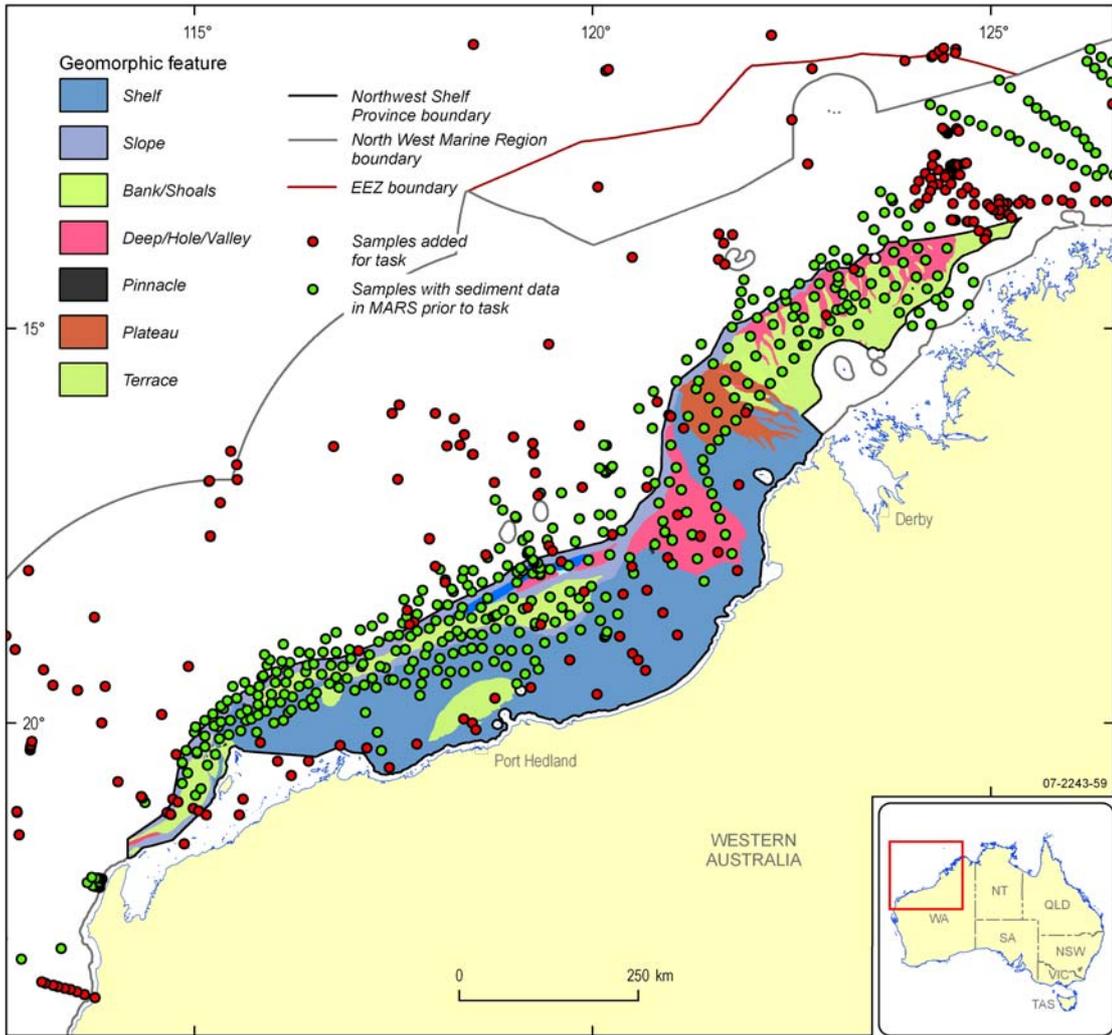
Terraces in shallow water (<200 m) in the NWSP contain 112 samples. Samples are mainly distributed across the area of a large terrace included in the north of the bioregion and a single smaller terrace on the inner shelf off Larrey Point. Samples are relatively evenly distributed within the area of these features, achieving an average density of 1:410 km².

The Leveque Rise contains 10 samples relatively evenly distributed across the feature, giving an average density of approximately 1:970 km². Deeps/holes/valleys contain 46 samples, relatively evenly distributed, with an average sample density of 1:570 km². Banks/shoals contain four samples, giving an average density of 1:800 km².

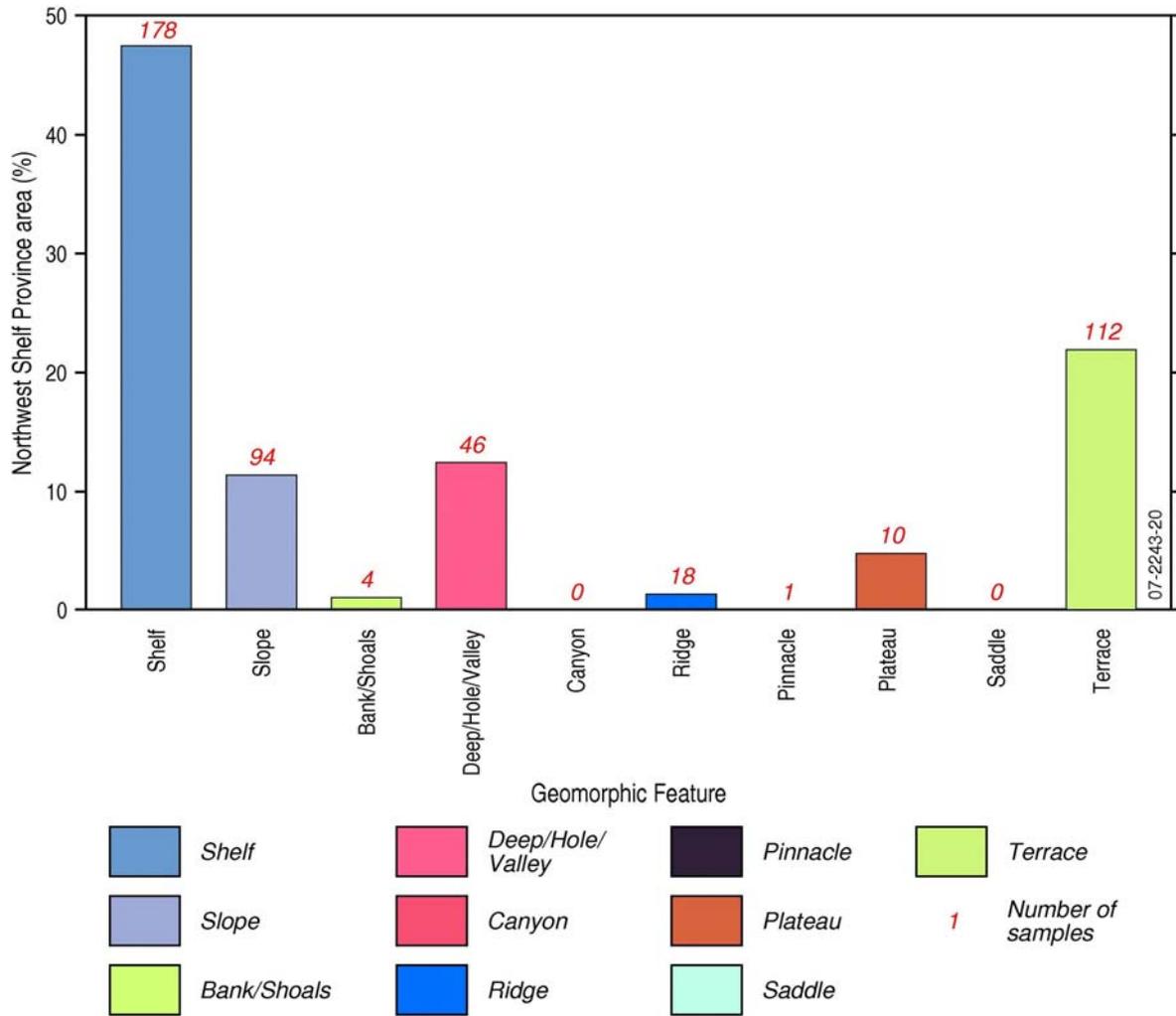
Only two samples were collected from pinnacles, neither of these occurs within the area of pinnacles identified as significant. No samples were available for tidal sand wave/sandbanks. Sedimentology for these features is discussed in Chapters 3, 4 and 6.

A total of 51 samples were added to the NWSP for this study; and, despite targeted sample addition, 23 of these were collected from shelf (unassigned). Samples from the current study increased coverage in deeps/holes/valley (4 samples added), plateau (1), ridge (1), slope (unassigned) (8) and terraces (13).

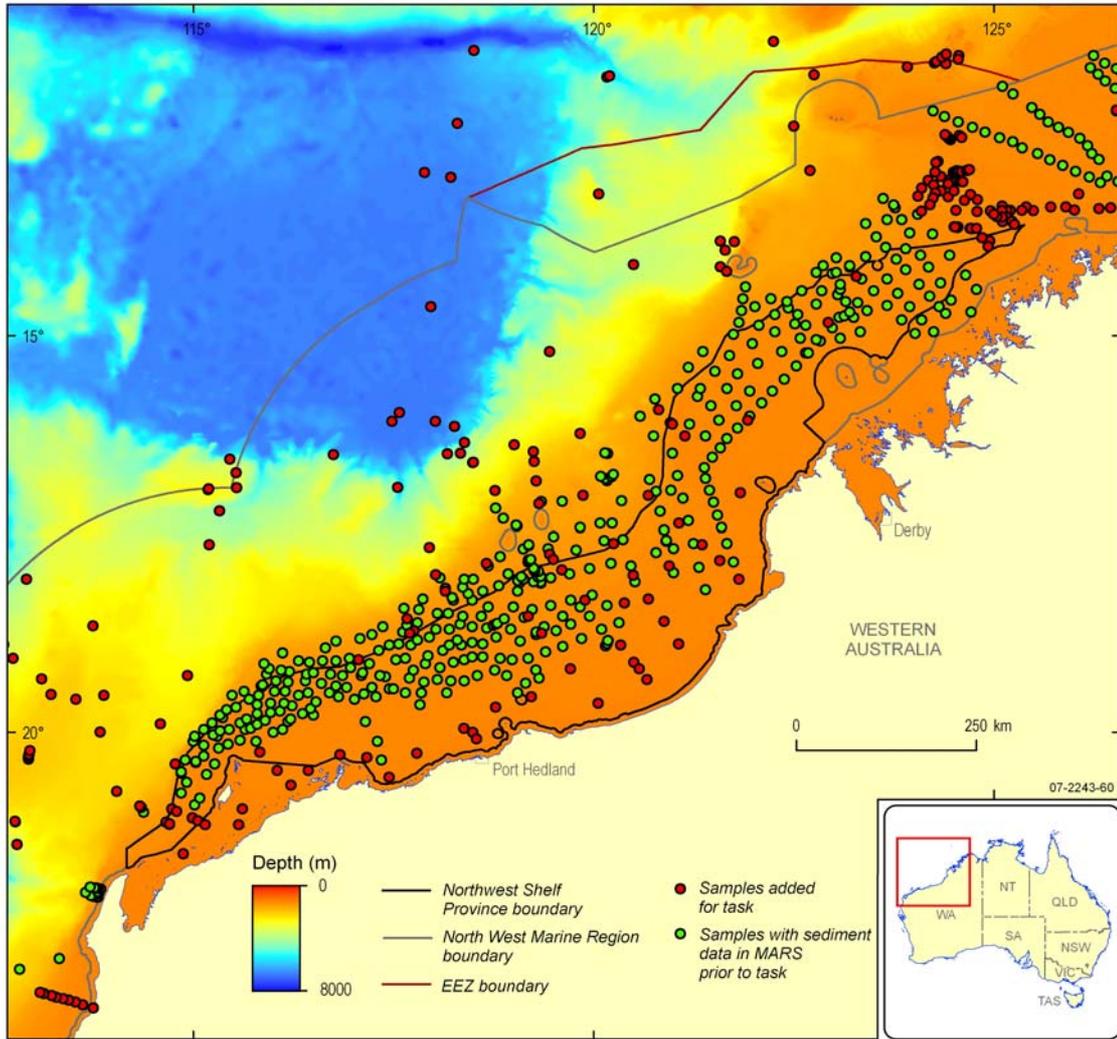
An uneven distribution of samples with higher densities on the outer shelf, particularly on the Rowley Shelf, means that assays are likely to be representative of the range of sediments occurring on the outer shelf but are unlikely to accurately represent the sedimentology of the inner-shelf. The few samples collected from banks/shoals means that the assays may not represent the range of sediments present in these features.



a)



b) Figure 5.12. a) Geomorphology of the Northwest Shelf Province with location of sediment samples; and b) Percentage area of each geomorphic feature within the NWSP with number of corresponding sediment samples.



a)
b)

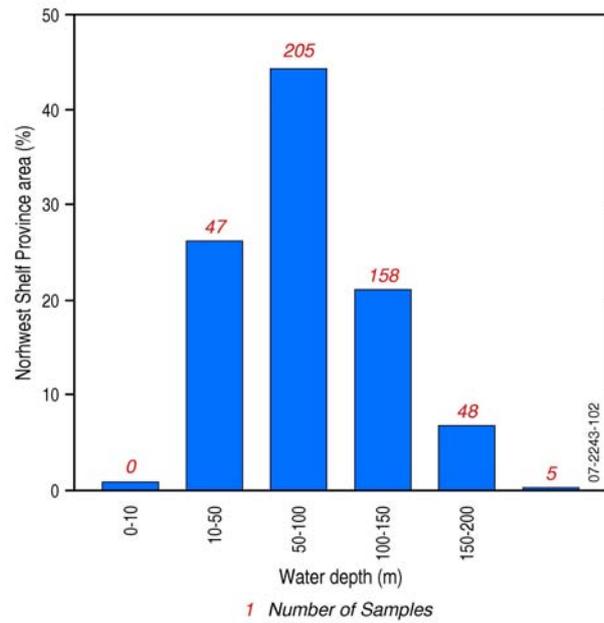


Figure 5.13. a) Bathymetry of the Northwest Shelf Province with location of sediment samples; and b) Percentage area of each bathymetry within the NWSP with number of corresponding sediment samples.

Table 5.6. Details of the geomorphology of the Northwest Shelf Province.

Feature	% of bioregion area covered	% of NWMR area this unit lies within this bioregion	% of EEZ area this unit lies within this bioregion
<i>Geomorphic Feature</i>			
Unassigned shelf and slope	58.64	-	-
Bank/Shoals	1.10	7.93	4.57
Deep/Hole/Valley	12.41	27.91	15.77
Canyon	0.10	2.03	0.21
Ridge	1.23	44.50	2.31
Pinnacle	0.09	29.20	3.87
Plateau	4.64	10.34	0.65
Saddle	0.05	2.85	0.61
Terrace	21.72	20.08	7.86

Table 5.7. Distribution of water depths covered by the geomorphology in the Northwest Shelf Province.

Feature	Depth Range (m)	Mean Depth (m)
<i>Geomorphic Province</i>		
Unassigned shelf and slope	0 – 250	95
<i>Geomorphic Feature</i>		
Bank/Shoals	7 – 120	60
Deep/Hole/Valley	25 – 205	100
Canyon	130 – 190	165
Ridge	115 – 185	145
Pinnacle	5 – 160	60
Plateau	25 – 120	75
Saddle	150 – 165	160
Terrace	10 – 190	90

5.4.3. Sedimentology of the Northwest Shelf Province

A total of 463 grain size assays and 341 carbonate assays are available for the NWSP. Sediments in the south of the NWSP differ significantly from those in the north. South of Broome, sediment texture is relatively homogeneous and dominated by sand. Sand content exceeds 60% in most samples and exceeds 70% in 220 (66%) samples. Sand comprises <10% in three samples on the Leveque Rise and a small terrace west of Dampier. Gravel contents are <20% in 293 (88%) samples in this area and exceed 80% in only two samples that occur along the shelf break. Gravelly sediments may be present at other locations on the shelf but have not been detected due to low sample densities. Mud content exceeds 50% in 45 samples, <20% in 240 (>72%) and <1% in 146 (44%) samples. Mud is slightly more abundant in sediments within 100 km of the

coast and within 100 km of the shelf break and is generally absent from sediments in the area between.

North of Broome, sediment texture is more variable. Sand and gravel dominate, with contents for both fractions ranging between 2 and 100%. The distributions of sand and gravel do not show any obvious spatial pattern. Mud content ranges from 0 to 78% in this area and exceeds 80% in three samples occurring on the slope adjacent to a deep/holes/valleys feature, but it does not attain 1% in 73 (50%) samples.

Bulk carbonate content exceeds 80% in 312 (91%) samples in the NWSP. South of Broome carbonate contents of <60% are present locally but generally exceed 70%. North of Broome, carbonate content is <80% in 70% of samples, with local concentrations of 40%. Few carbonate assays are available for textural size fractions. However, those present indicate sand and gravel in the NWSP comprise >80% carbonate, and carbonate content of mud ranges from 82 to 86%.

5.4.4. Sedimentology of Significant Geomorphic Features

5.4.4.1. Unassigned slope/shelf area

A total of 272 samples were obtained from the shelf and slope. Sand is the dominant size fraction with contents ranging from 8 to 100%, with 237 of the 272 samples containing >50% sand (Fig. 5.14f). Gravel is the next most abundant fraction with contents generally ranging from <1 to 100%, and 12 samples >50%. Mud contents generally range from <1 to 88%, with 22 samples containing >50%. Areas adjacent to plateaus have consistently higher gravel content than other areas of the shelf and lower mud content. The mud content is low (<20%) adjacent to the reefs. However, these areas display large variations in gravel content, with samples locally comprising up to 75% sand or 90% gravel. Bulk carbonate content varies between 64 and 99% with 121 samples containing between 90 and 100% (Fig. 5.15f). Carbonate sand ranges between 69 and 97%, carbonate gravel ranges from 50 to 100% and carbonate mud ranges between 76 and 89%.

5.4.4.2. Banks/shoals

A total of four samples were obtained from banks/shoals (Fig. 5.14a). Sand is the dominant fraction with contents ranging between 22 and 76%; three of the four samples contain >50% sand. Gravel is the next most abundant fraction with contents attaining 20 to 26% in three of the four samples. Mud content is <20% in three of the four samples, although one sample located between deep/holes/valleys contained 78% mud. Assays from banks/shoals in the NWIP suggest that these features may contain a high proportion of seabed sediments dominated by sand with minor gravel and little or no mud. Muddier environments may be present locally but are poorly represented or not sampled. Bulk carbonate content ranges from 60 to 93% (Fig. 5.15a).

5.4.4.3. Deep/hole/valleys

A total of 46 samples were obtained from deep/holes/valleys. Sand is the dominant fraction of the sediments with contents generally ranging between 15 and 100% (Fig. 5.14b); 34 of the 46 samples contain >50% sand. Gravel is the next most abundant fraction with contents attaining

<1 to 85% and six samples containing >50%. Gravel content of sediments is variable, ranging from 3 to 80%. Mud content ranges between <1 and 62% but attains 74% in one sample where sand content is low. Bulk carbonate content varies between 66 and 99%, with 47 samples containing >65% carbonate (Fig. 5.15b). Carbonate sand content ranges between 85 and 96% in 11 samples, and carbonate mud ranges from 80 to 88% in four samples. Carbonate gravel ranges between 55 and 100% in 11 samples.

5.4.4.4. *Leveque Rise (plateau)*

A total of 10 samples were obtained from the Leveque Rise. Sediments characterising these features have large variations in the sand:gravel ratio and contain relatively little (<1%) mud (Fig. 5.14c). Sediments around the margins of this feature show similar attributes to those on the surrounding shelf and terraces. Bulk carbonate content ranges from 76 to 96% with 6 samples containing >90% (Fig. 5.15c).

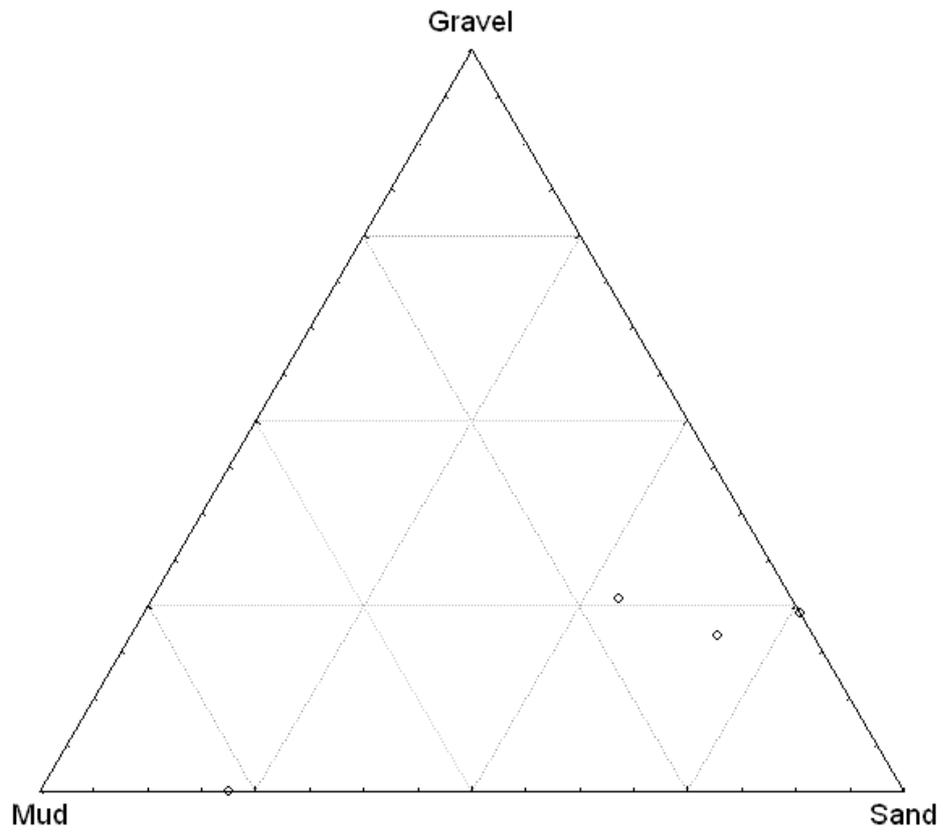
5.4.4.5. *Shallow-water Terraces*

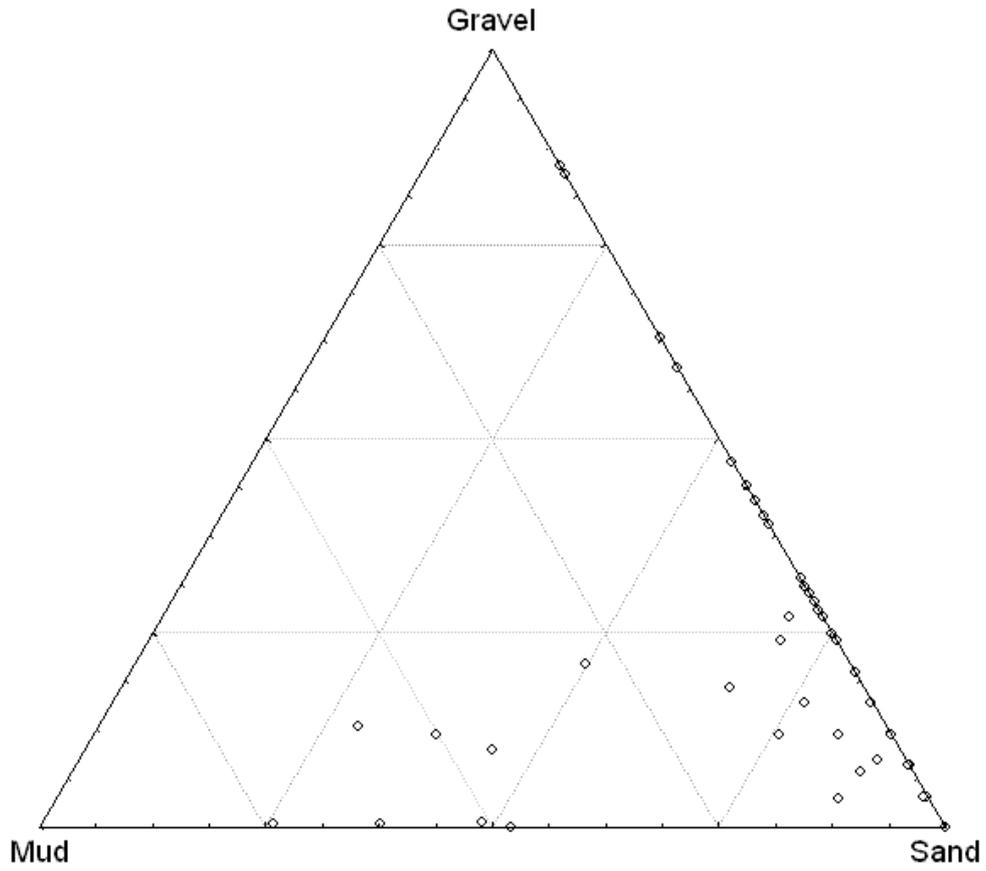
A total of 112 samples were obtained from terraces. Samples located adjacent to deeps/holes/valleys show highly variable sand:gravel ratios (Fig. 5.14e). Samples adjacent to areas of unassigned shelf showed less variable characteristics with sand dominating (30 - 55%) over gravel and mud (0-50%). Bulk carbonate content ranges from 63 to 100%, although one sample contains 42% carbonate. A total of 76 samples have bulk carbonate content >80% (Fig. 5.15e).

5.4.4.6. *Ridges*

A total of 18 samples were obtained from ridges. Mud is the most dominant sediment fraction with contents ranging between 9 and 77% and 11 samples containing >50% (Fig. 5.14d). Sand is the next most dominant fraction with contents ranging between 23 and 99% and five samples containing >50%. Gravel attains 20% on average and attains 36% in one sample. Bulk carbonate content ranges from 78 to 95% and attains >90% in six samples (Fig. 5.15d). Carbonate sand ranges between 93 and 98%, carbonate gravel ranges from 60 to 100% in seven samples and carbonate mud ranges between 88 and 89% in six samples.

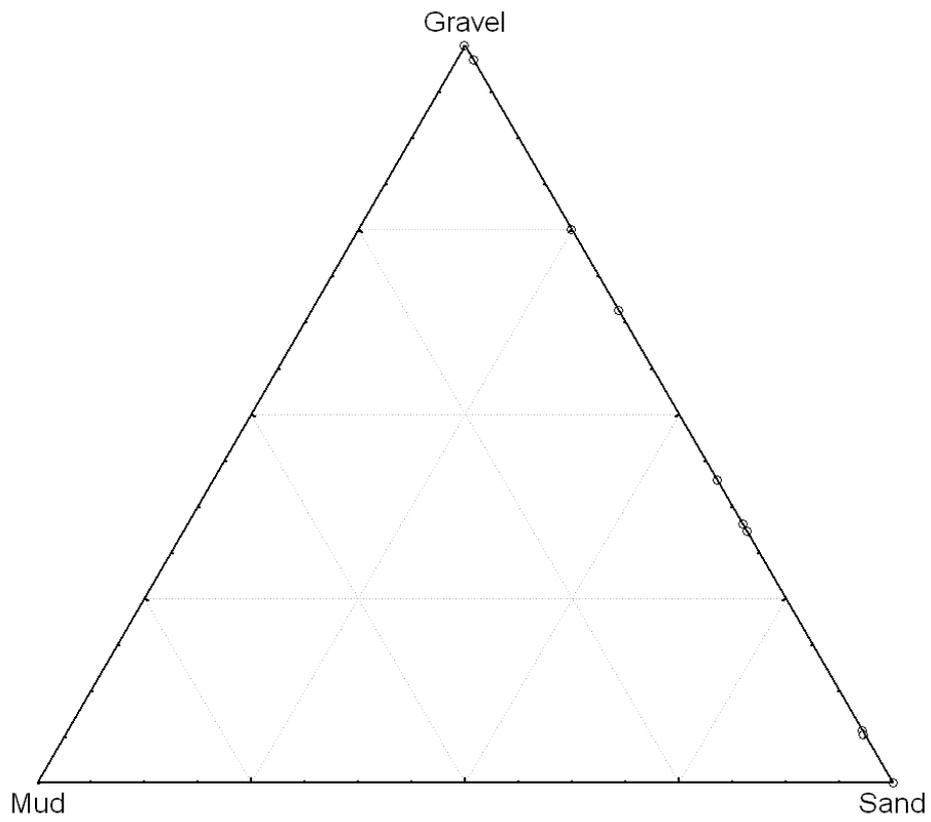
a)

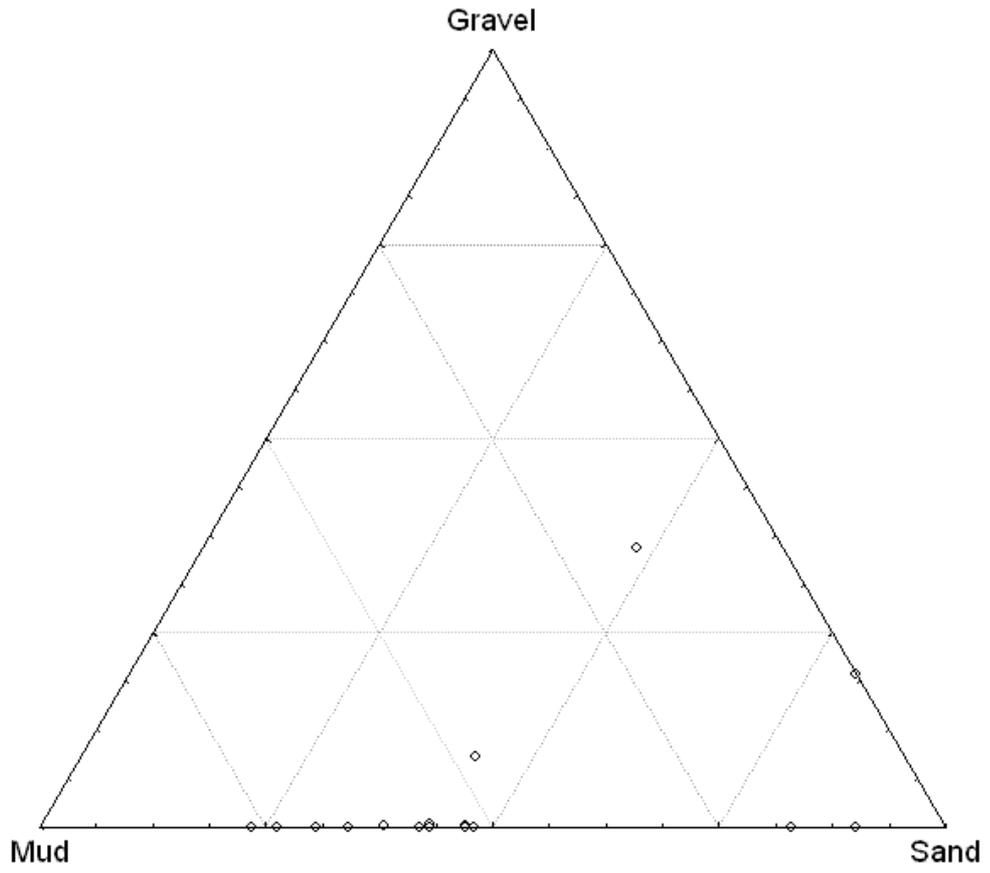




b)

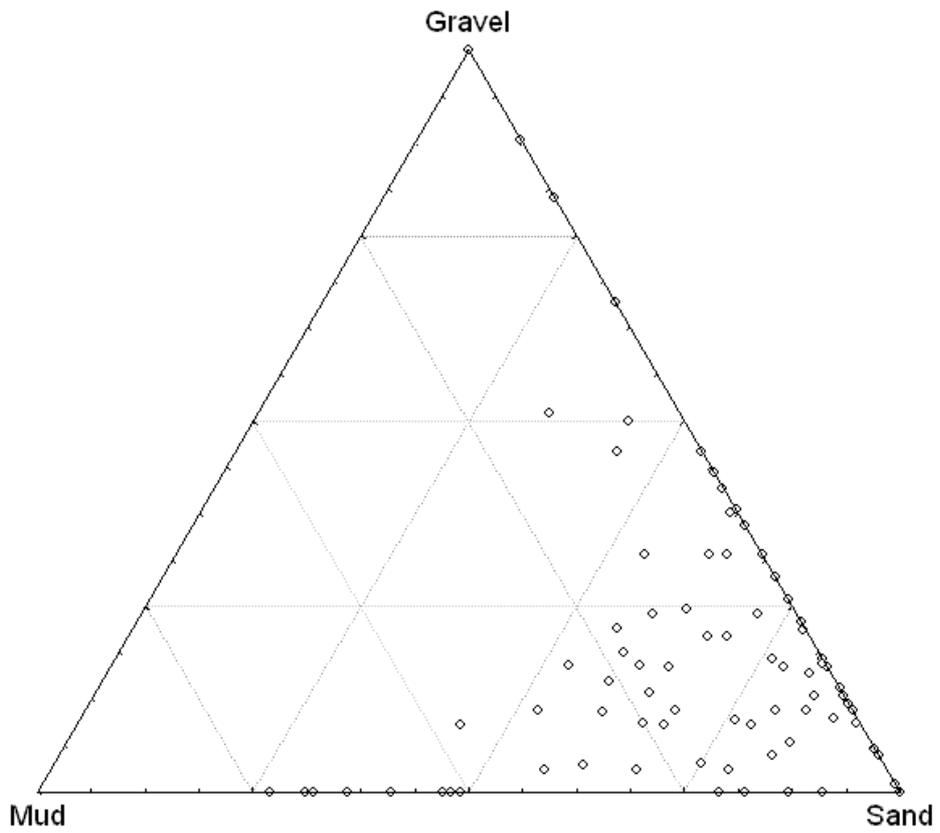
c)





d)

e)



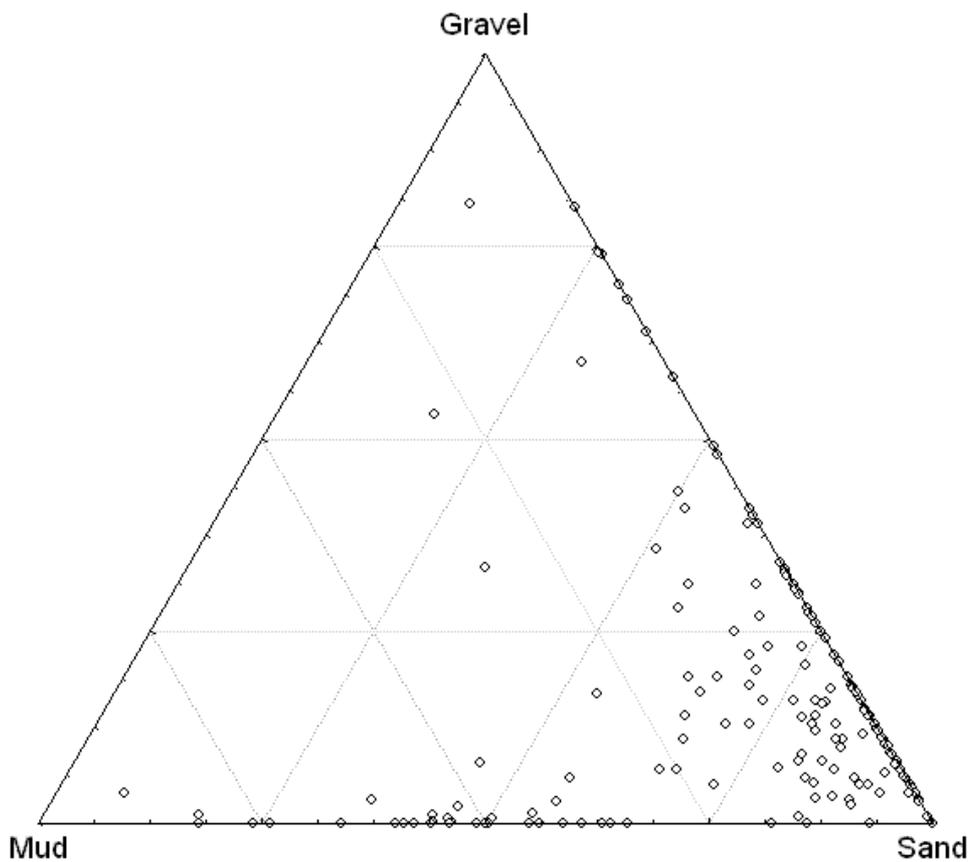
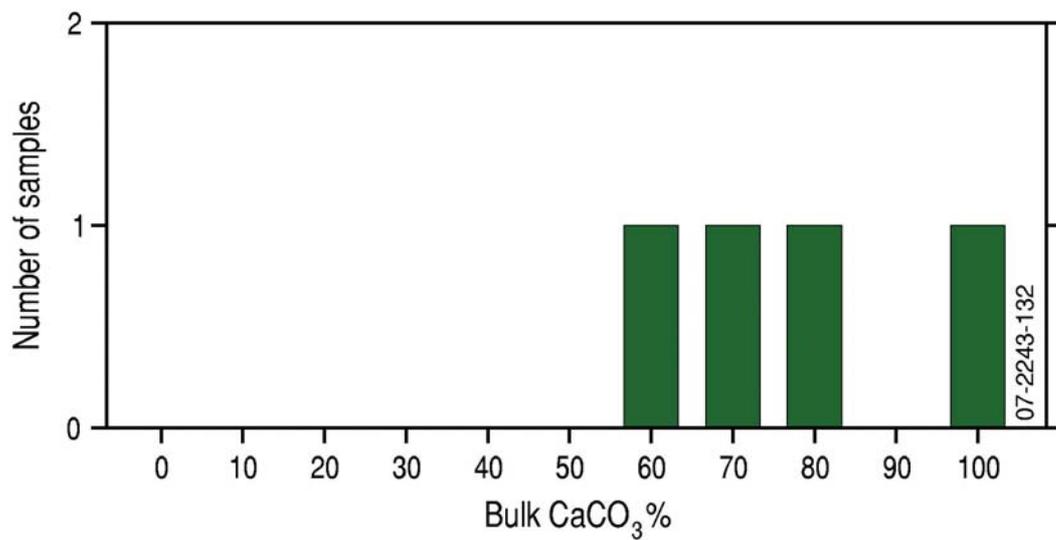
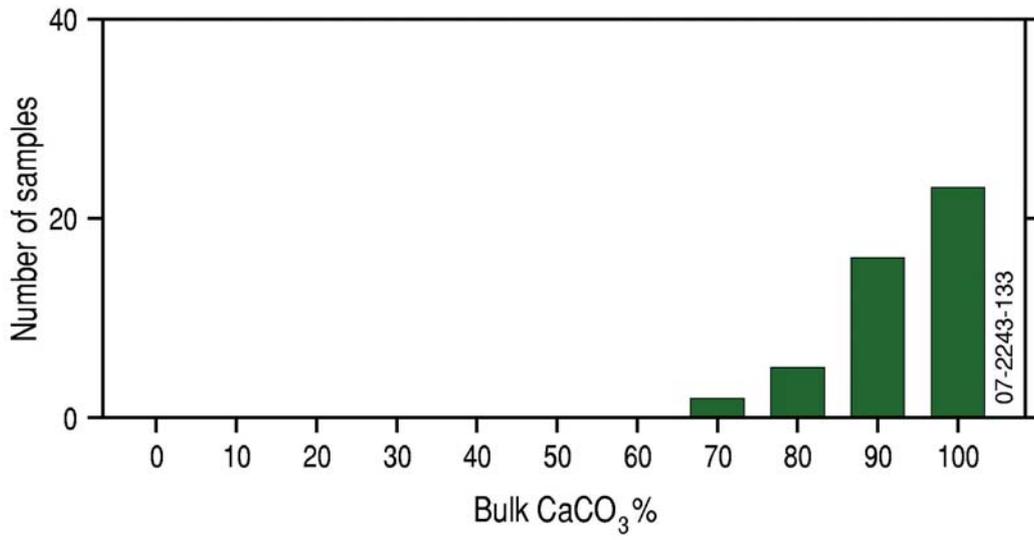


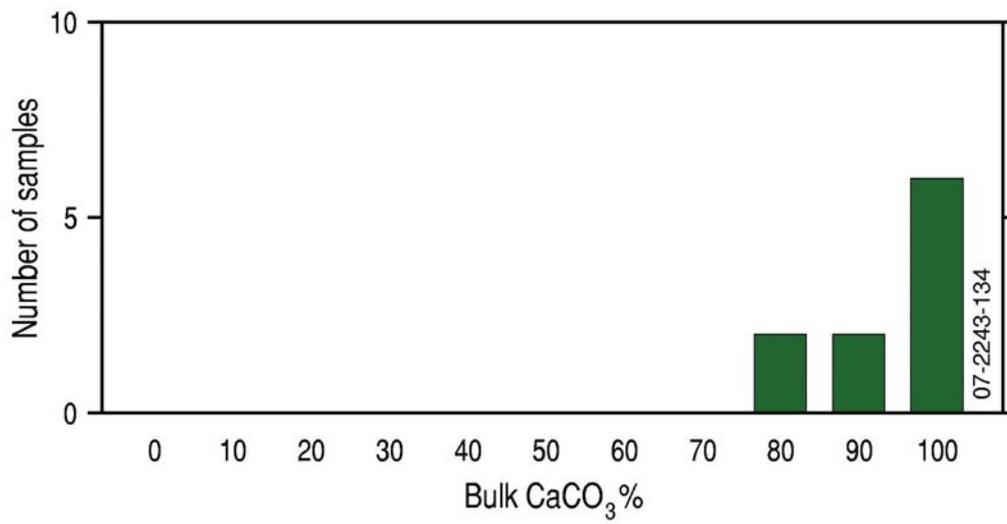
Figure 5.14. Textural composition (mud:sand:gravel ratio) of a) bank/shoal; b) deep/hole/valley; c) plateau; d) ridge; e) shallow water terrace; and f) shelf/slope sediments within the NWSP.

a)

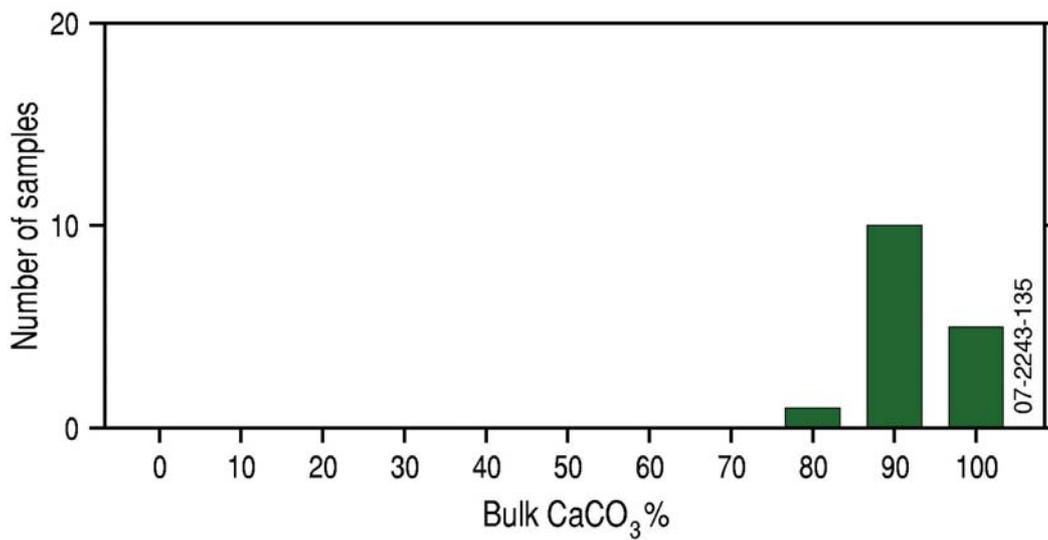


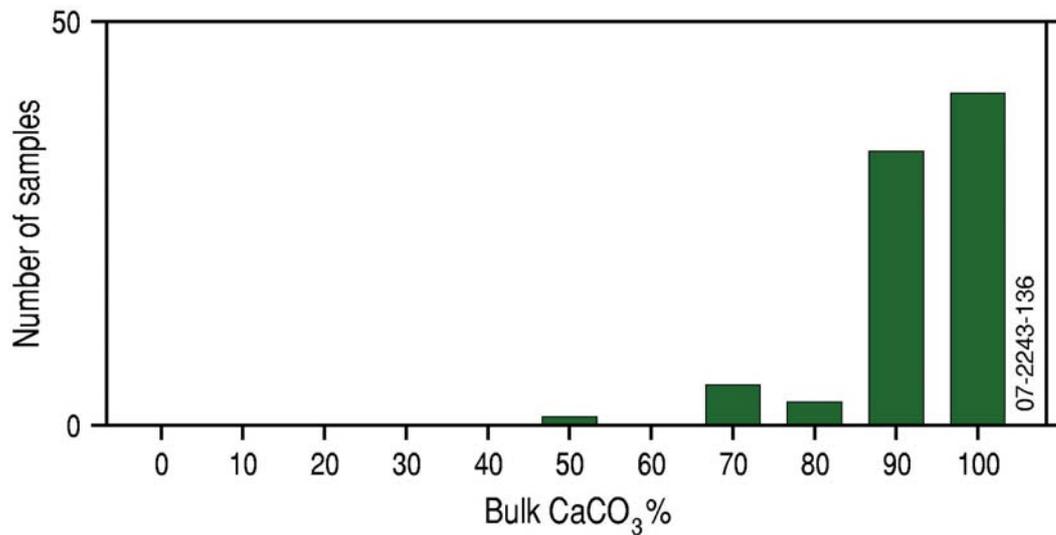


c)



d)





f)

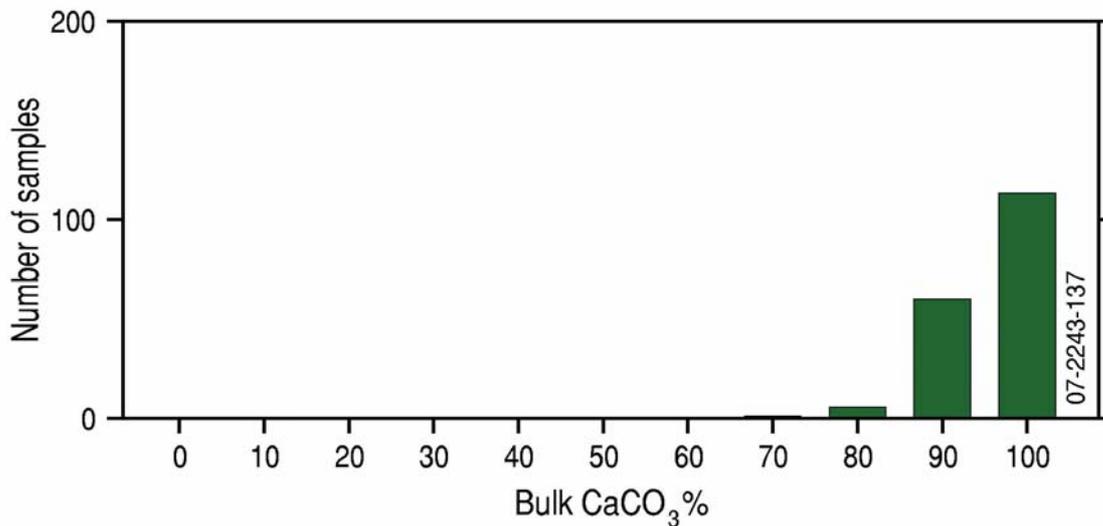


Figure 5.15. Carbonate content of a) bank/shoal; b) deep/hole/valley; c) plateau; d) ridge; e) shallow water terrace; and f) shelf/slope sediments within the NWSP.

5.5. NORTHWEST SHELF TRANSITION (NWST)

5.5.1. Geomorphology and bathymetry

The Northwest Shelf Transition (NWST) covers a total area of 308,450 km² of which 136,660 km² (56%) is situated in the NWMR and the remainder is found in in the North Marine Region (Fig 5.1). This bioregion represents 13% of the total area of the NWMR (Table 5.1).

The NWST extends from Cape Leveque to the eastern end of Melville Island. The NWMR boundary divides the bioregion through the centre of the Joseph Bonaparte Gulf (Fig. 5.1). The entire NWST is located on the shelf except for a single deep/holes/valleys feature that extends onto the slope (this is an extension of the same feature that occurs in the NWSP) (Fig. 5.16a; Table 5.8). The offshore boundaries of NWST are complex. In the NWMR, it abuts the NWSP, Timor Province, and the unallocated area of the EEZ. The NWST extends > 300 km across the shelf from the inner boundary of the NWMR.