

Figure 4.19. Carbonate content of geomorphic features within the NNMR: a) bank/shoal; b) deep/hole/valley; c) basin; d) ridges located in shallow water; e) plateaus on the shelf or near the shelf break; f) offshore plateaus and terraces; and g) terraces located on the shelf or near the shelf break

## 4.2. QUANTITATIVE DESCRIPTION OF THE NNMR

### 4.2.1 Geomorphology

Two geomorphic provinces occur in the NNMR (Fig. 4.20; Table 4.3). The shelf makes up the largest area (89%, 143,010 km<sup>2</sup>), followed by the slope (11%, 17,580 km<sup>2</sup>). The NNMR does not contain abyssal plain/deep ocean floor or continental rise provinces.

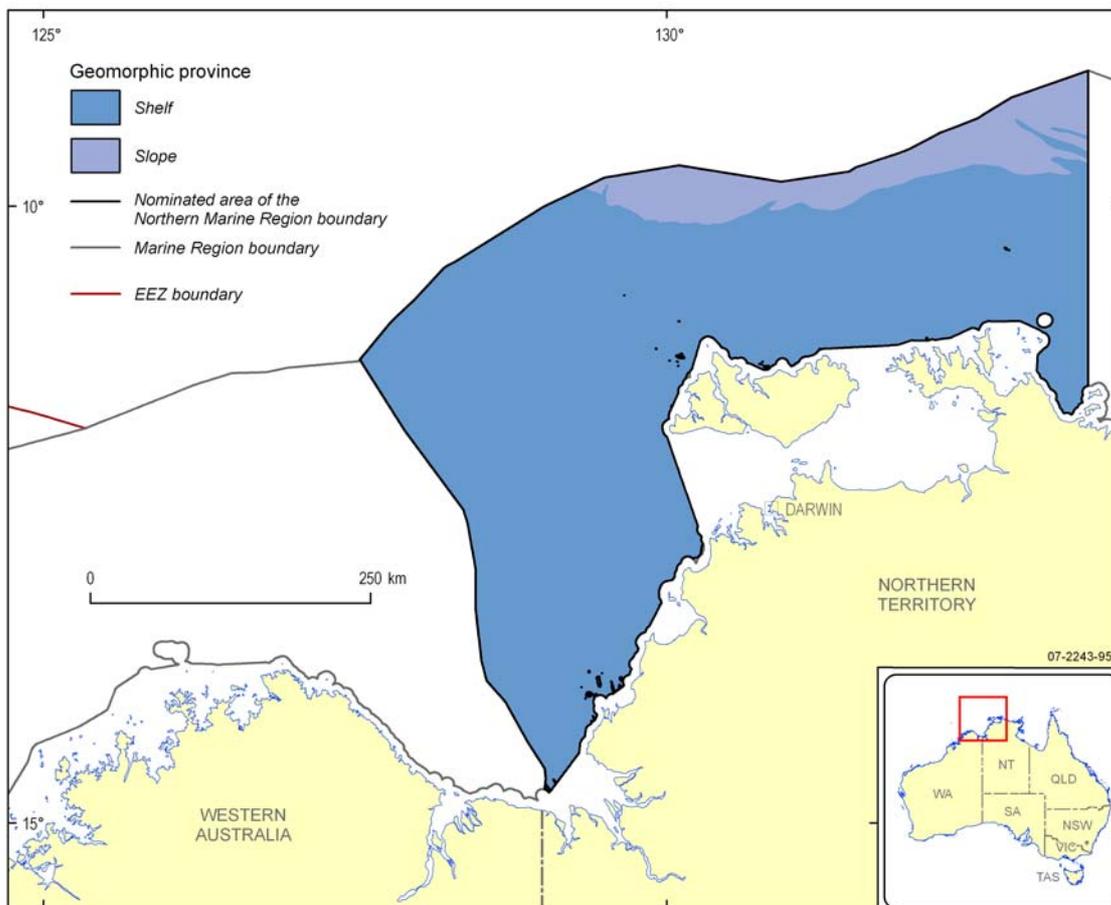
Of the 21 geomorphic features defined on the Australian margin, 12 are represented in the NNMR. Including shelf, slope, banks/shoals, deeps/holes/valleys, basin, reef, canyon, ridge, pinnacle, aprons/fans, terrace, and tidal sand wave/sand bank (Fig. 4.21; Table 4.3). Unassigned shelf covers 56% (90,660 km<sup>2</sup>) of the NNMR. The remaining area of shelf is comprised of banks/shoals, deeps/holes/valleys, tidal sand wave/sand banks and pinnacles. Unassigned slope covers <4% (5,680 km<sup>2</sup>) of the NNMR. The remaining area of the slope is comprised of canyons, apron/fans, deeps/holes/valleys, ridges, terraces, reefs and pinnacles.

A large proportion of the total area of aprons/fans and banks/shoals in the EEZ occur in the NNMR. The NNMR contains 33% (2,150 km<sup>2</sup>) of the total area of aprons/fans found in the EEZ and 17% (8,770 km<sup>2</sup>) of banks/shoals (Table 4.3).

Table 4.3. Statistics of geomorphic provinces and features of the NNMR.

Feature	Area in NMR	% total NMR Area	% EEZ Area	% Total area of features in EEZ located in NMR	Water Depth Range in NMR (m)	Water Depth Mean in NMR (m)
<i>Geomorphic Province</i>						
Shelf	143,010	89.05	21.76	5.21	15 - 290	70
Slope	17,580	10.95	44.42	0.46	15 - 380	170
<i>Geomorphic Feature</i>						

Shelf	90,660	56.45	13.79	7.31	5 - 195	65
Slope	5,680	3.54	15.23	0.41	20 - 320	200
Bank/Shoals	8,770	5.46	0.56	17.19	5 - 155	45
Deep/Hole/Valley	6,300	3.92	1.83	3.70	5 - 290	85
Basin	18,810	11.71	7.36	2.63	40 - 250	110
Reef	440	0.28	0.52	0.91	5 - 205	65
Canyon	1,820	1.13	1.18	1.70	120 - 245	140
Ridge	190	0.12	1.24	0.16	120 - 215	160
Pinnacle	360	0.23	0.06	6.59	10 - 350	115
Apron/Fan	2,160	1.35	0.13	32.67	120 - 250	195
Terrace	25,130	15.65	6.43	4.36	10 - 380	95
Tidal Sandwave/Sand Bank	270	0.17	0.27	1.15	10 - 55	25
<b>TOTAL</b>	<b>160,590</b>					



a)

b)

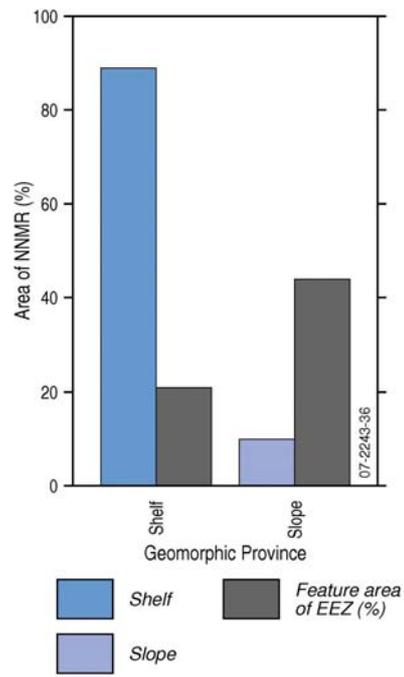
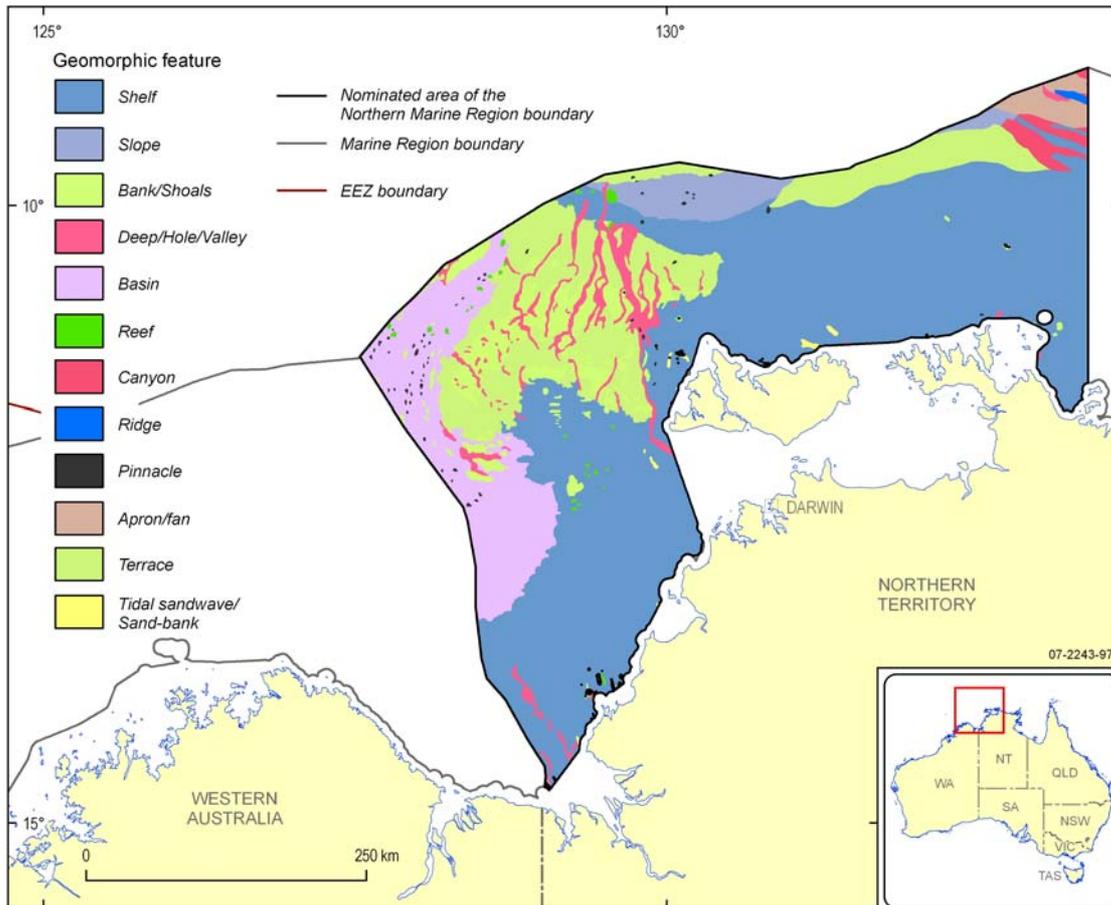


Figure 4.20. a) Geomorphic Provinces of the nominated area of the Northern Marine Region (NNMR); and b) Percentage area of each geomorphic province within the NNMR and EEZ.



a)

b)

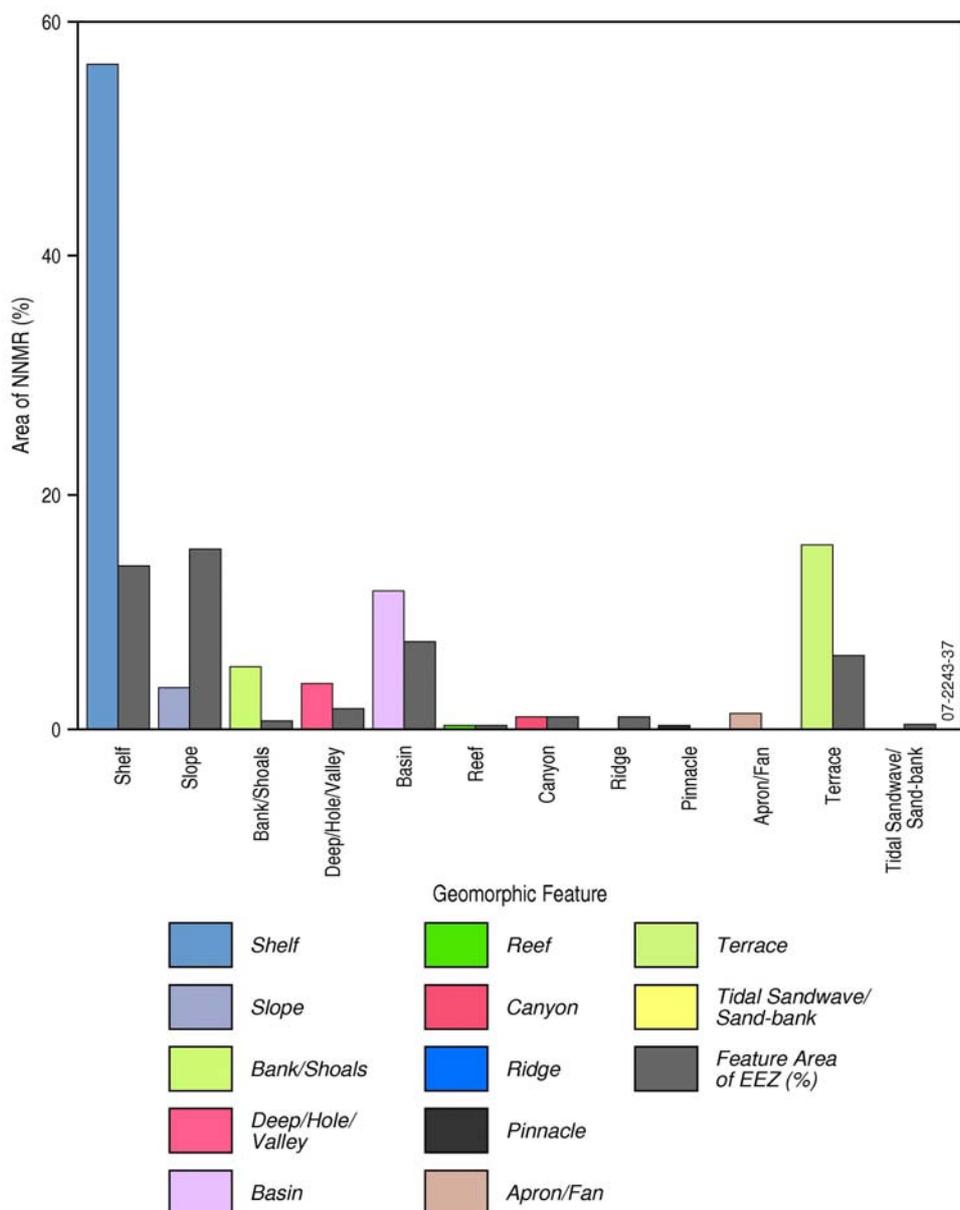


Figure 4.21. a) Geomorphic Features of the nominated area of the Northern Marine Region (NNMR); and b) Percentage area of each geomorphic feature within the NNMR and EEZ.

### 4.2.2. Bathymetry

The NNMR is relatively shallow with water depths ranging from 5 – 380 m (Table 4.4; Fig. 4.24). Approximately 75% of the total area occurs in water depths shallower than 100 m and approximately 25% in water depths between 100 and 350 m. Shallow water depths in the NNMR reflect the broad continental shelf of Australia’s northern margin.

Ridges, canyons, pinnacles and aprons/fans in the NNMR occur at a limited water depth range compared to those found in the remaining Australian margin. In the NNMR these features are

restricted to water depths shallower than 350 m (Table 4.3). Elsewhere in the EEZ, a large proportion of these features occur in water depths greater than 500 m (Potter et al., 2006).

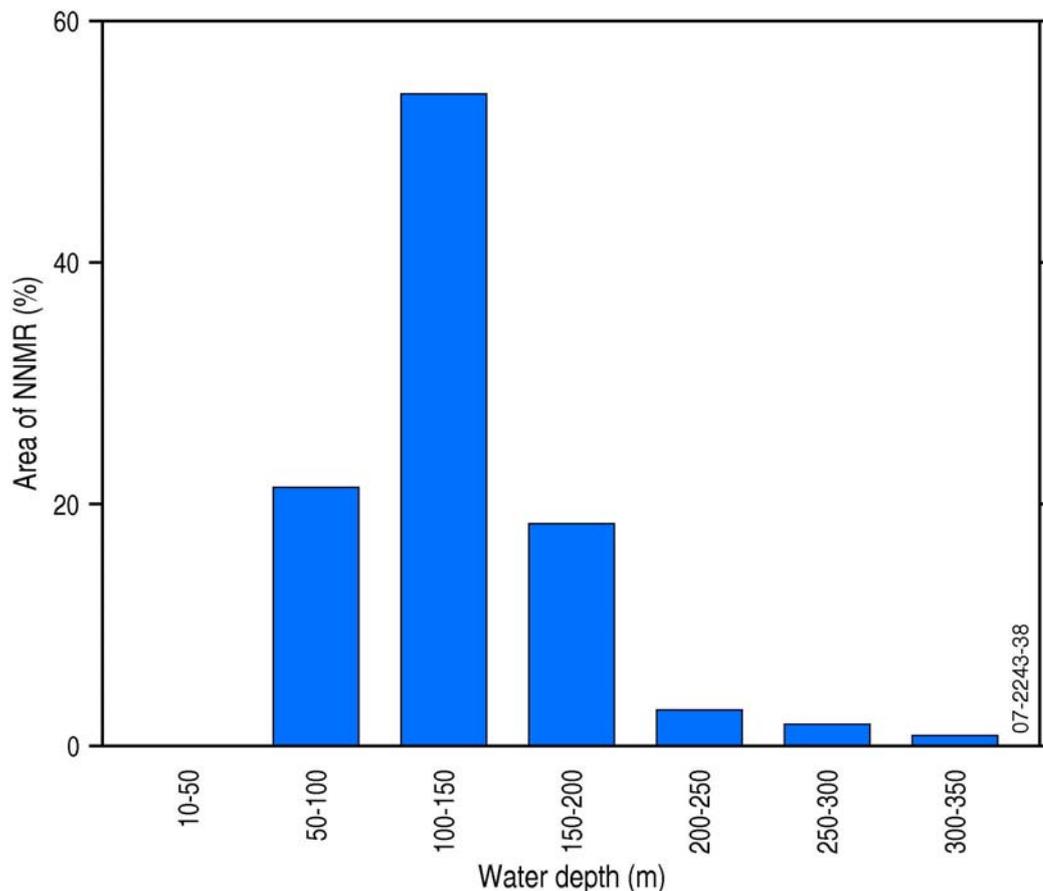


Figure 4.22. Distribution of water depth classes by percentage area within the nominated area of the Northern Marine Region (NNMR).

### 4.2.3. Sediment Data Coverage in the NNMR

#### 4.2.3.1. Quantitative Textural and Compositional Data

Sample distribution is relatively consistent across the NNMR (Fig. 4.23.). More than 80% of the total area of the NNMR contains between 10 and 50 samples per 1,000 km<sup>2</sup>. Less than 3% of the total area has a density of <1 sample per 1,000 km<sup>2</sup>. Lowest sample densities occur locally on the inner shelf and in the northwest corner of the NNMR (Fig. 4.24.). Samples are abundant and relatively evenly distributed across the remainder of the region (Fig. 4.24.).

A total of 272 samples (86% of samples in the NNMR) are from on the shelf, resulting in an average sample density of 1.9 samples per 1,000 km<sup>2</sup> (Fig. 4.24.; Table 4.4). A total of 46 (14%) samples are from the slope, giving a sample density of >2.6 samples per 1,000 km<sup>2</sup>. This sample coverage is considered adequate to assess the sedimentology for nine of the 12 geomorphic features present in the NNMR, including banks/shoals, deeps/holes/valleys, basins, canyons, ridges, aprons/fans and terraces. No samples were collected from reefs or pinnacles. One sample was collected from tidal sand wave/sand banks. Together, reefs, pinnacles, and tidal sand waves/sand banks, cover approximately 1,080 km<sup>2</sup> (<1%) of the NNMR (Table 4.4).

Of those features containing adequate samples for analysis, highest sample density occurs on ridges (27 samples per 1,000 km<sup>2</sup>) and aprons/fans (4.6 samples per 1,000 km<sup>2</sup>). Low numbers of samples and/or clustering of samples on some features mean that assays may not be representative of seabed properties for the entire feature across the NNMR. For example, tidal sand wave/sand banks average 3.7 samples per 1,000 km<sup>2</sup> but this is based on only one sample (Table 4.4). Low sample numbers may affect results for tidal sand wave/sand banks, canyons and ridges. Spatial clustering may significantly affect results for aprons/fans, deeps/holes/valleys, and ridges.

The distribution of all samples from the NNMR spans water depths between 10 and 315 m (Fig. 4.26). A total of 289 (90%) samples occur in water depths <150 m, and 15 samples (5%) occur in water depths >200. Sample coverage adequately represents the distribution of water depths in the NNMR with 233 (73%) samples present in areas of water depths <100 m that cover approximately 75% of the total area.

Table 4.4. Description of average density of samples in each geomorphic province and feature.

<b>PROVINCE/ # Feature</b>	<b>No. sample points</b>	<b>% NWMR Area</b>	<b>Average sample density (samples per 1,000 km<sup>2</sup>)</b>
<i>Geomorphic Province</i>			
Shelf	272	89.05	1.90
Slope	46	10.95	2.62
<i>Geomorphic Province</i>			
Shelf (unassigned)	185	56.45	2.04
Slope (undivided)	15	3.54	2.64
Bank/shoals	13	5.46	1.48
Deep/hole/valley	12	3.92	1.90
Basin	32	11.71	0.00
Reef	0	0.28	2.20
Canyon	4	1.13	26.86
Ridge	5	0.12	0.00
Pinnacle	0	0.23	4.63
Apron/fan	10	1.35	1.63
Terrace	41	15.65	3.65
Tidal sand wave/sand bank	1	0.17	1.70

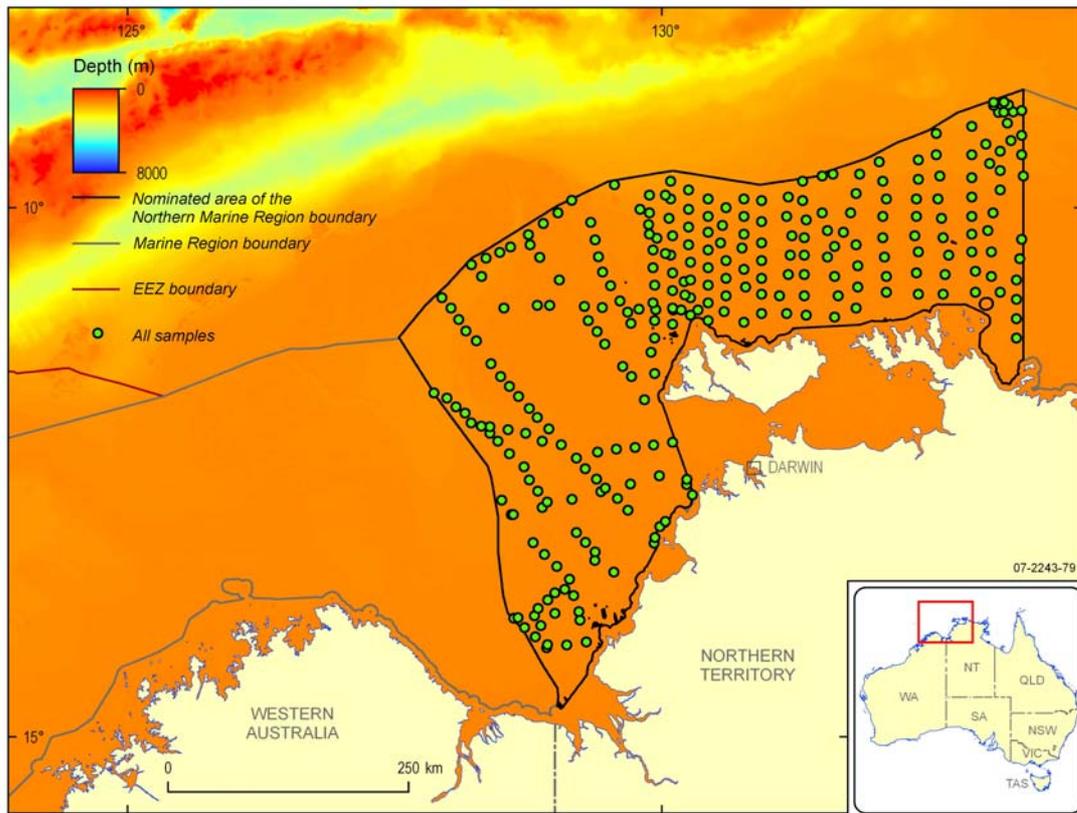
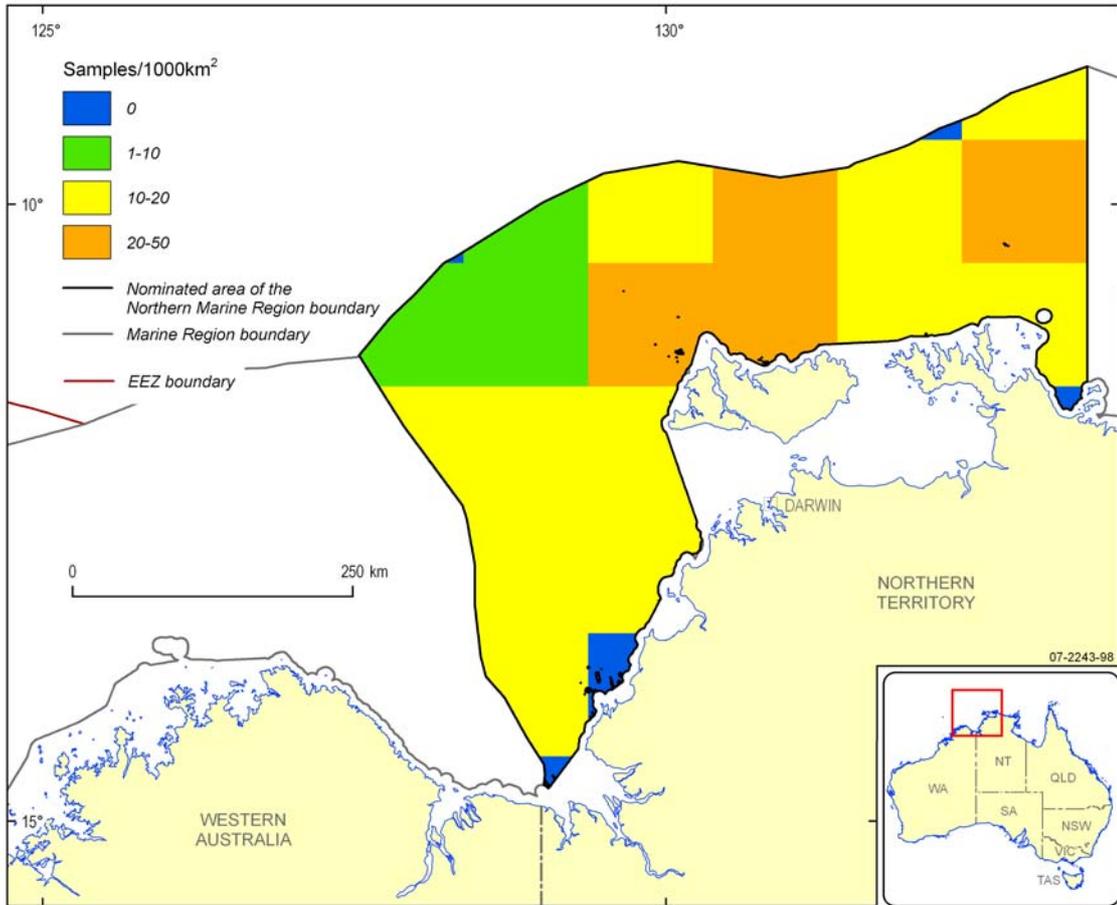


Figure 4.23. Location of all quantitative textural and compositional sample points for the NNMR in relation to bathymetry.



a)

b)

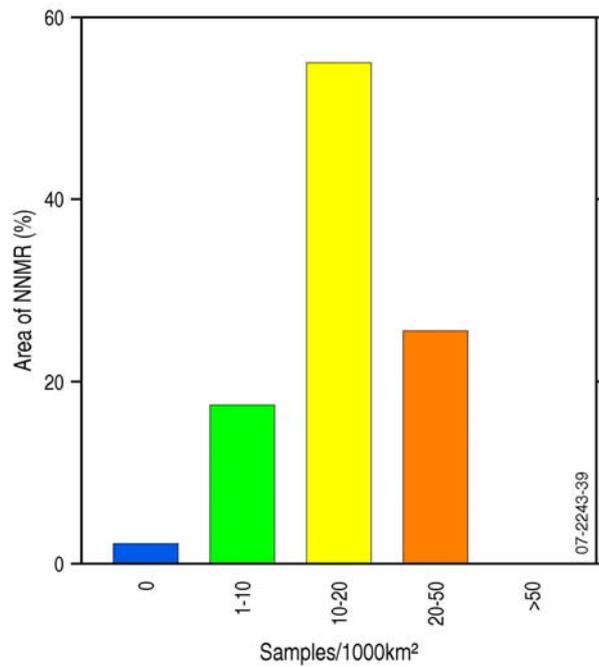


Figure 4.24. a) Sample density distribution across the NNMR and b) frequency distribution of sample density.

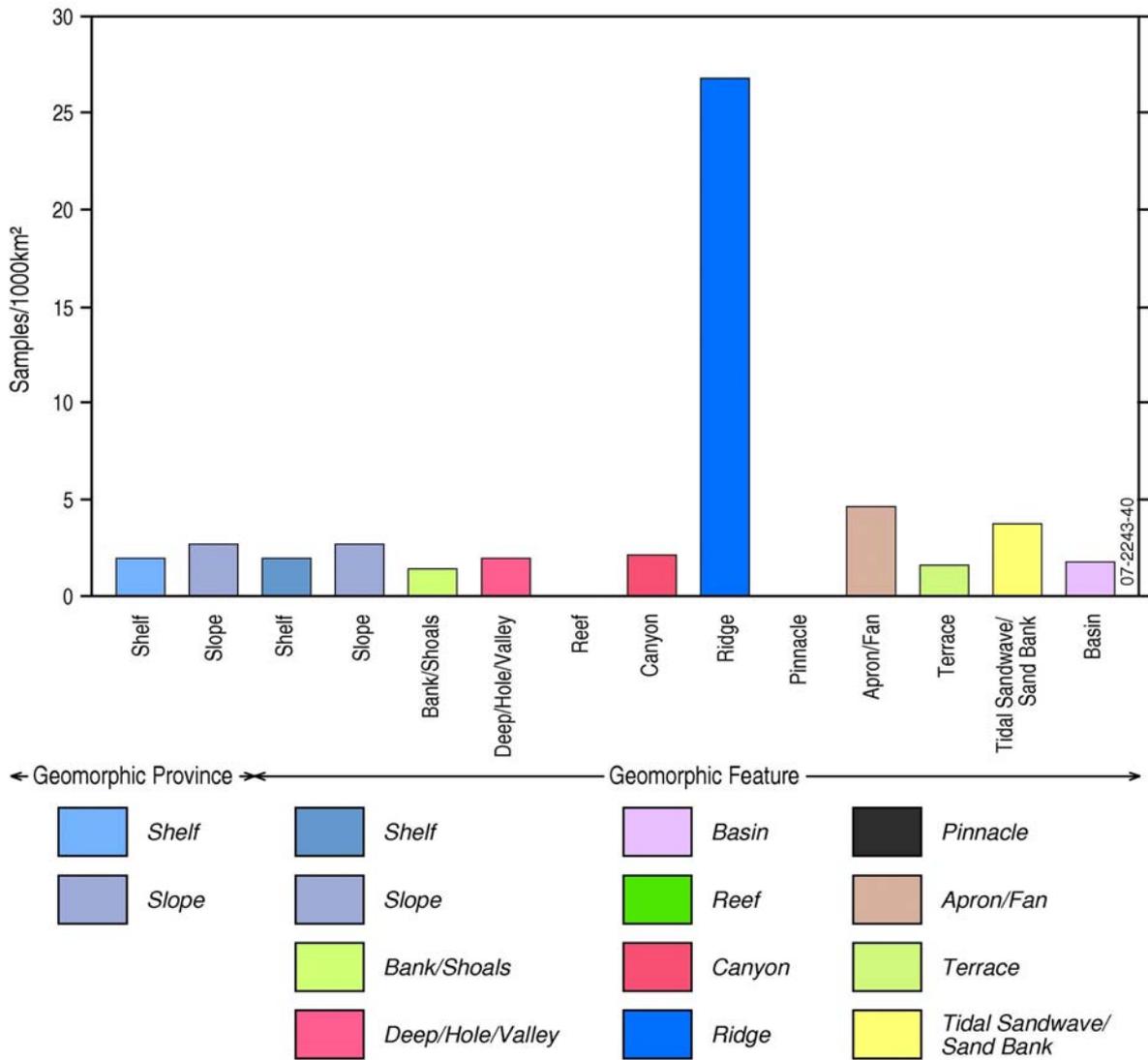


Figure 4.25. Sample densities of geomorphic provinces and features for the NNMR (y axis shows average density measured as samples per 1,000 km<sup>2</sup>).

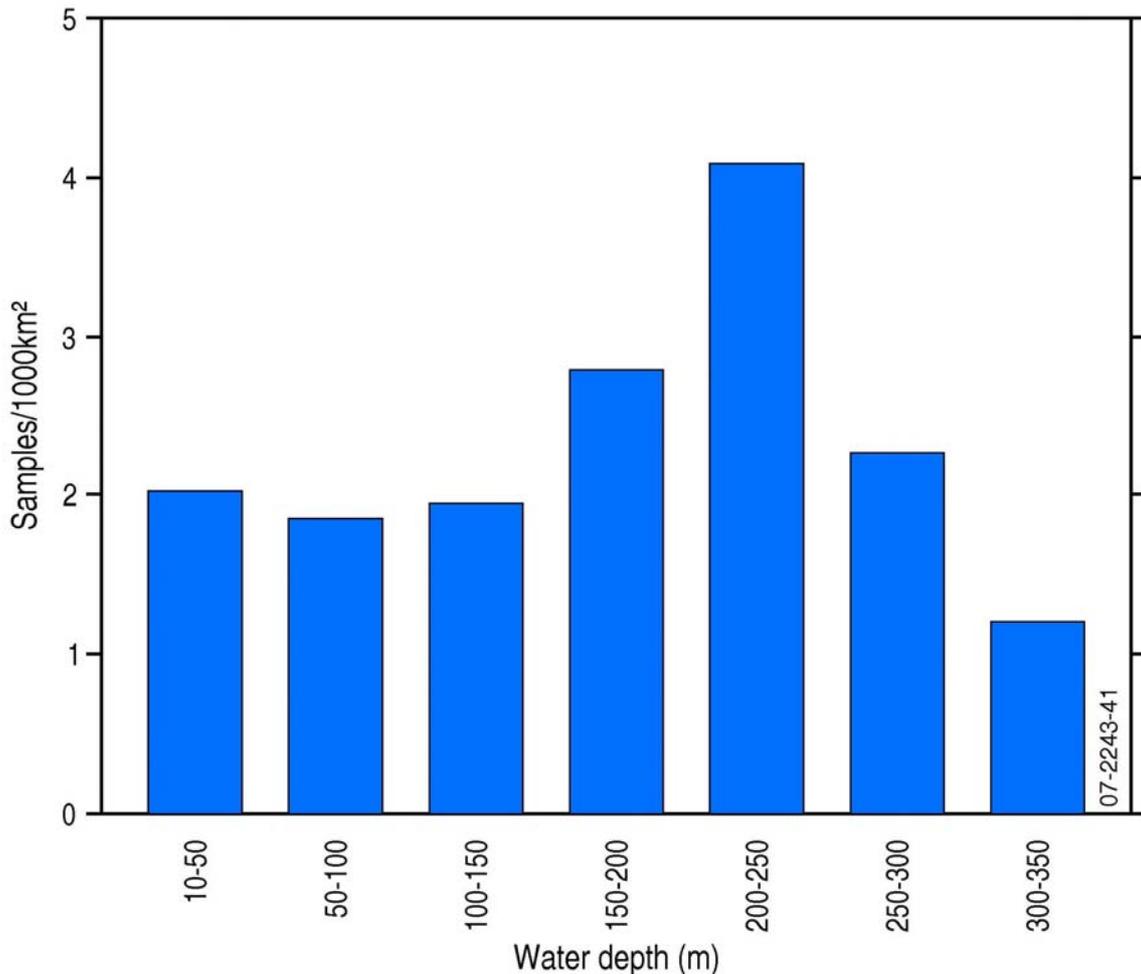


Figure 4.26. Sample densities for water depths for the NNMR (y axis shows average density measured as samples per 1,000 km<sup>2</sup>).

## 4.2.4. Quantitative regional sediment distribution in the NNMR

### 4.2.4.1. Overview of Distribution and Properties

Sample assays indicate that the seabed of the NNMR is characterised by a range of sediment types (Fig. 4.29, 4.30, 4.31 & 4.33). Sand is the dominant size fraction and ranges from 0 – 94%. A total of 250 samples (80%) contain >20% sand, and 89 samples (30%) contain >70% sand. Sand content is highest in samples located within the Joseph Bonaparte Gulf and on the outer shelf adjacent to the Van Diemen Rise (Fig 4.32). Mud content ranges from 0 – 100% and is highest to the northwest of Melville and Bathurst Islands where it comprises 80 - 100% of the total sediment volume (Fig 4.29). Elsewhere, mud content is significantly lower with 189 (60%) samples containing <50% mud and 45 (14%) containing <10% mud.

Gravel was detected in 208 (65%) samples but is the dominant size fraction in only two samples (<1%). Gravel forms a minor component (<10%) of sediment in 230 samples (72%). Gravel occurs most frequently on the inner shelf and within banks/shoals and aprons/fans of the Van Diemen Rise (Fig. 4.31a). The abundance and distribution of sediment containing gravel is likely

to be underrepresented in the data due to sparse sample coverage of areas of the NNMR closest to the coast (Fig. 4.23).

Sediments are predominantly calcareous with 179 samples (68%) containing >40% carbonate and 109 (41%) containing >70% carbonate (Fig. 4.28). Carbonate content generally decreases with increasing water depth and is highest within the Joseph Bonaparte Gulf and area surrounding the Van Diemen Rise (Fig. 4.32a). In these areas the carbonate content of sediments generally exceeds 60%. To the northeast of Melville and Bathurst Islands carbonate content is lower, generally between 20 and 40%.

Sand and gravel fractions within the NNMR are dominated by carbonate grains. The carbonate content of the sand fraction is known for 113 samples and ranges from 28 – 100%. A total of 105 (93%) samples contain sand that is >50% carbonate, and 75 (67%) contain sand that is >90% carbonate. The distribution of carbonate sand varies spatially with lower carbonate concentrations frequently observed in sand occurring nearest to the coast. Carbonate forms 100% of the gravel fraction in three (100%) samples occurring on the slope. These samples represent deeper water (>160 m) occurrences of gravel within the NNMR. The carbonate content of the mud fraction is generally lower, ranging from 22 – 31%.

Sediment assays were interpolated using the methods described in Chapter 2 to give an estimate of regional distribution of sediment properties in the NNMR. Interpolated grain size data achieves coverage of approximately 160,300 km<sup>2</sup> (99%) of the total NNMR. Interpolated bulk carbonate data and Folk classification cover a similar area.

Sediment texture and composition in the NNMR vary spatially from east to west and with increasing water depth. Areas with the highest mud (>80%) and lowest sand (<20%) content are located to the north east of Melville and Bathurst Islands, while areas with the highest sand (>80%) and lowest mud (<20%) content are located to the west of these islands. Mud and bulk carbonate content increase with increasing water depth and are highest on the outer shelf and slope (Fig. 4.29a & 4.29b). Bulk carbonate content is highest in sand dominated areas, predominantly to the west of Melville and Bathurst Islands where carbonate content ranges from 60 to 100%. Carbonate content is lowest (<40%) to the north of the Van Diemen Gulf. Gravel forms a minor component (<20%) of sediment in the NNMR. However, deposits of gravel (20 to 60% of sediment volume) occur locally in close proximity to the coast (Fig. 4.31a & 4.31b).

The Folk Classification (Fig 4.33) shows that the shelf to the north of Melville Island is dominated by gravely muddy sand (gmS) with smaller quantities of slightly gravely muddy sand ((g)mS) and gravely sand (gS) to the east of Melville Island. The slope is dominated by slightly gravely muddy sand ((g)mS) north of Melville Island. In the northeast area of the NNMR, sediments are a combination of slightly gravely sandy mud ((g)sM), gravely mud (gM) and muddy sandy gravel (msG). The abundance of muddy sand (mS), slightly gravely sandy mud ((g)sM) and sandy mud (sM) increase with increasing water depth and are most common within the slope province. A notable change in the sedimentology occurs to the north east of Melville and Bathurst Islands where an increase in the deposition of gravely muddy sand (gmS) is observed.

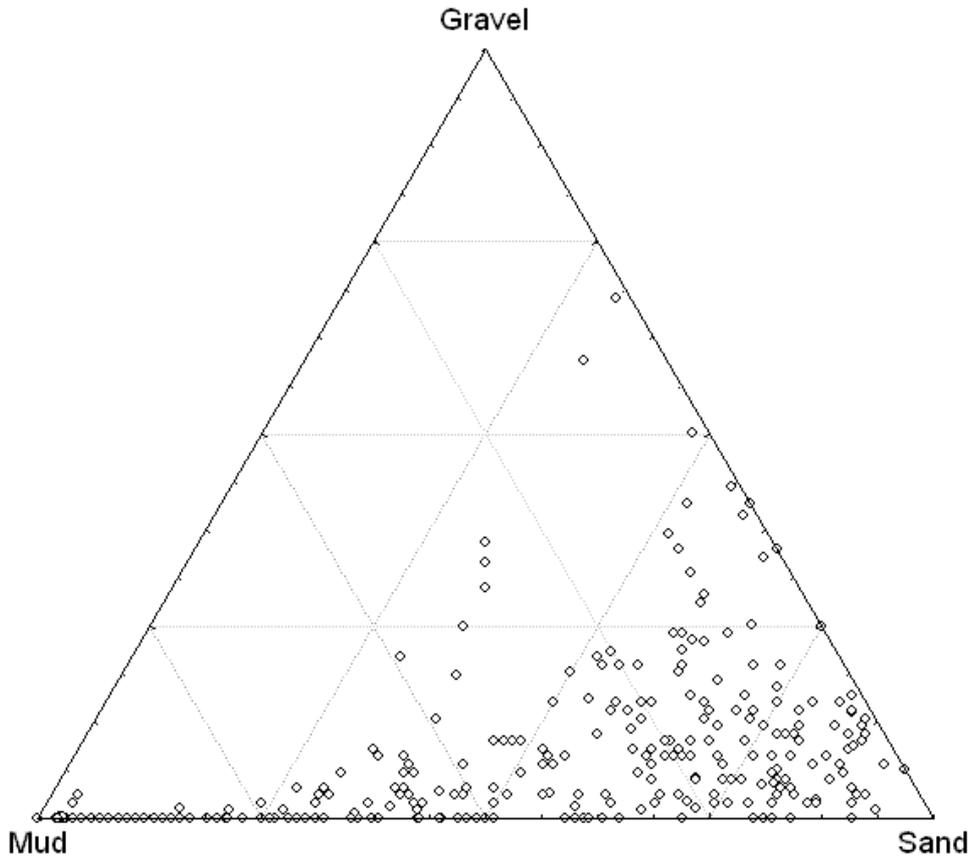
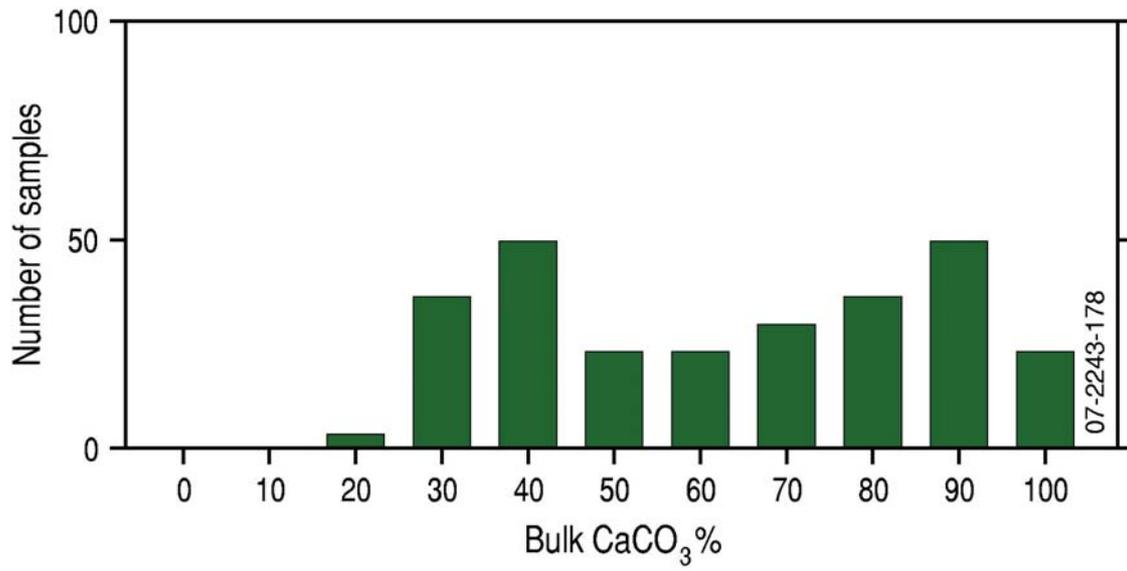
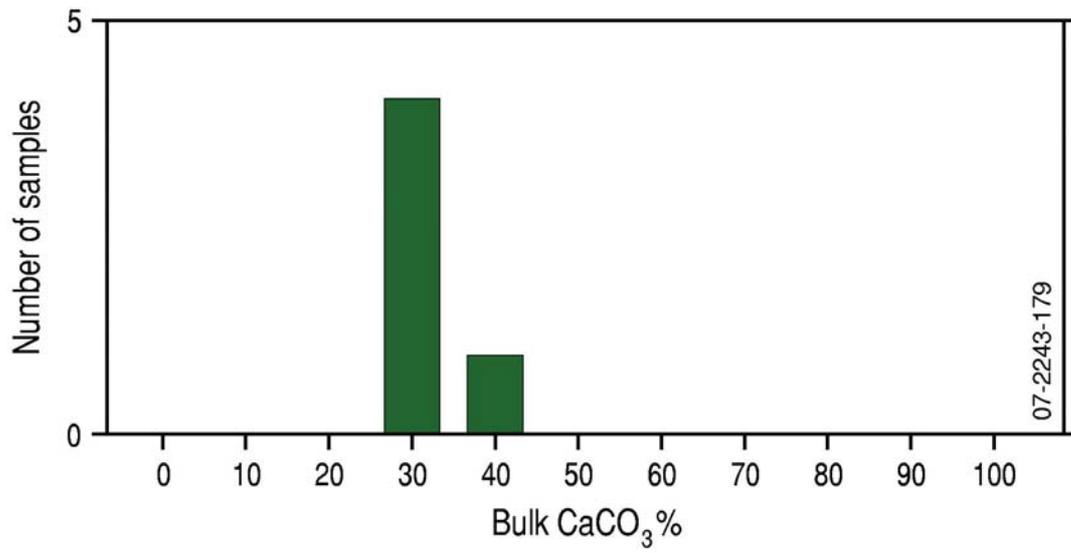


Figure 4.27. Texture (mud:sand:gravel ratio) of sediment in the NNMR.

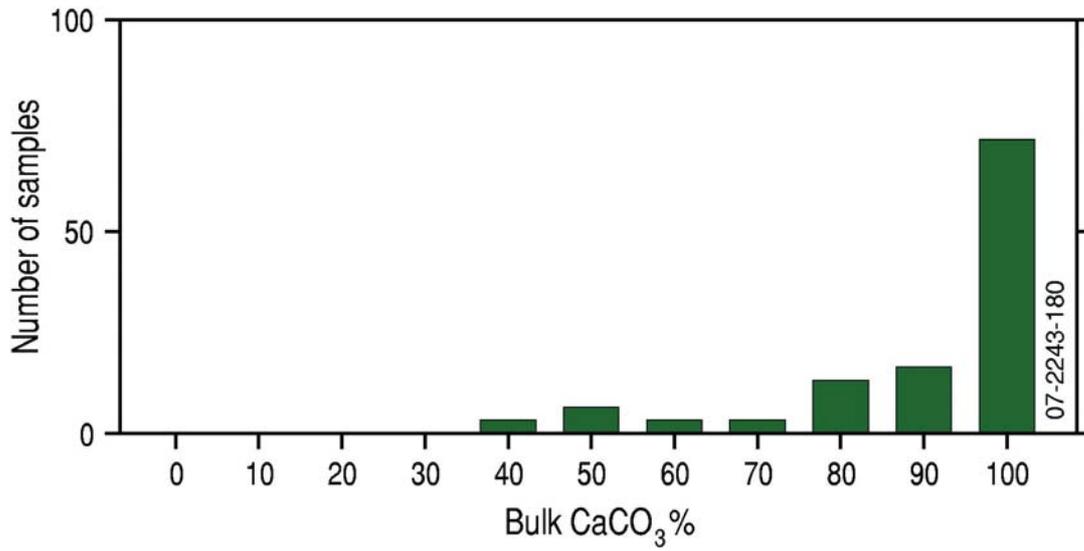
a)



b)



c)



d)

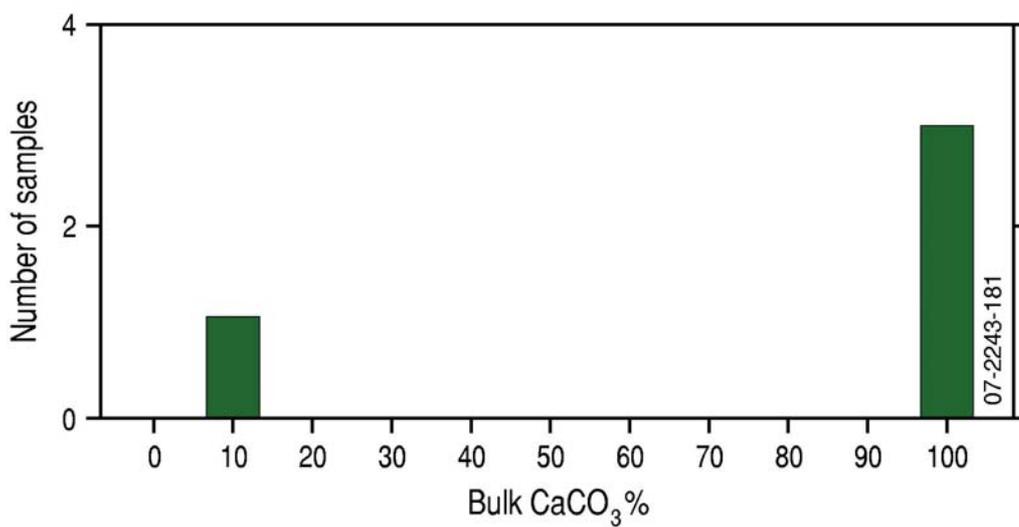
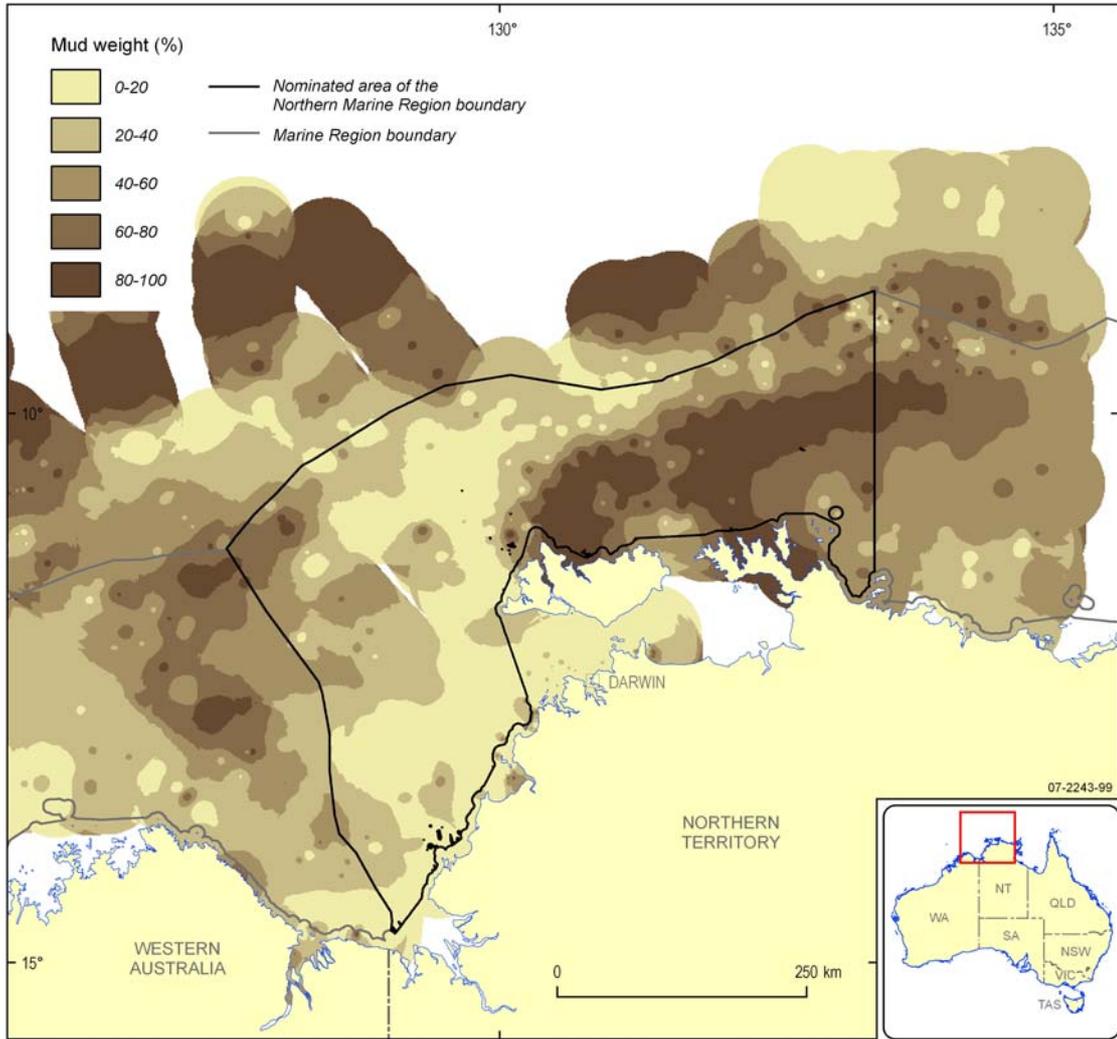


Figure 4.28. Carbonate content of NNMR sediment: a) bulk; b) mud; c) sand; and d) gravel.



a)  
b)

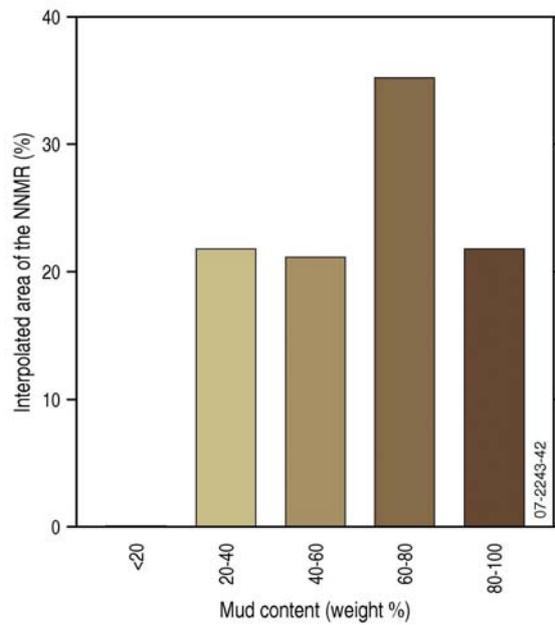
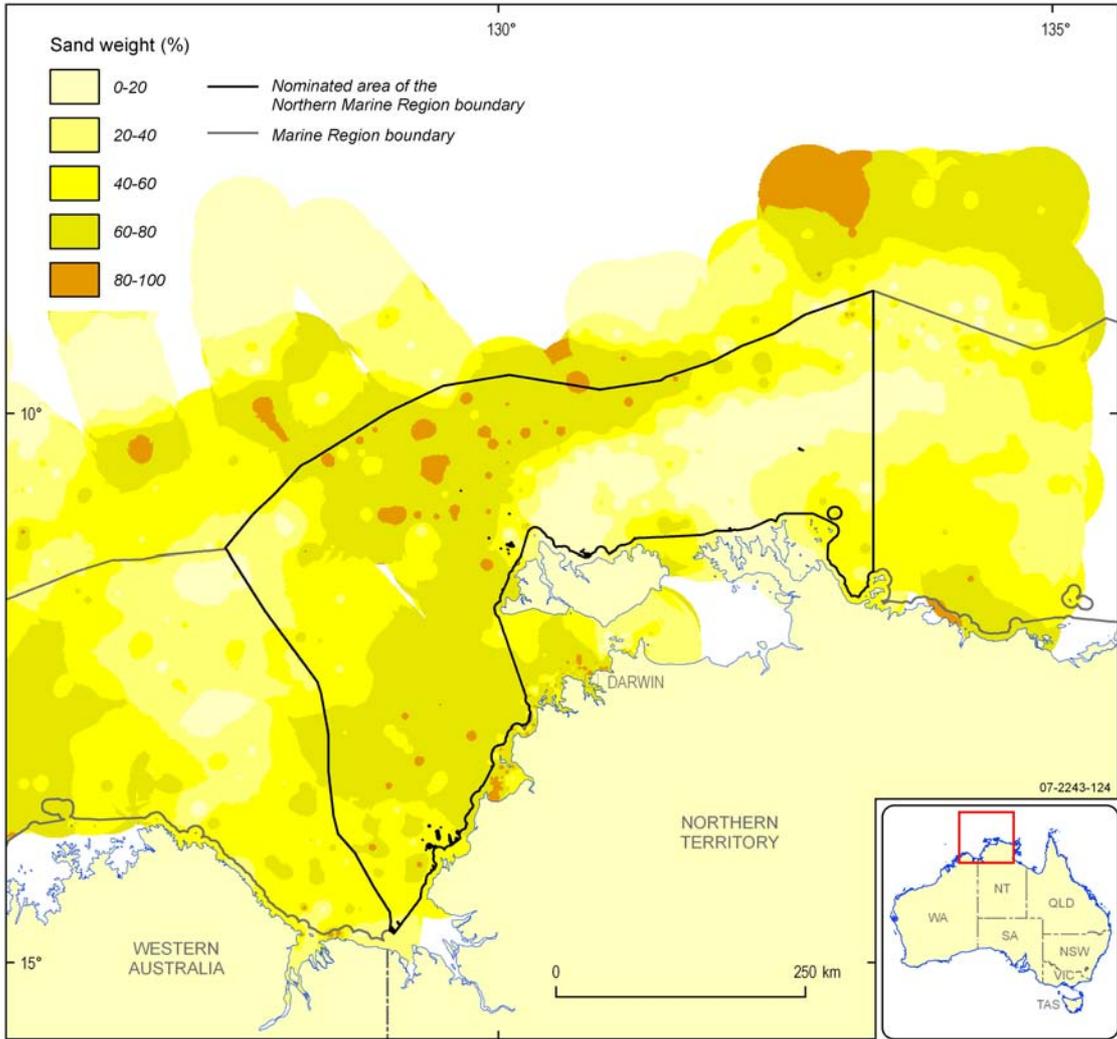


Figure 4.29. a) Mud distribution with b) the area covered by each class expressed as % of the interpolated area of the NNMR.



a)  
b)

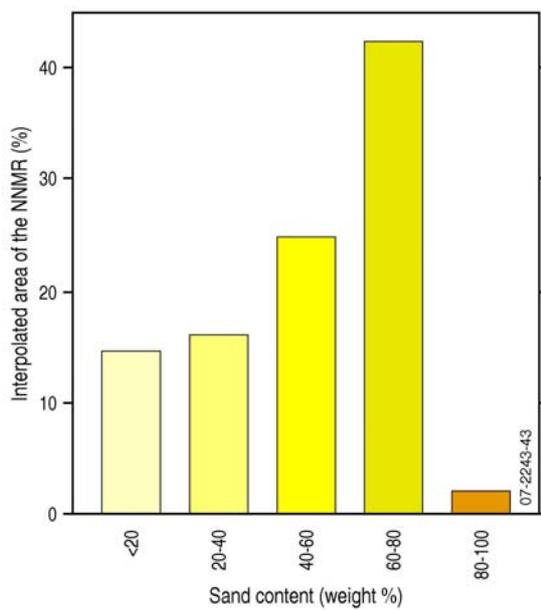
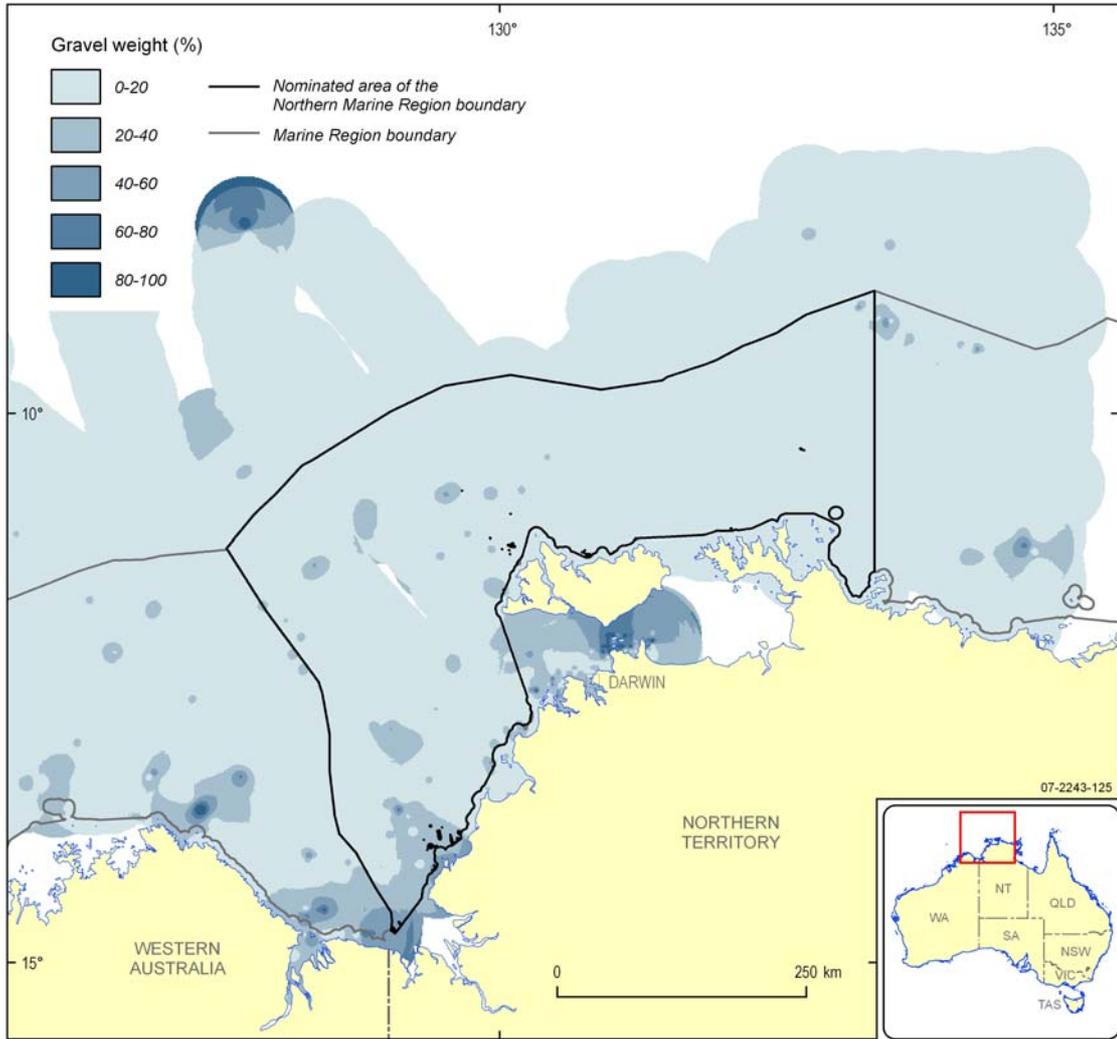


Figure 4.30. a) Sand distribution with b) the area covered by each class expressed as % of the interpolated area of the NNMR.



a)  
b)

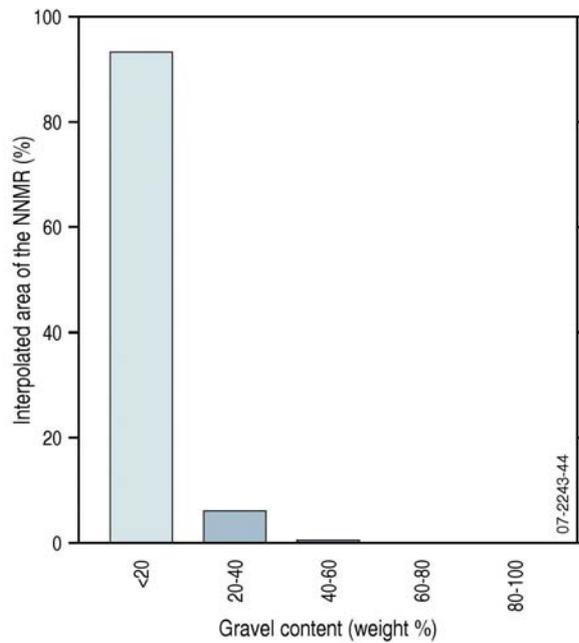
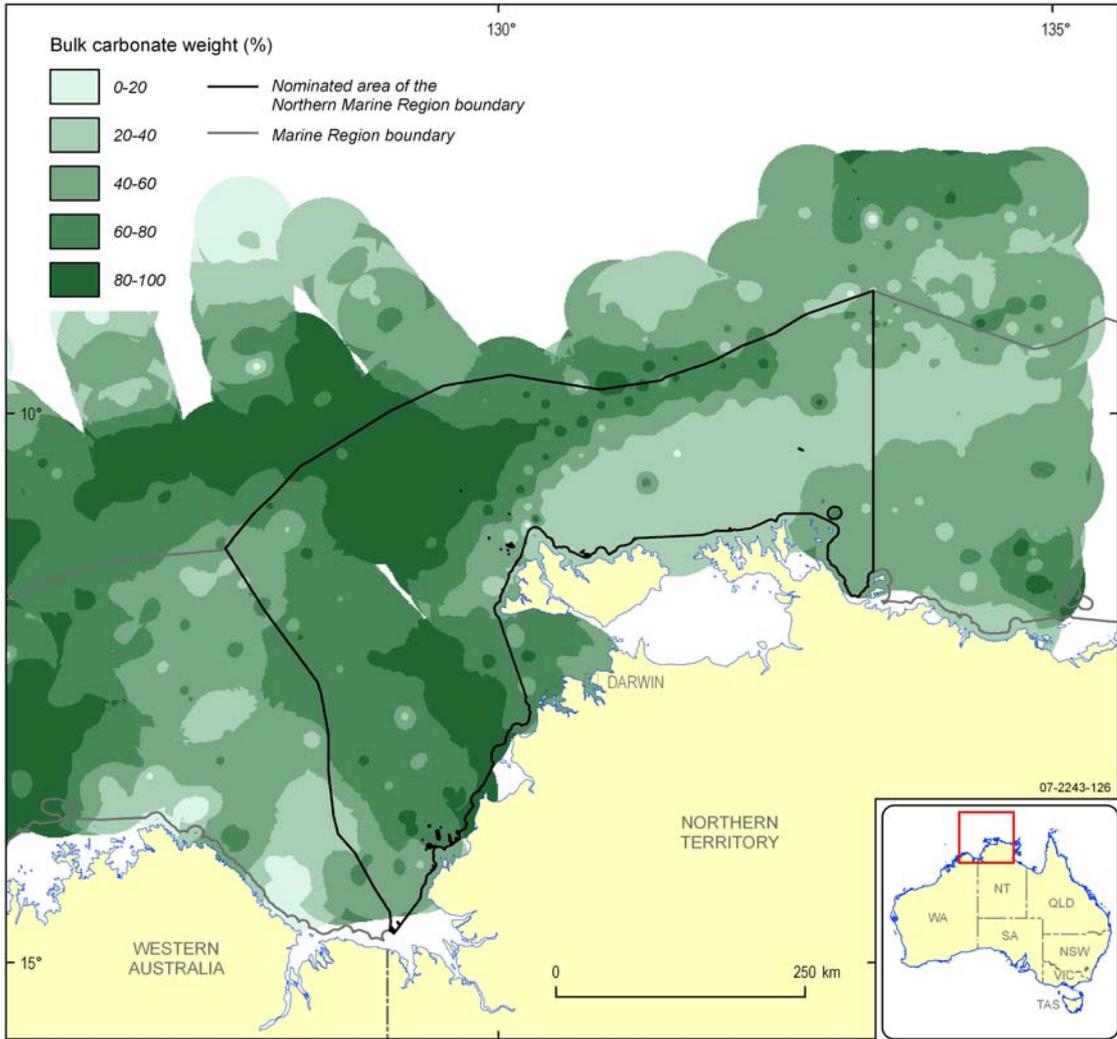


Figure 4.31. a) Gravel distribution with b) the area covered by each class expressed as % of the interpolated area of the NNMR.



a)  
b)

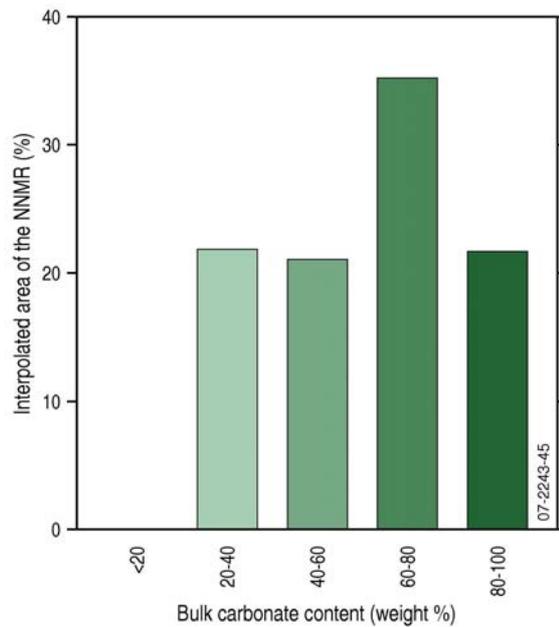
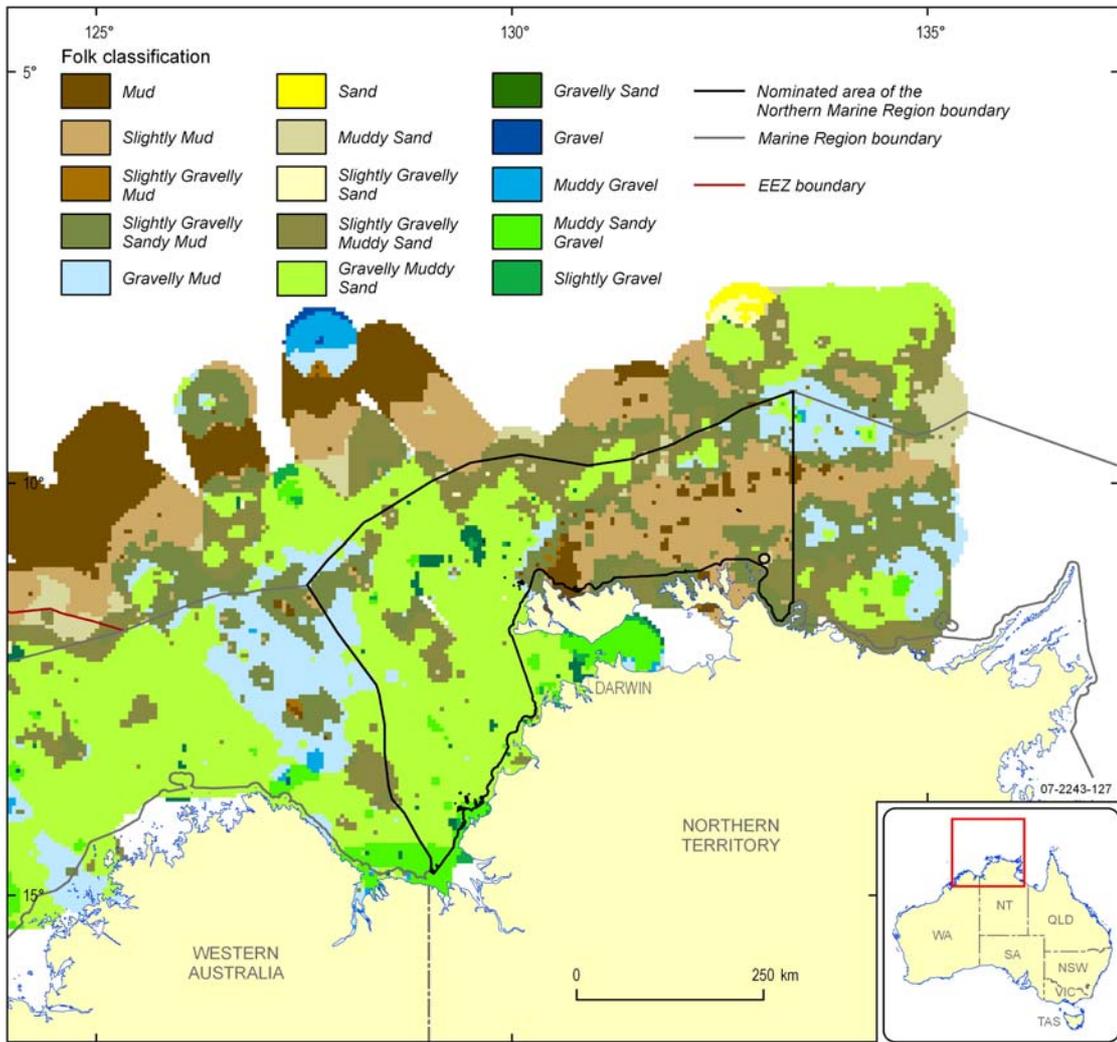
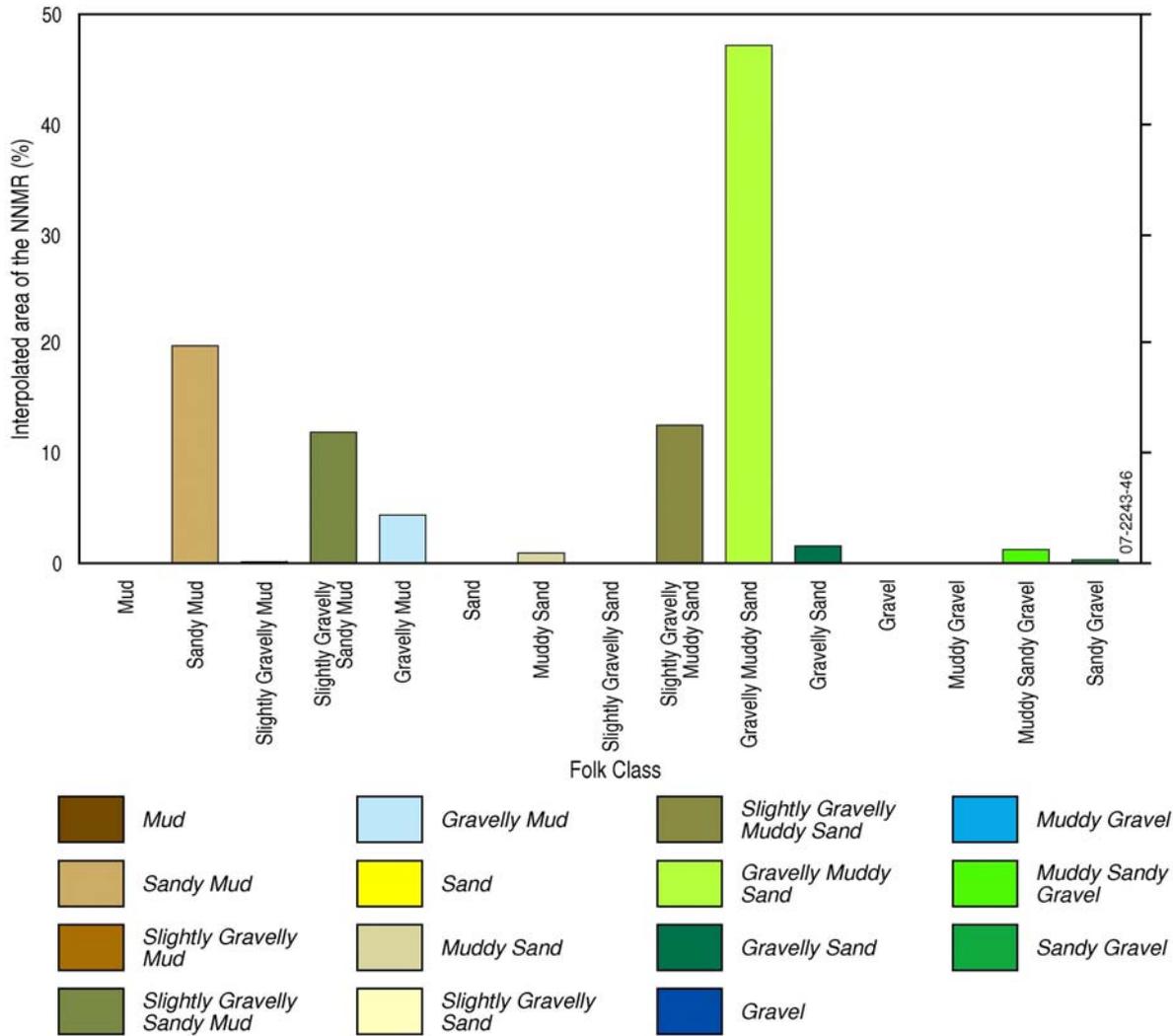


Figure 4.32. a) Bulk carbonate distribution with b) the area covered by each class expressed as % of the interpolated area of the NNMR.



a)



b) Figure 4.33. Interpolated grainsize data displayed as Folk Classes with b) the area covered by each class expressed as % of the interpolated area of the NNMR.

#### 4.2.4.2. Sedimentology of Geomorphic Provinces and Significant Features of the NNMR

Quantitative sedimentology is reported for features judged significant at a marine region scale and that attain adequate sample coverage. These features cover a large area of the NNMR, represent a relatively large percentage of the total area of this feature in the EEZ, or are judged to be unique to the NNMR based on physical properties such as area (km<sup>2</sup>) or water depth range. Where occurrences of a feature form distinct groups based on morphology or water depth, each group has been described separately. Where a feature is judged as significant, but does not attain adequate data coverage, features are noted as significant at a marine region or bioregion scale and properties and distribution of sediment within these features are, where possible, assessed from previous literature and summarised in Chapter 6.

## **Shelf Province**

The shelf in the NNMR is represented by 268 grain size and 218 carbonate assays. The majority of the shelf to the west of Melville Island is sand dominated with localised deposits of gravel and/or mud (Figs 4.31a, 4.32a & 4.33a). The sedimentology of the shelf varies from east to west, with sand dominating the Sahul Shelf in the west of the NNMR and mud dominating the Arafura Shelf to the east. Sand content ranges from 0 to 94%, forming >50% of sediment volume in 148 samples (55%), and >80% in 35 samples (13%) (Fig. 4.34a). Mud content ranges from 0 to 100%, forming <40% of sediment in 143 samples (53%), and >90% in 36 samples (13%). Gravel content ranges from 0 to 68% and forms <20% of sediment volume in 235 samples (88%).

Samples with a high mud content (>60%) are restricted to the outer shelf and area north to north east of Melville and Bathurst Islands. Mud content on the shelf to the west of Melville and Bathurst Islands is generally <20%, and sand content ranges from 40 to 80%. Sediment containing >80% sand occurs locally on the Van Diemen Rise. Sediment containing >40% gravel is found in localised areas on the inner shelf in close proximity to the coast and to the west of Bathurst Island.

The carbonate content of shelf sediments in the NNMR is highest to the west of Melville and Bathurst Island (Fig. 4.35a). Carbonate content ranges from 8 to 99% and exceeds 75% in 75 shelf samples (35%). Samples with <30% carbonate occur on the middle shelf to the north of the Van Diemen Gulf. Carbonate sand content ranges from 28 to 100% in the 106 samples available samples, all of which are located to the west of Melville Island. Carbonate gravel content was not measured for existing samples from the shelf province.

## **Slope Province**

The slope in the NNMR is represented by 45 grain size and carbonate assays. Sediment texture is zoned with water depth; accordingly, gravel and sand content decrease as mud content increases with water depth. Sand is the dominant size fraction across most of the slope comprising 0 to 91% of the sediment volume (Fig. 4.32a & 4.34b). A total of 27 samples (60%) contain >50% sand and six samples (13%) contain <10% sand. Mud content is highly variable, ranging from 2 to 100%, with 16 samples (36%) containing <20% mud and six samples (13%) containing >90% mud. Gravel content ranges from 0 to 59% and forms <10% of the sediment volume at 39 sites (87%) sampled. Gravel is abundant (20 – 60%) locally on the slope in the north east corner of the NNMR.

Carbonate content ranges from 19 to 88%, with 33 samples (73%) containing >50% carbonate and six samples (13%) containing <26% carbonate (Fig. 4.35b). The carbonate content of the sand fraction was measured for seven samples and exceeds 60% in six samples (86%). Carbonate content of the mud fraction was measured for five samples and ranges from 22 to 31% carbonate. Carbonate content of the gravel fraction was measured for four samples and attains 100% in all these samples.

## **Banks/shoals**

A total of 13 grain size and nine carbonate assays were obtained from banks/shoals. Sand is the dominant fraction and ranges from 35 to 93%. A total of 11 samples (85%) contain >50% sand, and four samples (31%) exceed 85% sand (Fig. 4.36a). Gravel comprises from 1 to 43% of the

sediment volume, and nine samples (70%) contain <20% gravel. Mud is less abundant, ranging from 0 to 43% with 10 samples (77%) containing <20% mud. Bulk carbonate ranges from 68 to 91%, and seven samples (78%) contain >90% carbonate. Carbonate sand was measured for nine samples and ranges from 97 to 100%, with eight samples (89%) attaining 100% carbonate sand (Fig. 4.37a). No carbonate mud or gravel contents were measured for existing samples in banks/shoals.

### **Deep/hole/valleys**

A total of 12 grain size and nine carbonate assays were obtained from deeps/holes/valleys. Sand is the dominant fraction ranging from 35 to 94%, with 11 samples (92%) containing >50% sand and five samples (42%) exceeding 80% sand (Fig. 4.36b). Mud is the next most abundant fraction, ranging from <1 to 39%, with nine samples (75%) containing <30% mud. Gravel content ranges from 3 to 37% and is <15% in nine samples (75%). Bulk carbonate content ranges from 68 to 96% and exceeds 70% in eight samples (67%) (Fig. 4.37b). Carbonate content of sand is consistently high, ranging from 81 to 100% in five samples (100%). No carbonate mud or gravel contents were measured for existing samples in deeps/holes/valleys.

### **Basins**

A total of 31 grain size and 28 carbonate assays were obtained from basins. Mud and sand are the dominant fractions ranging from 11 to 93% and from 55 to 79%, respectively (Fig. 4.36c). Mud content is variable with 24 samples (70%) containing <50% mud and two samples (7%), located on the eastern flank of the Bonaparte Depression, containing >85% mud. Mud is less abundant in basins near the shelf break, ranging from 11 to 29%. Sand content ranges from 7 to 79% with 19 samples (61%) containing 50 to 80% sand. Gravel forms <10% in 16 samples (51%) and is absent in four samples (13%). Bulk carbonate content ranges from 38 - 87% with 26 samples (84%) exceeding 50% carbonate (Fig. 4.37c). Carbonate content of sand is consistently high, ranging from 76 to 100% and attaining 100% in nine samples (29%). No carbonate mud or gravel contents were measured for existing samples in basins.

### **Canyons**

A total of four grain size and carbonate assays were obtained from two adjacent canyons located on the slope. Mud is the most abundant fraction of these samples and ranges from 35 to 58% with three samples (75%) containing >50% mud (Fig. 4.36d). Sand is the next most abundant fraction, ranging from 38 to 65%, with three samples (75%) containing <50% sand. Gravel does not exceed 7% of sediment volume and is absent from two samples (50%). Bulk carbonate content ranges from 39 to 57%, with three samples (75%) containing 50 to 57% carbonate (Fig. 4.37d). Carbonate content was not measured for any of the grain size fractions.

### **Ridges**

A total of five grain size and carbonate assays were obtained from ridges. Sand is the most abundant fraction ranging from 9 to 86%, however four of these samples (80%) contain >67% sand. Gravel is the next most abundant size fraction ranging from 0 to 25%, with three samples (60%) containing >10% gravel (Fig. 4.36e). Mud content is generally low, ranging from 2 to 9% in four samples (80%), but it exceeds 90% in one sample adjacent to an apron/fan feature. Bulk

carbonate content ranges from 19 to 82% and exceeds 50% in three samples (60%) (Fig. 4.37e). Carbonate content of the sand fraction was measured for three samples and ranges from 71 to 88%. Carbonate content of the mud fraction was measured for one sample and this attains 23%. All gravel fractions were composed entirely of carbonate.

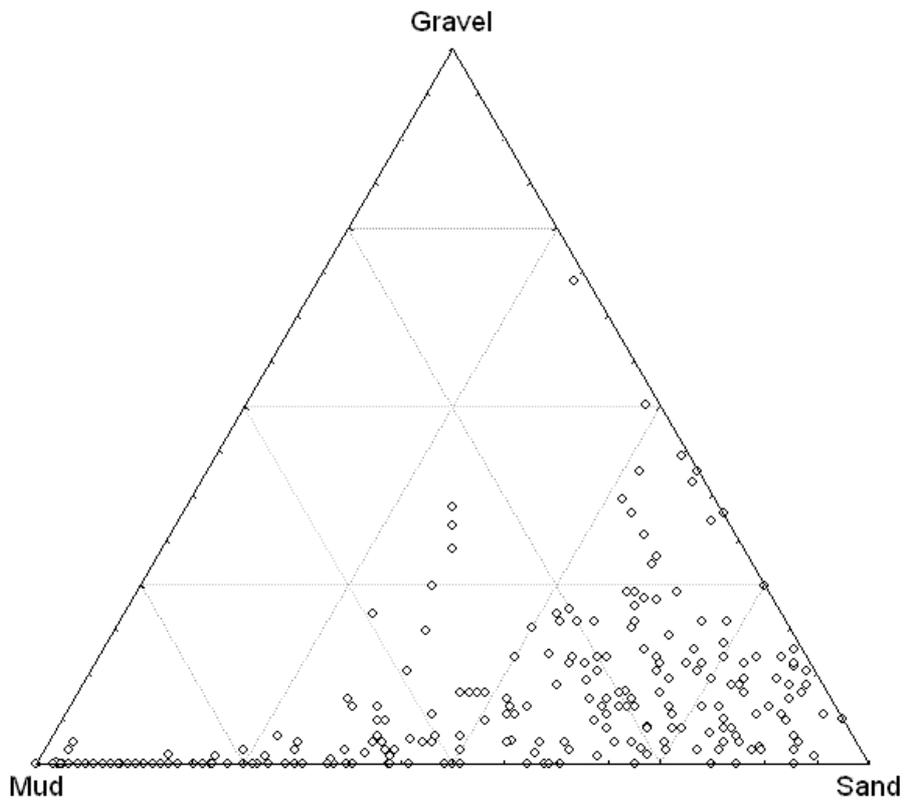
### **Aprons/fans**

A total of 10 grain size and carbonate assays were obtained from aprons/fans. Mud is the dominant fraction, ranging from 9 to 100% with eight samples (80%) containing >50% mud (Fig. 4.36f). Sand contents range from 2 to 80%, although eight samples (80%) contain <35% sand. Gravel generally ranges from 0 to 5% and is absent in four samples (40%)(40%), however one sample located adjacent to a ridge contains 59% gravel. Bulk carbonate content ranges from 23 to 67% and eight samples (80%) contain <50% carbonate (Fig. 4.37f). Carbonate content of the sand fraction was measured for two samples and ranges from 49 to 64%. Carbonate mud was measured for four samples and ranges from 22 to 31%. No carbonate gravel contents were measured for existing samples in aprons/fans.

### **Terraces**

A total of 40 grain size and 38 carbonate assays were obtained from terraces. Sand is the dominant fraction and ranges from 21 to 90%. A total of 32 samples (80%) contain >50% sand, and eight samples (20%) contain >80% sand (Fig 4.36g). Mud content is variable, ranging from 4 to 78% with 30 samples (75%) containing <40% mud and five samples (13%) containing >60%. Gravel content is <16% in 38 samples (95%). Two samples (5%) contain approximately 22% gravel, displaying similar properties to sediments found in adjacent banks/shoal features. Bulk carbonate content ranges from 43 to 98% and exceeds 50% in 35 samples (92%) and 85% in 11 samples (29%) (Fig. 4.37g). Carbonate content of the sand fraction was measured for 23 samples and ranges from 43 to 100% with 18 samples (78%) exceeding 95%. No carbonate mud or gravel contents were measured for existing samples in terraces.

a)



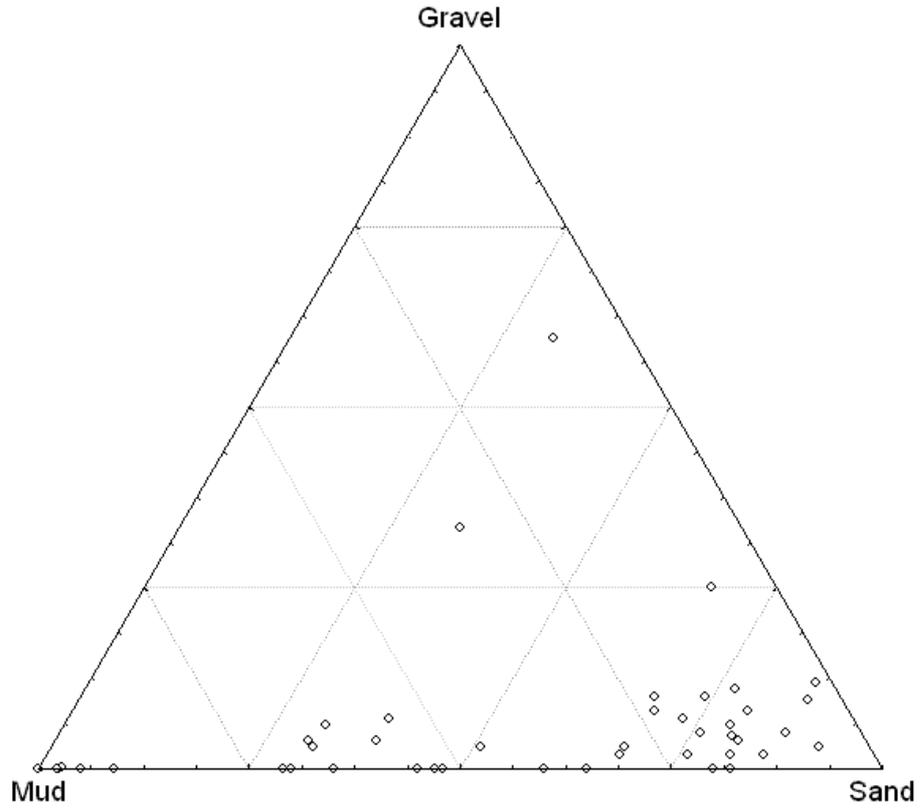
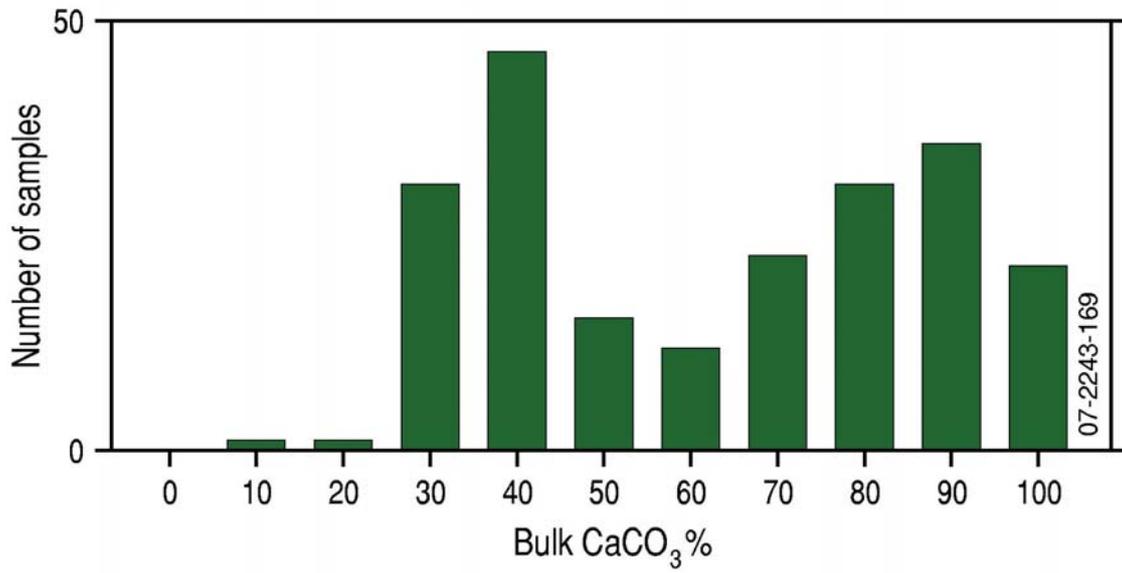


Figure 4.34. Texture of sediment in geomorphic provinces: a) shelf & b) slope of the NNMR.

a)



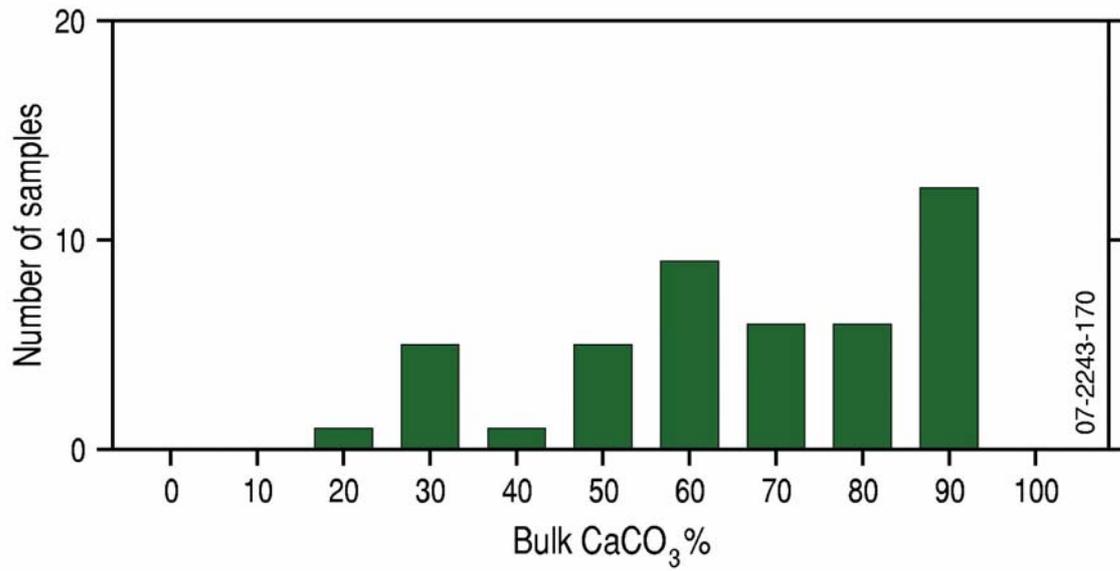
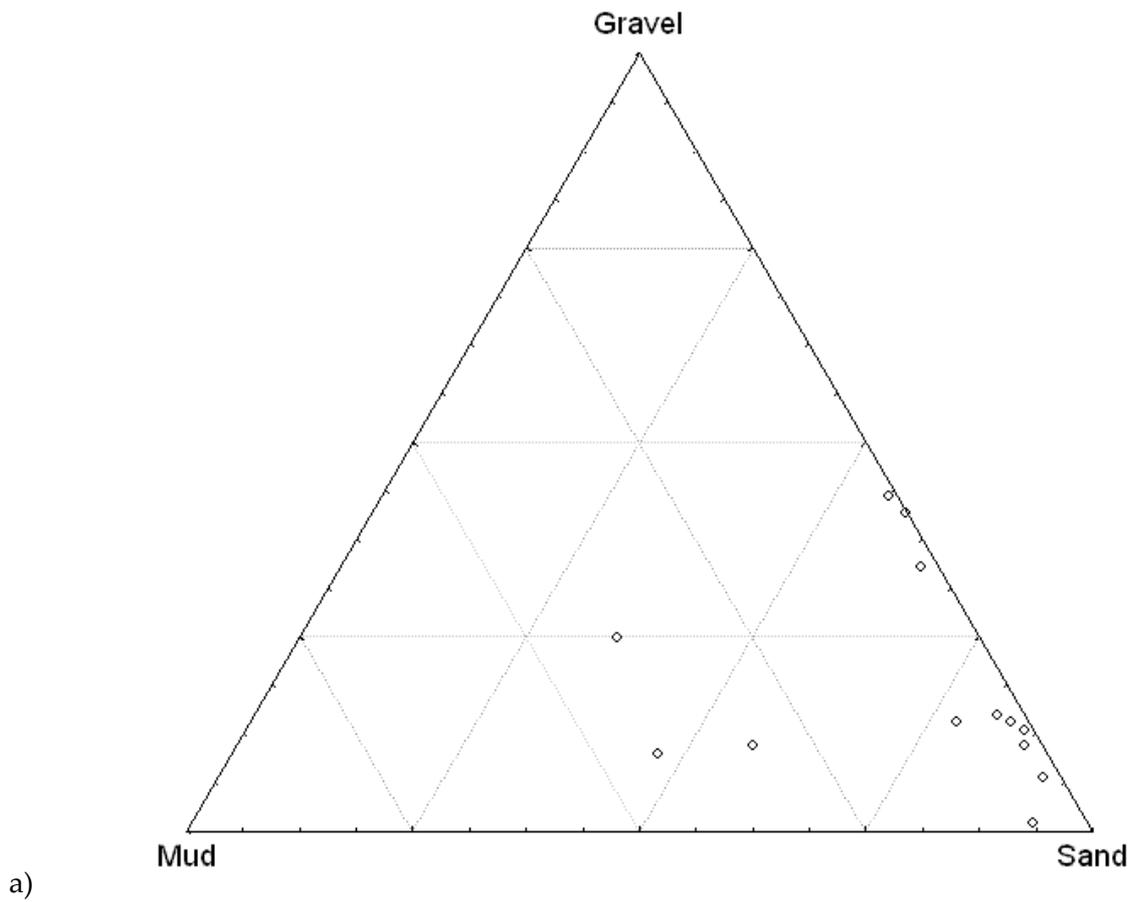
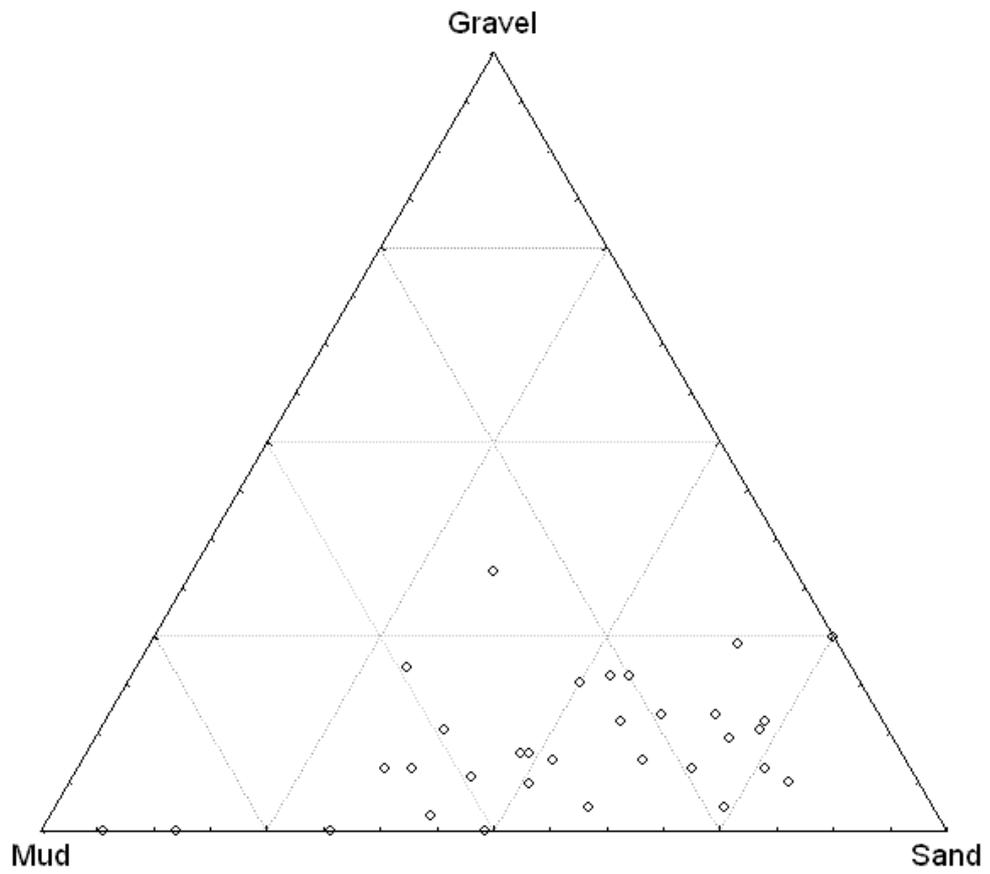
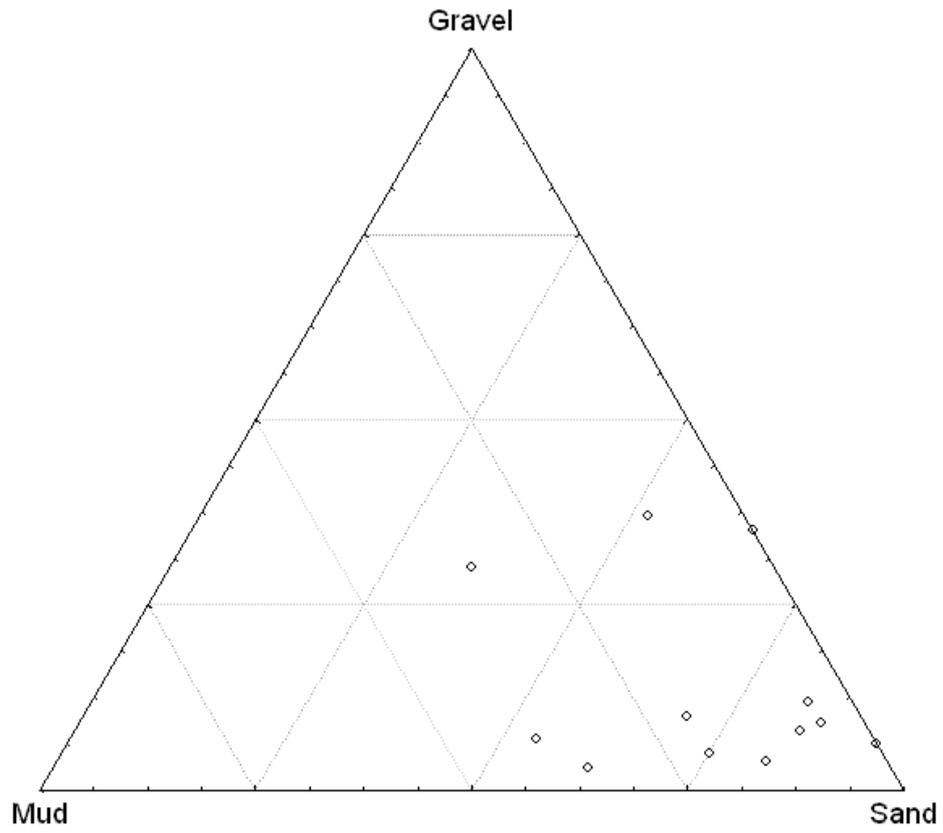
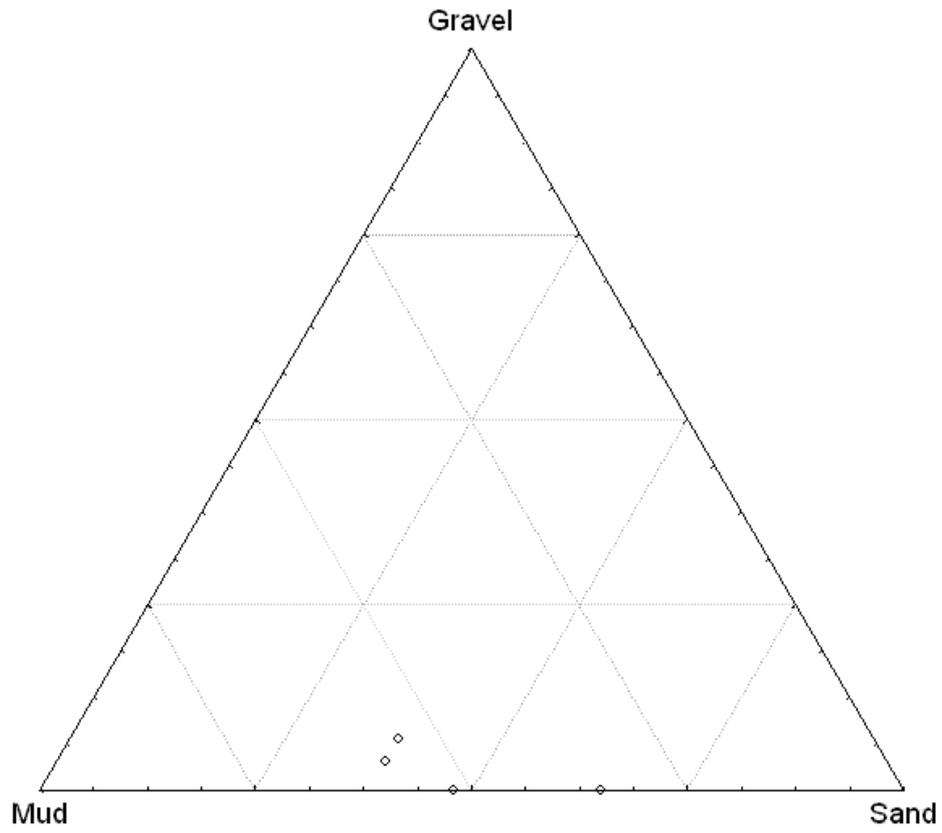


Figure 4.35. Bulk carbonate content of geomorphic provinces: a) shelf & b) slope of the NNMR.

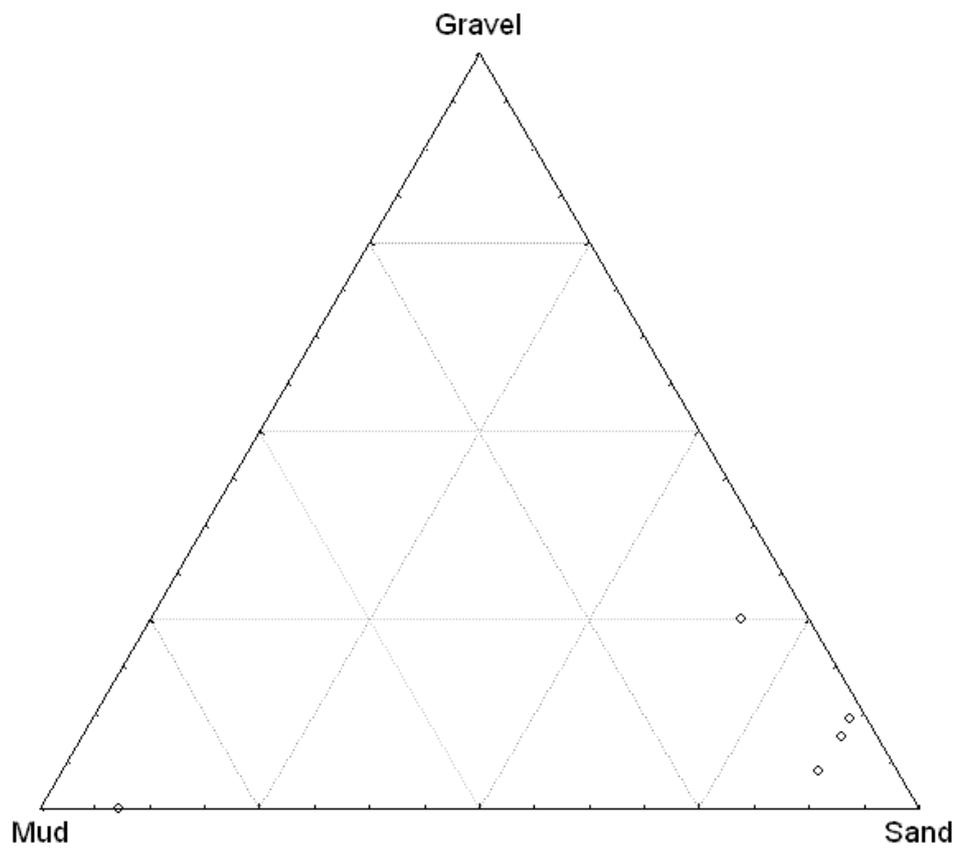


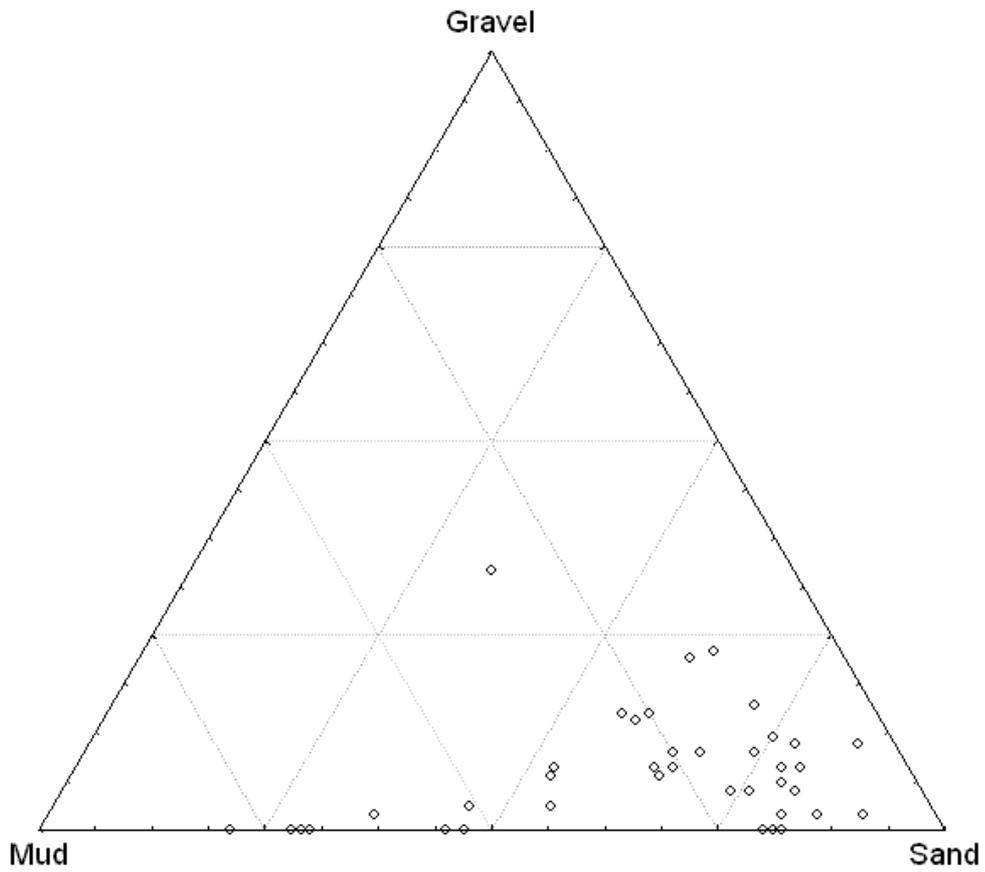
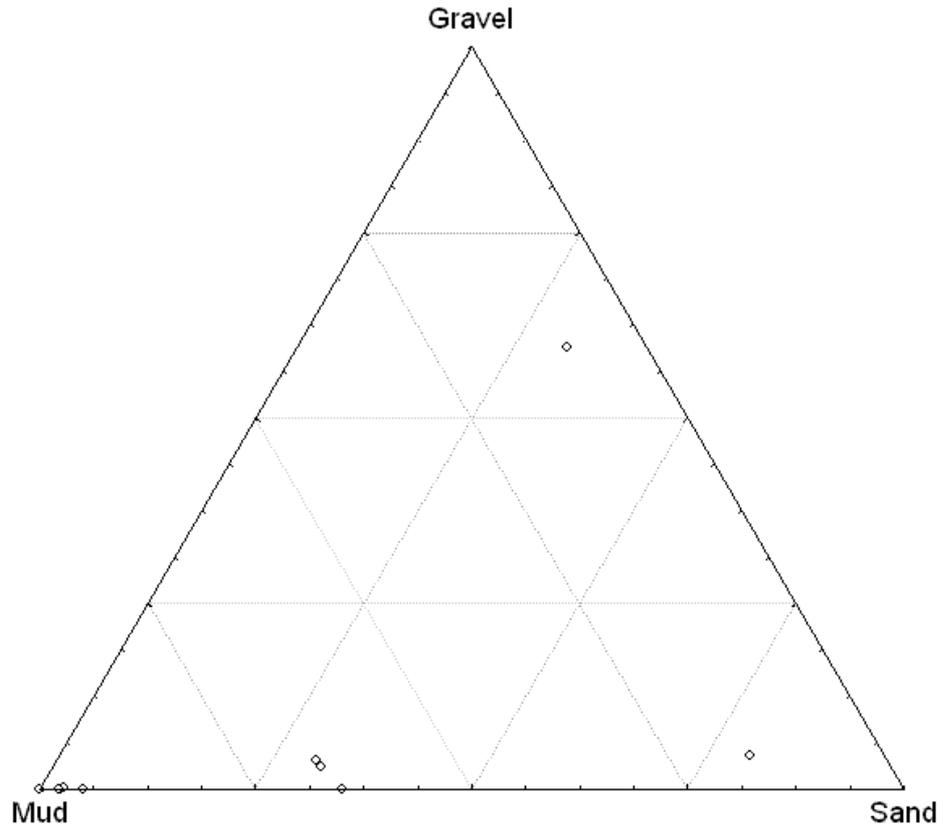


c)

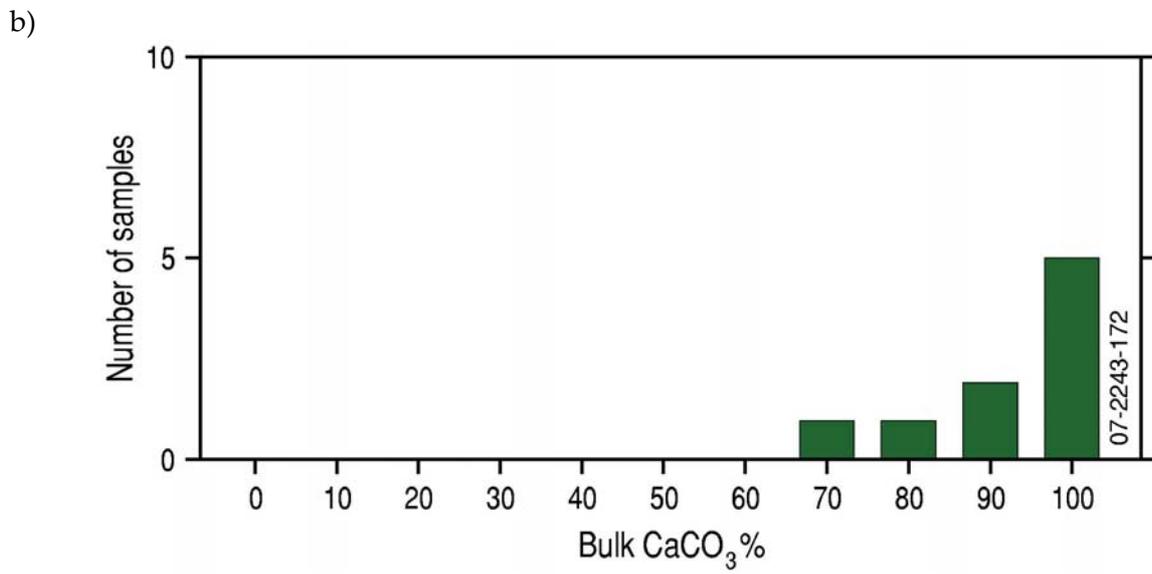
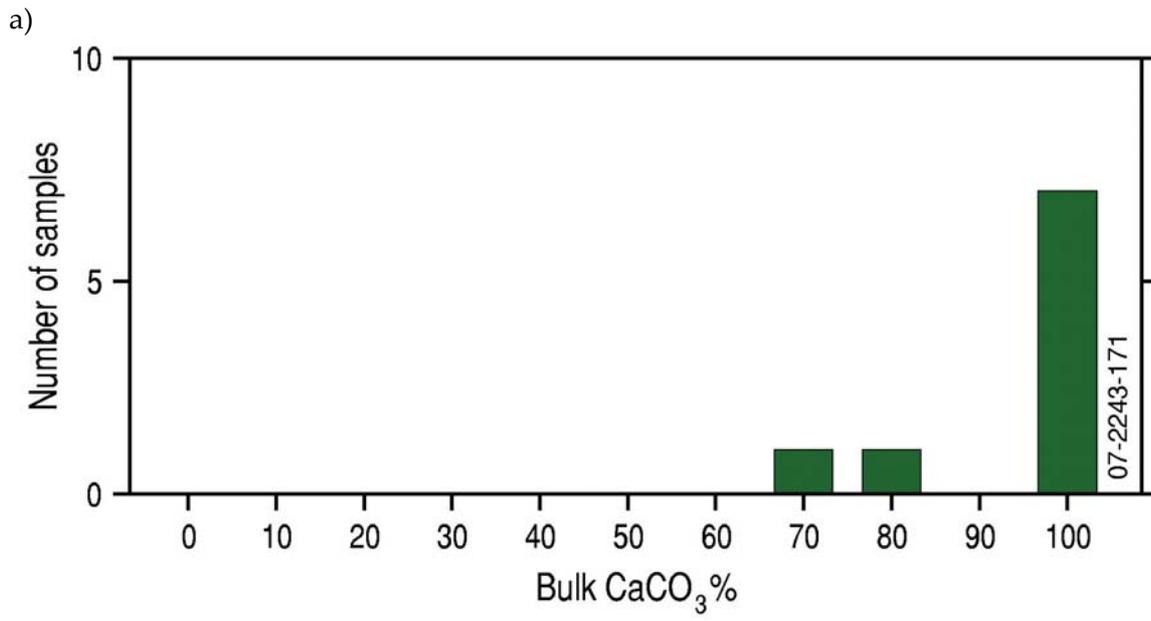


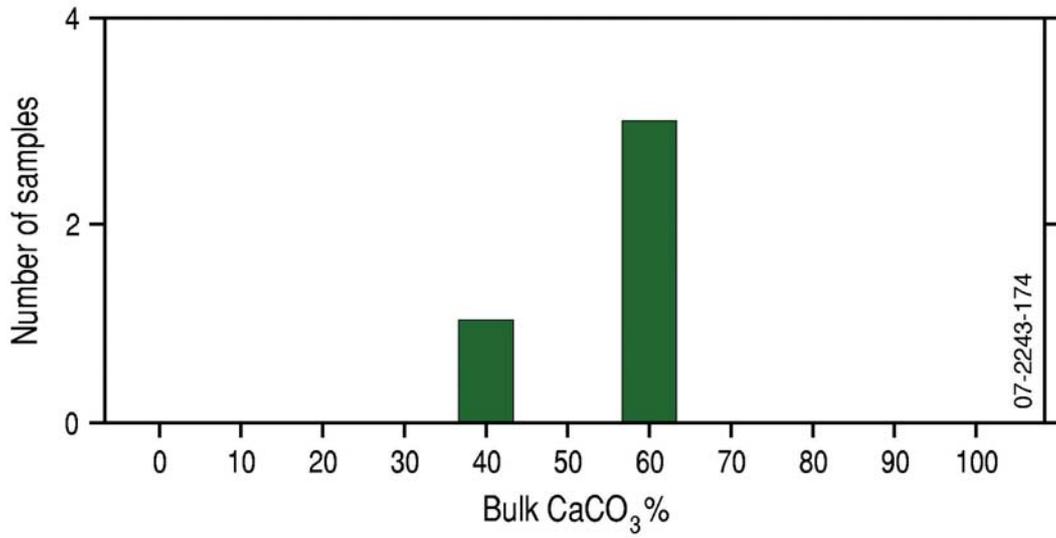
e)



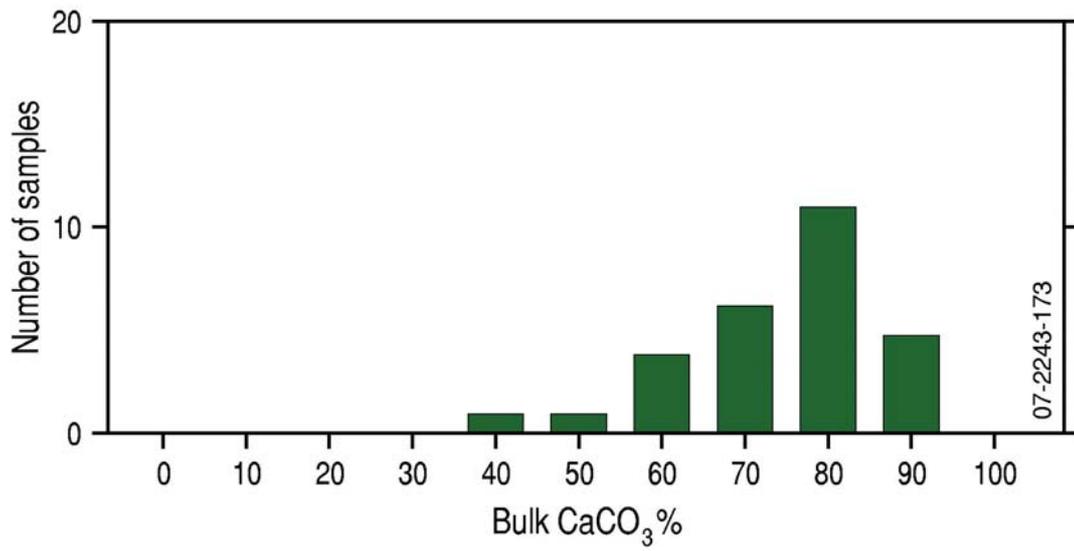


g)  
 Figure 4.36. Textural composition (mud:sand:gravel ratio) of geomorphic features in the NNMR: a) bank/shoal; b) deep/hole/valley; c) basin; d) canyon; e) ridge; f) apron/fan; and g) terrace.

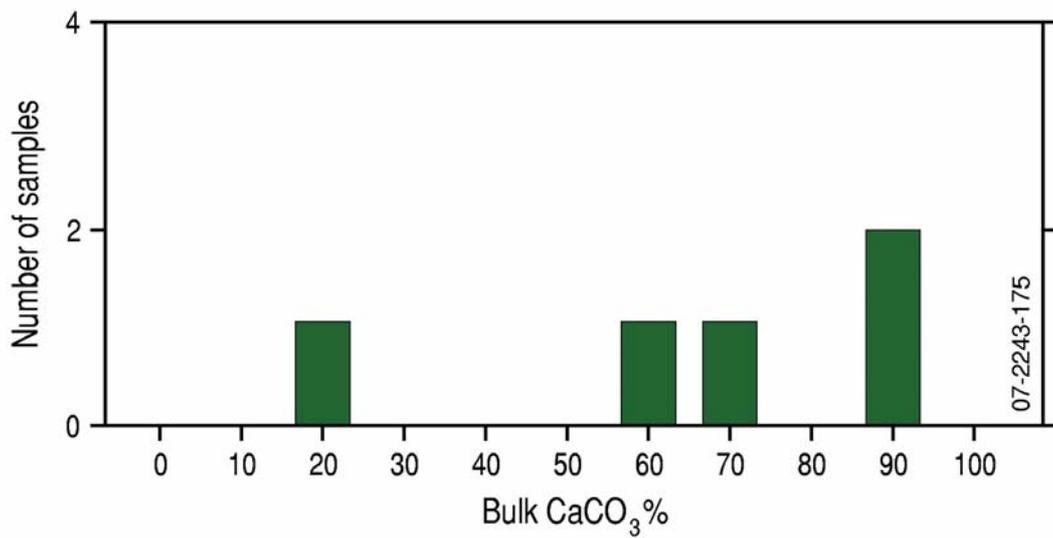




d)



e)



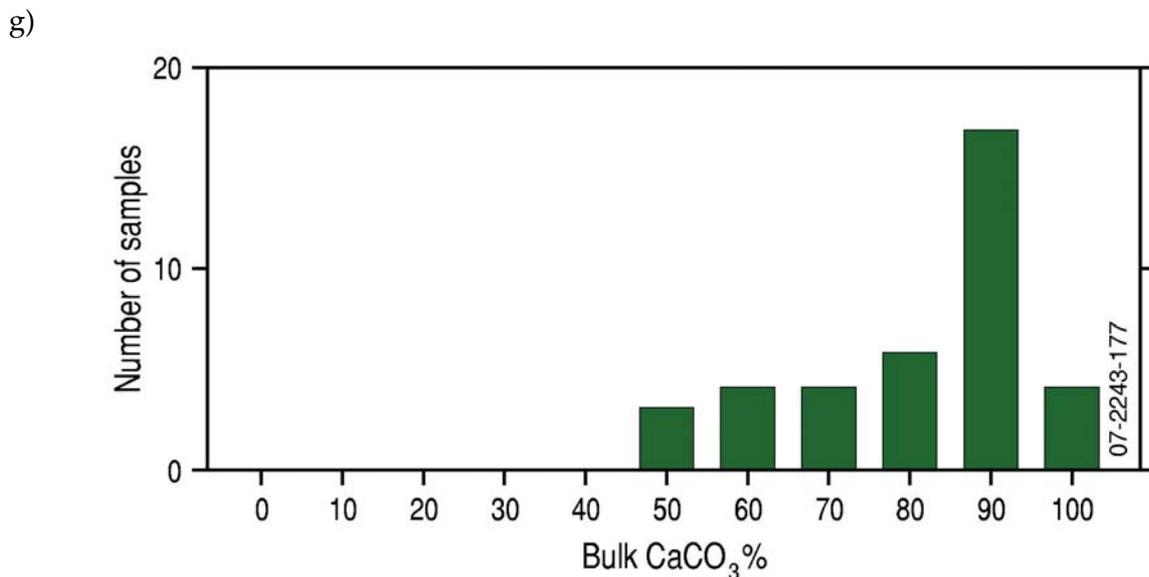
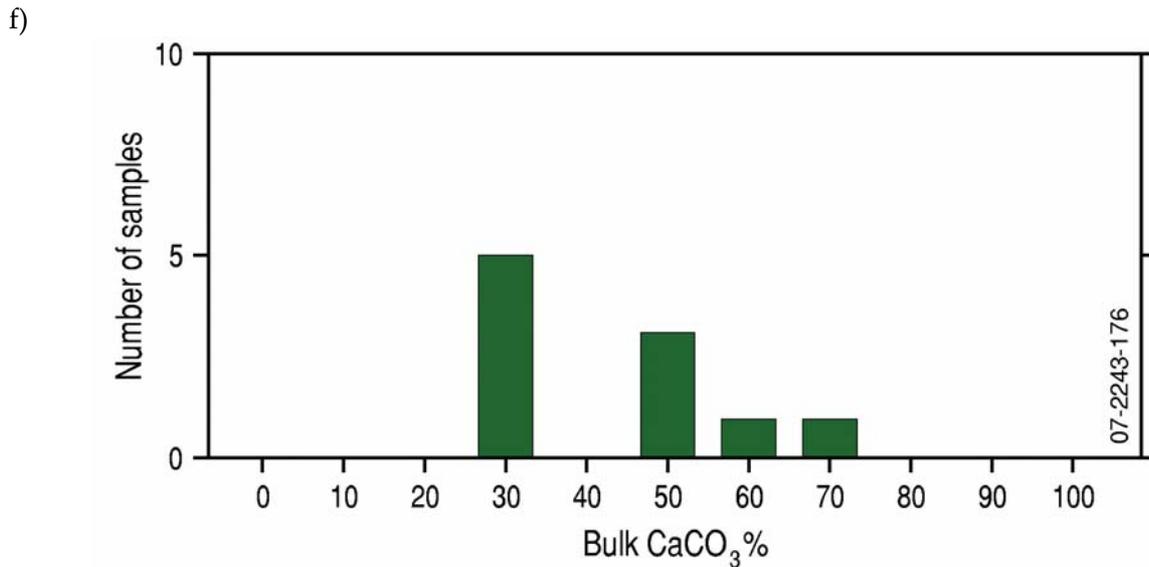


Figure 4.37. Composition of bulk carbonate content in geomorphic features of the NNMR: a) bank/shoal; b) deep/hole/valley; c) basin; d) canyon; e) ridge; f) apron/fan; and g) terrace.

## 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.