Figure 9.33 Operations and details of the YMG Galatea-trawl dredge

9.3.15 Marine Survey

During CCZ13 a TOML contract surveyor operated Caris HIPS (Hydrographic Data Processing System) software through the multibeam system's dual head GPS array and maintained a digital survey log. Deployments and co-ordinates were written into a log book. Communications were verbally to the bridge on the same level and via hand held radio to the back deck.

During CCZ15 R/V Yuzhmorgeologiya's survey department coordinated operations and logged events (TOML personnel also kept a log book). Various sensors (e.g. GPS, weather station, USBL) all fed to a central computer with most data read into Hydropro software. The main navigation screen from Hydropro was replicated on the bridge so that the officers there received real-time updates on current and planned movements. Communication between Hydrographer, Bridge, Pinger Operator, Winch Operator and Back Deck Supervisor was via a dedicated open intercom system. A USBL antenna was deployed through a small opening in the base of the ship and an IXSEA Posidonia 6000 gen1 system used this and an umbilical to transmit to the MAK deep tow system, and to communicate with a variety of 12 KHz beacons.

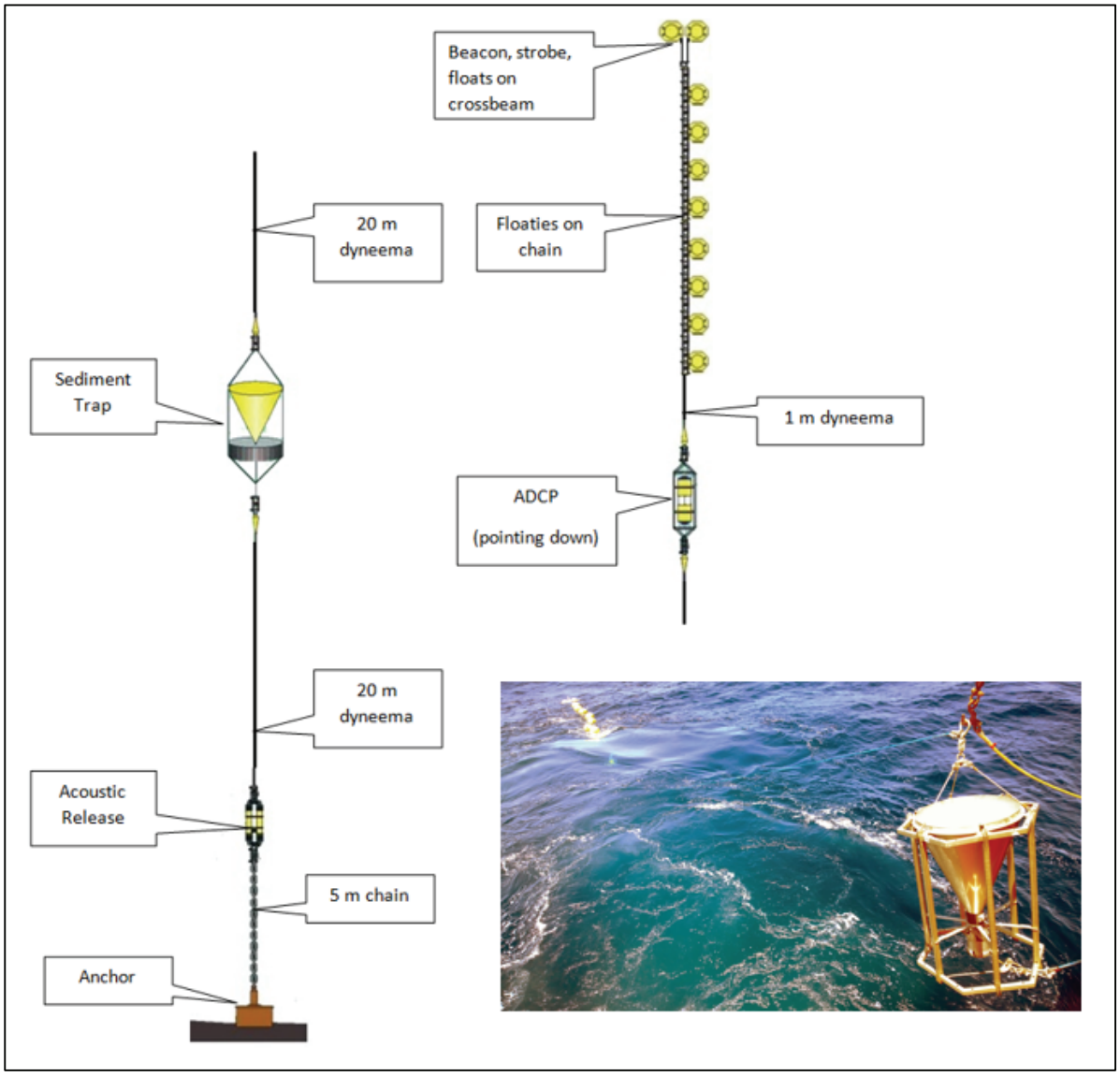
9.3.16 Other Programmes

9.3.16.1 Long Term Moorings

During and shortly after CCZ15, two moorings were deployed, one in Area C (S01) and one in Area B (S03).

The moorings were designed to be simple and inexpensive and to have a minimum two year life (Figure 9.34). Engineering was by Sound Ocean Systems Inc based on environmental parameters provided by the Nautilus environmental team and an Erias Group (Melbourne, Australia) consultant.

Figure 9.34 CCZ15 Mooring Design and deployment of Mooring S01 in Area C



9.3.16.2 Other Environmental Data

A complete summary of environmental data collected during the CCZ15 cruise is presented in Table 9.8 below. Other specific data collected was:

- CSMF, or marine mammal observations, were recorded on a log by the bridge. During CCZ13 marine mammals were only seen outside the CCZ and during CCZ15 two mammal sightings were made with a solitary dolphin to the east of Area A and two whales (likely Sperm Whales) within Area D. Birds were seen on both cruises but were only logged during CCZ15 (Figure 9.35)
- Weather Information, including logs, weather reports as well as interpretation of these data (i.e. as summarised in Item 5).

Figure 9.35 CCZ15 CSMF Events

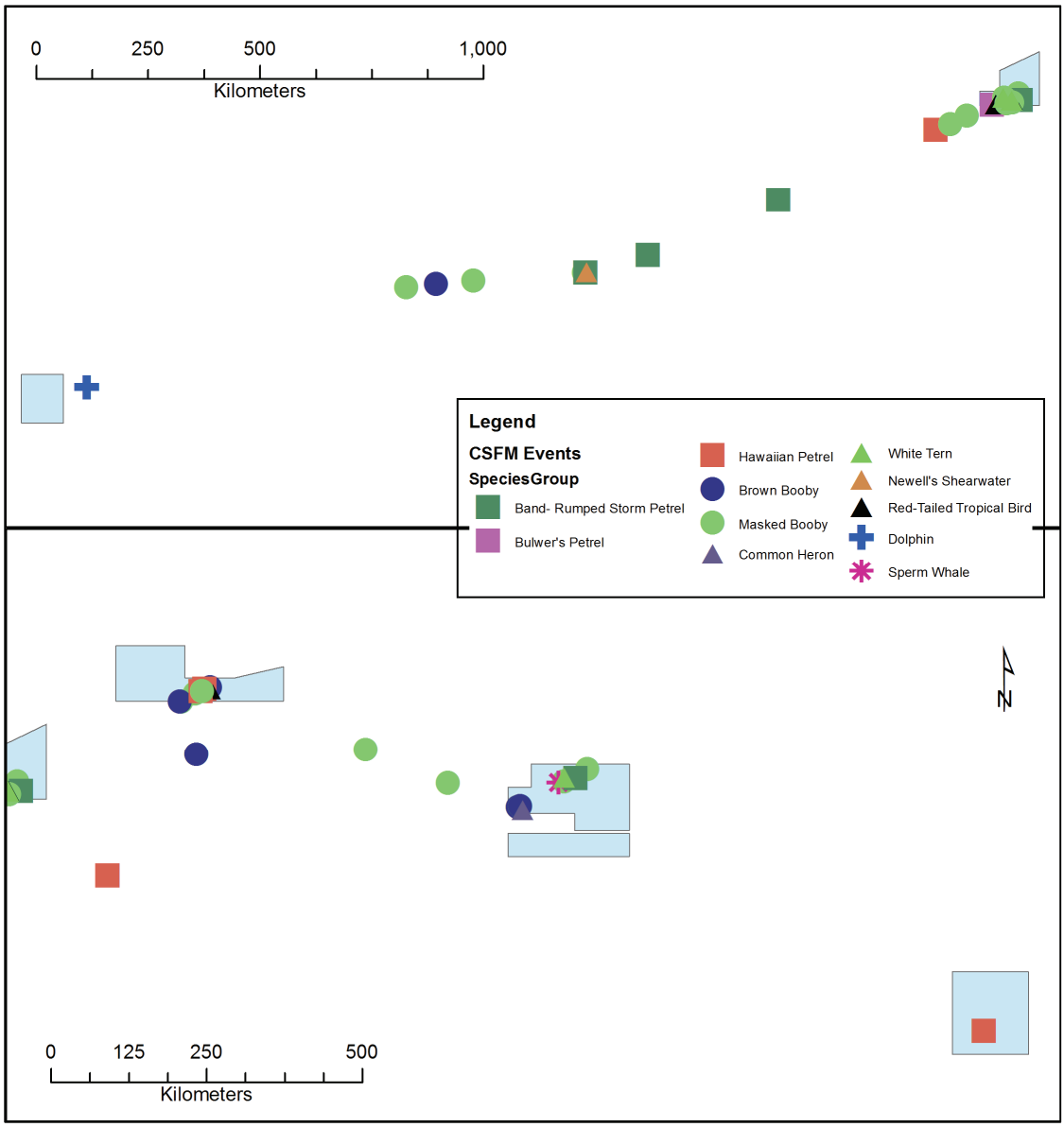


Table 9.8 CCZ15 Environmental Data Matrix

	Benthic Fauna Characterisation							Geological and Geomorphological Characterisation				Water Column Quality/Chemistry				Oceano-graphy	Ecosystem Function
	Mega	Macro	Meio	Micro	Overlying Fauna	Nodule Fauna	Benthic Fauna Morphology	SC	PSD	Geo-morphology	Substrate	TM	TSS	pH	Water Column Profiles (Temp °C & NTU)	Current Profiles	Sinking Particle Flux
Number of Samples	84	1195	997	458	78	383	see below	83	86	see below	see below	112	98	112	108	16	2
Logged Photographs	20857	20857	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Logged Video (hrs)	192	192	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Abundance	✓	✓	✓	✓	✓	✓	NA	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA
Biological Diversity	✓	✓	✓	✓	✓	✓	NA	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA
Community Composition	✓	✓	✓	✓	✓	✓	NA	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA
Relation to Nodule Abundance/ Size	✓	✓	✓	✓	✓	✓	NA	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA
Morphological Taxonomy	✓	✓	✓	NA	✓	✓	NA	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA
Molecular Taxonomy	✓	✓	✓	✓	✓	✓	NA	✓	✓	NA	NA	NA	NA	NA	NA	NA	NA
Biotope Mapping	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA	NA	NA	NA	NA
Sampling Equipment	Photo Sled/ Boxcore	Photo Sled/ Boxcore/ Sub-cores	Boxcore/ Sub-cores	Boxcore/ Sub-cores	Boxcore	Boxcore	Photo Sled	Boxcore/ Sub-cores	Boxcore/ Sub-cores	Photo Sled / MBES / Side-Scan	Photo Sled / SBP/ MBES	Niskin Rosette	Niskin Rosette	Niskin Rosette	MAPR	ADCP / WCP	Near-Bottom Sediment Trap

Note: Sub-cores sectioned at 3 to 4 horizons, dependent on fauna type. Horizons: 0-2 cm, 2-5 cm, 5-10 cm and 10-20 cm.

Glossary							
SC	Sediment Chemistry	TM	Trace Metals	Photo Sled	576 line km	Side-scan + SBP	sub-bottom profiler - 286 line km
PSD	Particle Size Distribution	TSS	Total Suspended Solids	MAPR	Mini Autonomous Plume Recorder	WCP	Water Column Profiler
				ADCP	Acoustic Doppler Current Profiler	MBES	Multibeam Echosounder - 64,000 km2

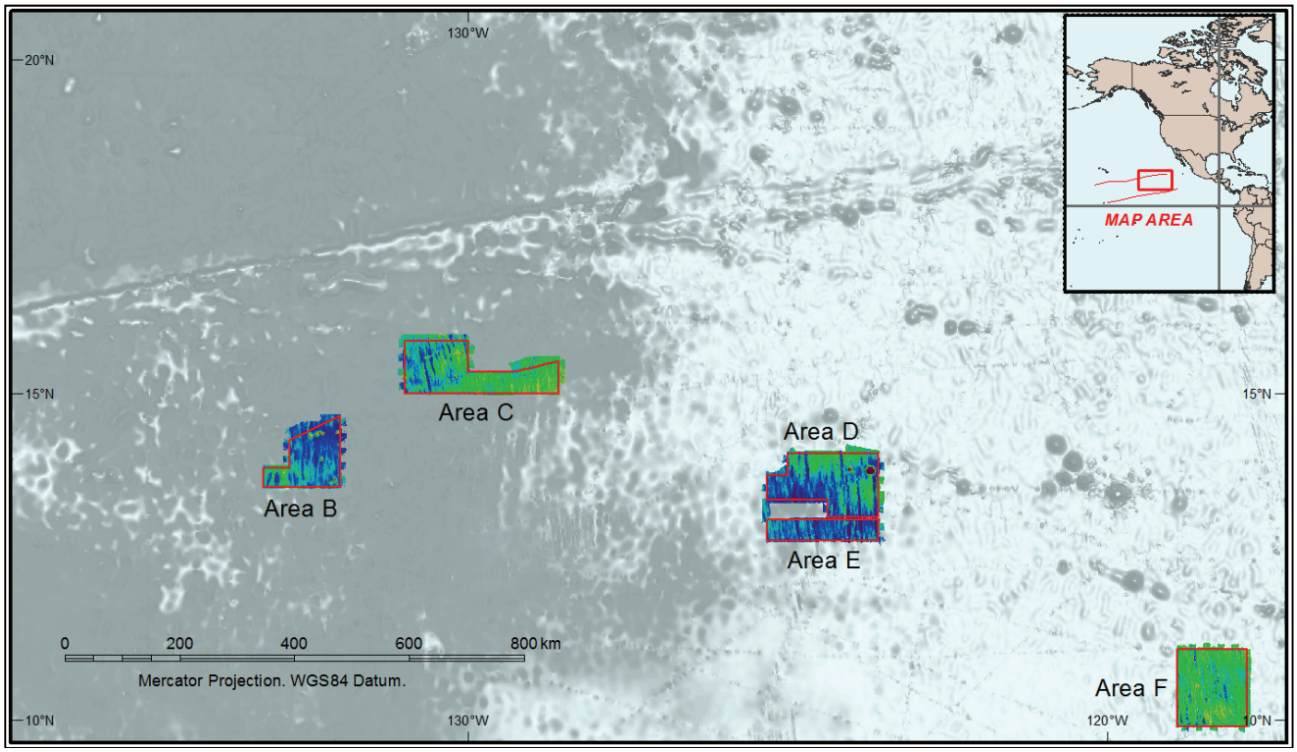
9.4 TOML Exploration Results

The exploration results discussed here include all data relevant to the mineral resource estimate. Much of the supporting data collected during the TOML CCZ13 and CCZ15 cruises is still being processed. This includes much of the environmental and geotechnical data collected, but also includes mineralogy from samples and detailed geological interpretation from acoustic survey. This information will be reported, as relevant, at a later time.

9.4.1 TOML MBES results

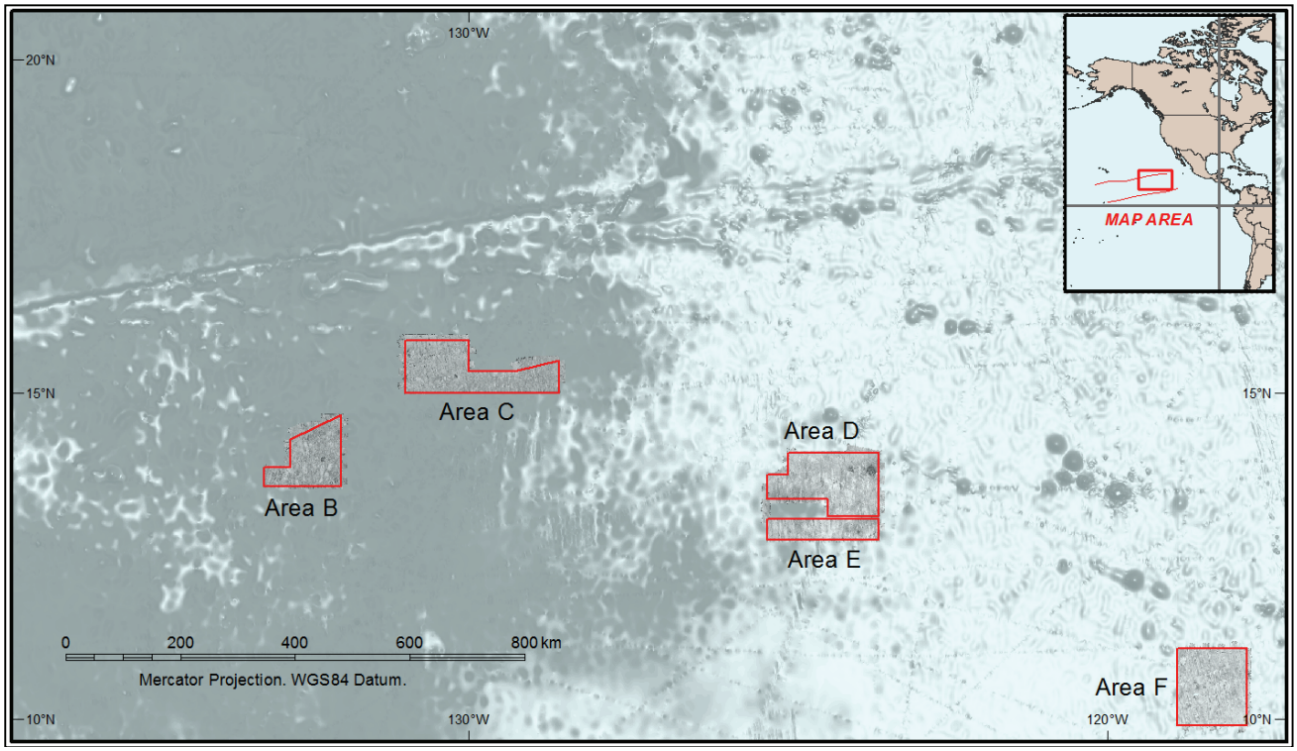
The multibeam results are shown at a small scale in Figure 9.36 and Figure 9.37. As mentioned in Item 7 the bathymetry shows that almost the entire area is composed abyssal hills and as quantified in section 8.3 the bathymetry and backscatter together show that most of the area is covered by nodule bearing sediment.

Figure 9.36 CCZ13 Multibeam bathymetry coverage



Relief range blue to yellow is about 400 m scaled by each area. Background is the GEBCO bathymetric product (BODC, 2014)

Figure 9.37 CCZ13 Mutlibeam backscatter coverage



Background is the GEBCO bathymetric product (BODC, 2014)

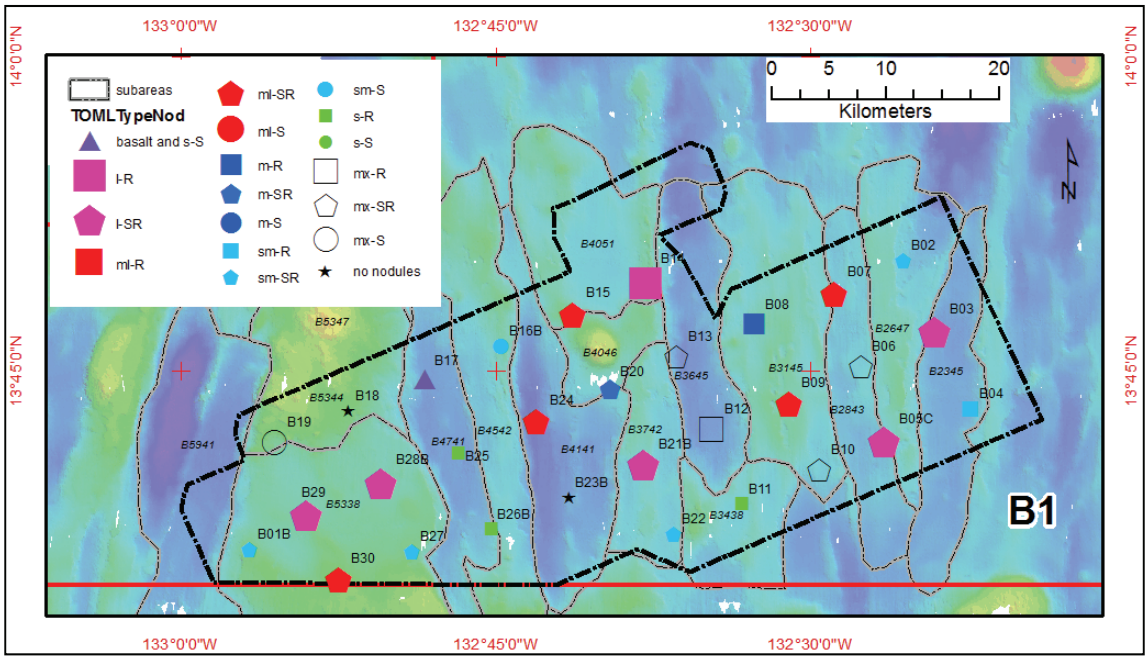
The MBES bathymetry is used repeatedly in the following figures as the backdrop to the box-core results.

9.4.2 TOML Box-core results

Figure 9.38 to Figure 9.52 summarises nodule and sediment characteristics of the box-core sites. Note that data exists at many of the same sites for water column characteristics and chemistry and fauna numbers and taxonomy data.

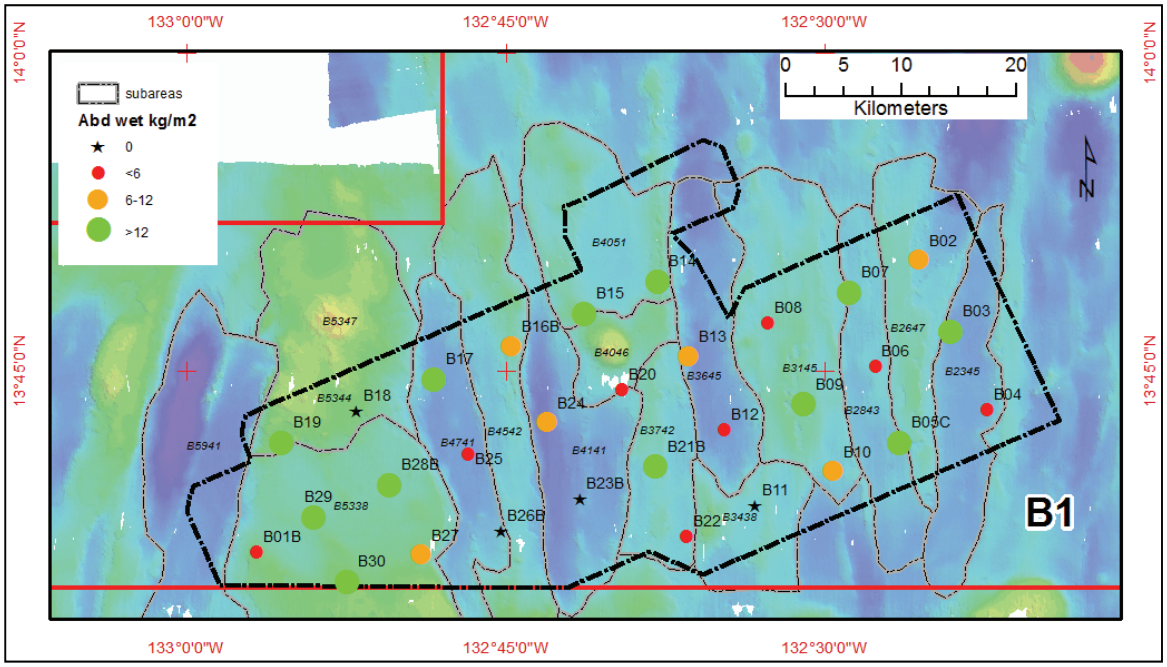
Nodule types are as per the TOML classification in Item 8, with size descriptors of small, medium and large and type as smooth, smooth-rough or rough.

Figure 9.38 Nodule Types, Area B1



Nodule abundances are reported in wet kg/m^2, estimated using the process and principles discussed in section 7.5.6.

Figure 9.39 Nodule Abundance, Area B1



Shear strength is classified per the process and classification detailed in Section 9.3.7.

Figure 9.40 Shear Strength Class, Area B1

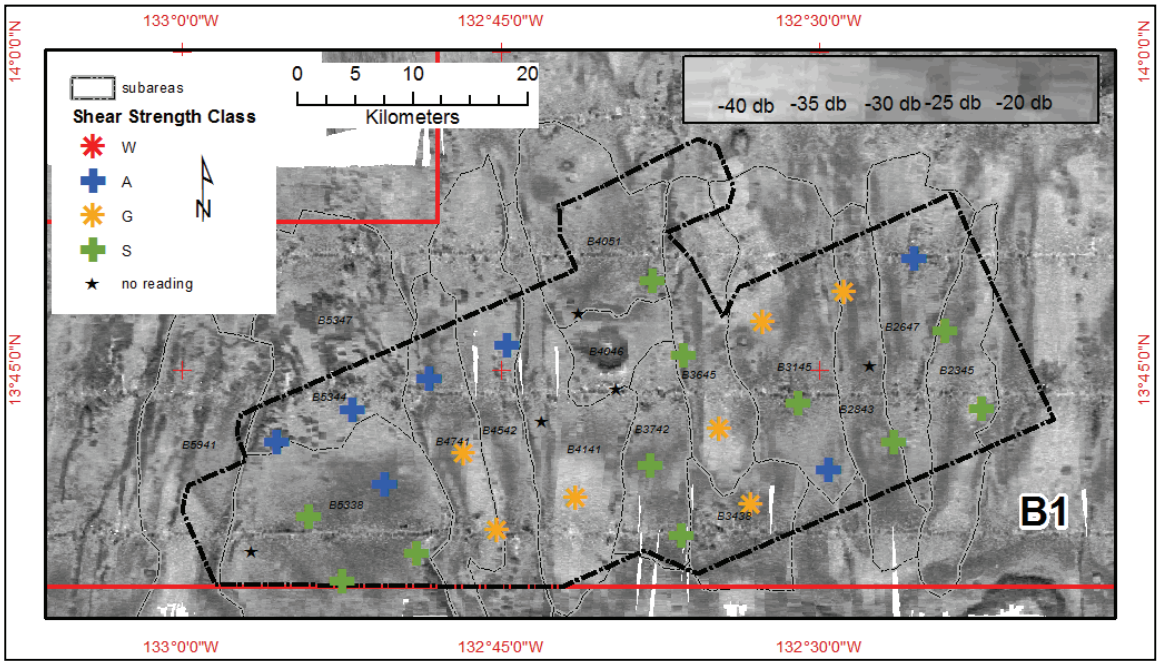


Figure 9.41 Nodule Types, Area C1

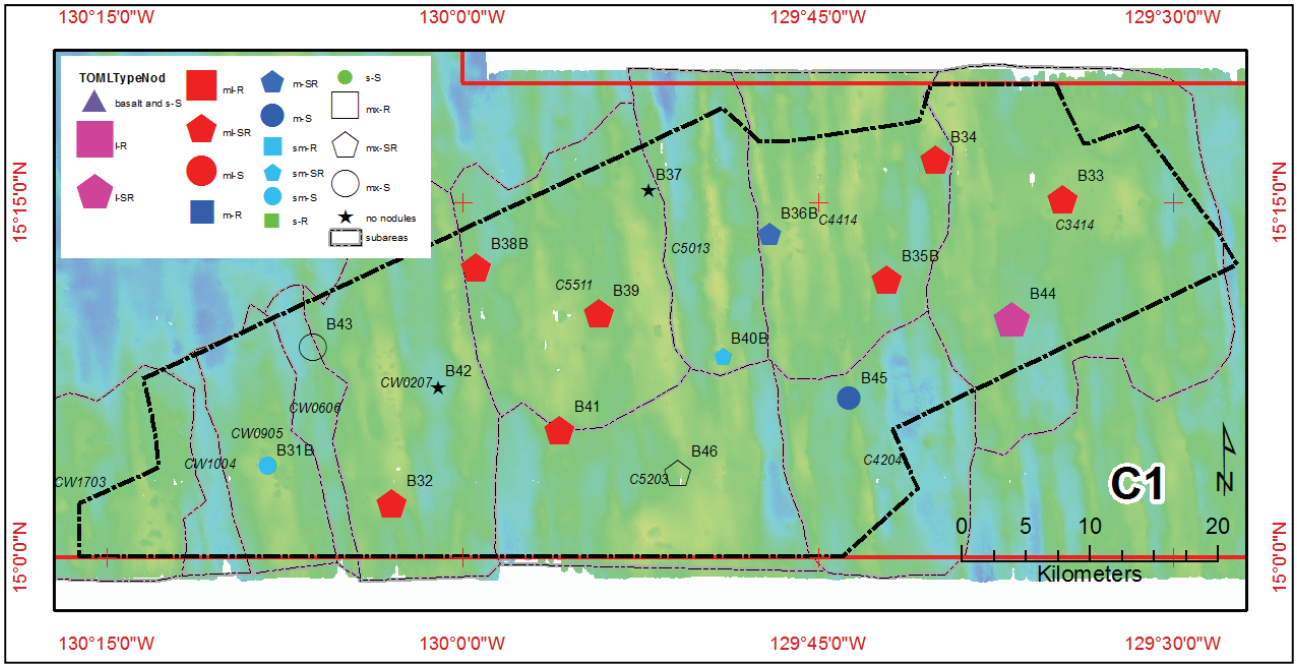


Figure 9.42 Nodule Abundance Area, C1

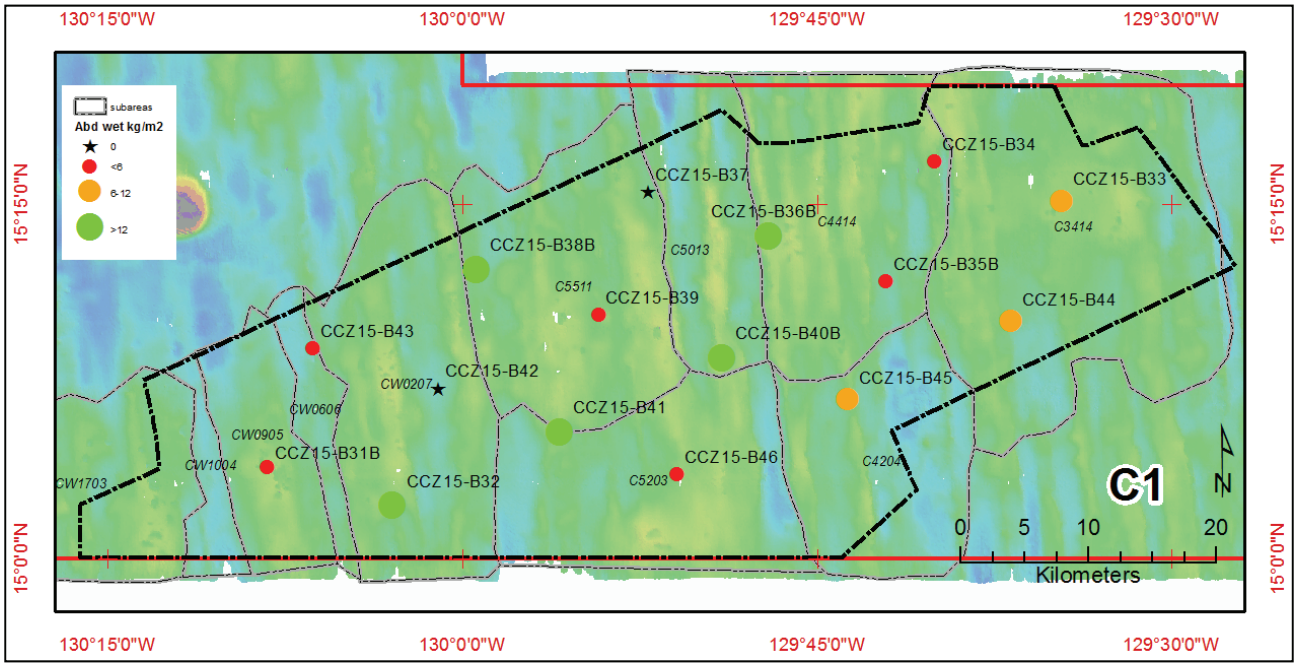


Figure 9.43 Shear Strength Class, Area C1

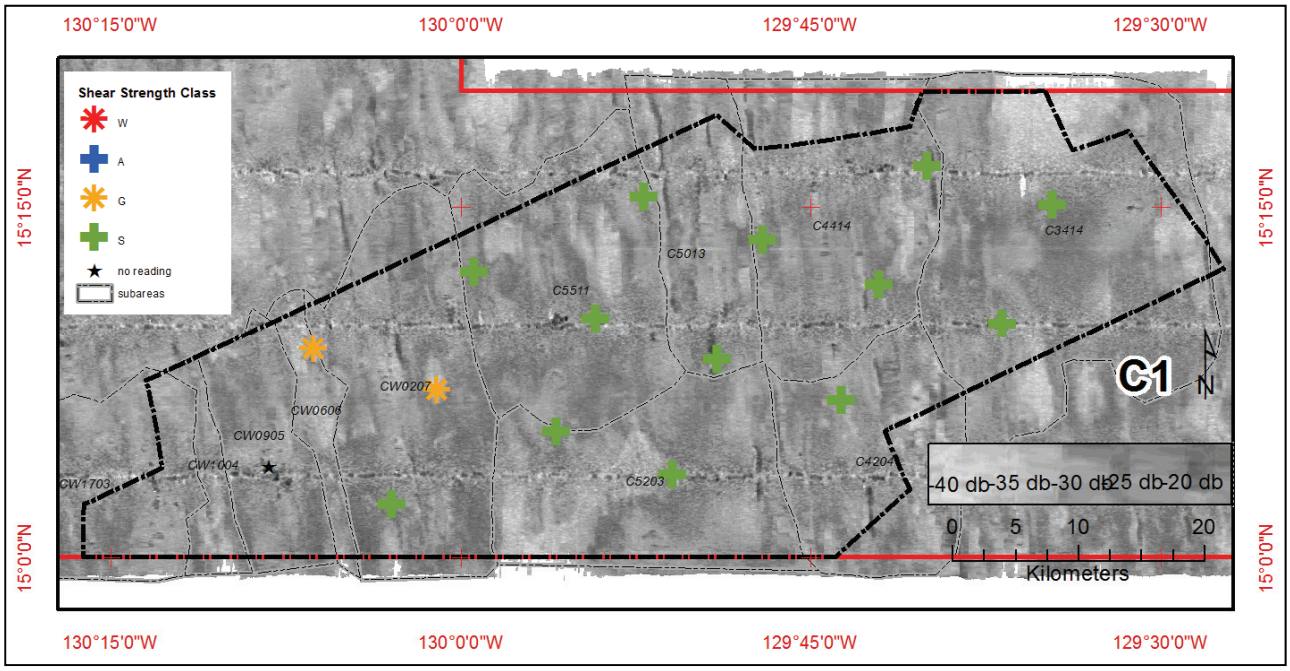


Figure 9.44 Nodule Types, Area D2

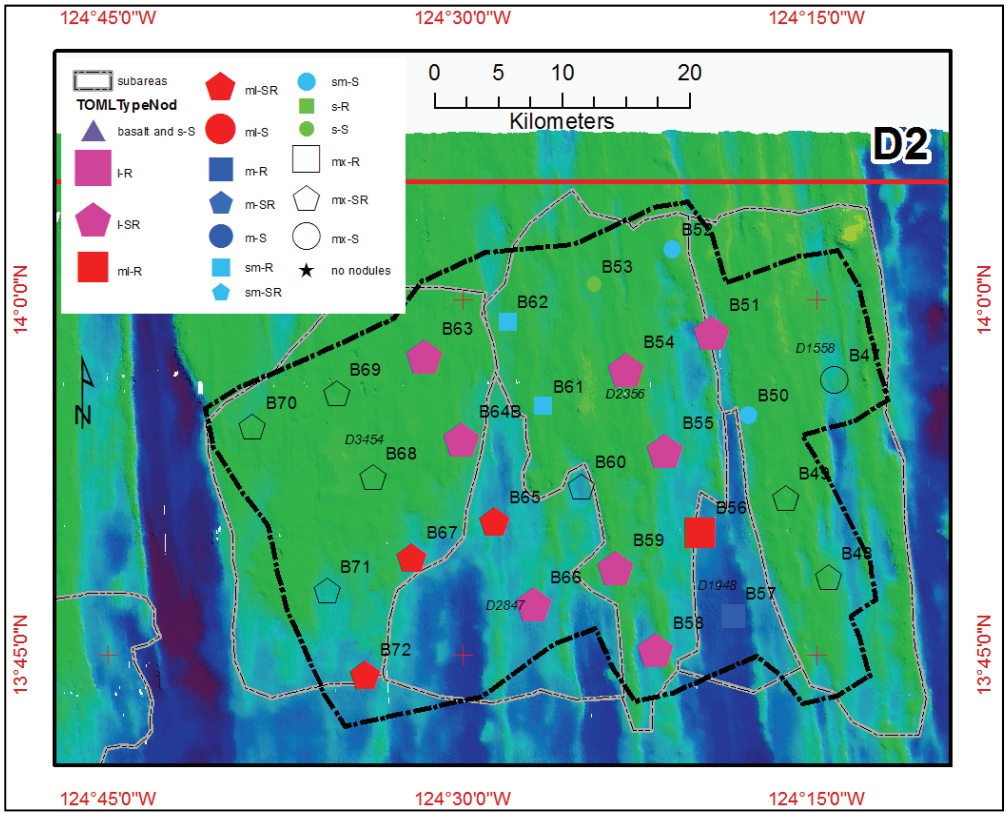


Figure 9.45 Nodule Abundance Area, D2

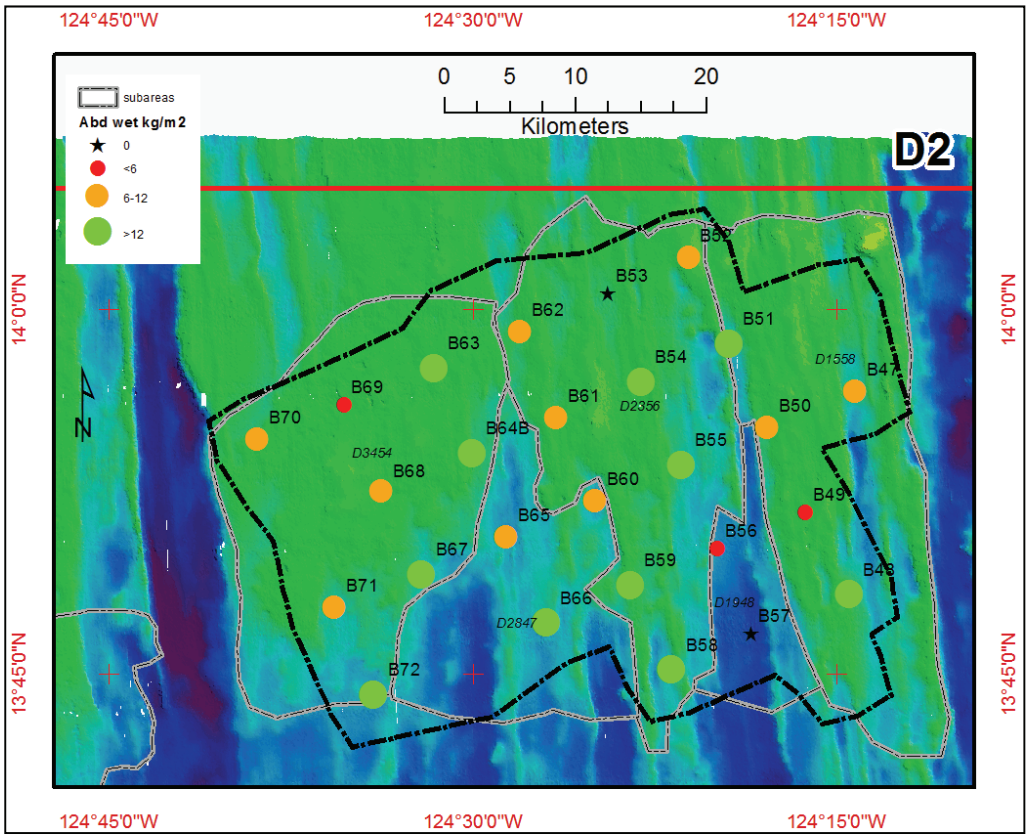


Figure 9.46 Vane Shear Strength Class, Area D2

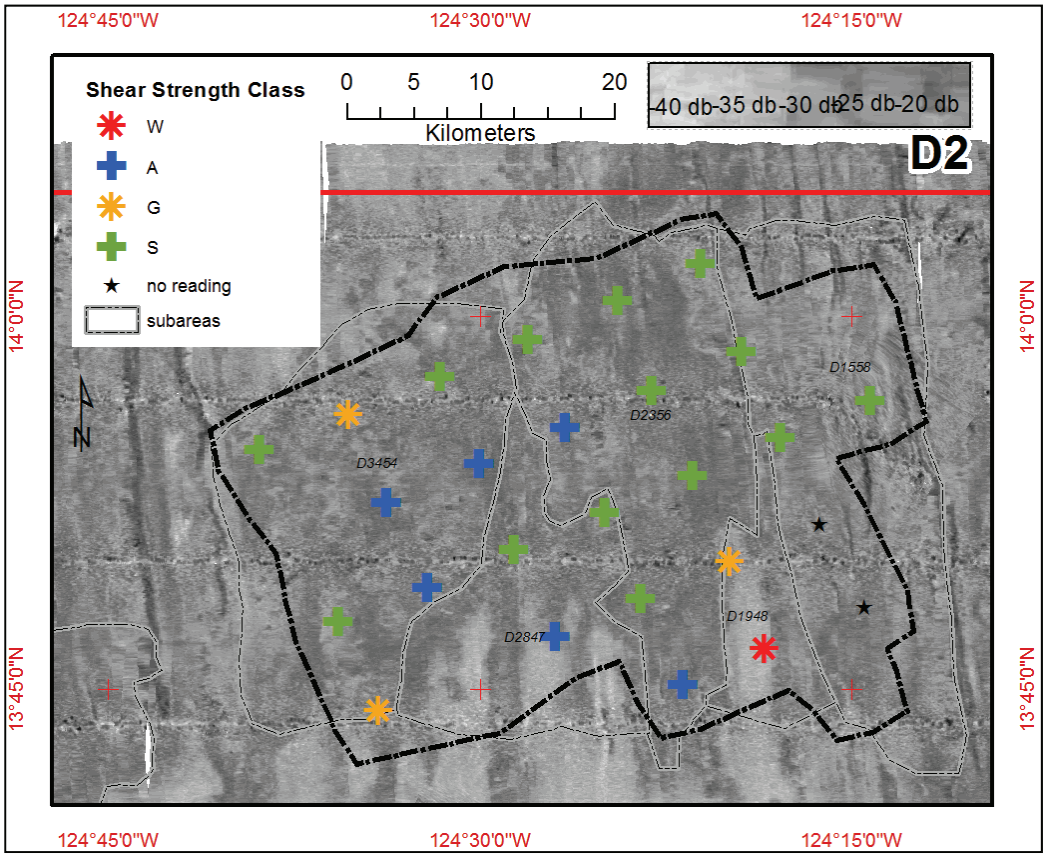


Figure 9.47 Nodule Types, Area D1

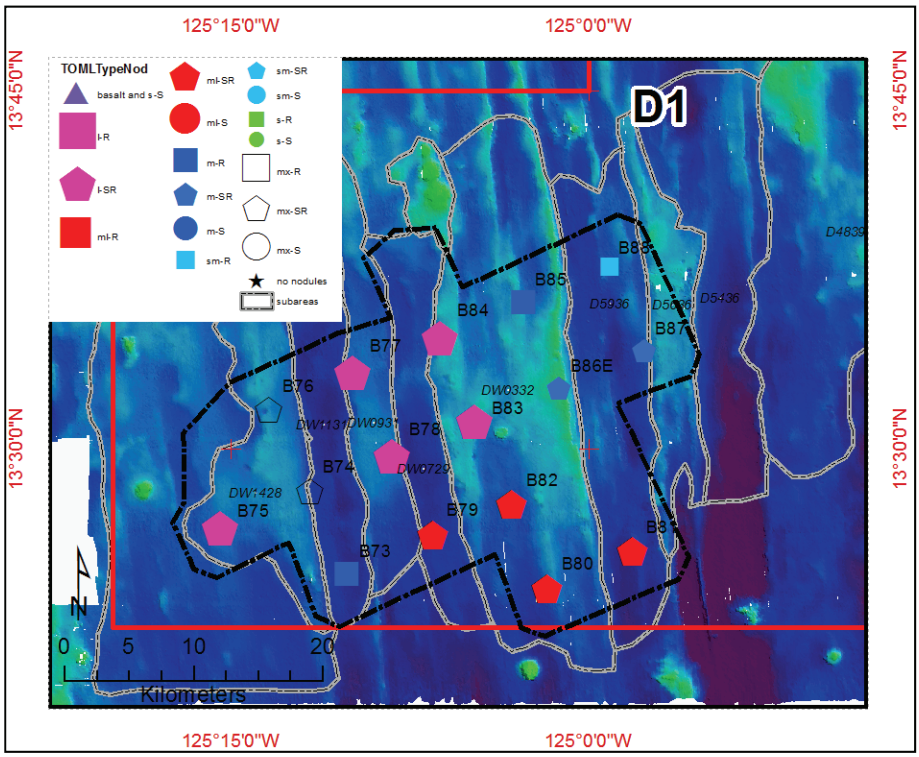


Figure 9.48 Nodule Abundance, Area D1

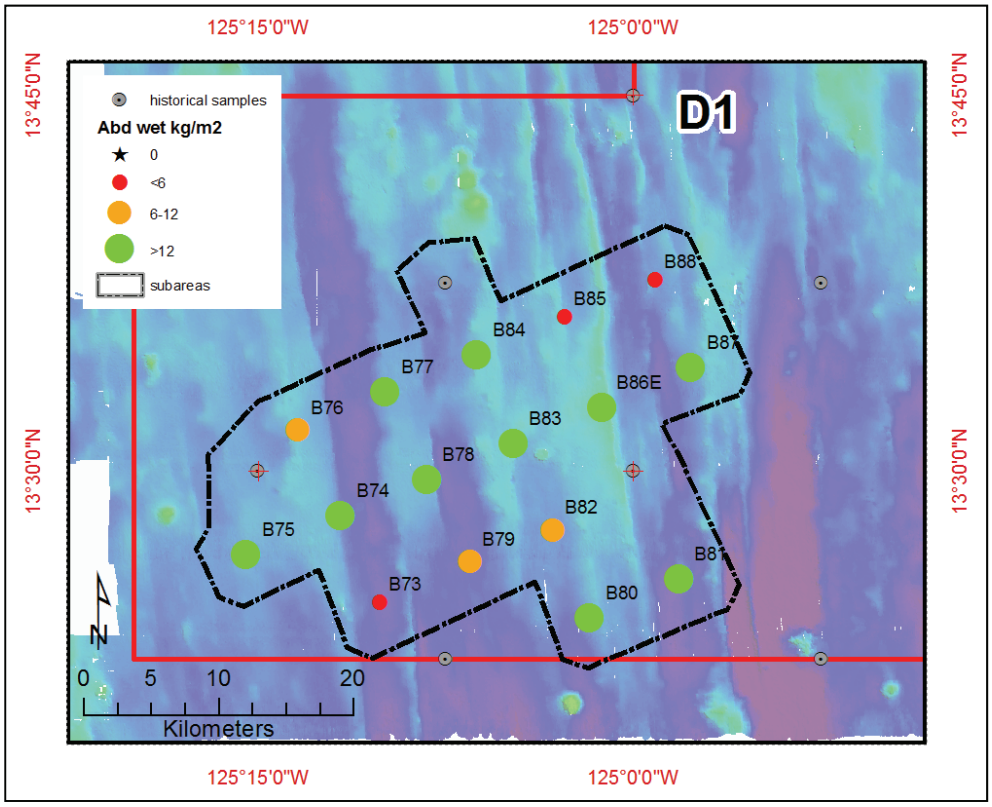


Figure 9.49 Vane Shear Strength Class, Area D1

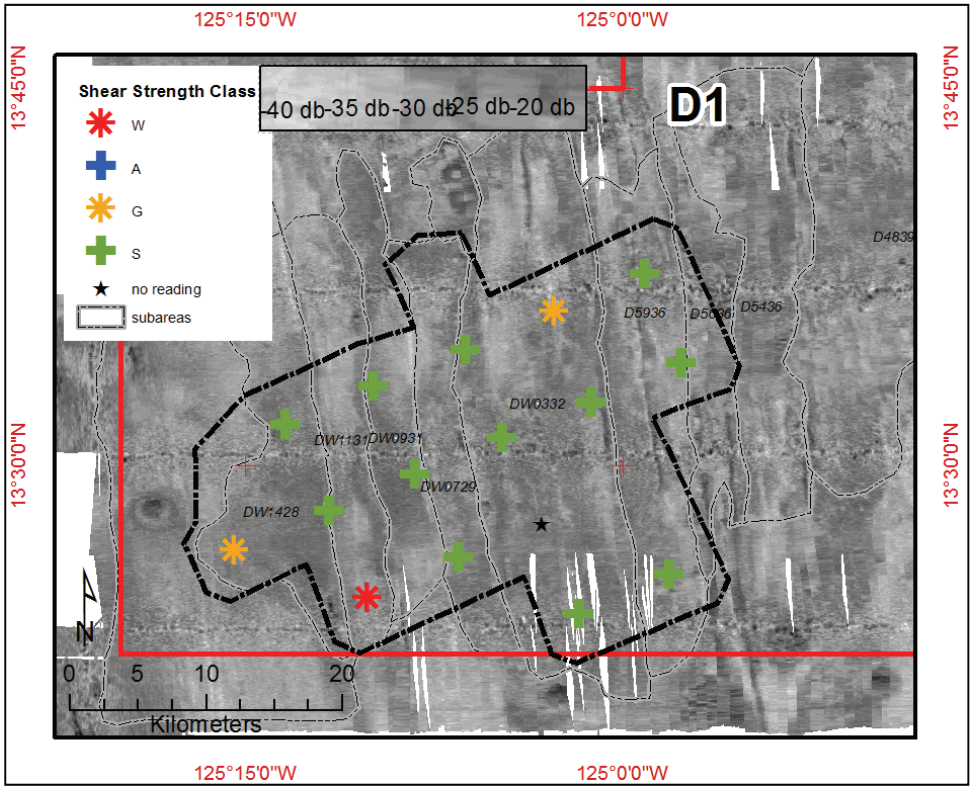


Figure 9.50 Nodule Types, Areas F and F1

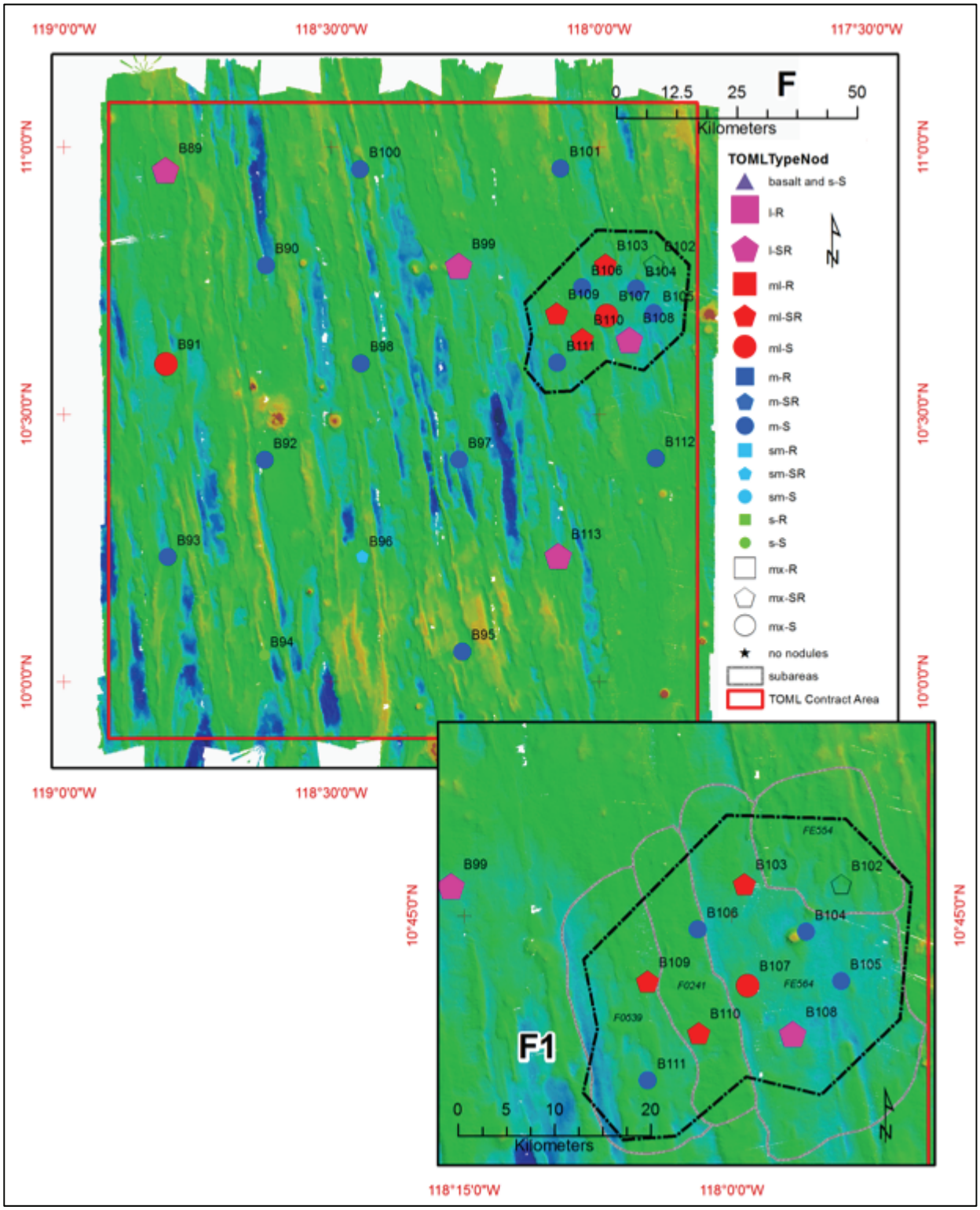


Figure 9.51 Nodule Abundance, Areas F and F1

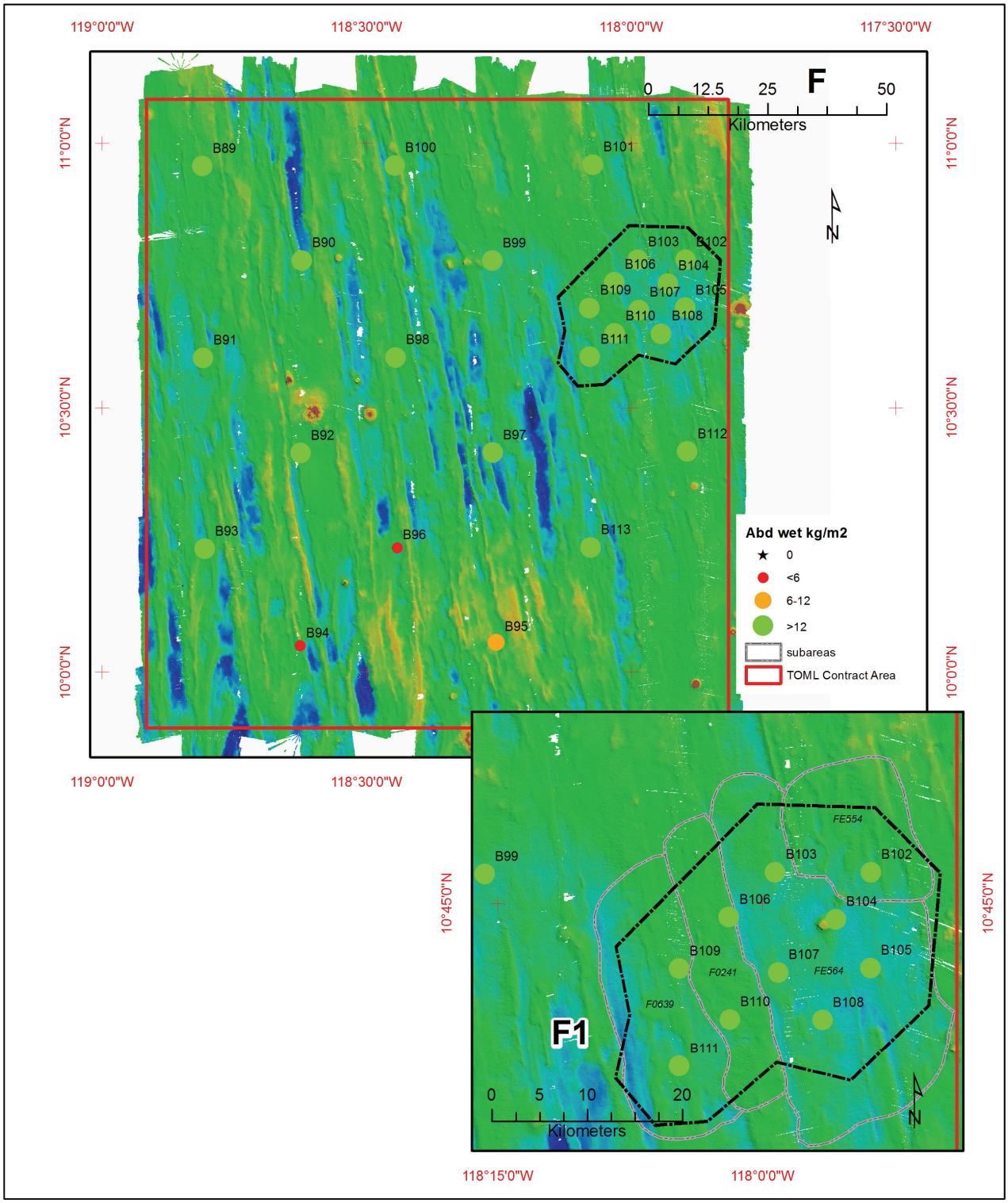
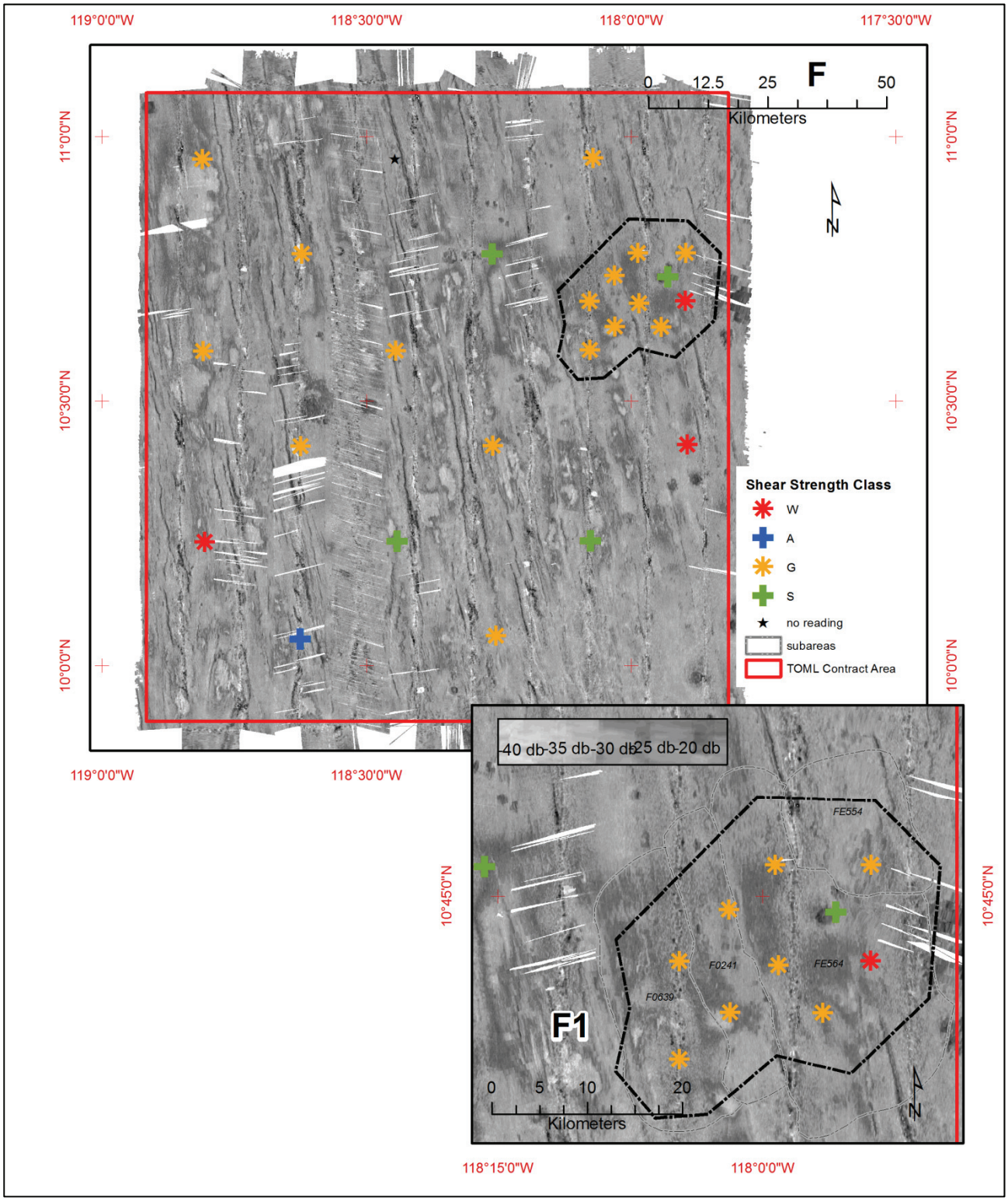


Figure 9.52 Vane Shear Strength Class, Areas F and F1



9.4.3 TOML Photo-profile results

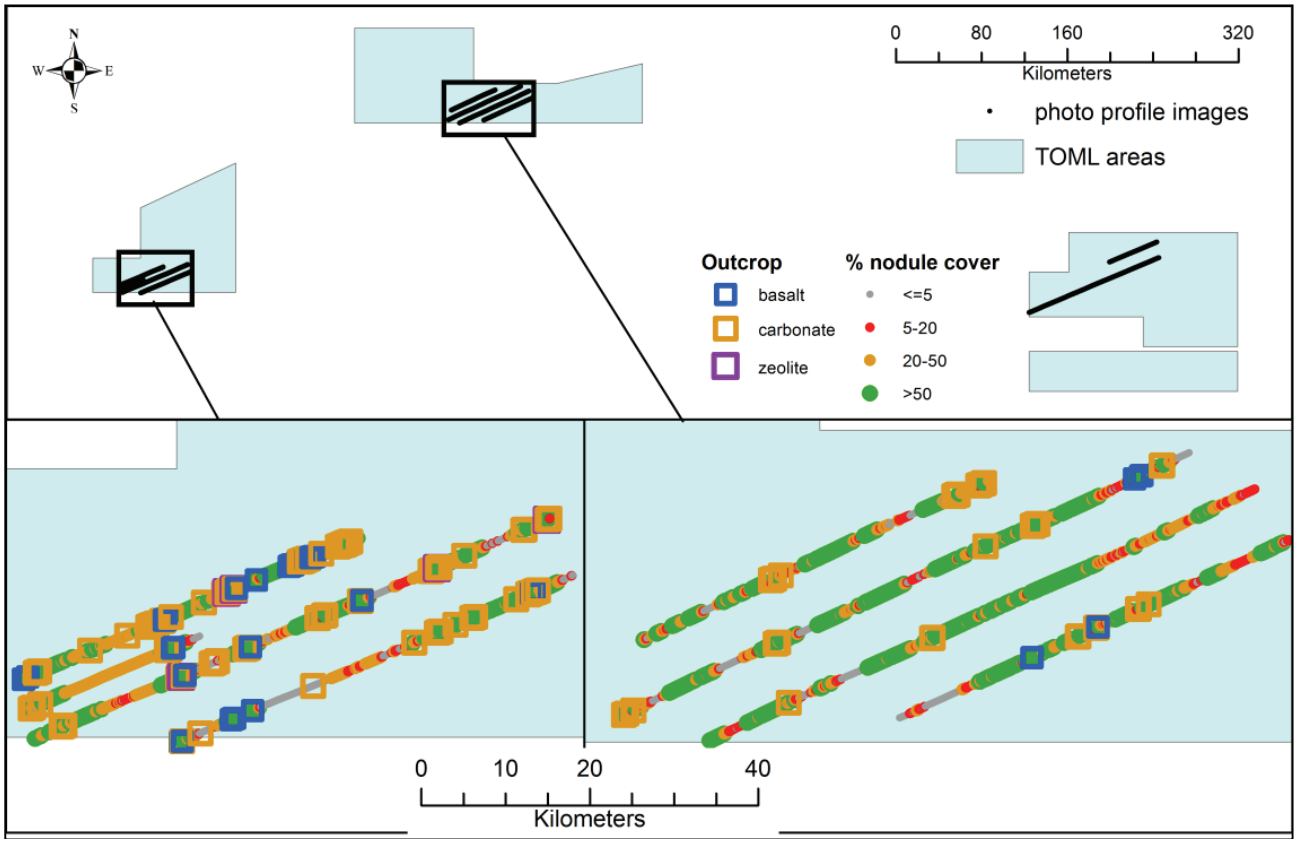
Photo-profiling provided key data on nodule type (per classification in Item 8) and abundance (per process described in Item 12) as well as for baseline logging of mega-fauna. Ten lines were completed, with one in two parts after equipment repair (Figure 9.53).

Use of photographs in nodule abundance estimations is not new and is discussed by Felix (1980) and by UNOETO (1979). These results are included with the box-core based abundance data used for mineral resource estimation in Item 14.

An estimation of nodule cover (% visible cover by nodules on the seafloor) was also possible. This is much simpler to measure than nodule long axis as it is a simple colour contrast. Percentage cover does relate to abundance, but the relationship is much weaker than nodule long axis, so nodule cover was not used in the mineral resource estimate except to support interpreted and measured continuity (Item 14).

When combined with observations of outcrop, the nodule coverage plots in Figure 9.53 give a good indication of the high levels of continuity for the nodules amongst the fault bounded abyssal hills. The process clearly does not work in Area D where sediment cover is high.

Figure 9.53 Neptune Photo-profile logging of % cover and outcrop types



Insets only shown for Area B (L) and C (R)

Nodule size analysis (combined with box core observations) is shown in Figure 9.54. An understanding of nodule sizes and other characteristics such as rugosity and strength will be useful in designing the mining system. Considerable information was collected in respect of long axis measurements taken from photo-profile images (roughly every 100th image for abundance estimation purposes).