ITEM 8. Deposit Types

Surface and near surface polymetallic seafloor nodules are the only mineralisation type classed as a deposit in this report. Other types of mineralisation possible within the "greater" CCZ are described in Item 7.3.

8.1 TOML Nodule Types

There are almost as many nodule classification systems published as there are contractors in the CCZ. Classification systems include examples with a strong focus on the morphology of the nodules individually (e.g. Halbach and Özkara, 1979, Yegiazarov and Zyka, 1985) and others that combine areas into type facies (e.g. Ifremer's Menot et al. 2010, KIOST's Chang et al., 2005, YMG's Kruglyakov, 2014). Application of these classification systems and facies can be quite elaborate.

Ultimately a facies system of some sort seems to be convenient for characterizing some prospect scale areas (10-100 km range) and it has been used by biologists to try and classify fauna (Menot et al 2010 and Veillette et al 2007). However, facies do not seem to be easily applied other areas further afield with limited applicability over greater distances. Menot et al 2010 found that they had to define other variants of the French facies (e.g. termed BP, C+, C+M, CP, 0, "Western" or mixed) and ultimately these defined a continuum of types mostly between and around the three main facies. TOML experienced similar issues with application of the Russian Yuzmorgeologiya system during the CCZ15 cruise (Item 9).

ISA (2010; Item 7) present a simplified system that was defined at a 2003 ISA workshop that included most of the experienced Contractors of the time, and ultimately TOML developed a nodule classification based on this ISA system. This accommodates easily the range in textures and forms mapped from the TOML areas that almost span the entire CCZ (Figure 4.1). A key benefit is that logging is more easily consistent between different geoscientists and can be applied to both seabed photos and physical samples.

TOML's classification system was developed near the end of the CCZ15 cruise, once a wide range of characteristic nodules had been studied (Table 8.1). The classification aims to be simple and modular with two required codes (size then type, as per the ISA system) and three optional suffix codes (aspect of the nodules form, degree of fragmentation typically seen, and degree of development of botryoidal texture); as summarised in Table 8.1. Examples of the size of nodules encountered in the TOML area are included with the discussion on mineralised nodule formation in the CCZ in Item 7. Examples of type are also shown in Figure 8.1 and Figure 8.2.

Table 8.1 TOML CCZ15 Nodule classification and proportions seen in logging during CCZ15

		1:size Long Axis					
		=<2 cm		2-5 cm		>5 cm	
		s (small) 8%	**sm** 11%	**m** (medium) 20%	**ml** 24%	**l** (large) 18%	**mx** (mixed) 18%
2: type	**S** (smooth) 10%	*s-S 1%*	*sm-S 2%*	*m-S 5%*	*ml-S 1%*	*l-S 0%*	*mx-S 1%*
	SR (smooth-rough) 84%	*s-SR 7%*	*sm-SR 8%*	*m-SR 13%*	*ml-SR 22%*	*l-SR 18%*	*mx-SR 17%*
	R (rough) 6%	*s-R 1%*	*sm-R 2%*	*m-R 2%*	*ml-R 1%*	*l-R 0%*	*mx-R 1%*

Table 8.1 continued

<table>
<tr><th colspan="15">3:aspect/oblate</th></tr>
<tr><th colspan="3">high</th><th colspan="3">regular</th><th colspan="3">low</th><th colspan="3">irregular</th><th colspan="3">prolate</th></tr>
<tr><td colspan="3">-hi</td><td colspan="3">-rg</td><td colspan="3">-lw</td><td colspan="3">-ir</td><td colspan="3">-pr</td></tr>
<tr><th colspan="15">4:fragmentation</th></tr>
<tr><th colspan="5">rare</th><th colspan="5">mod</th><th colspan="5">common</th></tr>
<tr><td colspan="5">-ra</td><td colspan="5">-md</td><td colspan="5">-cm</td></tr>
<tr><th colspan="15">5:botryoidal</th></tr>
<tr><th colspan="5">well dev.</th><th colspan="5">poorly dev.</th><th colspan="5">absent</th></tr>
<tr><td colspan="5">-bo</td><td colspan="5">-po</td><td colspan="5">-no</td></tr>
</table>

From Table 8.1 it is apparent that in the TOML area at least, smooth-rough nodules are the most common, especially in the medium to large size range.

Figure 8.1 Sections through a S-type Nodule (left) and a R-type Nodule with a S-type core (right)

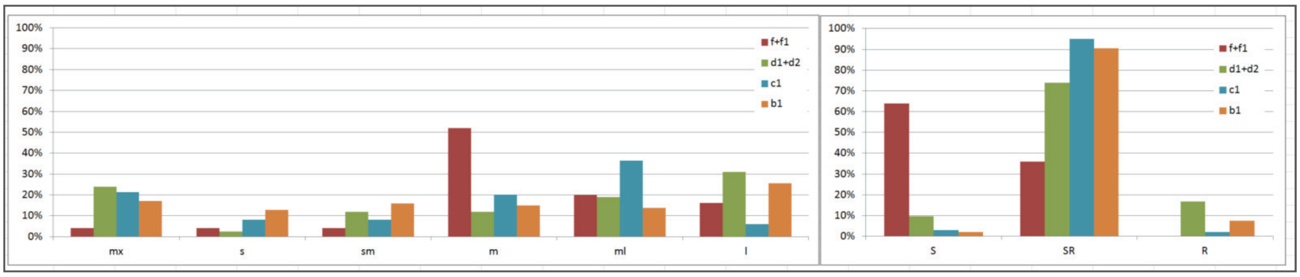
Source: von Stackelberg and Beiersdorf, (1991).

Figure 8.2 Example nodules found in the TOML area

Smooth (top left), smooth-rough (top right), rough (bottom left) and overturned smooth-rough (bottom right) types

Item 9 includes summary maps of nodule types in each explored area. Between TOML tenement areas B - F there are notable differences in the sizes and types of nodules present (Figure 8.3). Area F is distinctive for having generally more medium S type nodules than the other areas (although it also contains large SR type nodules of generally high aspect). Area C1 has very few truly large nodules with medium to large SRs dominating. Areas B1, and D1-D2 have a wider range of sizes again mostly (70 - 90%) of SR type although B1 has some discrete areas of smaller nodules. Two dredge samples from Area A contained mostly small smooth nodules, and as mentioned below one of these looks to be mostly of hydrogenetic character.

Figure 8.3 Nodule size and type within the areas sampled during TOML CCZ15



Codes are per Table 8.1

8.2 Variation in TOML Nodule Grades

Grade variation in CCZ nodules is remarkably low. Basic statistics pertaining to grade are included with the Mineral Resource data review in Item 14.

During the CCZ13 and CCZ15 TOML cruises (Item 9), dredge samples were taken for metallurgical test work and the opportunity was taken to analyse numerous (~30 per dredge) sub-samples of nodules to better establish grade variation within a small area.

These dredge sub-sample results are compared below with box-core and historical results for Ni, Cu, Co and Mn (Figure 8.4 and Figure 8.5). Bear in mind that the three datasets all cover different areas with:

- historical samples covering all of TOML A-E;
- TOML box-cores (BC) all of selected sub-areas in Areas B, C, D and F; and
- dredge samples in select locations.

Key conclusions from this comparison are that:

- There is generally good to excellent agreement between dredge samples and the more widely sampled but internally consolidated samples from box-cores;
- There is generally excellent agreement between the historical data (section 9.1) and the TOML dredge and box-core samples with the exception of Mn (higher in the TOML samples from some areas as discussed in Item 11);
- Some of the regional grade trends mentioned in Item 7 are seen between the TOML Areas (e.g., Area B has generally higher Ni and lower Cu than Area C, while Area F has distinctly lower Co);
- The lower grade nodules from box-cores from Area B1 seen in Figure 8.4 and Figure 8.5) tend to be found in a single area in the central-eastern part of the area (B3645 and surrounds; Item 9), that is characterised by typically R-type nodules and frequently low to very low abundances;
- Area A and B nodules have a greater range in grade consistent with more variable ratios of diagenetic to hydrogenetic formation (higher Co and Fe).

Figure 8.4 Nodule variance in Ni and Cu for dredge and box-core samples in the TOML Areas

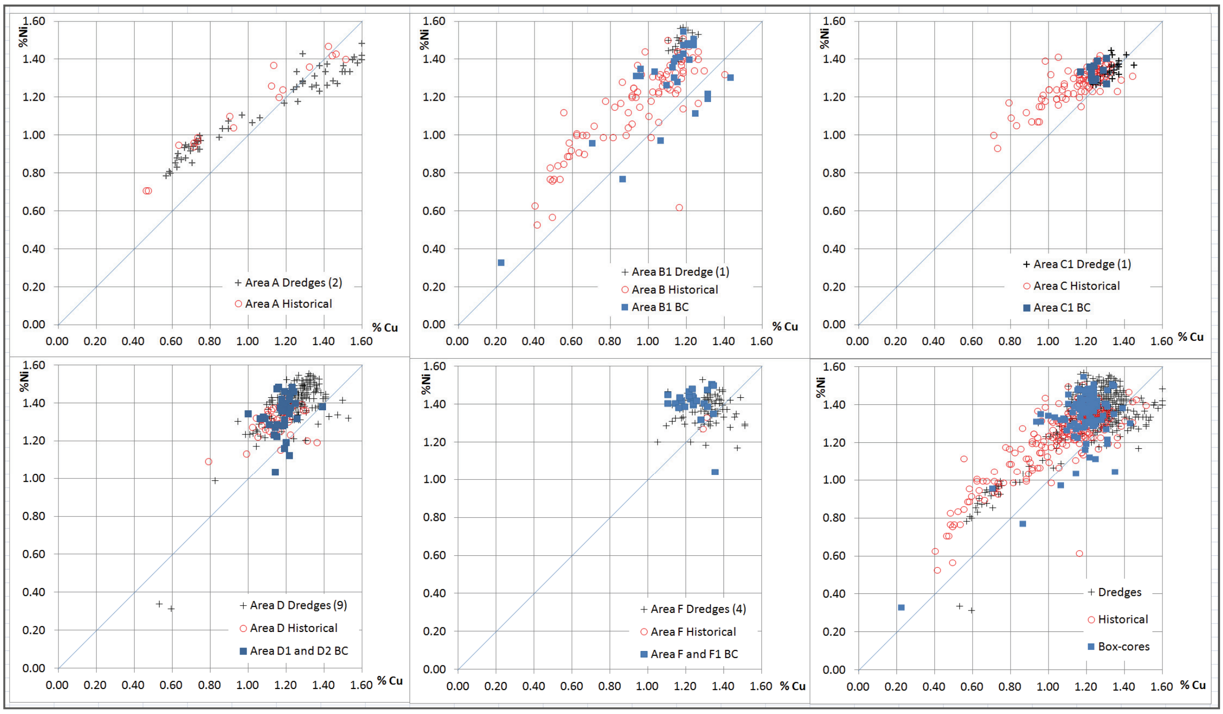
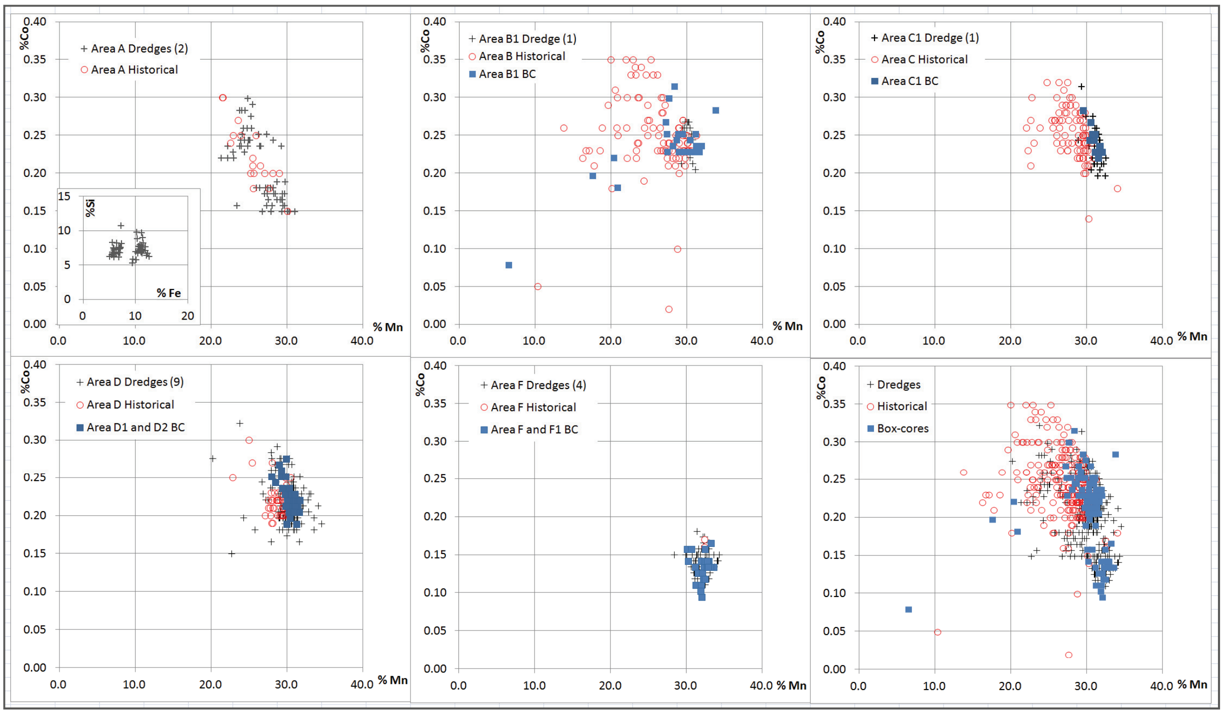


Figure 8.5 Nodule variance in Mn and Co for dredge and box-core samples in the TOML Areas



8.3 Nodule Distribution

As discussed in Item 7, the distribution of nodules though the CCZ is not constant, and likewise their abundance varies within the TOML contract areas. Areas with few or no nodules that can be discriminated in mapping are:

- Volcanic areas (seamounts and more recent flows)
- Slopes or escarpments (from ongoing normal faulting and both of basement basalt and overlying sediment)

- Areas of “no nodules on ooze” (Nnoo) that are thought to be areas of drifting sediments that preclude nodule formation.

As noted in Table 8.2, only the volcanic areas and Nnoo sediment drifts were domained separate to the sediment bearing nodules in the mineral resource estimate.

Table 8.2 MBES mapped seabed classification and percentage proportions

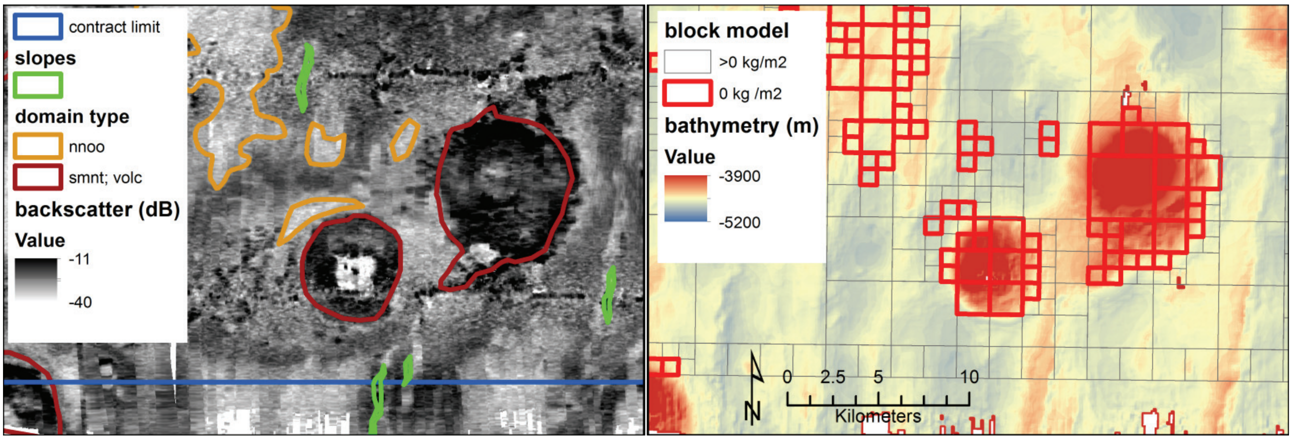
Area	Volcanic exposure	Nnoo sediment	Slopes	Nodule bearing
B	5.9	6.0	3.9	84.2
C	1.8	5.6	3.2	89.4
D + E	3.0	12.9	4.2	79.9
F	1.5	2.1	4.9	91.6

Note that without multibeam survey, it is not possible to estimate the proportions of the above mapped units in Area A.

Strictly speaking, most of the above discriminated areas still contain some nodules. Small nodules are found on seamounts and in amongst the escarpments. Sediment drifts also usually contain the occasional nodule as seen in seafloor photos (Item 7). There may also be nodules buried near the edge of sediment drifts.

Dealing with these areas in the mineral resource estimate is described in Item 14. Mapping based on multibeam (e.g. Figure 8.6) estimates the area with no or insignificant nodules to comprises 10 to 20% of the total area (Table 8.2).

Figure 8.6 Mapped areas of volcanic rocks, slopes and Nnoo sediment in part of TOML Area B



Note that over-estimation of area of slopes is likely due to smoothing from the relatively coarse (60-120 m) resolution of the shipborne 12 kHz multibeam and the nature of interpretation. Slopes were not significant enough to be domained out in the mineral resource estimate (Item 14). There is also the possibility that many of the mapped volcanics of lower relief are partly covered with sediment and nodules. Box-core sampling of Nnoo type areas was done if that unit was covered by the planned sample grid in the CCZ15 cruise (Item 9).

Note also that direct correlation of nodule abundance with multibeam backscatter is relatively poor as discussed in Item 9.

8.3.1 Importance of buried nodules

As already mentioned in Item 7, sediment is thought to cover even surficially located nodules from time to time, due to ongoing sedimentation and the effect of seafloor currents. In many cases, grazing holothurians clear any accumulated sediment off the nodules (Figure 7.33).

In logging during TOML’s CCZ15 cruise, a clear distinction was made between:

1 **Powder** a thin coating of sediment, usually so little (~ 5 mm) that the outline of the nodule can be seen in a photograph;

2 **Cover** is up to several centimetres of sediment, obscuring the nodule completely from vision, maintaining the nodule within the geochemically active layer and with the amount of cover irrelevant to sampling and collecting methods;

3 **Buried** was defined as when there is greater than 10 cm of sediment on the nodule. Buried nodules often are below the geochemically active layer. As they are likely located too deep for a nodule collector, they were collected from the box-cores in CCZ15 purely for reference purposes and their weights and chemical analyses were **not included** in the dataset supporting the mineral resource statement.

Buried nodules often have a very soft brown powdery surface, which is thought to reflect surface 'corrosion' due to reduction and breakdown of the nodule (Figure 8.7). However, this was always seen on the surface of nodules and no extensively degraded remnants were seen. Many buried nodules have the size and textures of large to medium SR type (see TOML classification in Table 8.1 above) indicating that they were at the surface for a long period of time before burial. When present in the box-cores, the buried nodules were often found in groups at the same depth, and it is suspected that they became buried by falling into burrows due to undermining.

Figure 8.7 Opposite views of a buried nodule

CCZ15-B56: image at left looks to have been the smooth top of an SR type nodule and image at right the base; grid is 1 cm

Buried nodules are not very common (Figure 8.8); 16 out of the 113 box cores taken during CCZ15 had buried nodules, however all of these were located in Area D and F. If just Areas D and F are considered then buried nodules were found in about 23.8% of samples which is a similar ratio to that described by Kotlinski and Stoyanova (2006) who found 22.6% within the part of the IOM contract area (59 of 261 sample sites).

Other characteristics of buried nodules are also similar to those described by Kotlinski and Stoyanova (2006). Buried nodules tend to be of much lower abundance (Figure 8.8), and to be larger than the average nodules found at the surface.

Figure 8.8 Location and percentage of buried nodules found during CCZ15