ITEM 10. Drilling

TOML has not yet conducted any drilling on its tenements within the CCZ. All known past exploration for polymetallic seafloor nodules within the CCZ involved surface sampling, such as box-coring, (refer Item 9) rather than drilling.

Surface sampling is sufficient to define the mineral resource given that intrinsic value exists for just the polymetallic nodules found at the surface of the seafloor.

Given the size of the nodules and the soft nature of the sediment in which they lie, any drilling would need to be of an exceptionally large diameter to avoid significant negative sample bias.

Some sediment cores have also been collected to study the sediment composition, but none are specifically known to be from the TOML Exploration Area.

ITEM 11. Preparation, Analyses and Security

11.1 Historical preparation, analysis and security

11.1.1 Historical sample preparation

The sampling programmes undertaken by previous explorers in the TOML tenement area, which comprise an important data set used here for resource estimation, include Japanese, French, and Russian data sets (Figure 9.3). In 2012, for an earlier technical report on the project, independent consultants Golder Associates (Golder, 2013) sent requests to the agencies responsible for each of these data sets but only received partial responses from Yuzhmorgeologiya (Russia; TOML Exploration Area B) and DORD (Japan; TOML Exploration Areas A and D) which are included below.

A Golder Associates subcontractor, (Dr Charles Morgan) had been previously directly involved with one of the US exploration programmes (OMCO) that was carried out during the same period as these other programmes, working as a Senior Scientist for Lockheed. This work included direct participation in resource assessment survey expeditions to the CCZ and development and implementation of sample preparation and analysis procedures. The description of sample preparation and analysis methods provided below is based on this experience.

Prior to establishment of the ISA, explorers working under different jurisdictions settled claim boundary overlaps through a process of negotiation and data exchange (e.g. NOAA, 1987; Item 4). Though data were generally not exchanged until after negotiations related to exploration claim boundaries were completed, Morgan conferred with representatives of these consortia at several formal professional meetings and informal settings, comparing methods and procedures used for sample collection, analysis, and quality control. Many aspects of the OMCO procedures were used by the other explorers.

As described below, documentation of sample treatment methods has been provided by Professor Valeriy Yubko, Deputy Director of the Russian oceanographic institution Yuzhmorgeologiya, based in Gelendzhik, Russia and operating under the jurisdiction of the Russian Federal Agency of Natural Resources. Professor Yubko was a senior member of the Russian team that explored for polymetallic nodule deposits in the CCZ and delineated the Yuzhmorgeologiya exploration claim under the ISA. As shown in the following sections, the Russian methodology was very similar to the methodology practiced by the Lockheed group. Some details have also been provided by Dr Okazaki on the DORD sampling and analytical procedures. Dr Okazaki is current exploration manager for the CCZ nodule field for DORD. Ongoing use of wet weights for abundance by the BGR is also explained below.

11.1.1.1 OMCO procedures

Polymetallic nodule samples collected with FFG samplers were transferred directly from the sampler into individual plastic bins and carried below deck to the geochemical laboratory. In the laboratory they were laid out separately on a white surface marked with a scaled grid and photographed to permit determination of nodule size distribution. They were then sealed in labelled fibreglass-reinforced collection bags and stored in the ship’s hold for the balance of the exploration cruise.

The bins and lay-out surface were cleaned between samples using filtered seawater and dry paper towels. No cleaning of the nodules was usually necessary, since any mud adhering to them would be swept off the nodule surface through the open mesh of the sampler collection net during the ~4,500 m ascent from the seafloor. Samples collected with box corers were processed in a similar manner, except that the adhering mud had to be rinsed off each nodule as it was removed from the box corer.

The collected sample bags were transported from the ship that almost always docked at a pier in San Diego Bay, to the Lockheed Ocean Laboratory, which was also located on the Bay at Harbor Island. Transfer of the samples from the ship to the secured laboratory storage facility was the first priority when the ship came to port and was always handled personally by the expedition crew and other Lockheed employees.

Prior to weighing, the samples were removed from the sample bags and placed in a single layer in labelled, open trays on tables in the air-conditioned laboratory for at least 12 hours to ensure a uniform degree of air drying. The samples were then weighed using a high-capacity laboratory scale and divided into two subsamples of approximately equal weight. As a portion of the nodules was to be kept uncrushed, the technicians were instructed to ensure as much as possible that both subsamples contained similar nodule size distributions to the original samples. One subsample was placed in a labelled jar and kept as a permanent archive. The second subsample was prepared for Atomic Absorption Spectrographic (AAS) analysis, as described below. This is a potential source of sample bias but OMCO minimised this risk by randomly selecting which sample was used for archive.

The second subsample was crushed using a jaw crusher (similar to the Retsch™ BB51 currently available; see Retsch, 2012) to produce a product with a maximum size of less than about 1 mm. The crushed sample was then mixed using a 3-axis shaker to achieve uniform mixing and to preclude any separation of the less dense detrital (siliceous) component from the more dense metal oxide component of the sample. The mixed sample was passed through a laboratory sample splitter as required to produce a 5 to 10 g subsample for AAS analysis. The remainder of the sample was then stored as a second, crushed archive sample. The subsample was further ground to a fine powder using a laboratory ball mill prior to assaying.

The powdered subsample was placed in a 110° C drying oven for at least 6 hours to remove adsorbed water. It was then immediately transferred to a sealed desiccator to cool to ambient temperature. Cooled samples were weighed using a Mettler™ analytical balance and then transferred to Parr™ Teflon-lined high pressure digestion vessel. Reagent grade hydrofluoric, boric, and hydrochloric acids were introduced to the vessel, which was then sealed and heated for several hours to complete the digestion. The digested samples were then diluted as necessary with filtered, distilled water for AAS analysis using a Hewlett-Packard instrument. Standard analysis included determination of Mn, Fe, Co, Ni, Cu, Zn, Si, Ca and Mg.

Analytical accuracy was confirmed by periodic introduction of standards made from crushed, mixed, and powdered bulk nodule samples that had also been sent to three independent commercial laboratories for determination of these metal contents. Additional confirmation was achieved using standards formulated by the U.S. Geological Survey (A-1 and P-1; see Flanagan and Gottfried, 1980). These standards were subjected to the entire preparation procedure to ensure that no significant contamination was occurring and that no systematic analytical errors were being included in the process.

11.1.1.2 Yuzhmorgeologiya procedures

The measurement of abundance of nodules at the sample site was carried out using an ‘enclosed’ Ocean-0.25 grab sampler (Figure 11.1) with a 0.25 m^2 gripped surface and a depth of sampling of approximately 30 cm. The grab sampler was combined with GFU-6-8 photography unit. This device takes ocean bottom photos at the sampling point.

Figure 11.1 Ocean-0.25 Grab Sampler (Yubko, 2012)

The procedure for sub-sampling was:

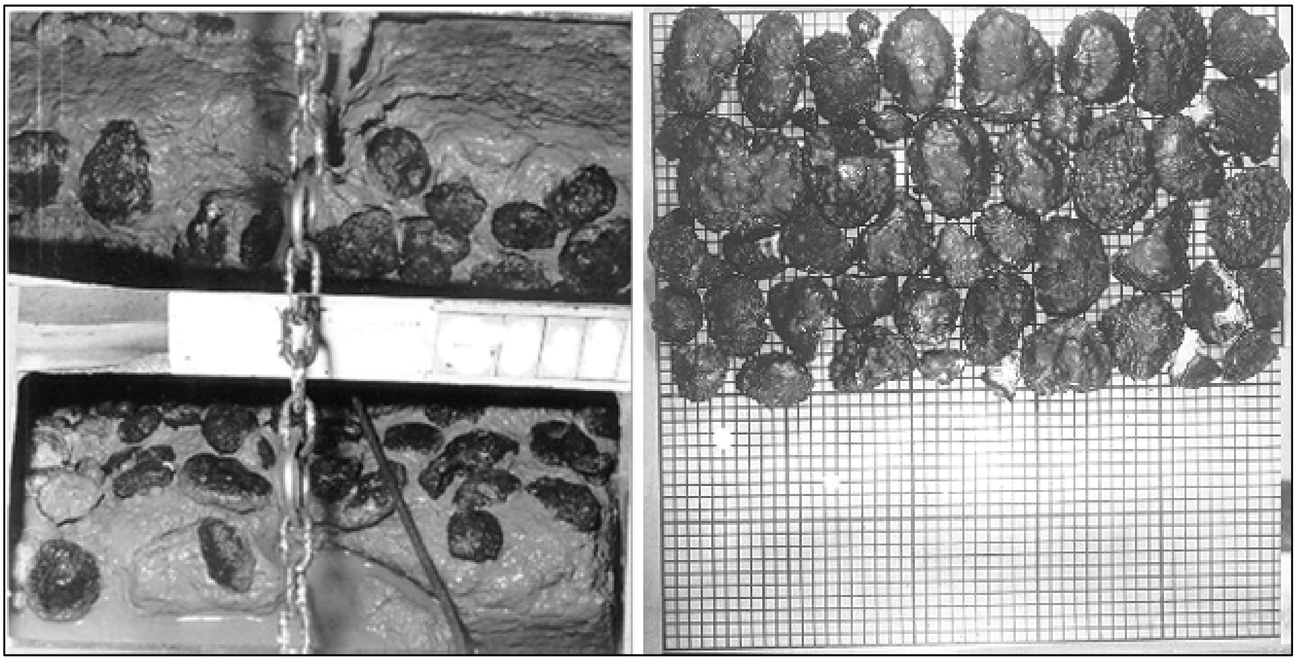
1 Extraction of all nodules from the grab sampler (Figure 11.2)
2 Crushing of all nodules to a maximum particle size of up to 10 mm
3 Drying (approximately 24 hours) of all samples at 105° C until constant weight was achieved
4 Crushing of all samples to 1 to 2 mm particle size and splitting of 400 to 500 g using a splitting device

5 Pulverizing of the split sample (not less than 400 g) was carried out in the vibrating grinder up *100 mesh* particle *size (*0.074 mm)

6 Formation of analytical sample (200 g) and its duplicate (200 g).

Chemical analyses were carried out on sub-samples with an approximate weight of 0.5 g, selected from the analytical sample. Determination of Ni, Cu, Co and Fe content was carried out by AAS and the content of Mn by a method of photometric (electrometric) titration.

Figure 11.2 Mn-nodules Inside Grab Sampler (left) and Outside Grab Sample (right) (Yubko, 2012)



11.1.1.3 DORD procedures

DORD's procedure for sampling (Okazaki, 2012) is understood to include:

- Each sample station is a combination of three sub-sampling points which effectively form an isosceles triangle with lengths of sides 1.4 nm, 1.4 nm and 2.0 nm.
- Collection was mostly by free fall grab, but at occasional stations a box corer was used at one of the three sub-sample points
- In later cruises at least (which may not include the TOML Exploration Area) a ship-borne X-ray fluorescence analyzer was used for the chemical analysis with some representative samples being assayed at an on-land laboratory to assess precision and accuracy.

11.1.1.4 BGR procedures

Ruhlemann et al. (2011) describe the sediment and nodule sampling process used by the BGR in recent times (2006) which is largely not relevant to the Pioneer Contractor data from the TOML Exploration Area. One exception however is their citing the ongoing use of a BGR procedure in the 1980s of washing sediment from collected nodules with specially cleaned seawater before determining their wet weight and converting this to a dry weight by means of a simple 30% reduction factor.

11.1.2 Historical Quality Assurance and Quality Control procedures

No systematic QAQC information is available as this information was not provided to the ISA. QAQC was known to be undertaken at the time of sampling as part of the scientific process used by each consortia (country). Data quality was assured using comparative measures between the different datasets (section 9.1.1) to prove that the samples within the TOML Exploration Area were not statistical outliers. This level of quality assurance was deemed suitable for a Mineral Resource at an Inferred level of confidence.

As part of the requirements by ISA, the Pioneer Contractors were required to relinquish half of their claim to the ISA as reserved blocks. During this process the ISA reviewed the sampling data to ensure that the splitting of the claim was even with equal abundance and grade occurring in the retained portion of the claim and the parts being relinquished. As such, the ISA has accepted the data (and quality) supplied by the Pioneer Contractors.

11.1.3 Historical adequacy of sample preparation, security and analytical procedures

Free fall grab samplers consistently underestimate the actual abundance but provide samples that can be used to determine adequate estimates of the grade of the surface nodules (Hennigar, Dick and Foell, 1986). Even today they are the most efficient tool available for sampling the nodules at the seafloor. This is because a number of them can be deployed at any one time from the survey vessel allowing an order of magnitude greater speed in collection i.e. approximately 10 to 20 samples per day for a FFG versus 2 to 3 samples per day for a BC that is winched to and from the seafloor.

In many cases, it is unknown exactly when the nodule weights have been taken by the Pioneer Contractors. Thus it has been assumed that the samples were weighed shortly after recovery on board the exploration vessels (or back at base) and usually before any splitting or crushing. This partial assumption is more conservative in any tonnage estimate than the alternative that the abundance weights are for dried nodules. It also fits well with Dr Charles Morgan’s experience with sampling in the CCZ and the process description provided by Yuzhmorgeologiya.

Overall, the comparison of the sampling and assaying between the Pioneer Contractors show that the data are adequate for geological modelling and are reliable for Mineral Resource estimation at an Inferred level of confidence. This is supported by the very similar grades obtained in the TOML sampling (Item 12).

11.2 TOML preparation, analysis and security

11.2.1 Sample Chain of Custody

Refer also to Item 9 regarding TOML’s exploration programme, including sampling methodology.

For box-core samples the **Primary Sample** handling from sample tube handover to lab was managed only by the TOML ship-based science team under the supervision of one Chief Scientist and two Lead Scientists.

Primary Samples were weighed on deck or in the lab (preliminary weight), washed, weighed again (washed weight) and then moved to the main lab and stored in an exclusive designated area.

At periodic intervals Primary Samples were laid out by Chief Scientist and the Lead Scientist Responsible in the main lab (which was closed to all other people during the process). After air-drying to remove surface water, the Primary Samples were weighed again (air-dried weight; used for abundance estimation for the Mineral Resource estimate) and then some samples were split for **Field Duplicates** by cone and quarter and for all samples by picking for **Reference Samples** (~1-6 nodules proportional to the sample size). The sample remaining after these splits were removed is the **Main Sample**, and the chemical analysis of this was used to support the grade estimation for the Mineral Resource estimate. Weight estimates were recorded on a dedicated written log by the Lead Scientists and Chief Scientist, with scanned backups, and then typed into a master Excel spreadsheet by the Chief Scientist. Recorded washed weights were included in the Daily Progress Reports sent to the head office.

Main samples were then sealed using tamperproof tape or tags into specially marked drums that were sealed with tamperproof tape. The drums were escorted by the Chief Scientist or Lead Scientist Responsible to a storage reefer on the deck of the vessel. The reefer was repacked twice during the voyage due to processing of biological samples and to aid quarantine clearance, with only partial supervision at this stage by the Chief Scientist or Lead Scientist Responsible.

On arrival into port (Panama), the container was sealed by the Chief Scientist using a padlock. Spare keys were held by the agent in case inspection was needed, but in the end this was not required. The Field Duplicates were couriered to the specialist laboratory at Jacobs University Bremen and the Reference Samples were couriered to the Brisbane office of TOML parent company Nautilus Minerals.

The Field Duplicates were received by Laboratory Staff at Jacobs University, prepared at the BGR laboratory in Hannover and analysed using ICP at Jacobs. Results were emailed in an excel spreadsheet to the Chief Scientist.

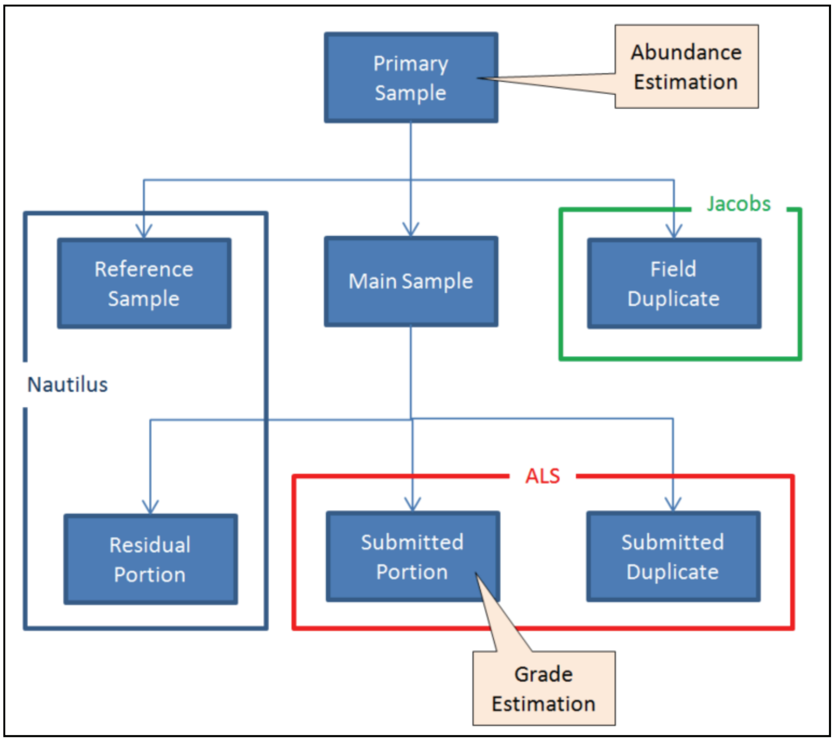
On arrival of the container into Brisbane (where the analytical laboratory is located), the opening of the container was supervised by the Mineral Resource Qualified Person. The drums were inspected and all tamperproof tape was intact. The drums were collected by an employee of Australian Laboratory Services and transported to their lab in Brisbane.

At the laboratory, the Mineral Resource Qualified Person and an assistant cone and quarter split the Main Sample again; for all samples a **Submitted Portion** was taken for crushing, grinding and chemical analysis, and for samples of sufficient size a **Residual Portion** was retained for storage. For some samples a **Submitted Duplicate** was also collected. The Submitted Portion and Submitted Duplicate were prepared then analysed by ALS in Brisbane using XRF (details below) and the results emailed as datasheets in excel format and by certificate in pdf format to the Chief Scientist. ALS maintain certified sample handling systems (see below) with step by step monitoring, which can be produced/interrogated on request. This includes the use of Blanks, Laboratory Duplicates and Certified Standards. Processed pulps of the submitted portion and submitted duplicate are stored at ALS for the moment. The Residual Portion was collected from ALS by TOML staff and stored in Nautilus Sample Repository in Virginia, Queensland, where it has been used for characterisation test work.

Chemical data received by the Chief Scientist is stored in raw format on a server and captured with relevant sample information within a Nautilus Acquire database system.

Sample COC is summarised in Figure 11.3. Chain of Custody for the abundance estimation has been overseen by Chief Scientist and the two Lead Scientists. Chain of Custody for the grade estimation extends from them to the Mineral Resource Qualified Person and ALS Staff. The Chief Scientist is also serving as Qualified Person for Geology and Mineralisation and for Deposit Types.

Figure 11.3 COC sample flow (box-core samples)



Process for the dredge samples was simpler as their results do not inform the Mineral Resource estimate. In both the CCZ13 and CCZ15 cruise dredge-variance sub-samples Submitted Portions were sent to ALS and Field Duplicates were sent to Jacobs. The dredge samples are bulk samples (between 40 and 800 kg) so the Reference Sample is the bulk of the material. There is no Residual Portion or Submitted Duplicate involved in the dredge samples.

Jacobs was selected as the check laboratory as it has a long history of working with nodules, including considerable work on REE. Jacobs does the analyses for the German Contractor (BGR). Samples were analysed by a combination of ICP-MS and ICP-OES.

ALS was selected as the main laboratory as it has full commercial QAQC procedures in place and is expert in analysing manganese ores. Samples were analysed by both fused disk XRF (for reported Ni, Cu, Co, Mn) and ICP-AES for trace and minor elements.

11.2.2 Laboratory analysis methods

11.2.2.1 ALS

ALS Laboratory Group in Brisbane, Australia has extensive experience in the analysis of high manganese materials by the XRF method. ALS operates quality systems based on international standards ISO/IEC17025:1999 "General requirements for competence of calibration and testing laboratories" and ISO9001:2000 "Quality Management Systems -- Requirements".

ALS-Brisbane described their preparation processes as:

> Samples are sorted into sequential order. Samples are then transferred to barcode labelled aluminium trays and loaded onto trolleys which are placed in a large natural gas fired oven for drying. Oven temperature is a maximum of 105 degrees but more typically, temperature is ~90 degrees. After drying, samples are jaw crushed in a Jacques jaw crusher to bring particle size to less than 10mm. Assuming samples weigh less than 3 kg, the crushed samples is then pulverised in an LM5 mill to a powder with typical particle size >85% passing 75um. Very small samples are pulverised in a smaller bowl using an LM2 mill.
>
> Firstly for our fusion / XRF method, it is standard practice for us to:
>
> - Place an approximate 0.33 g aliquot into a glass vial, which is then placed in an oven at 105 degrees for a minimum of 1 hour (usually more);
> - The sample is then removed from the oven and immediately weighed in the vial (still warm);
> - The dried sample is then transferred to the tared platinum crucible for fusion.
>
> Note that our XRF26s procedure is specifically designed for difficult to fuse chromite and manganese ores, hence the small aliquot.
>
> Our normal procedure for our ICP method is not to re-dry samples after the initial drying prior to crushing and pulverising. Nautilus originally specified a drying temperature of only 90 degree Celsius. However when we initially compared the nodule elements that had been reported both by XRF and ICPAES, in general, the XRF results were higher. We realised from some drying testwork we were doing and our experience with bauxites and nickel laterites that was likely due to reabsorption of moisture. We then went back and:
>
> - Placed the boxes of pulverised samples in paper bags in an oven for 6 hours at 105 degrees;
> - The box was removed from the oven prior to weighing the sample aliquots and one by one each sample was weighed.
> - There was no dessication and the last few samples in the box may have been out of the oven for almost an hour prior to being weighed.
>
> This in general resulted in ICPAES results much closer to those reported by XRF.

ALS supplied analytical data by chromite/manganese ore fused disk XRF method (ME-XRF26s) for all samples:

- LOI, Al_2O_3, BaO, CaO, Cr_2O_3, CoO, Fe_2O_3, K_2O, CuO, MgO, MnO, Na_2O, P_2O_5, SO_3, SiO_2, NiO, TiO_2, PbO, ZnO

They also supplied data by high grade four acid ICP-AES method (ME-ICP61a) for select samples (including all box-cores):

- Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Sr, Th, Ti, Tl, U, V, W, Zn

Many of the above elements were at levels below the detection limit of ME-ICP61a.

11.2.2.2 Jacobs

Jacobs is the Laboratory operated by the Integrated Environmental Studies Program Group, Earth and Space Sciences Program, at Jacobs University in Bremen, Germany. This group has been involved in nodule analysis and study for over 10 years and have been integral to much of the development of nodule standards used in the industry. They describe their preparation as follows:

> The Fe-Mn nodules provided were powdered. In case of small sample bags the whole material was first crushed and then homogenized and powdered in an achate ball mill. Material provided in large (several kilograms) sample bags was first crushed and then splitted using a riffle splitter. One representative sample split (100-200 g) was then homogenized and powdered using the achate ball mill.
>
> For sample decomposition, the nodule powders were dried for approximately 12 hours at 105°C prior to digestion. Precisely weighed 50 mg aliquots of each dried sample were digested in 30 ml PTFE (polytetrafluoroethylene) pressure vessels using a PicoTrace DAS acid digestion system (Bovenden, Germany). The dried powders were dissolved with ultrapure concentrated acids, initially with 5 ml of a mixture of hydrochloric (HCl), nitric (HNO_3), and hydrofluoric (HF) acids (ratio of 3:1:1, respectively), at 180°C for 12 hours. After cooling, samples were evaporated at 120°C for approximately 2 hours to near dryness, re-dissolved with 3ml 20% HCl and heated again at 120°C to near dryness. The residues were taken up again in 3ml 20% HCl and heated at 120°C to near dryness. Finally, the residues were diluted to 50.0 g in 0.5 M HNO_3 / 0.05 M HCl and immediately analyzed.
>
> Major and minor element analysis was carried out using Inductively Coupled Plasma Mass Spectrometry (ICP-MS, Perkin Elmer NEXION 350X quadrupole instrument) for the determination of REE, Y, Sc, Ti, Rb, Zr, Nb, Mo, Cs, Ba, Hf, Ta, W, Pb, Th, U, while Fe, Mn, Mg, Ca, Na, Al, P, Sr, Cu, Co, Ni, Zn, V were determined with Inductively Coupled Plasma Optical Spectrometry (ICP-OES, SpectroCiros SOP instrument).
>
> Accuracy and reproducibility of chemical analyses were checked with the certified reference materials Nod-P-1 (USGS). The measured concentrations are in very good agreement with published data (Table 2), proving the accuracy of the analytical methods. We also report the method precision of the ICP-MS and ICP-OES measurements, which is defined as the precision of multiple sample decomposition and measurement of a reference standard as % relative standard deviation (%RSD). The method precision of the ICP-MS measurements is generally very good and better than 2 % for all elements of the reference standard NOD-P1 (n=4), except for Rb (3%) and Ta (9%). Method precision of ICP-OES is better than 2% for most elements, except for Ca, Co, Li, Ni, and V (<3%) and for P and V (<5%).

Jacobs thus supplied data by single acid (0.5M HNO_3) ICP-OES for all samples:

- Al, Ca, Co, Cu, Fe, K, Mg, Mn, Na, Ni, Sr, V, Zn

They also supplied data by 0.5M HNO_3 ICP-MS for selected samples:

- Li, Be, Sc, Ti, Rb, Y, Zr, Nb, Mo, Te, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Pb, Th, U

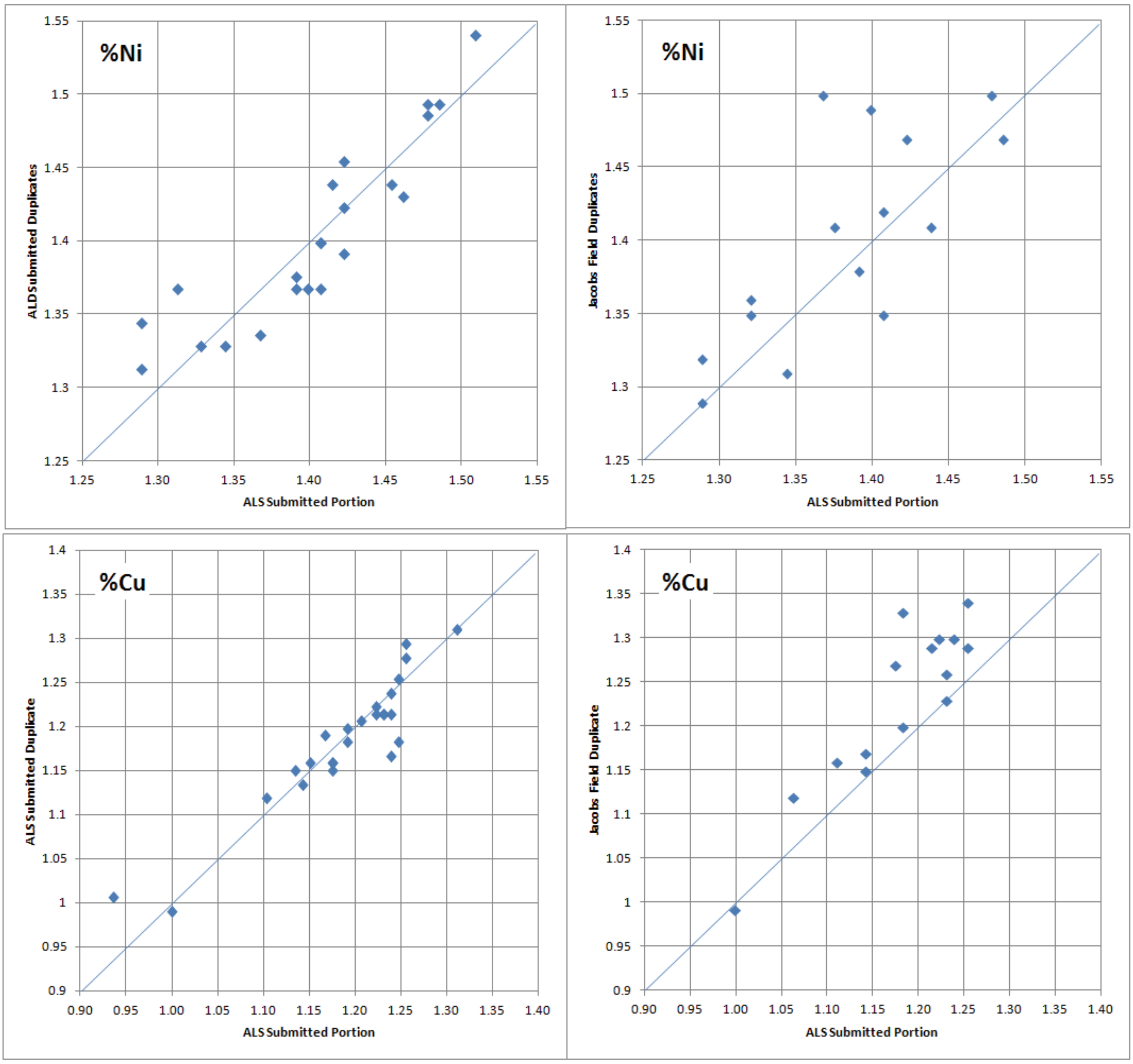
11.2.3 TOML Quality Assurance and Quality Control procedures

For the 104 box-core Submitted Portion samples submitted to ALS, 34 were duplicated (32.6%) with:

- 25 Submitted Duplicates to ALS (24.0%); and
- 15 Field Duplicates to Jacobs (14.4%).

Six Submitted Portion samples were duplicated both as Submitted Duplicates and Field Duplicates (5.7%).

Figure 11.4 Comparison of Nickel and Copper grades in duplicates



Field Duplicates from the box-core Primary Samples were produced using the cone and quarter technique once the final air-dried weighing step was completed.

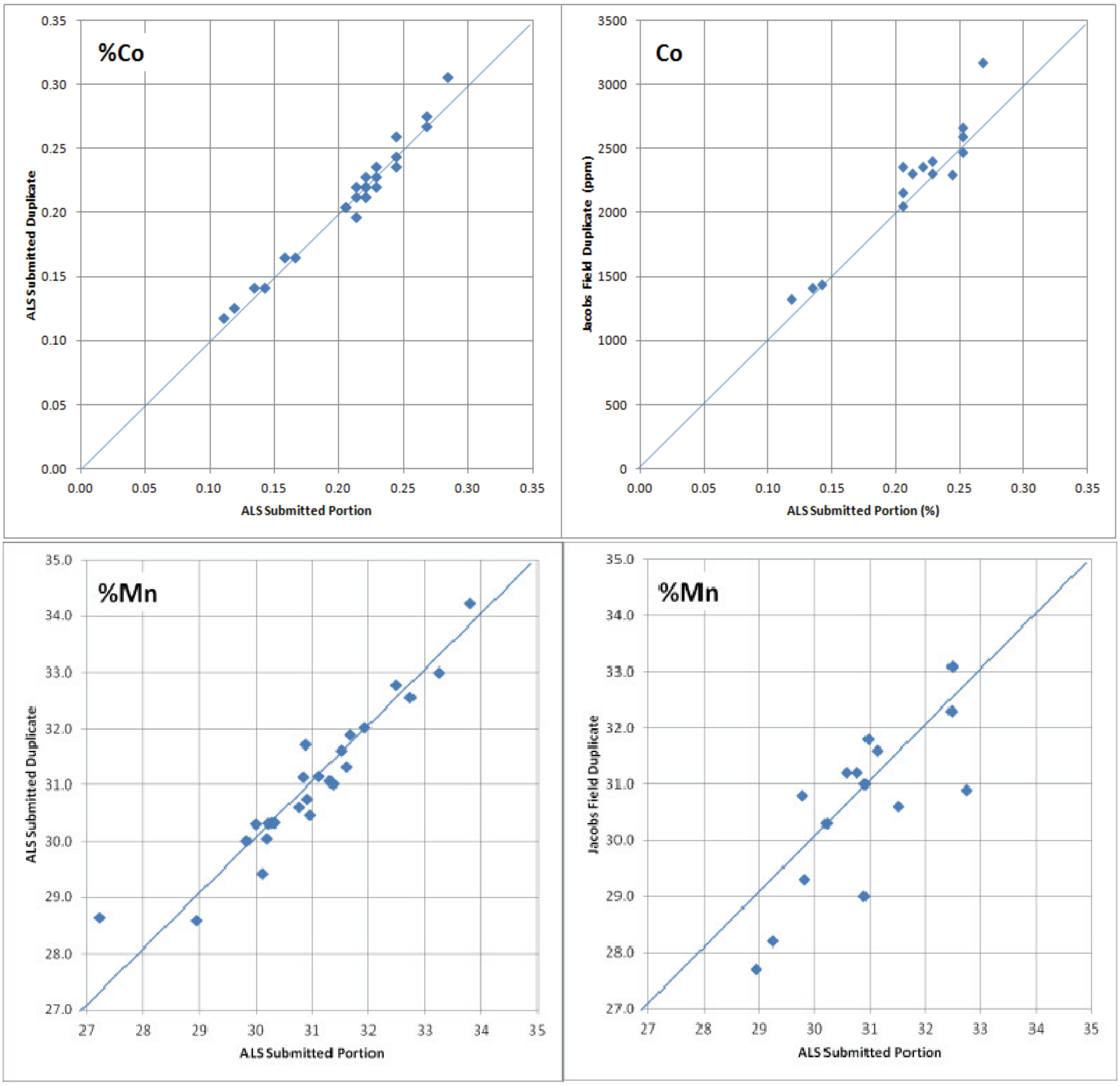
Reference samples from the box-core Primary Samples were taken at the same time but were selected on the basis of preference for entire nodules over a range of sizes and textures (if such a range was present) with an intent to include the most common forms of nodules.

Submitted Duplicates from the box-core Main Samples were produced using the cone and quarter technique.

Dredge “variance” samples were picked from all sides of the dredge pile with an attempt not to bias based on size or form. Dredge “variance” sample Field Duplicates were taken by snapping picked samples in half. These results (Item 12) give a good indication of the degree of inter-sample variance that might be expected.

Comparisons of duplicate results for Ni, Cu, Co and Mn are illustrated in Figure 11.4 and Figure 11.5. With Half Relative Difference analysis in Table 11.1 and Table 11.2.

Figure 11.5 Comparison of Cobalt and Manganese grades in duplicates



All Submitted Duplicates correlate very well with their Submitted Portion pairs). Field Duplicates correlate well with their Submitted Portion pairs except for high copper samples (bias high to Jacobs) and maybe low grade manganese (but the number of samples is too few to be sure and the relative difference is low; Table 11.2).

Table 11.1 Half Relative Difference Submitted Portions and Submitted Duplicates

	Co	Cu	Mn	Ni
Min	–3.44	–3.70	–2.55	–2.09
Max	3.84	2.99	1.13	1.42
Mean	–0.455	0.0995	–0.0506	0.0131

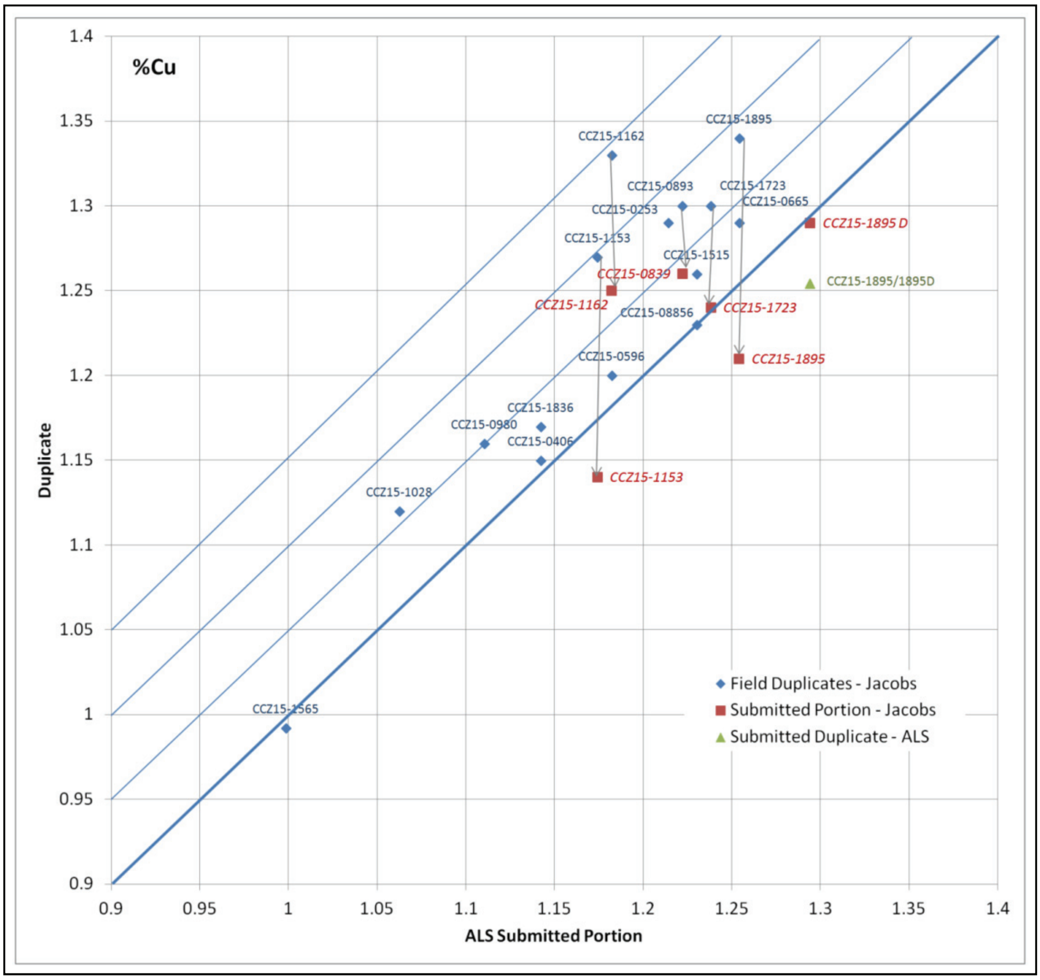
Half Relative Difference = difference between samples divided by their mean and times 0.5 and times 100

Table 11.2 Half Relative Difference Submitted Portions and Field Duplicates

	Co	Cu	Mn	Ni
Min	–8.62	–5.88	–1.70	–1.09
Max	2.93	0.330	3.15	50.0
Mean	–2.70	–2.07	0.399	30.0

Field Duplicates sent to Jacobs (analysis by ICP) generally compare very well with Submitted Portion analysed by ALS (XRF) with the exception of high copper samples (Figure 11.6), where there appears to be a bias of the order of 0.05 to 0.1 % Cu with Jacobs reading higher than ALS. On a relative basis this difference is not severe (Table 11.2).

Figure 11.6 Comparison of high grade copper duplicates



Selected high copper samples were reanalysed with additional standards by ALS without appreciable difference, then an aliquot of the Submitted Portion pulp was sent to Jacobs. Jacobs analysis of these aliquots is in broad agreement with the ALS results, indicating either contamination of the Field Duplicates during preparation or most likely a change in instrument calibration at Jacobs. The analysis supports that the ALS analysis of the Submitted Portion is valid for Cu at all grades.

11.2.4 Blanks, Laboratory Duplicates and Standards

Numbers of blanks, laboratory duplicates and standards are presented below. Note that Jacobs refers to duplicates as replicates.

Table 11.3 Blanks Laboratory Duplicates and Standards

	ALS			**Jacobs**
	XRF	**LOI**	**ICP**	**ICP**
Box-core samples analysed[i]	131			–
Laboratory duplicates	6	9	8	4[iii]
Blanks	4		8	–
Non-nodule standards	12	9	8	–
Dredge samples analysed[ii]	–			–
Laboratory duplicates	11	9	–	2
Blanks	6		–	–
Non-nodule standards	17	9	–	–
Nodule standards	5	–	–	7[iv]

[i] Includes 25 submitted duplicates as well as a crust and a buried nodule analysed for research purposes

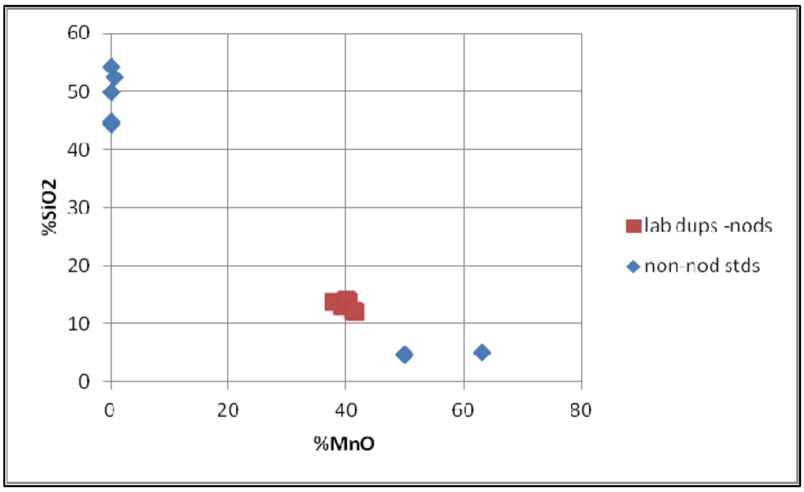
[ii] For the purposes of this note only samples collected during CCZ15 included here

[iii] Two duplicates being replicate digestion from the same pulp split and two being replicates from a separate pulp split

[iv] Jacobs analysed dredge and box-core samples as a single batch; ALS analysed the dredge samples approximately 7 days after the box-core samples

All ALS blanks were below detection limit for the key elements of interest (reported in the mineral resource), i.e. Ni, Mn, Cu, Co. One batch of four blanks retuned Ga values of up to 28% of the mean for nodules but other elements were below or near detection limits.

Figure 11.7 ALS Laboratory duplicates and non-nodule standards



Within the ALS box-core QAQC set, the range of non-nodule standards are compared with the laboratory duplicates in Figure 11.7 for the two most relevant elements Mn and Si. For these elements all of the analysed standards were within acceptable bounds.

Figure 11.8 ALS Laboratory duplicates compared to submitted portions

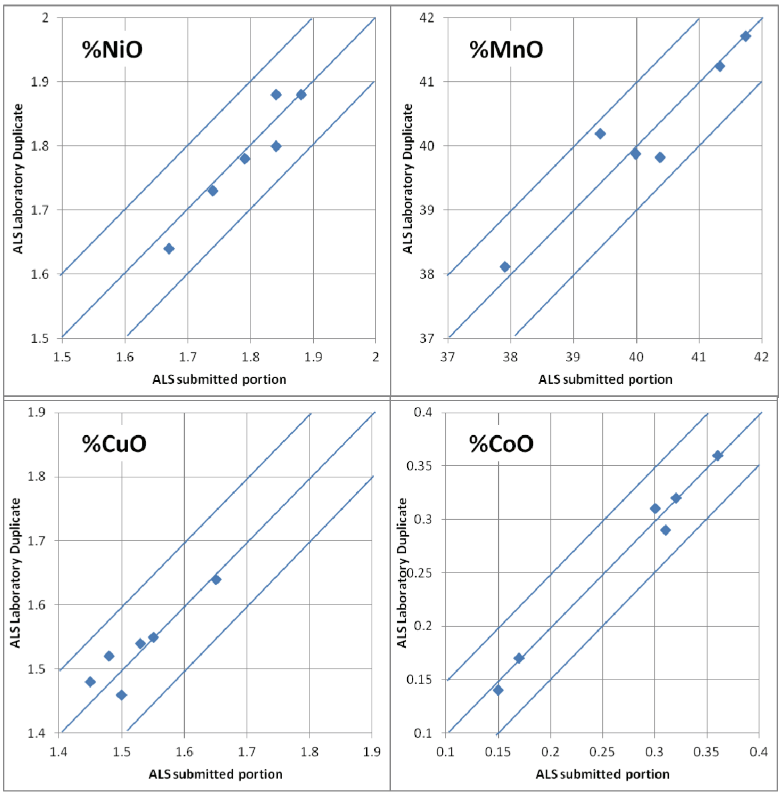
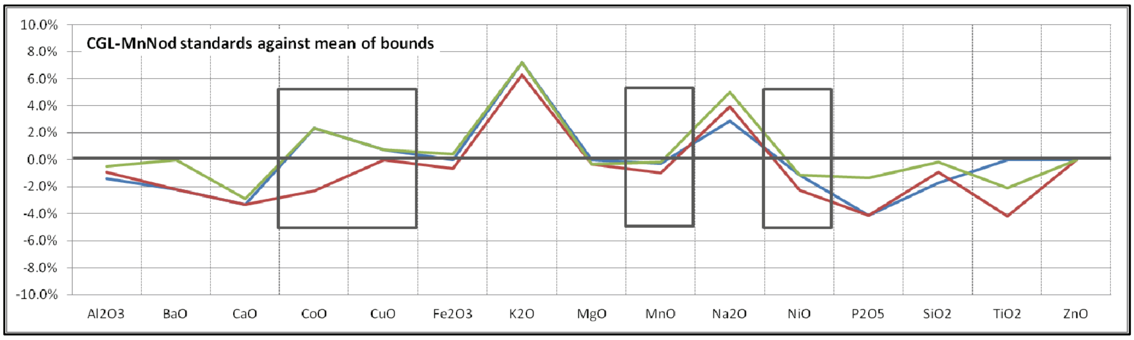


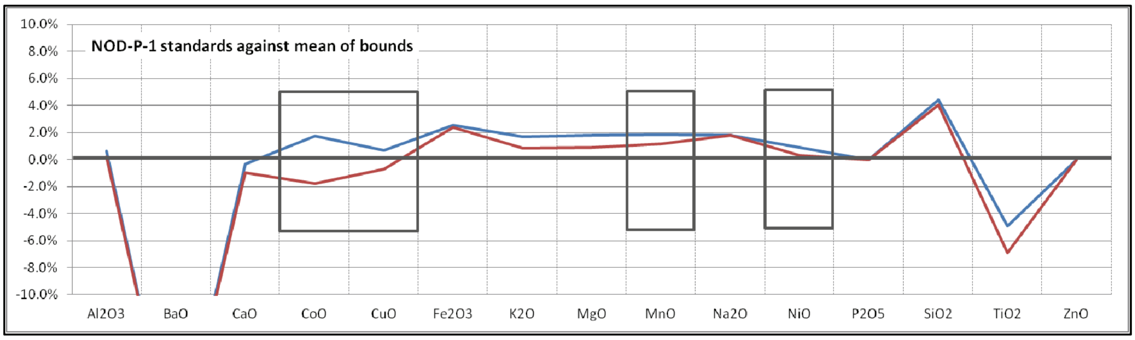
Figure 11.8 shows the close agreement between ALS laboratory duplicates (separate aliquot from pulverised material) and the original analyses of the Submitted Portions. Laboratory duplicates by Jacobs for Ni, Cu, Co and Mn are all within 3% relative agreement.

Figure 11.9 ALS performance against the CGL-131 nodule standard



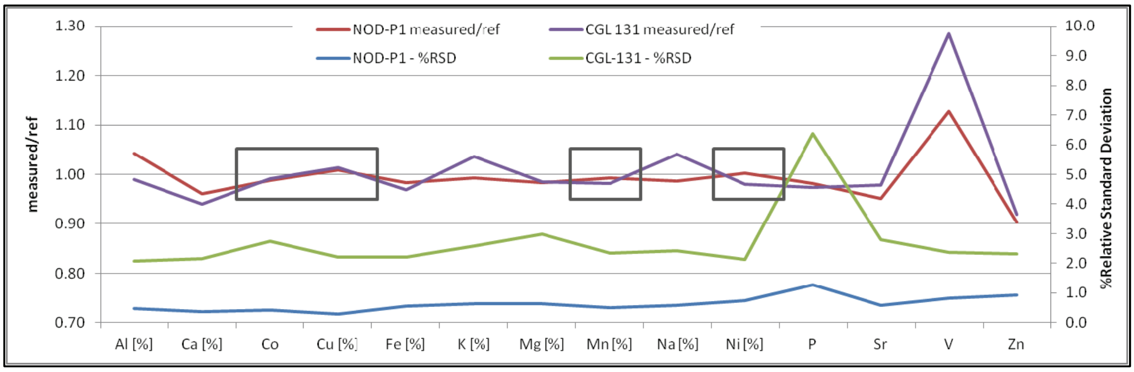
Grey boxes are ±5% relative for key elements of interest

Figure 11.10 ALS performance against the NOD-P1 standard



Grey boxes are ±5% relative for key elements of interest

Figure 11.11 Jacobs performance against the CGL-131 and NOD-P1 standards for Cu re-analysis work



Grey boxes are ±5% relative for key elements of interest – the special run of these standards are not included in Table 11.1

11.2.5 TOML photo abundance estimates Chain of Custody

Nodule abundance was estimated by TOML using two methods:

1 Physical samples using a box-corer (see COC above)
2 Long axis based estimates from photographs

The exploration processes leading to these estimates are described in Item 9 with validation of the photograph based estimates in Item 12.

Photographs were taken during the CCZ15 cruise by contractor Yuzhmorgeologiya. The photos were transmitted from the towed camera sled in real time to a camera operator and were automatically named with the date and time (in UTC) of the survey. File posting location was on a secure server (airwalled) with access by camera operator, surveyor and geoscientists.

Location of the camera sled at the time of photography was recorded separately by the Yuzhmorgeologiya hydrographic surveyor on watch using a combination of vessel GPS and either USBL signal or estimate of position from length of line out. Survey periods are recorded in the bridge log, vessel log and daily progress reports.

Photos were logged in near real time for geology and biology, with periodic updates of photo files to the filing on the TOML master computer.

Abundance estimates were made only for select photos due to the intense nature of the work and issues with sediment cover in some areas. Normally in TOML Areas B1 and C1 every 100th photo was selected. The selected photos were georeferenced to a template in a GIS program by a geoscientist and the long axis of each nodule within selected swaths was digitised. Each photo was checked by the Lead Geoscientist on watch and by the Lead Geoscientist designated accountable for data quality. The Chief Scientist ran a routine to measure the digitised lengths and also compiled the data into a MS Access database.

Copies of the processed data were passed, via email, to the Mineral Resource Qualified Person midway through the photo-profiling programme and after the cruise.

11.2.6 TOML adequacy of sample preparation security and analytical procedures

TOML had clear and secure chain of custody for the nodule samples collected during their exploration cruises. Sufficient Field and Submitted Duplicates have been taken to demonstrate lack of significant error in the chemical analyses. TOML also followed rigorous procedures for abundance estimation using both physical samples and photographs, with good correlation and validation (Item 12).

Data storage is secure and there is no evidence of any tampering of grade and abundance measurements.

Overall, the data are reliable for Mineral Resource estimation. This is supported by the very similar grades and abundances obtained in the historical sampling (Item 9, Item 12).

ITEM 12. Data Verification

12.1 Historical data

Sampling data were collected by six Pioneer Contractors during the 1970s to 2000s. As part of the ISA requirements to relinquish half of the registered Pioneer Contractor's claims, the data for the relinquished portions were made available to the ISA where they were archived. This entire data set was first provided to TOML in a comma delimited format, and then independently to Golder Associates in 2012 who were then compiling a technical report on this same project (Golder Associates, 2013). Mineral Resources QP in this report, Matthew Nimmo, was the lead QP for the Golder Associates technical report.

The database provided by the ISA contains multiple independent datasets that were independently collected and sampled using similar methods (FFG or BC sampling) but with slightly different equipment and were assayed by different laboratories. Because the database contains multiple datasets the datasets can be compared with each other for the purpose of validating the internal consistency of the data. Additionally, there are a number of published summaries of data that have not been provided to the ISA but show similar mean grades to the data within the TOML Exploration Area (Table 12.1).

Golder Associates contractor Charles Morgan is familiar with the procedures and processes that were used in collecting and assaying the samples. He has also been involved with collection, inspection and analysis of samples, photographs and video coverage of the polymetallic nodule deposits for Lockheed Martin while on board the exploration ship MV Governor Ray. Dr Morgan has also been involved with reviewing the Pioneer Contractors work and results, through his role on the ISA Legal and Technical Commission (ISA LTC), and in the compilation of ISA Technical Bulletin No. 6.

The sample data are supported by independent third party data, have been reviewed by the ISA LTC during the process of granting licences to the Pioneer Contractors, and are maintained by the independent ISA. Golder concluded that these data are suitable for Inferred Mineral Resource estimation purposes.

12.1.1 Data independence

QP Matthew Nimmo received the available data collected from within the CCZ and the TOML Exploration Area from the ISA via Charles Morgan. The data set was received on June 22 2012 from Dr Vijay Kodagali, Senior Scientific Officer of the International Seabed Authority (Email: vkodagali@isa.org.jm) who sent the data by email in Microsoft Excel format.

This data set is identical to the one used for the resource assessment provided by TOML, verifying the source of the sample data.

The database includes all data submitted to the ISA that were collected in the Reserved Areas of the CCZ. The data were collected by parties completely independent of TOML or Nautilus Minerals and retained exclusively in the custody of the ISA prior to their transfer. The data sets were also subject to third party review by the ISA's LTC, as part of the process of granting Pioneer Contractors Exploration Areas.

12.1.2 Historical data integrity

The original assay sheets from the laboratories for the individual nodule samples within the TOML Exploration Area are not available. Neither are the quality control procedures used by the laboratories and the ISA. It is reasonable to infer that the historical data is of sufficient quality for an Inferred Mineral Resource estimate because:

- The ISA is an independent agency with significant accountability under the Law of the Sea. Part of its mandate is the receipt and storage of sea floor sampling data suitable for the estimation of nodule resources and the legally binding award of licenses. It is reasonable to assume that a reasonable level of care was applied by the ISA.
- Comparison of the six independent data sets from the CCZ shows a high level of consistency in abundance and grade and, conversely, provides no evidence of bias or systematic error in the TOML data.
- Recent TOML nodule sampling confirms the existence, and abundance and grade continuity of the polymetallic nodules within the TOML Exploration Areas (refer to Item 14).

12.1.3 Data comparisons for the entire reserved areas

The Quality Assurance/Quality Control (QAQC) data for the historical samples are not available. Some QAQC is known to have been completed at the time, but there was no requirement to submit the results to the ISA. All the Pioneer Contractors collected samples by slightly different methods and assayed using different laboratories from what is effectively a single deposit. Due to the vast size and relative consistency of grade of the deposit the comparison between the data sets can be used as a proxy for QAQC.

Data covering the reserved blocks of ISA contained only a small number of anomalous values that may be suspected to be erroneous (four out of 2212 data points). These included:

- A Co value of 3.23% (next largest is 0.56% Co)
- Two Cu values of 157.0% and 66.0% (probably 1.57% and 0.66% respectively) (next largest is 1.62% Cu)
- A Mn value of 288.0% (probably 28.8%) (next largest is 35.62% Mn)

All these anomalous values are likely data entry errors and are contained within one contractor dataset (Yuzhmorgeologiya) and do not occur within the TOML Exploration Area, these data points were not used in any way for the resource estimate.

The box plots and log-probability plots (Item 14) comparing the data sets show that the distributions for Ni, Co, Cu, Mn and abundance are very similar between the different data sets, and across the CCZ. Variations between the data sets are attributed to both spatial variability and minor differences in sampling and assaying methods.

Quantile-Quantile (QQ) plots comparing the assay distributions of the samples within the TOML Exploration Area with all other available data from the reserved blocks are presented in Item 9. These plots show that Ni, Cu and Mn compare well but with divergence at the tails of the distributions, while Co and nodule abundance tend to be biased slightly lower for the TOML data.

The samples within the TOML Exploration Area used for the Mineral Resource estimate were collected by Yuzhmorgeologiya, DORD and Ifremer. These three data sets show no significant differences.

Overall the results confirm the consistency of the mineralisation across the entire CCZ and the TOML Exploration Area which form a small part of the CCZ.

12.1.4 Comparison with non-ISA sourced data

Table 12.1 Mean Grades of the CCZ Nodules from Various Sources lists the mean grades of the nodules from different parts of the CCZ that were based on data that is not included in the data obtained from the ISA. These mean grades are very consistent with each other and with the mean grades of the data that falls within the TOML Exploration Area.

One example is from the Scripps Institution of Oceanography (SIO) which compiled a database of polymetallic nodules information from numerous sources (referenced in the database), last updated in 1981 (NOAA, 2013 a). As a comparison exercise, this dataset has been clipped to the CCZ and analysed for comparison with the available ISA database. Note that as the vast majority of these samples were collected by dredging and coring, abundances have not been estimated or recorded, and therefore only grade analysis is possible.

The dataset is available at http://www.ngdc.noaa.gov/mgg/geology/sionar.html and was downloaded and imported into Microsoft Access, with some minor format alteration in the process. This database was then saved and accessed directly from ArcGIS.

A polygon representing the boundaries of the CCZ was used to query the database, and create a subset containing only samples within this zone. The mean values are included in Table 12.1.

Table 12.1 Mean Grades of the CCZ Nodules from Various Sources

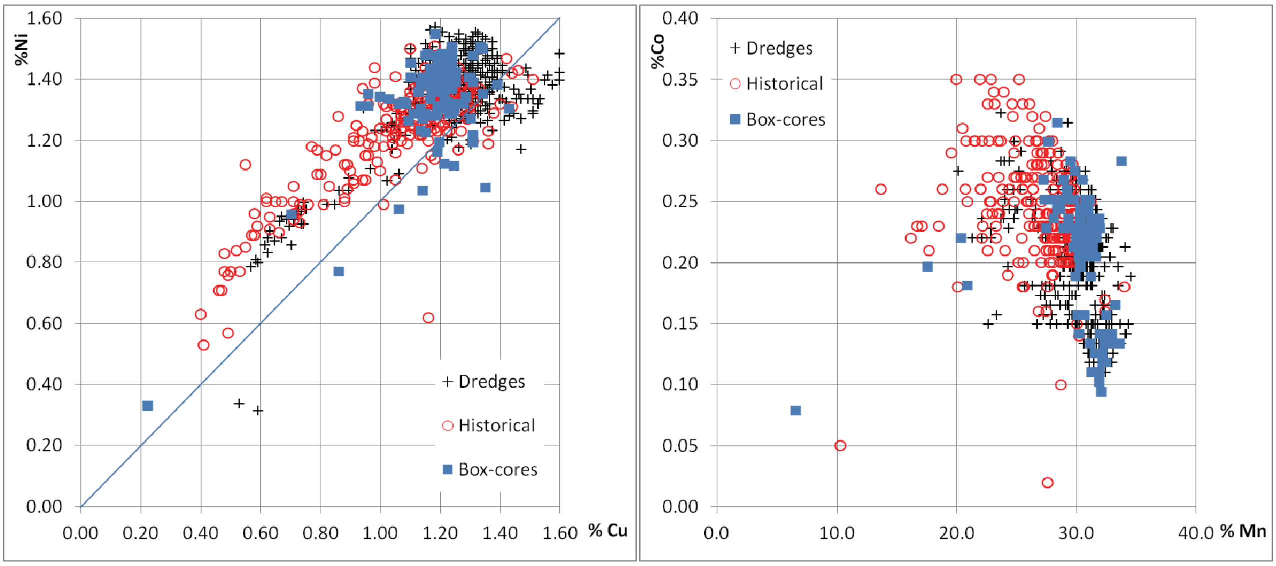
Ni (%)	Cu (%)	Co (%)	Mn (%)	Abundance (wet kg/m2)	Number of Samples	Source
1.24	1.03	0.22	27.2	6.5	2196	Data supplied by ISA (All CCZ)
1.22	1.06	0.24	26.9	8.5	255	Data supplied by ISA (TOML Exploration Area)
1.20	0.98	0.20	26.3	–	–	McKelvey et al, 1983
1.22	0.97	0.16	24.5	–	160	SIO (NOAA, 2013a)
1.29	1.19	0.23	29.1	–	–	Friedrich et al, 1983
1.28	1.16	0.23	24.6	–	–	Mielke (1975)
1.3	1.0	0.23	24.6	17	141	Ruhlemann et al (2011) west area
1.3	1.1	0.17	24.6	10	237	Ruhlemann et al (2011) east area

12.2 TOML data

12.2.1 Comparison of historical and TOML data

The CCZ13 and CCZ15 sample results of TOML were compared with historical samples. There is good correspondence given that the areas sampled are different. High Cu and Mn grades are less common in the historical samples but the ranges are the same and QA/QC for these elements (Item 11) show no issue with the TOML analyses of these elements.

Figure 12.1 Comparison between TOML analyses and historical analyses



The TOML analyses are from the submitted portion (Item 11); the same plots by area are included in Item 8

12.2.2 Nodule variation test work

Even without domaining, grade variation between nodule box-core samples is very low, with coefficients of variation typically around of 0.05 to 0.2 compared to nodule abundance which is typically around 0.5 to 0.7 (Table 12.2). Even extensive sub-sampling (dredge “variance” samples) did not expose any significant variance in grades (CV <=0.06).

Table 12.2 Undomained coefficients of variation for historical and TOML nodule samples

Number of samples		Area/sample type	Coefficient of variation				
Primary	**Sub**	**Nodules**	**Mn**	**Ni**	**Cu**	**Co**	**Abundance**
2	60	Area A TOML Dredge “variance”	0.09	0.18	0.34	0.22	n/a
18	0	Area A Historical	0.10	0.21	0.35	0.18	0.50
27	0	Area B1 TOML BC	0.20	0.21	0.21	0.18	0.90
1	20	Area B1 TOML Dredge “variance”	0.02	0.03	0.04	0.09	n/a
89	0	Area B Historical	0.17	0.20	0.27	0.22	0.67
14	0	Area C1 TOML BC	0.02	0.03	0.03	0.07	0.73
1	30	Area C1 TOML Dredge “variance”	0.03	0.03	0.04	0.11	n/a
87	0	Area C Historical	0.08	0.08	0.13	0.13	0.44
38	0	Area D1 and D2 TOML BC	0.03	0.07	0.05	0.09	0.61
10	187	Area D TOML Dredge “variance”	0.06	0.10	0.10	0.12	n/a
42	0	Area D Historical	0.05	0.06	0.08	0.10	0.53
12	0	Area E Historical	0.10	0.15	0.17	0.18	0.56
25	0	Area F and F1 TOML BC	0.03	0.06	0.06	0.13	0.23
4	82	Area F TOML Dredge “variance”	0.03	0.05	0.08	0.10	n/a
2	0	Area F Historical	0.00	0.03	0.01	0.04	0.27

The dredge “variance” samples were groups of up to 30 sub-samples collected from each dredge in order to study the grade variance or nugget of a sample point. As the dredges were often landed several times in a deployment (Item 9) a much larger range was covered than would be expected in a single box-core.

Figure 12.2 compares the CVs of the historical data and TOML dredge and box-core samples. The size of the circle is proportional to the CV (or spread) of the grades of the samples.

12.2.3 Nodule long-axis estimate validation

Photographs were used by commercial explorers in the 1970s to estimate polymetallic nodule abundance (Felix, 1980; Kaufman and Siapno, 1972).

The benefits of photos over physical sampling were immediately recognised i.e.:

- Quicker and cheaper
- Larger primary sample (area)

This relationship works through measurement of each nodule’s long (or major) axis and the outcome is much better than estimates from photo based nodule coverage or acoustic response (Item 9). The process of estimating the weight of nodules was called Long-Axis Estimation (LAE).

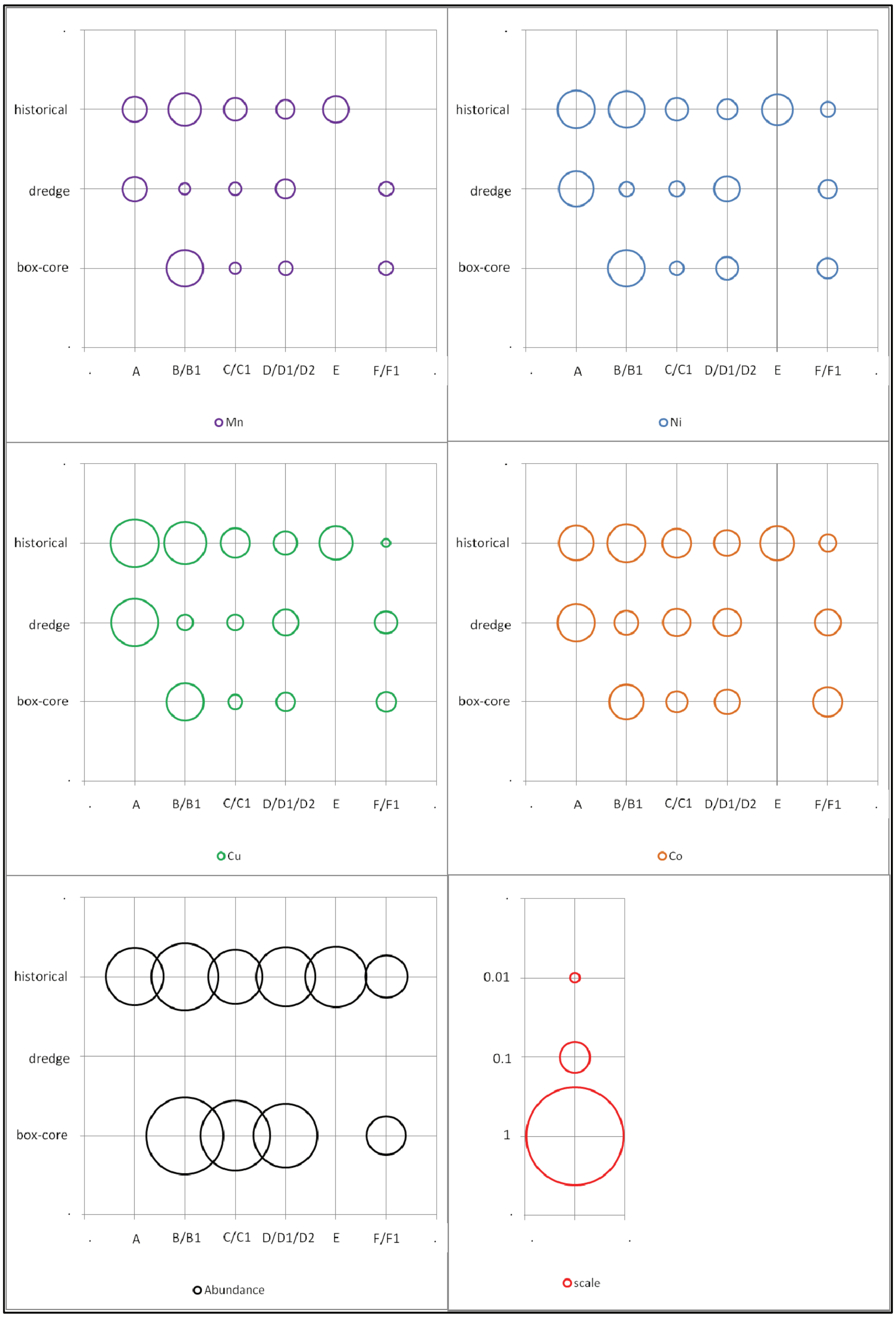
As discussed below, a key limitation of photo-based abundance estimation was that in some areas sediment ‘powder’ or ‘cover’ was sufficient to mask too many of the nodules to allow an accurate estimate. A correction factor might be possible in some of these cases, but this has not been applied to date on the TOML areas as it is likely crude and development requires more work.

Felix (1980) proposed a formula for nodules within part of the Kennecott area as follows:

$$\mathrm{Log}_{10}\mathrm{wt.} = (2.71)(\log_{10}\mathrm{LA\_cm})-0.18$$

Where wt. is the wet mass of the nodule in grams and LA_cm is the long or major axis of that nodule in centimetres. This formula was modified slightly in both TOML Areas B1 and C1 based on calibration results.

Figure 12.2 Comparison of coefficients of variation for historical and TOML nodule samples



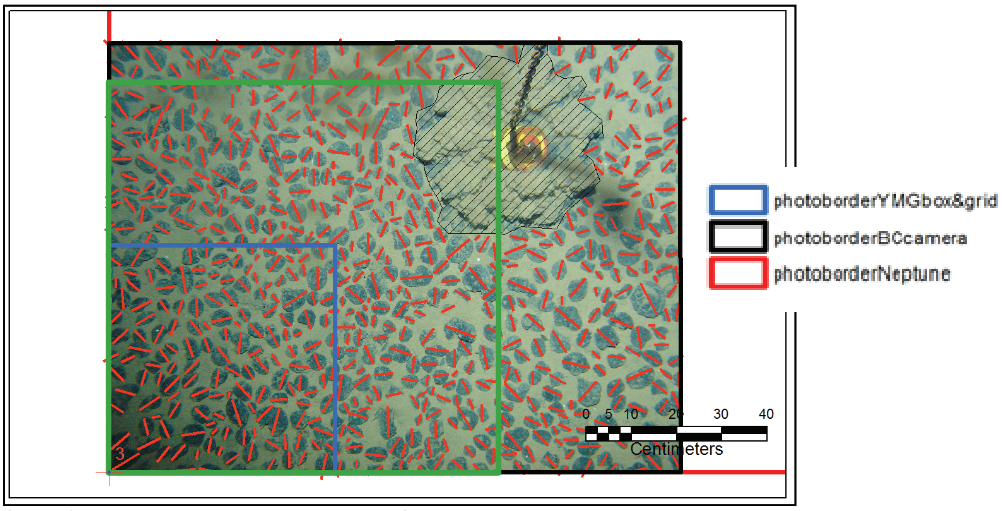
Values from Table 12.2

12.2.3.1 Photo-based estimates in the TOML Area

During 2015 TOML collected seabed photos using a box core mounted camera system to collect seabed photos from areas B,C, D and F (bottom shots) and a towed camera system (called the Neptune) to collect seabed photos from areas B,C and D.

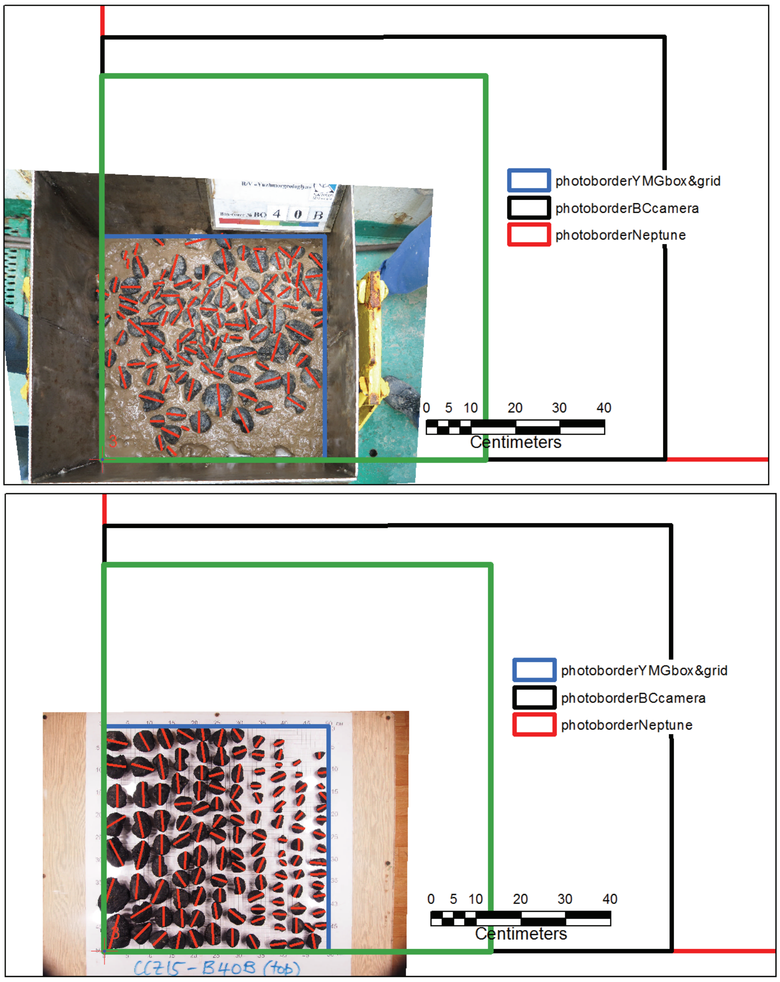
In areas B and C it proved possible to use the bottom shots (e.g. Figure 12.3) as well as photos of the box-core samples taken on the vessel to calibrate and modify the Felix (1980) formula (above) to accurately estimate the weighed abundance of each box-core. The photos taken on the vessel included topshots of the sample in the box-core as it landed on deck and grid photos of the nodules from the box-core after washing off mud (e.g. Figure 12.4).

Figure 12.3 Example LAE measurement – bottom photo



Green frame is the area sampled by the KC box-corer

Figure 12.4 Example LAE measurement – top shot (YMG box) and grid photo

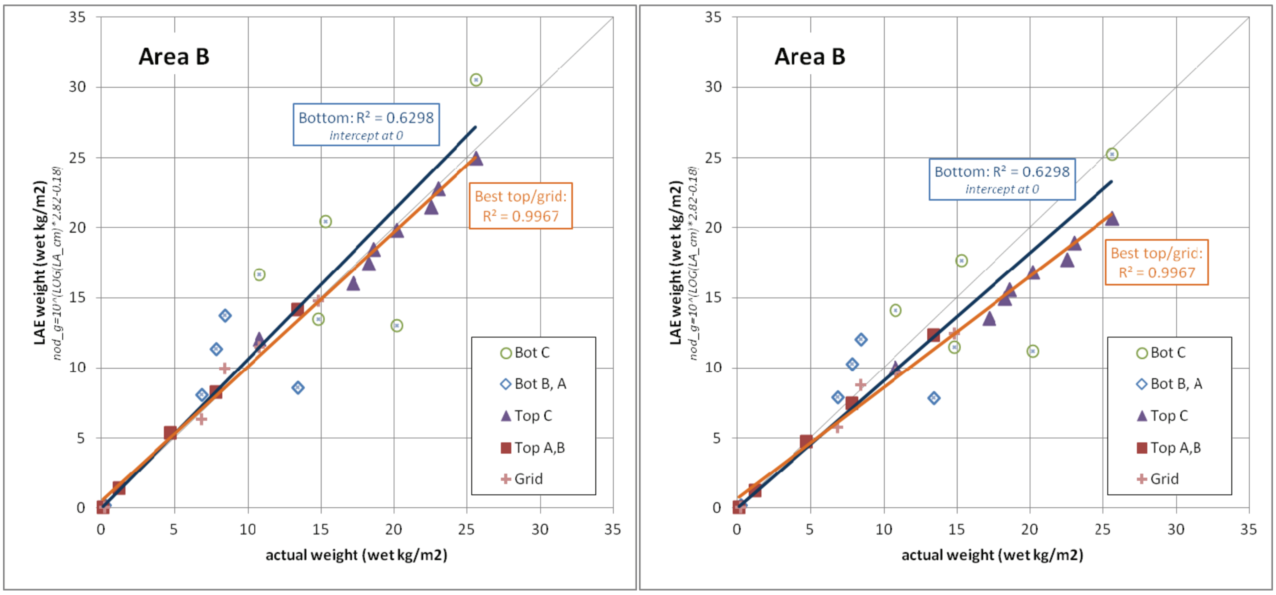


Green frame is the area sampled by the KC box-corer

The process involved referencing the photos to scale in a GIS package, using an average field of view based on a variety of images of the trigger weight-scale. Then a line was digitised along the long axis of each nodule before recording the length of each line into a database. The line measurements were then analysed in MS Excel, comparing the total calculated weight with the total actual sample weight. Accurate weighing of individual nodules was not possible due to the heave of the vessel, but a motion compensated scale could accurately weigh entire box-core samples (+- 50 g).

Initially the formula of Felix (1980) was used but a much better fit was achieved if the factors were modified (Figure 12.5). The need to modify the factors probably relates to difference in nodule's thickness:area aspect ratios between areas, that in turn could relate to differences in the hickness of the geochemically active layer (Item 7).

Figure 12.5 Area B correlations with best fit factors (L) and Felix 1980 factors (R)

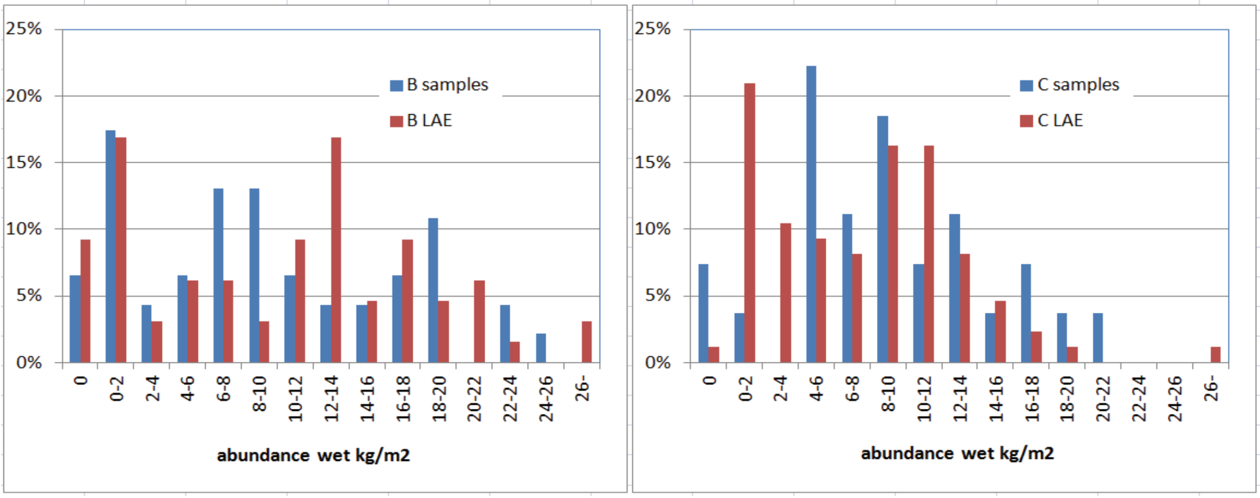


In Area B, long-axis estimates made use of box-core seafloor photos, topshots and, where needed, sample grid photos, as in some cases the camera on the box-corer didn't work, and in other cases the sample arrived on deck scrambled into the sediment. Area B was compared by type of nodule (Contractor Yuzhmorgeologiya facies A, B, C) as well as combined types with no noticeable difference in relationship.

The calibrated relationship stood up very well (Figure 12.5); better than some nodule by nodule point counting that was also tried and so the formula was applied to the Neptune photos (approximately every 100th) with results broadly agreeing with the box coring (Figure 12.6) but providing much more detail.

The processing involving the Neptune towed camera sled photos was broadly similar to the calibration work done with the box-core bottom photos except that the Neptune images were referenced to an average field of view from images that clearly showed two centrally located laser pointers (30 cm spacing) carried on the towed camera sled. Although an electronic altimeter triggered the camera at near identical heights above the seafloor, each image varied slightly in terms of field of view due to flare and rocking of the sled in response to vessel motion.

Figure 12.6 Comparison of physical samples and LAE in Areas B and C

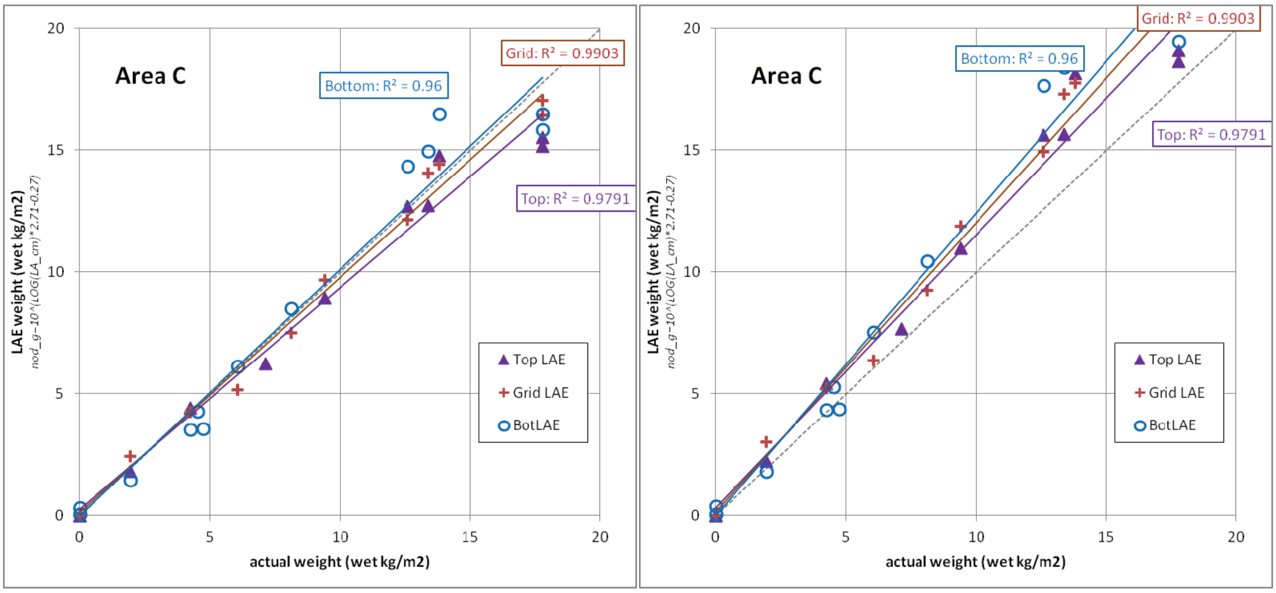


Due to the very large volume of readings (>90,000) the digitised nodule lengths were compiled into and reported from a MS Access database. They were also studied using the statistical program R.

The process was then extended to Area C, and with agreement of the mineral resource Qualified Person only half the box-cores were taken (for calibration and grade estimation) as the Neptune photos were seen to be the better dataset due to area covered in each shot and frequency of photos available for measurement-interpretation. Again the factors in the Felix (1980) formula were adjusted to improve accuracy (Figure 12.7).

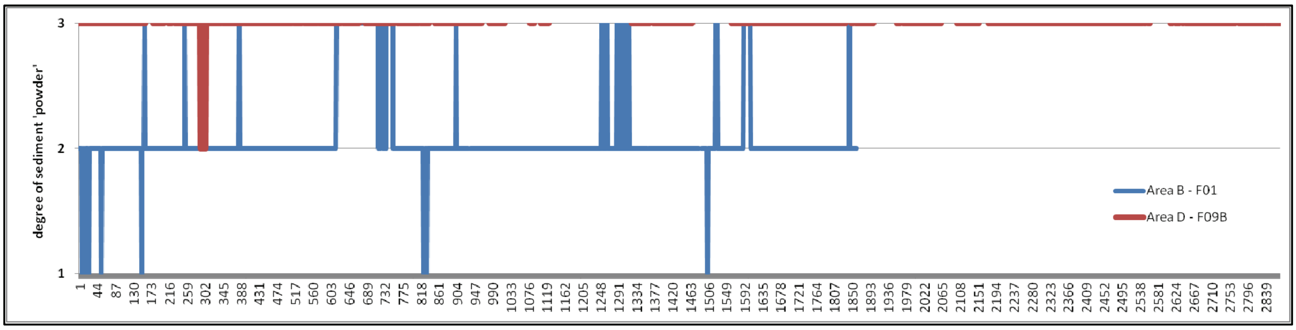
In Area C the correlations between bottom photos based estimates and actual weights show less scatter – this might be due to a slightly different camera with a wider field of view being used.

Figure 12.7 Area C correlations with best fit factors (L) and Felix 1980 factors (R)



In Area D however, the degree of cover (Figure 12.8, Figure 12.9, Figure 12.10) confounded the process. This possibility of this had been warned by Felix (1980), so after the orientation Neptune lines were complete, the survey focused on box-cores and there is no Neptune LAE data from this area for mineral resource estimation purposes.

Figure 12.8 Degree of powder on visible nodules in Area D vs Area B



Note that level 3 cover is the highest possible per the logging schema used during the CCZ15 cruise.

Figure 12.9 High degree of sediment “powder” and cover in Area D

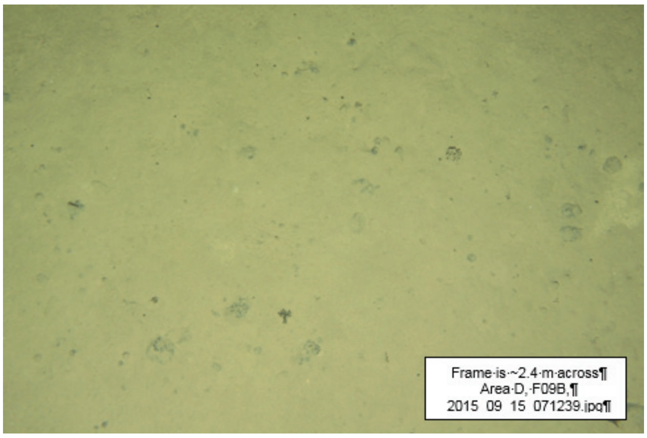


Figure 12.10 Covered nodules B75, Area D2

In Area F no towed camera survey was done but a visual comparison between bottom photos, topshots and grid photos reveals good exposure of nodules.

Abundance variance for both box-core samples and LAE estimates are summarised and compared in Table 12.3. Area B1 and Area C1 have higher box-core based global coefficients of variation than Area D1 and Area D2, while Area F and Area F2 are especially continuous. Thus the Neptune LAE results are helping in the two more variable areas, and would probably have been less critical in the others.

Table 12.3 Summary statistics of abundance between box-cores and LAE

Area	Type	Count	Stdev	Average	CV
B1	BC	30	8.25	9.35	0.88
B1	NeptLAE	75	7.74	10.16	0.76
C1	BC	16	5.54	7.80	0.71
C1	NeptLAE	86	5.40	7.34	0.74
D2	BC	26	6.86	11.59	0.59
D1	BC	16	8.20	13.84	0.59
F	BC	15	6.81	15.80	0.43
F1	BC	10	4.63	21.65	0.21
Historical data used in 2012 NI43-101 Inferred estimate (count = 255)					0.62

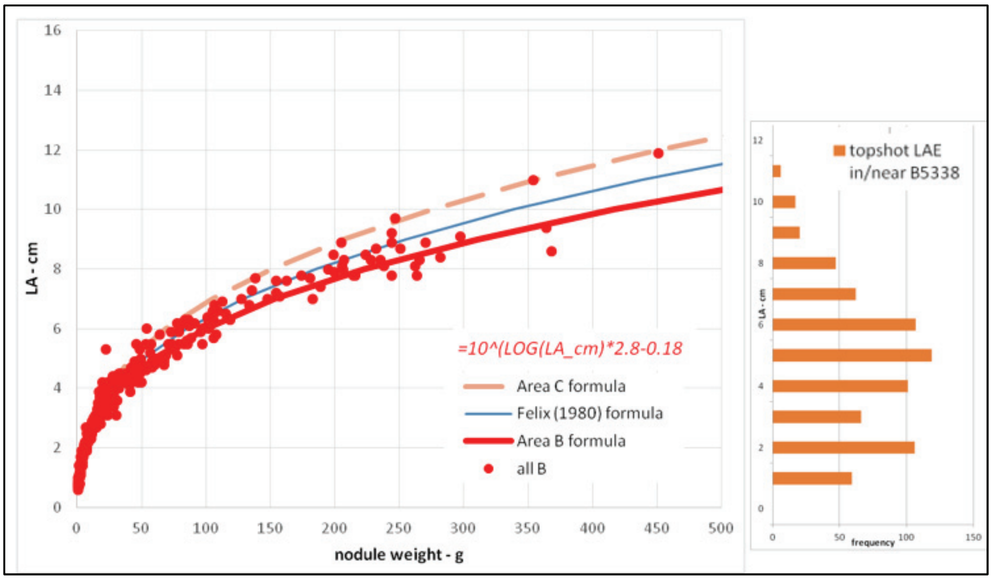
12.2.3.2 Confirmation Study

In April 2016 individual nodules were weighed on shore to check the relationships obtained and applied at sea.

More accurate weighing of individual nodules was possible, now that the work could be done on land without the influence of vessel heave, but the samples used were necessarily residues of the collected samples that had been already been split and sub-sampled for grade, reference and mineragraphy. Also the samples had been transported several times and were then more 6 months old and so were often comprised mostly of broken nodules which could not be measured. Never the less some 390 nodules were each weighed and measured with results as follows:

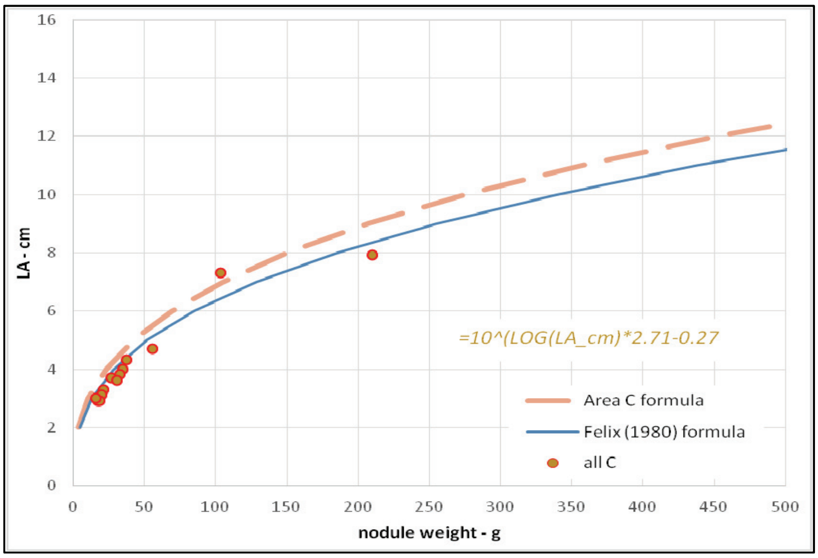
In TOML Area B1 there was a good fit between the formula used at sea and individual nodules weighed (Figure 12.11) confirming a valid relationship. While a slightly better visual fit might have been possible regarding the larger nodules it is likely that the unbiased correlation in Figure 12.7 would be adversely impacted (e.g. using Felix's factors in Figure 12.5). Large nodules are not that common and it is not clear how representative the individuals weighed actually are (irregular nodules might be more prone to breakage).

Figure 12.11 Confirmation nodules weights Area B and histogram of nodules by long-axis length



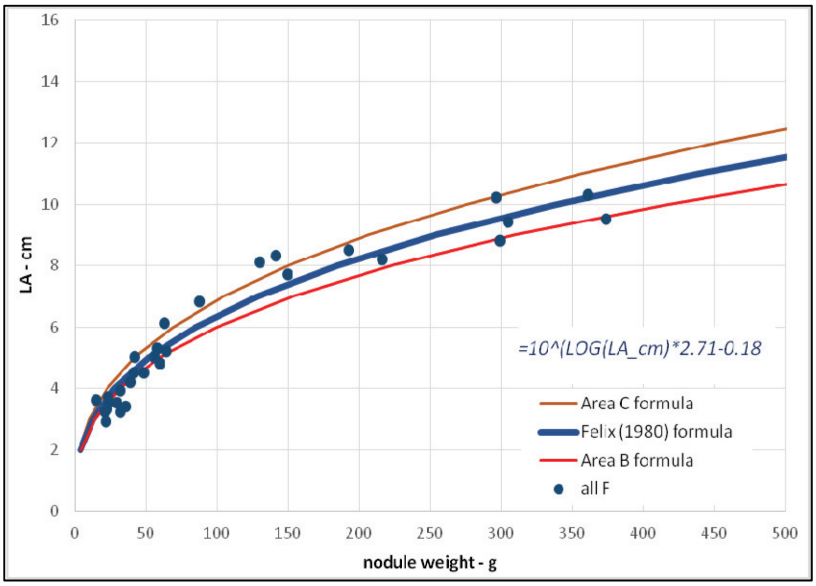
For Area C there was a shortage of whole nodules especially larger ones (which are naturally rare in Area C; Figure 12.12) but the relationship and formula was confirmed. There is a chance that the formula is a little conservative (i.e. factors a little closer to Felix's or Area B's could have been used), but again care needs to be taken considering the strong correlation obtained using the best fit factors versus the imparted bias using Felix's factors in Figure 12.7.

Figure 12.12 Confirmation nodules weights Area C



For TOML Area F, if LAE is used in the future, then the factors published by Felix look to be potentially suitable (Figure 12.13). It is worth noting that TOML Area F is near the southern side of the Kennecott "Frigate Bird" exploration area, and that the larger nodules there are known to be distinctly thinner in aspect (Item 8).

Figure 12.13 Confirmation nodules weights Area F



12.3 Adequacy of data

Matthew Nimmo, Qualified Person for the Mineral Resource, considers the historical nodule sample data to be suitable for the purpose of estimating Mineral Resources to an Inferred level of confidence. The QP also considers that the combination of the TOML and historical nodule sample data (physical samples and photo based long axis estimates) combined with detailed backscatter, photo profiling and geological interpretation is sufficient to estimate polymetallic nodule Indicated Mineral Resources and in one small especially data rich area Measured Mineral Resources.

The primary characteristic of the polymetallic nodule deposit that separates this deposit from typical terrestrial manganese, nickel and copper deposits is that the nodules themselves can be accurately mapped through photo-profiles and backscatter acoustic response. The bulk of the polymetallic nodules sit on top of the seabed allowing them to be photographed. However, in some areas such as TOML Area D some nodules are partially covered by sediment making it more difficult to detect the presence and abundance of the nodules. The most accurate method for determining nodule abundance is through physical sampling by box-core or free fall-grab sampling. However, these methods are costly and result in wide sample spacing. Due to the fact that nodules are visible, photography can be used in many areas to estimate nodule abundance directly. The two methods for doing this are estimating the nodule percent coverage (percent of exposed nodule surface area within the photo) and measuring each individual nodule long-axis and then using these measurements to calculate abundance using variants of the formula defined by Felix (1980). The long-axis estimation (LAE) method is the most accurate and preferred method but comes at a cost in the time to manually process each photo - limiting the number of photos that can be used for estimating abundance. The benefit of using photographs is being able to demonstrate continuity between physical sample location and accurately quantify nodule abundance. TOML is developing an automated method of doing these measurements for future application.

The QP considers the abundance estimates derived from photographs to date from TOML Areas B and C, to be suitable for estimating nodule abundance for the Mineral Resource.

ITEM 13. Mineral Processing and Metallurgical Testing

13.1 Historical Work

Considerable mineral evaluation and metallurgical testwork on nodules from the CCZ has been reported. This was predominantly at a laboratory scale, with some test work at a pilot plant scale (Sen, 2010). All published historical work indicates that processing of nodules is technically feasible. To maximise recoveries of valuable metals the manganese lattice has to be broken down, either through pyrometallurgical or hydrometallurgical/biohydrometallurgical action.

Haynes et al (1985), in a NOAA funded US Bureau of Mines managed study, examined in detail the chemistry, morphology, and mineralogy of the nodules as well as five discrete processing routes. The processing routes are either hydrometallurgical or combinations of pyrometallurgical and hydrometallurgical processes, and were investigated at the bench top scale with nodule feed, with a specific focus on tailing and slag composition (Haynes et al, 1985). The potential process routes (Figure 13.1) include:

- Gas reduction and ammoniacal leach process (Caron process)
- Cuprion ammoniacal leach process (as developed by Kennecott in their nodule studies in 1970s and 80s)
- High temperature and high pressure sulfuric acid leach process (HPAL)
- Reduction and hydrochloric acid leach process
- Smelting and sulfuric acid leach process

The first three processes are three-metal recovery systems with manganese reporting to a waste stream, with the last two also recovering manganese. The cuprion process operates at atmospheric pressure and temperature and flotation of the tailings can produce commercial grade manganese concentrates (NIOT, 2008).

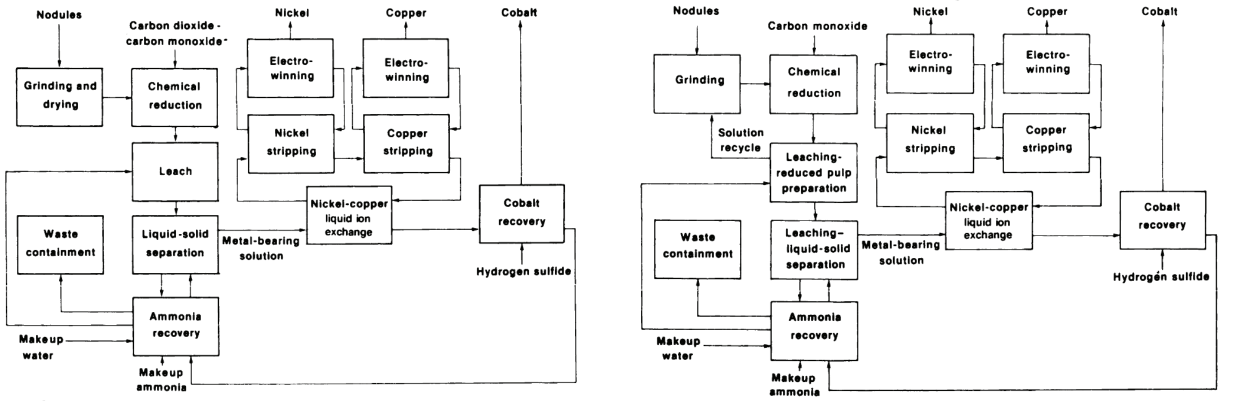
Additional process routes, including biohydrometallurgy and alternative reducing agents, have been studied, e.g., Wang and Li (2005, Figure 13.1) and general reviews by Mukherjee et al. (2004) and Sen (2010).

Haynes et al (1985) and Wang and Li (2005) both conclude that the studied flow sheets for nodules are technically feasible. At the laboratory (bench top) scale Ni, Cu and Co recoveries vary but for the processes not using ammonia leach generally exceeded 90%. For the ammonia leach type processes recoveries vary with Haynes et al (1985) achieving greater than 90% for Ni and less for Co and Cu and Wang et al. (2005) achieving 95% for Cu, 65% for Co and 84% for Ni.

Neither Haynes et al (1985) nor Wang and Li (2005) reported Mn or REE recovery, although the smelting process produced Mn rich tailings and a ferro-manganese product, and the hydrochloric acid leach process could also produce manganese. Sen (2010) reports process options with manganese recoveries of 85%. In NIOT (2008) COMRA reports that pilot tests on ‘smelting – oxidative leaching-SX’ returned metal recoveries of Ni, Cu and Fe of greater than 90%, Co of 89%, and Mn of 82%, while IOM, who studied both hydrometallurgical and pyrometallurgical process routes, report extraction efficiencies via sulphur-dioxide leaching of greater than 98% for Ni and Mn and greater than 90% for Co.

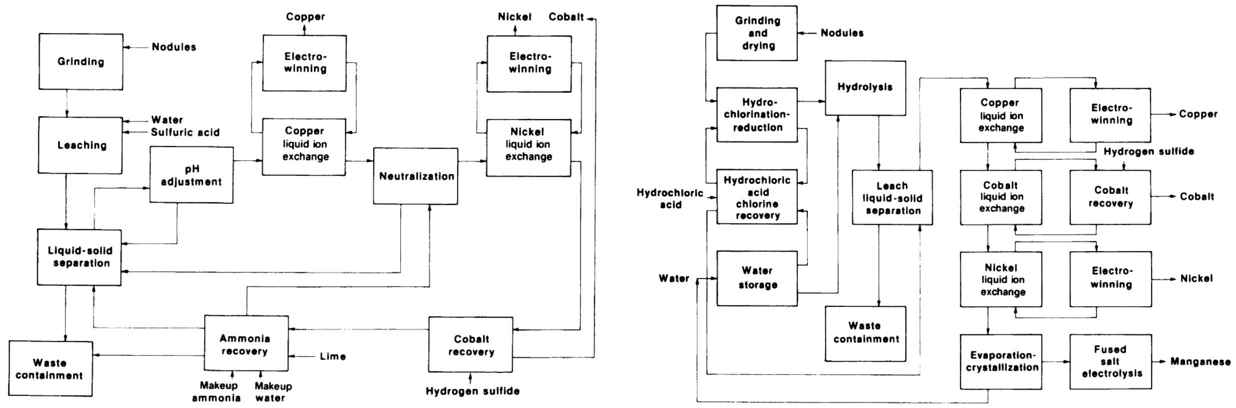
Spickermann (2012) did not look at how REE could be extracted, but notes that any hydrometallurgical process that extracts all of the Mn, Ni, Co and Cu (without REE losses or reagent additions) would effectively create a tail with over 3 times the original REE grade. This could be very competitive compared to other REE sources, with substantially lower environmental risks due to the negligible uranium and low thorium contents of nodules.

Figure 13.1 Potential process flow-sheets for seafloor nodules.



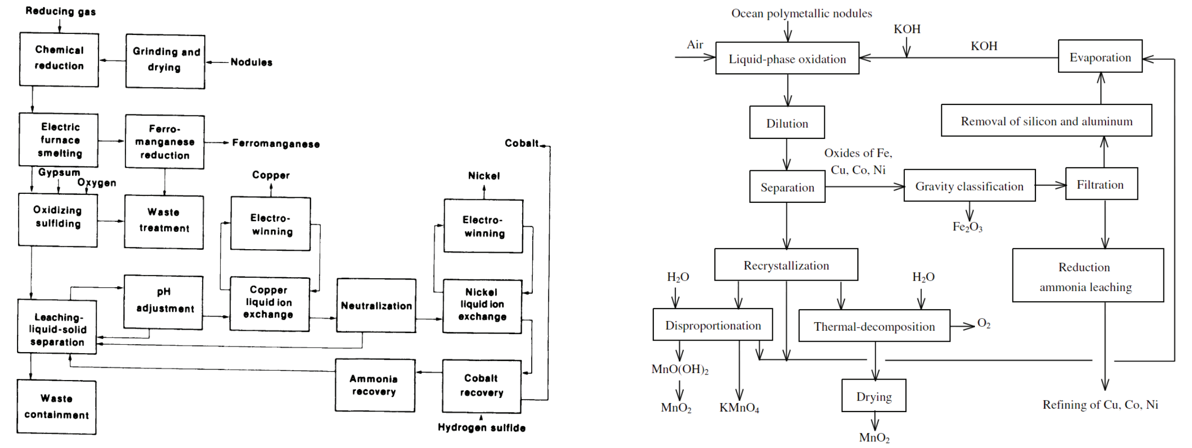
1. Gas reduction and ammoniacal leach

2. Cuprion ammoniacal leach



3. High temperature/pressure sulfuric acid leach

4. Reduction and hydrochloric acid leach



5. Smelting and sulfuric acid leach

6. Potassium hydroxide oxidation ammonia leach

1-5 studied by Haynes et al. (1985) and 6 by Wang and Li (2005)

13.2 Confirmatory Work by Nautilus

Confirmatory work by Nautilus is still largely proprietary in nature but has included:

- Extensive literature reviews and a market review;
- Mineral and chemical characterisation;
- Mass-energy balance and stoichiometric modelling and optimisation;
- Bench-top scale test-work.

The results of the work are consistent with the historical mineral process and metallurgical work.

ITEM 14. Mineral Resources

Estimation of tonnage and grade for TOML Exploration Areas A, B, C, D, E, and F within the CCZ was undertaken in the second quarter of 2016. The estimates are based on the historical box-core and free fall-grab nodule sampling (262 samples) supplemented with recently acquired TOML nodule box core (113 samples) and photo-profile data (20,857 frames over 587 line km). Only sample data within the TOML tenement Area was used to inform the estimates.

The Mineral Resource estimate reported here follows and supersedes a maiden NI 43-101 Inferred Mineral Resource estimates reported by Golder Associates (2013). Differences between the two estimates are consistent and explicable.

The modelling methodology used for estimating the Mineral Resource was determined through careful consideration of the scale of deposit, geological mechanism and controls behind nodule formation and nature of the sampling method (refer also to Item 7). The approach involved estimating nodule abundance and grades into a two-dimensional block model. Abundance, in wet kg/m^2, was used for calculating tonnage. Abundance and grades were estimated using ordinary kriging (OK). Inverse distance weighting (IDW) and nearest neighbour (NN) estimates were used to validate the OK estimates.

The Qualified Person, Matthew Nimmo, has assessed the available geological, mining and processing information regarding the manganese nodules and concluded that there are reasonable prospects of economic extraction; refer to Item 16 for further details.

14.1 Mineral Resource summary statement

The global Mineral Resource estimate at various nodule abundance cut-offs for the TOML Exploration Area within the CCZ polymetallic nodule deposit is presented in Table 14.1. The Mineral Resource estimate at an abundance cut-off of 6 wet kg/m^2 is the selected base case scenario considering a non-selective bulk mining operation. The effective date for the estimate is 30 March 2016 (Effectively the cut-off date of ongoing data collection and analyses and the date when the QP received the data from TOML).

Table 14.1 2016 Mineral Resource Estimate for the TOML Exploration Area within the CCZ at a series of nodule abundance cut-offs

Abundance Cut-off (wet kg/m^2)	Mineral Resource Classification	Abundance (wet kg/m^2)	Mn (%)	Ni (%)	Cu (%)	Co (%)	Polymetallic Nodules (x10^6 wet t)*
4	Measured	11.81	27.57	1.33	1.05	0.23	2.6
	Indicated	11.84	30.30	1.35	1.18	0.21	69.6
	Inferred	11.31	29.02	1.29	1.14	0.20	695.9
5	Measured	11.81	27.57	1.33	1.05	0.23	2.6
	Indicated	11.99	30.31	1.35	1.18	0.21	69.1
	Inferred	11.39	29.03	1.29	1.14	0.20	692.7
6	Measured	11.81	27.57	1.33	1.05	0.23	2.6
	Indicated	12.19	30.32	1.35	1.18	0.21	68.1
	Inferred	11.52	29.05	1.29	1.14	0.20	685.3
7	Measured	12.29	27.61	1.33	1.05	0.23	2.5
	Indicated	12.59	30.34	1.35	1.18	0.21	65.7
	Inferred	11.74	29.07	1.29	1.14	0.20	668.0
8	Measured	12.61	27.63	1.33	1.05	0.23	2.4
	Indicated	13.12	30.35	1.35	1.18	0.21	62.0
	Inferred	12.26	29.16	1.29	1.14	0.19	620.4

*Variations in Totals are due to rounding of individual values

Mn, Ni, Cu and Co assays on samples dried at 105°C

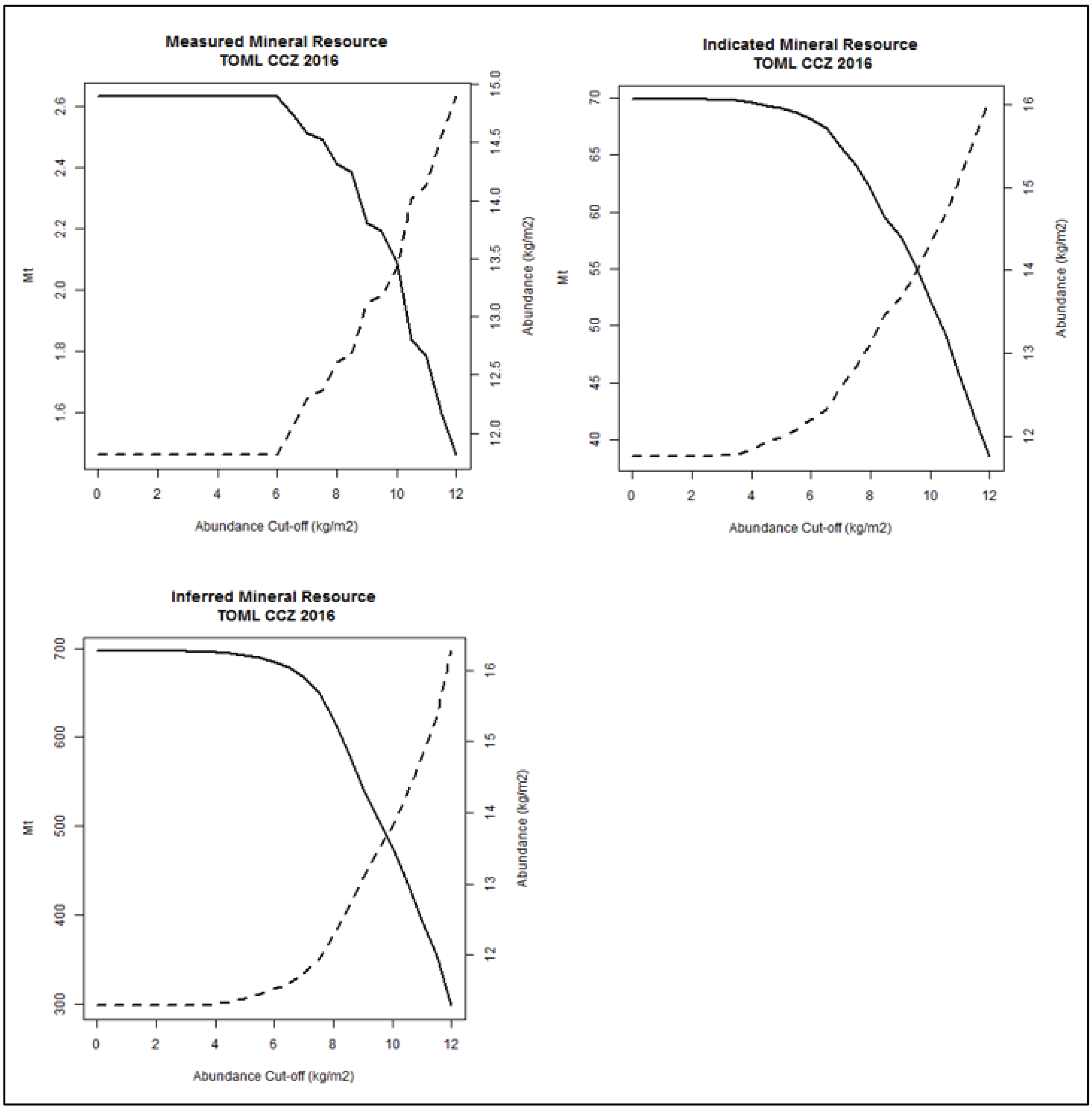
Moisture content of nodules is estimated at 29% (free water removed after drying at 105°C)

Note that for the Mineral Resource estimate the nodule weight is assumed wet (Sections 7.5.6 and 7.6).

The QP has assessed the available information regarding mining and processing of the polymetallic nodules (refer to Item 16) and concluded that there are reasonable prospects for economic extraction.

The nodule abundance and tonnage curves for various nodule abundance cut-offs are presented in Figure 14.1. At abundance cut-offs of 7 kg/m^2 or less the tonnage and grade are relatively insensitive. Above 7 kg/m^2, global tonnage declines rapidly.

Figure 14.1 Nodule Abundance – Tonnage Curves



This Mineral Resource was estimated independently by Matthew Nimmo, the Qualified Person for Mineral Resource estimates. A summary of technical items of interest includes:

Tenure (Item 4)

- All resources are held by TOML, a wholly 100% owned subsidiary of Nautilus. TOML is registered in the Kingdom of Tonga and is subject to all appropriate Tongan mining and civil laws and Tongan taxes and royalties.
- The resource falls within the six areas within the Exploration Area granted to TOML, which covers the exploration for polymetallic nodules and formalises the rights of TOML to apply for a “contract for exploitation”.

Exploration (Item 9)

- Historical samples were collected by Pioneer Contractors prior to TOML acquiring the property.

- Box-core and photo-profile data were collected by TOML during their 2015 cruise.
- Box-core sampling: nodules were separated from the mud, washed and weighed using a motion compensating scale. The nodules were then laid out on a grid and photographed and then air dried for 30 to 90 minutes. Reference and duplicate samples were selected and all samples placed into plastic bags and then put into drums. The drums were sealed with tamper proof tape.
- The sample chain of custody and sample security was maintained. There was no evidence of tampering of the samples.
- Additional duplicate samples were selected at the ALS laboratory by TOML during sub-sampling prior to submission to ALS.
- ALS used their chromite/manganese ore fused disk XRF method to analyse elements including Mn, Ni, Cu and Co. They also used high grade four acid ICP-AES for selected samples.
- Jacobs used 0.5M HNO_3 ICP-OES and 0.5M HNO_3 ICP-MS to analyse selected samples.
- Nodule abundance was determined from box-core using the weight of the nodules divided by the area of the box-core used. Additional nodule abundance observations were derived from 1 in every 100th photo from the photo-profile lines using the manual long-axis estimation method. The long-axis estimation method involves measuring every nodule long-axis within the photo and then using this in the equation derived by Felix, 1980. The parameters in the equation were calibrated from box-core abundance and the sea-floor photos at the same location as the box-core.

Quality control (Item 11)

- There is no duplicate or QAQC laboratory data available for the historical sample results.
- There were six groups that sampled the CCZ deposit over various parts using different sampling and assaying methods. Comparison of the data between each of the groups shows that the different sampling achieved similar results over vast areas.
- TOML sub-sampled the box-core samples and collected a random set of 25 duplicate samples for assay by ALS. Comparison of the box-core duplicate sub-samples show no issues with sub-sampling or assaying.
- TOML also submitted 15 duplicate samples to Jacobs laboratory. Comparison between Jacobs and ALS shows good agreement for Ni and Co while the Jacobs analyses for Mn shows a slight bias low and Cu a slight bias high.
- Both ALS and Jacobs also analysed internal standards (certified reference material), blanks and duplicates. All analyses results were with acceptable limits.

Resource Estimation (Item 14)

- Polymetallic nodules occur on the surface of the seafloor at varying abundance across the CCZ.
- Grades were estimated from sample assays using ordinary block kriging.
- Based on the sampling process it was conservatively assumed that the weights in the abundance measurements reported/collected by Pioneer Contractors were wet but there was some uncertainty as it was not clearly specified by each of the pioneer contractors who collected the data or the ISA who supplied it.
- Based on the reported sample analysis processes, the metal grades were reported on a dry weight basis.
- Estimate of tonnage was based on area and nodule abundance (wet kg/m^2). Area was used as there was no effective sampling below the immediate seafloor and mining is only expected to recover nodules from the top 10 cm.
- Abundance was estimated using FFG and box core samples, supplemented by estimates derived from photo profiling. Calculation of abundance from photo profiling using nodule long axis follows the procedure described in Felix (1980) and confirmed by laboratory measurements by TOML.
- Estimate of Inferred Mineral Resource abundance is likely to be biased low as most of the historical samples including FFG samples, were within the Inferred Mineral Resource area. FFG samples typically underestimate the abundance of nodules. Correction factors to adjust the likely nodule abundance bias have not been applied.
- Quantitative kriging neighbourhood analysis was performed to check selected estimation parameters.

Mineral Resource Uncertainty

- The highest uncertainty is in estimating nodule abundance due to the nature of the spatial distribution of nodules. However, the photo profile lines demonstrate the continuity in nodule abundance between sample locations and confirm the range of spatial continuity (autocorrelation). The variogram range determined from photo profile percent nodule coverage is consistent with the range determined from the wider spaced samples used in estimating the Mineral Resource. Multibeam backscatter survey results cover the entire area in 30 - 60 m resolution and were used to aid in domaining areas with nodules from areas with very low or no nodules.
- Classification of the Mineral Resource into Measured, Indicated and Inferred categories, in accordance with Canadian Institute of Mining, Metallurgy and Petroleum (CIM) definitions, considered: the nodule sample quality, uncertainty in the nodule sample abundance and grades, continuity of nodule abundance and grade and scale of the deposit.
  - Inferred Mineral Resource classification was based on sampling by Pioneer Contractors on a nominal spacing of 20 km, the variation and uncertainty in the sample quality, and the likely presence of short range variation to nodule abundance.
  - Indicated Mineral Resource classification was based on box core sampling by TOML on a nominal spacing of approximately 7 km by 7 km (including photo profiling in some cases at 7 km by 3 km), supplemented by sampling by Pioneer Contractors.
  - Measured Mineral Resource was based on box core sampling by TOML on a nominal spacing of approximately 7 km by 7 km plus photo-profiling on a nominal spacing of 3.5 km by 3.0 km, supplemented by sampling by Pioneer Contractors.

Development

- No development of deep-sea resources has been attempted or demonstrated other than some historical trial mining.
- In the considered opinion of the QP the Mineral Resource estimate meets the requirement of reasonable prospects for economic extraction (refer also to Item 16). With reference to the other relevant items of this report, particular factors of note are:
  - Seabed and sea conditions in the TOML Exploration Area are not materially different from other parts of the CCZ
  - Nodules have been successfully extracted in trials in the past and technological advances are likely to make the next attempts much more efficient; today there are twelve other parties considering development
  - While TOML and Nautilus have not published any economic assessment for mining seafloor nodules in the CCZ, others have (e.g. Yamazaki 2008) and they consider cut-off values in line with those listed in Table 14-11.

This Mineral Resource estimate is based upon and accurately reflects data compiled or supervised by Mr Matthew Nimmo, Independent Principal Geologist, who is a Member of the Australian Institute of Geoscientists. Mr Nimmo has sufficient experience that is relevant to the style of mineralisation and the type of deposit under consideration and to the activity which he has undertaken to qualify as a Competent Person as defined in the 2012 edition of the ‘Australasian Code for the Reporting of Exploration Results, Mineral Resources and Ore Reserves’ and as a Qualified Person under NI43-101.

14.2 Mineral Resource domains

The occurrence of polymetallic nodules within the CCZ is influenced on a regional scale by two large scale geological features: the boundary of the CCZ deposit and the presence of seamounts.

The boundary limits of the CCZ defining the region where nodules have been found to occur is bracketed by the Clarion and Clipperton Fracture Zones to the north and south respectively. The deposit extends to the west and east between the two fracture zones. The limits to the CCZ occur well outside the boundaries of the TOML Exploration Areas. Accordingly, 100% of the TOML Exploration Area fall within the CCZ polymetallic nodule deposit.

Bathymetric features only play a role in distribution of polymetallic nodules at a regional scale (Refer to Item 7). There are principally two regional scale bathymetric domains: sea mount ranges and abyssal hill province. Based on interpretation of the GEBCO bathymetry data from the ISA, and TOML’s own bathymetry (Item 7), less than 2% of the TOML Exploration Area is covered by isolated sea mounts (Item 7). Effectively, the entire TOML Exploration Area falls within the abyssal hill domain.

Within the TOML Exploration Area there are small disconnected zones where there are no polymetallic nodules present or the polymetallic nodule abundance is very low. These zones are controlled by local geology (presence of basalt or carbonate ooze) and bathymetry (seamounts; Item 7).

The TOML Exploration Area has been split into two domains. Areas with polymetallic nodules and areas predominately without polymetallic nodules. The multibeam bathymetry and the backscatter data was used to interpret the parts of TOML Area B through F with no polymetallic nodules. For the Mineral Resource estimate two broad domains have been interpreted from the data. These are:

1 NOD – polymetallic nodule domain. This domain exists almost everywhere and extends beyond the boundaries of the TOML Exploration Areas.

2 NON – areas with no or low nodule abundance of polymetallic nodules. This domain includes the No Nodules on Ooze (Nnoo), seamounts and areas with basalt. Nodule abundance in the NON areas was set to zero in the block model. It is not defined in Area A as that area has not been surveyed by Multibeam.

Figure 14.2 through to Figure 14.6 show the TOML Exploration geological domains used for the Mineral Resource estimate. Sample locations are indicated by white circles.

Figure 14.2 TOML Exploration Area A geological domains

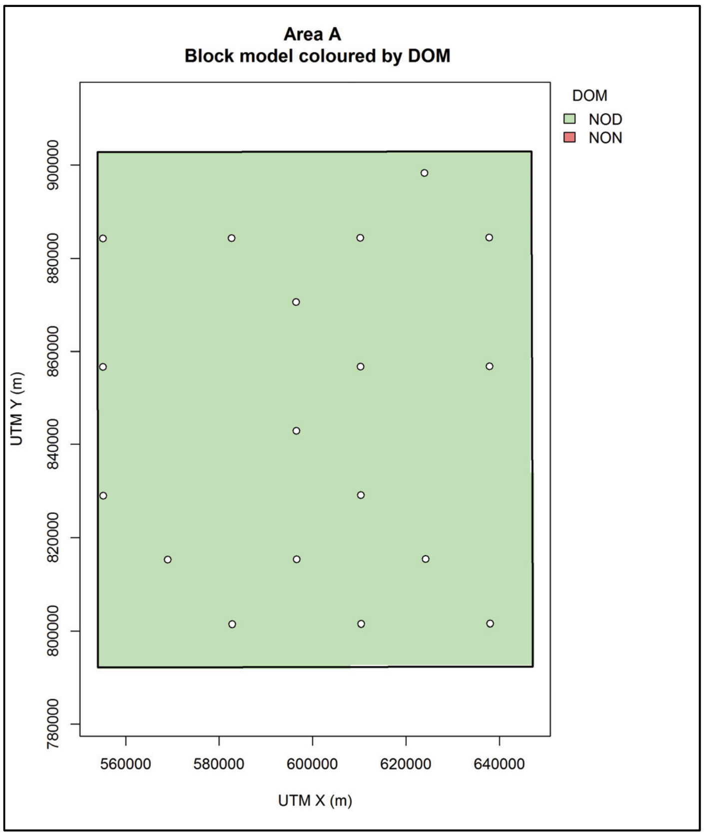


Figure 14.3 TOML Exploration Area B geological domains

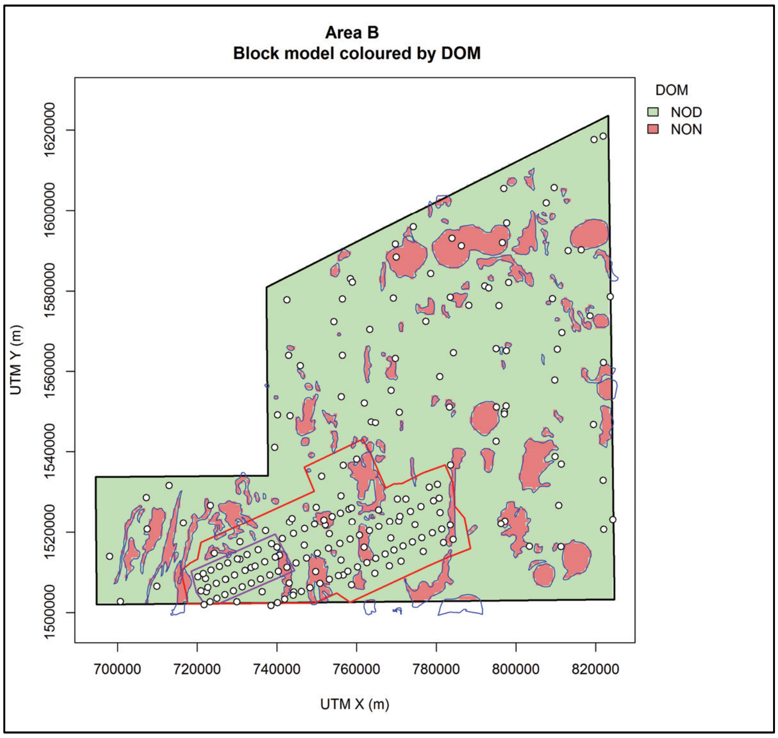


Figure 14.4 TOML Exploration Area C geological domains

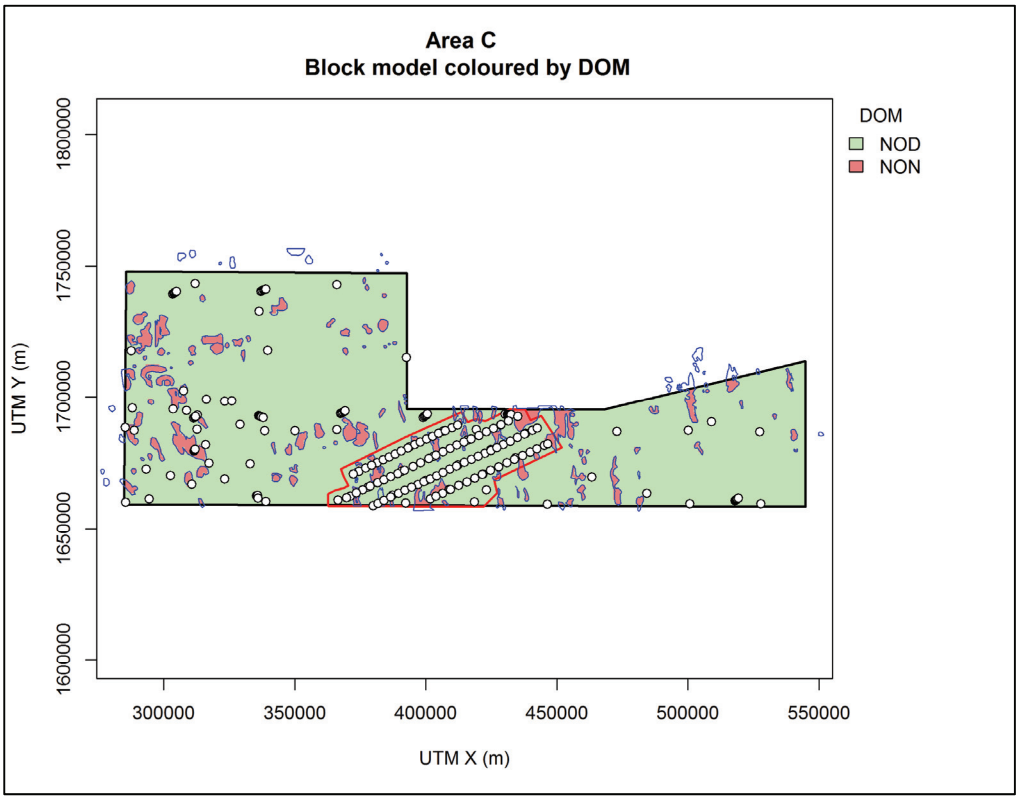


Figure 14.5 TOML Exploration Area D and E geological domains

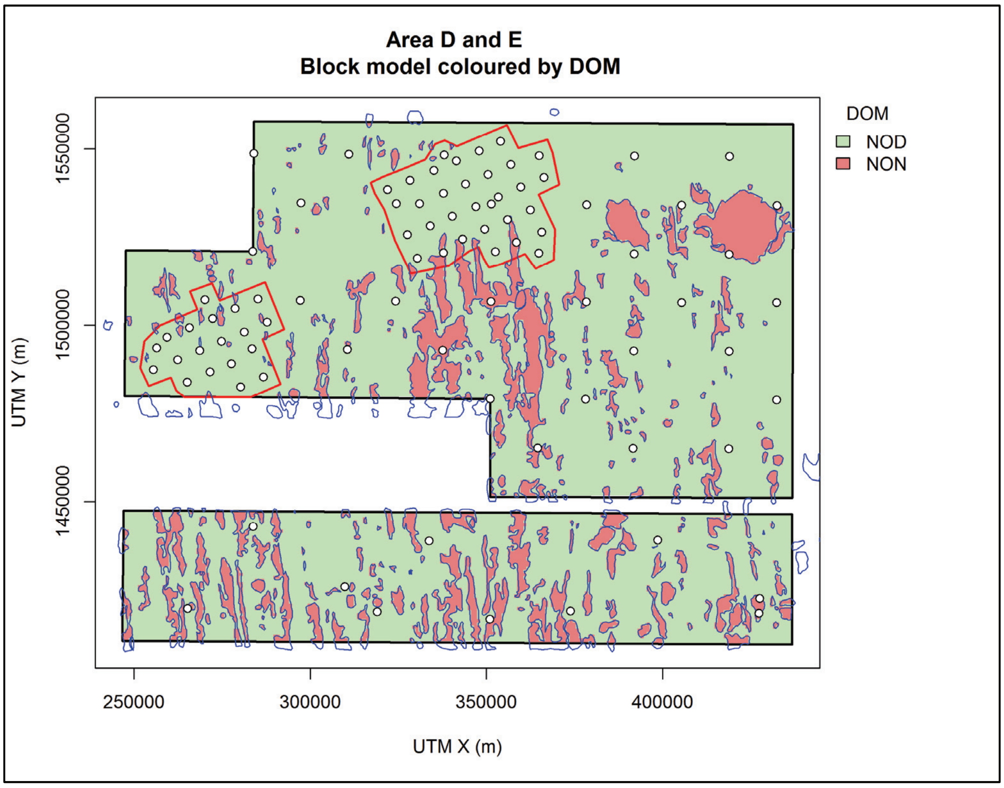
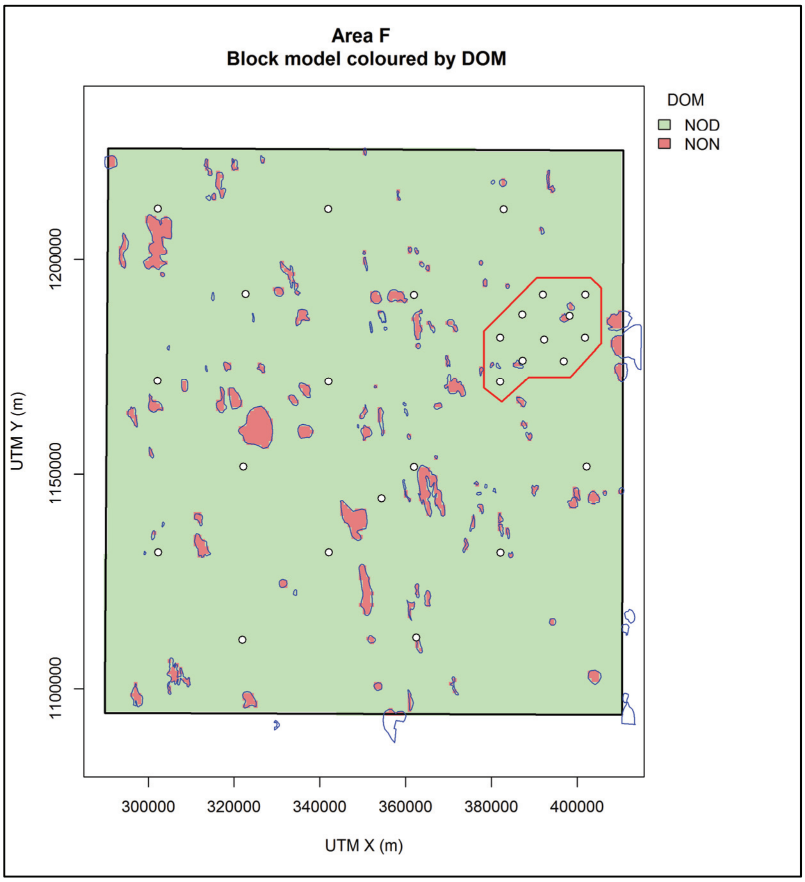


Figure 14.6 TOML Exploration Area F geological domains



14.3 Manganese Nodule Data used for the Mineral Resource Estimate

14.3.1 Description of data

Historical box-core and free fall grab sampling data was initially provided by Dr Vijay Kodagali, Senior Scientific Officer of the International Seabed Authority (Email: vkodagali@isa.org.jm) who sent the data by email in Microsoft Excel format on June 22 2012. This data included samples for TOML Exploration Areas A, B, C, D, E and F (1 sample location). An additional eight samples within Area E were provided by Tomasz Abramowski from Interoceanmetal Joint Organization (IOM) on 21 November 2014. The data were provided in comma delimited format (CSV).

The historical polymetallic nodule sample data consists of 2211 records of which only 268 of the nodule samples fall within the TOML Exploration Area.

Polymetallic nodule samples collected during the TOML 2015 cruise within the TOML Exploration Areas B, C, D, and F were analysed by ALS Laboratories and provided to the QP on 17 March 2016 in a single text file. A total of 104 box-core samples were collected and sampled.

A separate data set containing the manganese nodule abundance for the 113 TOML box-core samples and calculated abundance for 536 sea floor photos was provided by TOML. The calculated abundance was derived from every 100th photo of the TOML 2015 sea floor photo-profiling, providing an average spacing of 2.7 km between photo observation points. The photos were processed manually by measuring the long axis of every nodule within the photo or within a subset of the photo. This enabled an accurate estimate of the nodule abundance in each photo (Item 12).

The spatial coordinates of the data were in digital latitude and longitude. For spatial modelling and Mineral Resource estimation the coordinates were transformed into Universal Transverse Mercator (UTM) using the World Geodetic System (WGS 84) spatial reference system. Table 14.2 lists the minimum and maximum UTM coordinates for each TOML Exploration Area.

Figure 14.7 Location of the historical sample data provided by the ISA and IOM and the TOML data

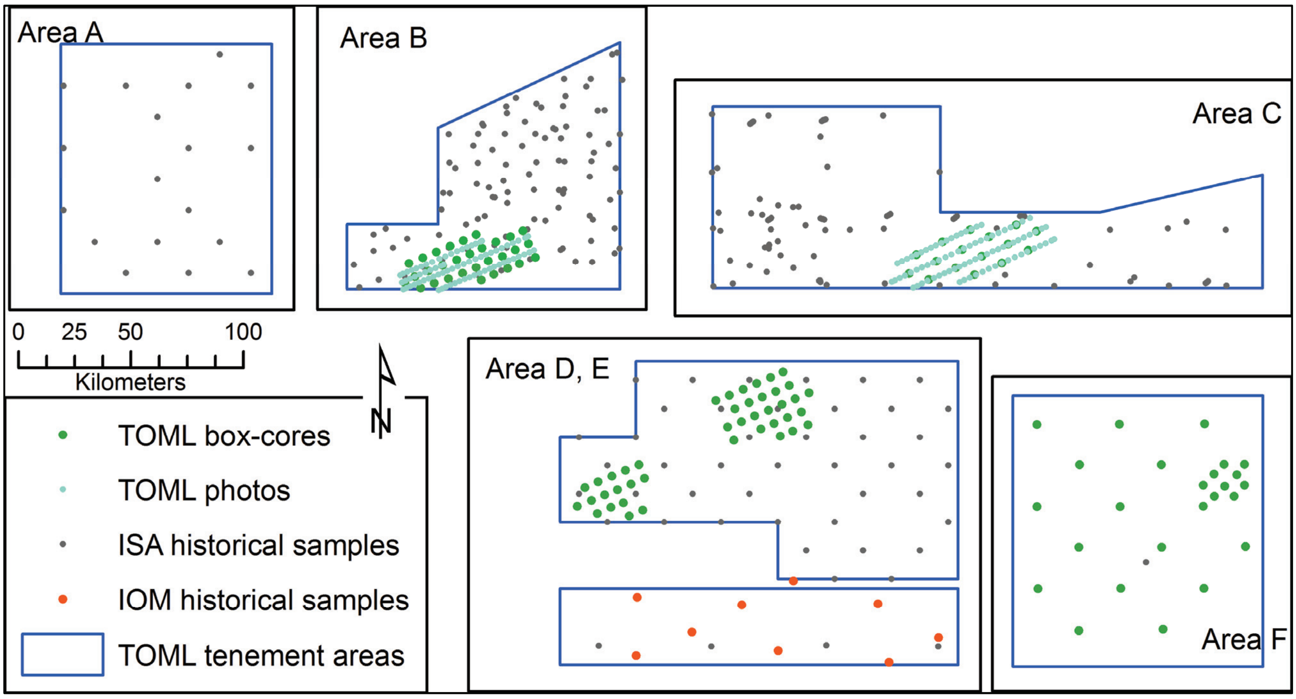


Table 14.2 Minimum and maximum UTM coordinates for each TOML Exploration Area

TOML Exploration Area	Easting		Northing		UTM Zone
	Min (m)	Max (m)	Min (m)	Max (m)	
A	553 976.1	647 191.3	792 205.9	902 969.6	5
B	694 523.4	824 684.8	1 502 007	1 623 606	8
C	284 947.0	544 795.5	1 658 368	1 747 831	9
D	247 296.3	437 027.2	1 451 032	1 557 860	10
E	246 691.9	436 798.9	1 409 560	1 447 514	10
F	289 837.4	410 806.1	1 093 913	1 225 830	11

The historical and recent TOML data were combined into a single data set and checked for anomalous or erroneous values. The 0 assay values in the historical data represent absent data and were reset to absent value where abundance is recorded as 0, and to 0.01 where abundance is greater than 0.

14.3.2 Sample statistics

The descriptive statistics of the nodule sample data are listed in Table 14.3 to Table 14.7. Comparison of the historical nodule samples within the TOML Exploration Area (Table 14.5) and the recently acquired TOML nodule samples (Table 14.6) indicate slightly higher mean grades for Abundance, Mn, Ni and Cu, and slightly lower Co for the TOML samples.

Table 14.3 Statistics of all samples within the TOML Exploration Areas

Variable	Samples	Missing	Min (%)	Max (%)	Mean (%)	Var	CV	Median
Abundance	527	9	0	30.77	9.50	43.088	0.69	8.79
Mn	338	198	6.54	33.79	27.91	13.426	0.13	28.9
Ni	338	198	0.33	1.55	1.26	0.034	0.15	1.31
Cu	338	198	0.22	1.51	1.09	0.046	0.2	1.16
Co	338	198	0.02	0.35	0.23	0.002	0.21	0.23

Var = variance; CV = coefficient of variation

Declustering weights were calculated and applied to the nodule sample data to assess the potential bias in the descriptive statistics that can arise from clustering of sample data. Table 14.4 lists the declustered nodule descriptive statistics for all samples within the TOML Exploration Area. Declustering the data resulted in a slight increase in the mean of Abundance, but no significant change for Mn, Cu and Co indicating that the statistics are not significantly affected by clustering.

Table 14.4 Declustered statistics of all polymetallic nodule samples within TOML Exploration Area

Variable	Samples	Missing	Min (%)	Max (%)	Mean (%)	Var	CV	Median
Abundance	527	9	0	30.77	10.20	39.35	0.61	9.16
Mn	338	198	6.54	33.79	28.09	10.414	0.11	28.71
Ni	338	198	0.33	1.55	1.26	0.03	0.14	1.31
Cu	338	198	0.22	1.51	1.11	0.045	0.19	1.16
Co	338	198	0.02	0.35	0.22	0.003	0.24	0.22

Var = variance; CV = coefficient of variation

Table 14.5 Statistics of historical samples within the TOML Exploration Areas

Variable	Samples	Missing	Min (%)	Max (%)	Mean (%)	Var	CV	Median
Abundance	253	9	0.03	26.0	8.82	27.134	0.59	8.09
Mn	234	28	10.3	32.4	26.88	11.097	0.12	27.67
Ni	234	28	0.53	1.51	1.22	0.034	0.15	1.27
Cu	234	28	0.4	1.51	1.06	0.053	0.22	1.13
Co	234	28	0.02	0.35	0.24	0.002	0.18	0.24

Var = variance; CV = coefficient of variation

Table 14.6 Statistics of TOML samples within the TOML Exploration Areas

Variable	Samples	Missing	Min (%)	Max (%)	Mean (%)	Var	CV	Median
Abundance	113	0	0.0	29.13	12.23	66.384	0.67	12.6
Mn	104	9	6.54	33.79	30.23	11.006	0.11	30.84
Ni	104	9	0.33	1.55	1.34	0.025	0.12	1.37
Cu	104	9	0.22	1.43	1.18	0.019	0.12	1.2
Co	104	9	0.08	0.31	0.21	0.003	0.24	0.22

Var = variance; CV = coefficient of variation

Table 14.7 Statistics of TOML photo samples within the TOML Exploration Areas

Variable	Samples	Missing	Min (%)	Max (%)	Mean (%)	Var	CV	Median
Abundance	161	0	0	30.77	8.65	45.745	0.78	8.78

Var = variance; CV = coefficient of variation

Figure 14.8 Histogram and log-probability plot of Abundance for all samples within TOML Exploration Areas

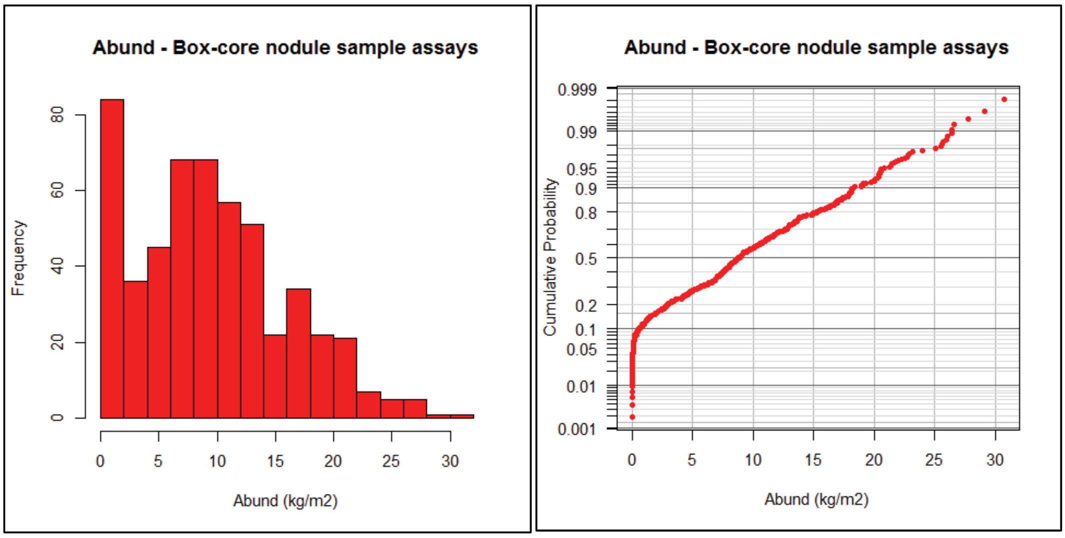


Figure 14.9 Histogram and log-probability plot of Mn for all samples within TOML Exploration Areas

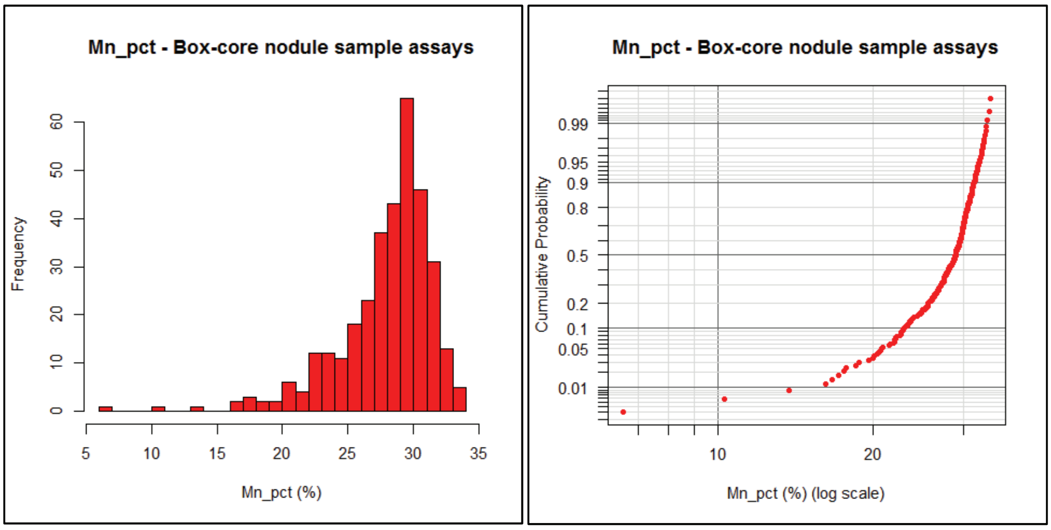


Figure 14.10 Histogram and log-probability plot of Ni for all samples within TOML Exploration Areas

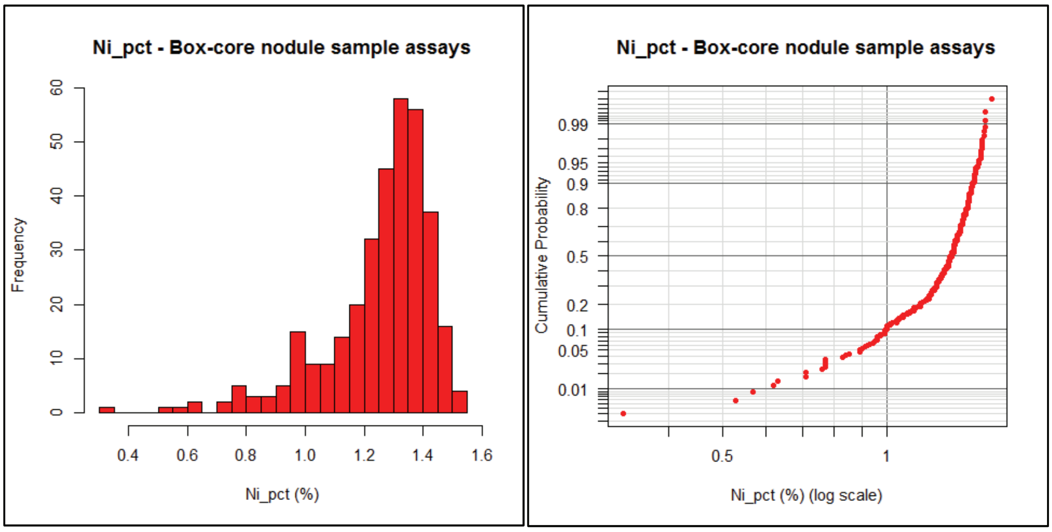


Figure 14.11 Histogram and log-probability plot of Cu for all samples within TOML Exploration Areas

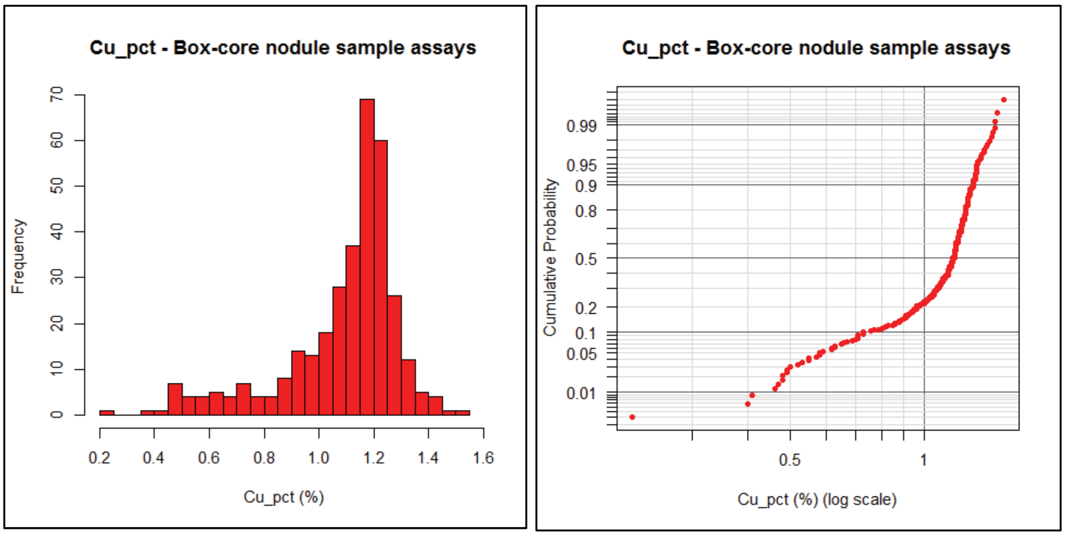
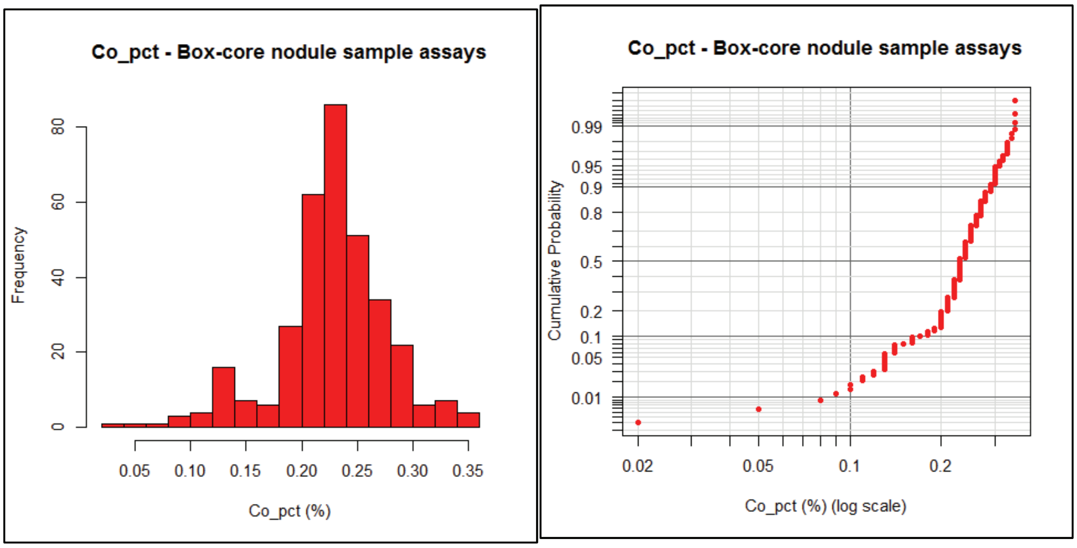
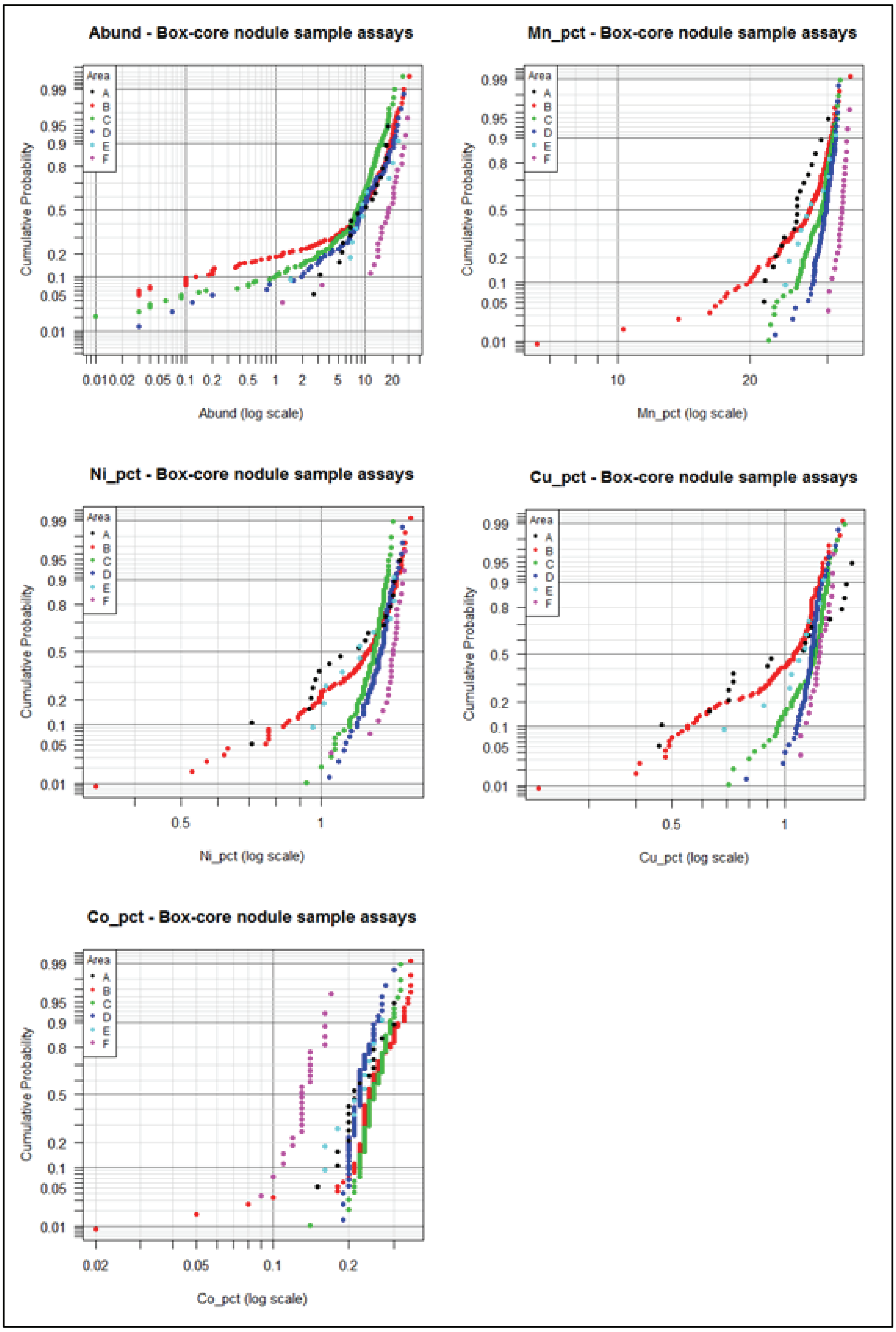


Figure 14.12 Histogram and log-probability plot of Co for all samples within TOML Exploration Areas



The log-probability plots (Figure 14.8) for Abundance, Mn, Ni, Cu and Co by TOML Exploration Area indicate variations in the grade distributions between the areas (note regional grade variations illustrated in Item 7). The distributions for Ni and Cu for samples in TOML Exploration Areas A, B and E are different than the samples in Areas C, D and F. This feature is also present in the full CCZ data set and is interpreted to be due to regional-scale geological differences such as the relative populations of hydrogenetic and diagenetic nodules (refer to Items 7 and 11). Nodule samples from Area F show significantly lower Co than samples from all the other areas while Mn shows a gradual increase from Areas A and B through to Area F.

Figure 14.13 Log-probability plots for Abundance, Mn, Ni, Cu and Co by TOML Exploration Areas



Box plots provided in Figure 14.13 clarify the differences in assays between TOML Exploration Areas. These plots also reveal that the variance in Ni and Cu is higher for TOML Exploration Areas A and B then the other areas. Also, Area E shows higher Ni variance similar to Area A and B. Area F appears to have anomalously high Mn with a much lower variance then all other areas. Area F appears to also have higher median Ni and Cu and significantly lower Co values.

Box-plots summarising molybdenum and the light and heavy rare earth elements are provided in Figure 14.15 to Figure 14.17. At this stage reasonable prospects of economic extraction have not been demonstrated for these elements and so they have not been estimated as part of the Mineral Resource.

Figure 14.14 Box-plots for Abundance, Mn, Ni, Cu and Co by TOML Exploration Areas

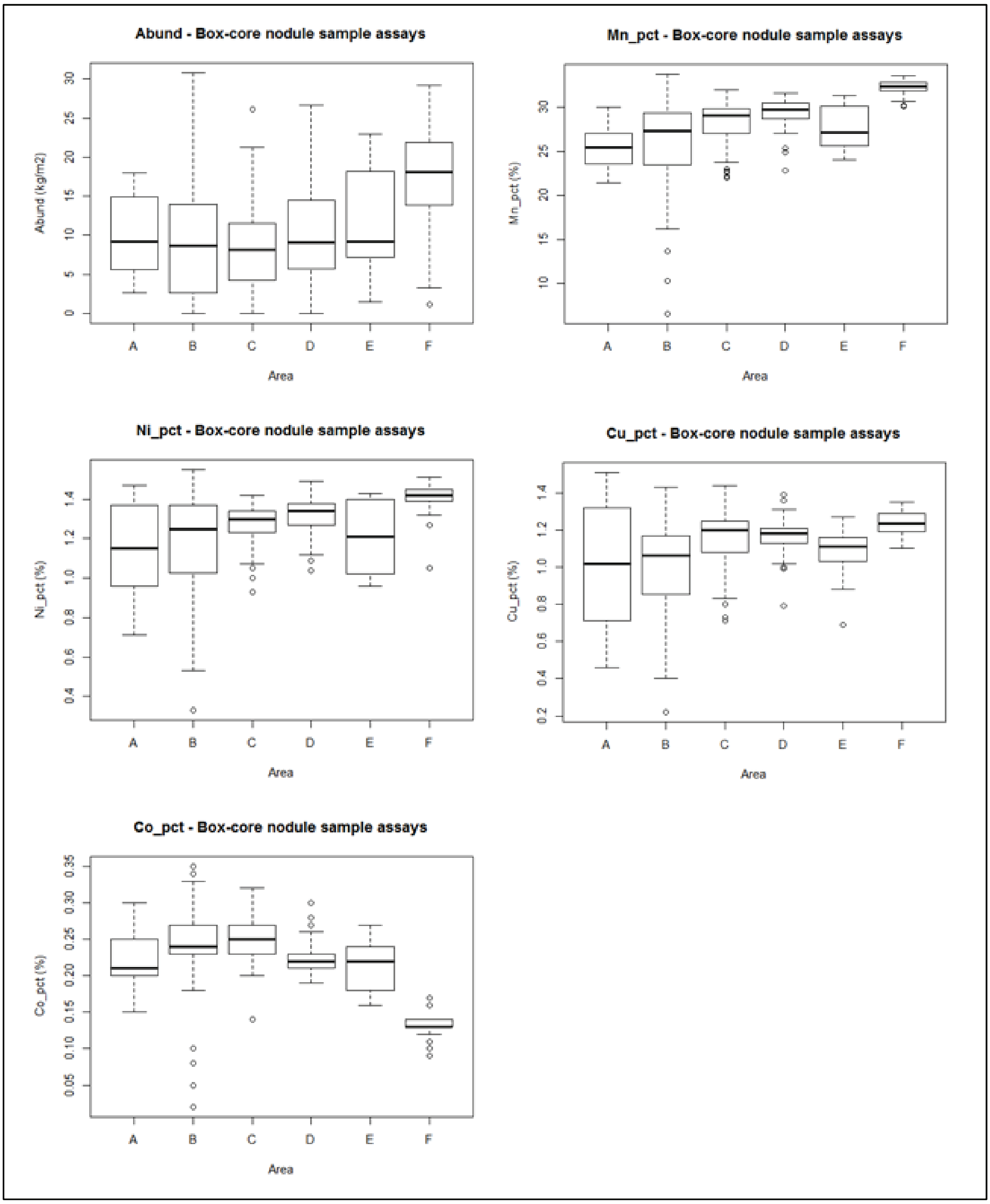


Figure 14.15 Box-plot of Mo for sample data within the TOML Exploration Areas

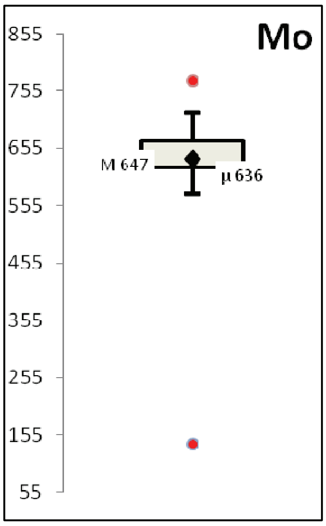


Figure 14.16 Box-plot of light rare earth elements for sample data within the TOML Exploration Areas

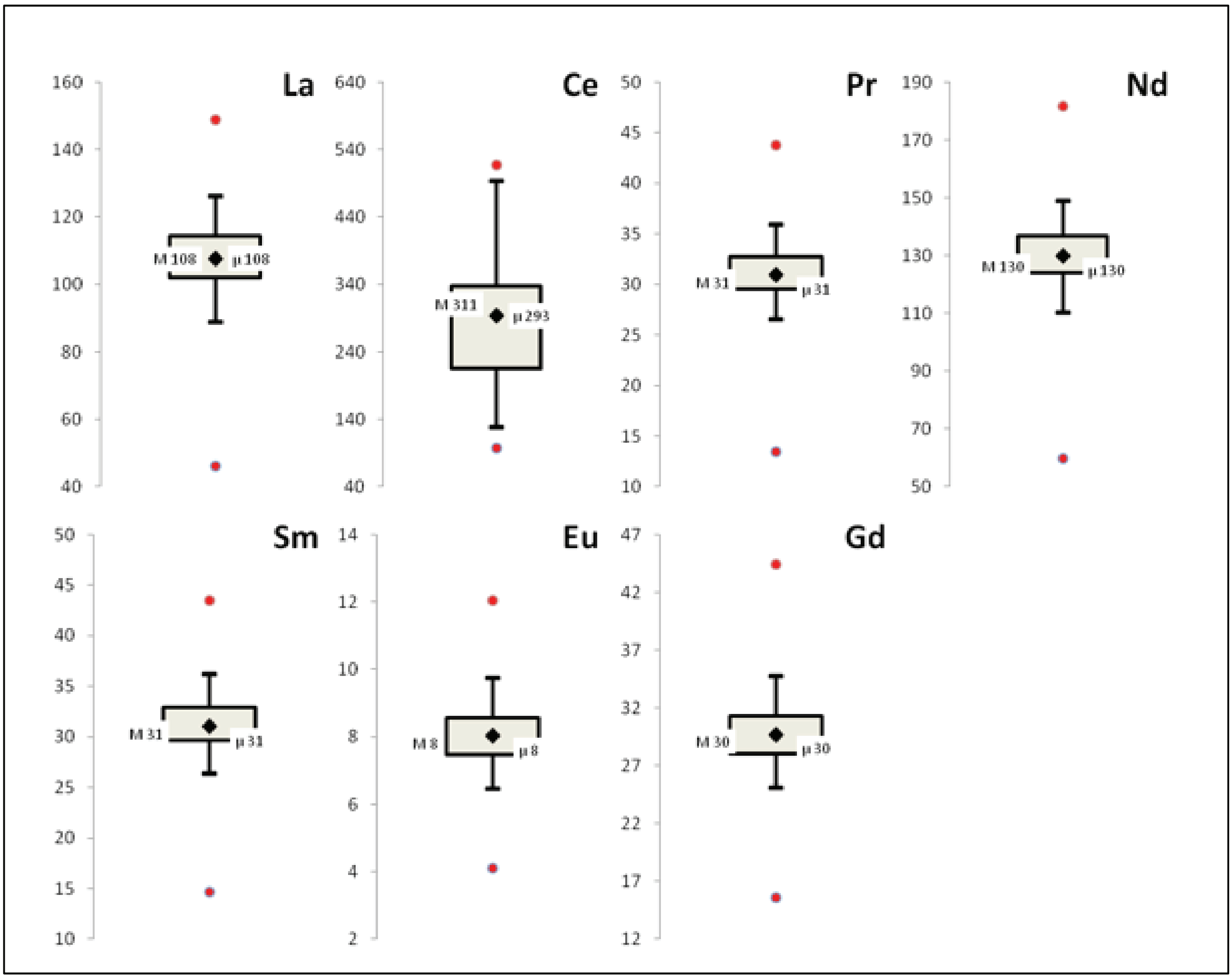
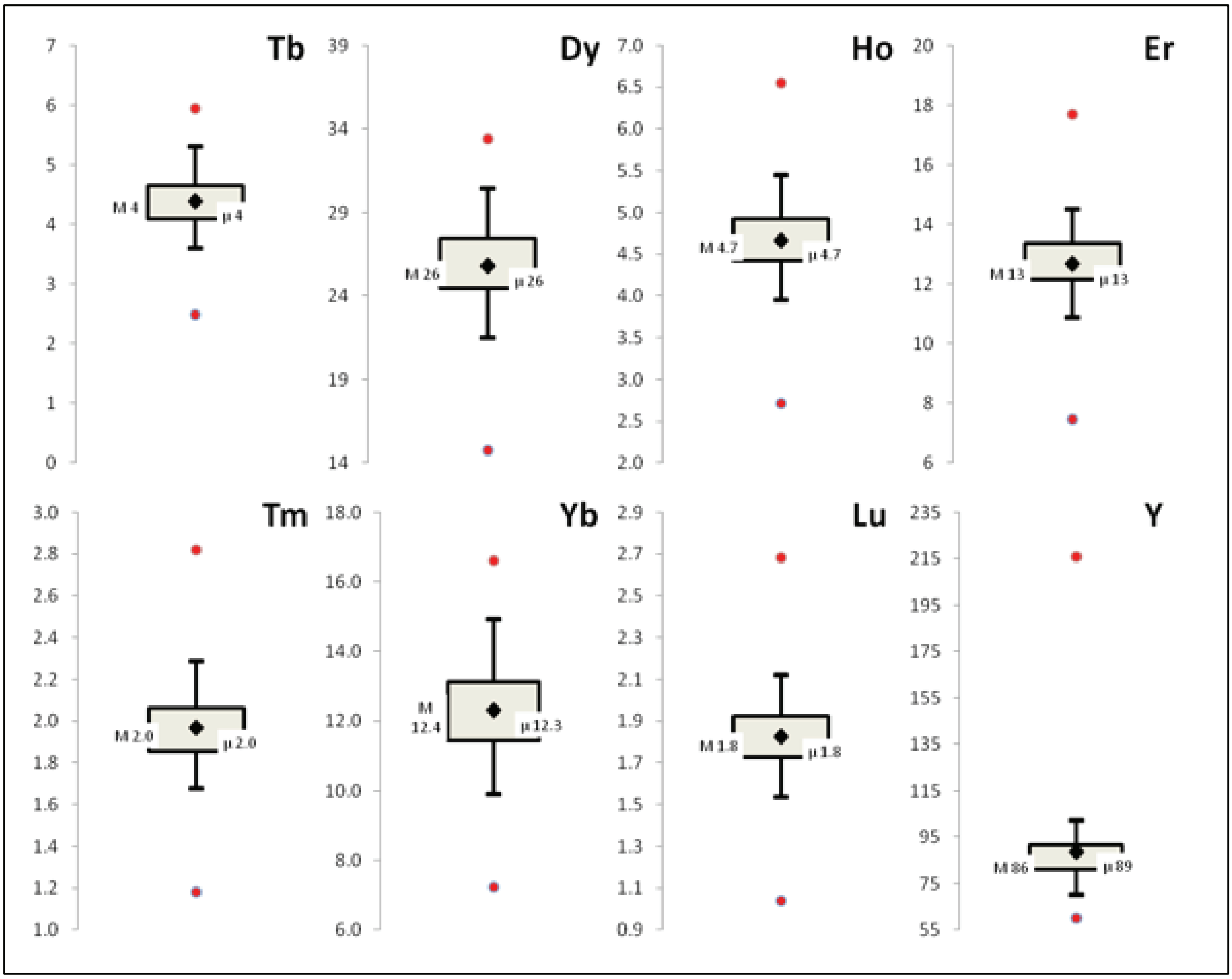


Figure 14.17 Box-plot of heavy rare earth elements for sample data within the TOML Exploration Areas



The coefficient of variation is very small for nodule Abundance, Mn, Ni, Cu and Co suggesting that the application of top-cuts is not necessary. Also, the approximate natural limits for absorption of the Ni (~6.02%), Cu (~8.03) and Co (~6.60%) metals, suggested in the study by Novikov and Bogdanova (2007), are significantly higher than the maximum values (Ni=1.55%, Cu=1.51%, Co=0.35%) in the data. This suggests that all the Ni, Cu and Co values are within natural limits.

The presence of outliers (or 'extreme' values) was assessed by examining the summary statistics and probability plots. No outliers were detected.

Top cuts were not applied to the data prior to grade estimation.

14.3.3 Representativeness of sampling

In-fill box core sampling by TOML in 2015 confirmed the presence of nodules at similar grade and abundance to the wider spaced historical sampling. A comparison between the mineral resource estimates is further below.

TOML also collected continuous sea floor photo profiles along three (3) lines in Area B and four (4) lines in Area C.

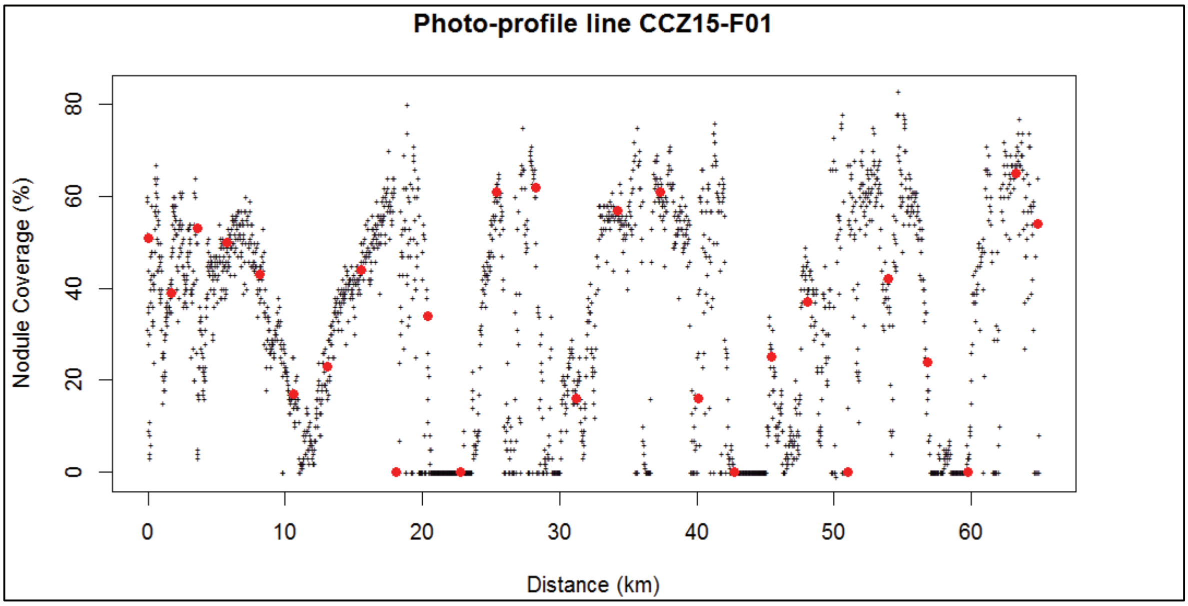
From these photos it is possible to derive the percent of nodule coverage using automated image processing techniques. The percent nodule coverage is the amount of image pixels identified as nodules divided by the total number of pixels in the photo. It is also possible to use the long-axis estimation method for determining nodule abundance. However, this method is time consuming to process a single image as the long axis of every nodule is picked manually. An accurate, repeatable and robust automated computer implementation of LAE is being developed by a Nautilus contractor and is currently in the prototype stage.

The nodule percent coverage estimated from the sea floor photos shows a positive correlation with nodule abundance (Figure 14.21). Nodule percent coverage can be used as a proxy for nodule abundance although it is at best a moderate estimator (Figure 14.21).

Plots of the nodule percent coverage for the three lines that cross the TOML Exploration sub-area B1 are shown in Figure 14.18 to Figure 14.20.

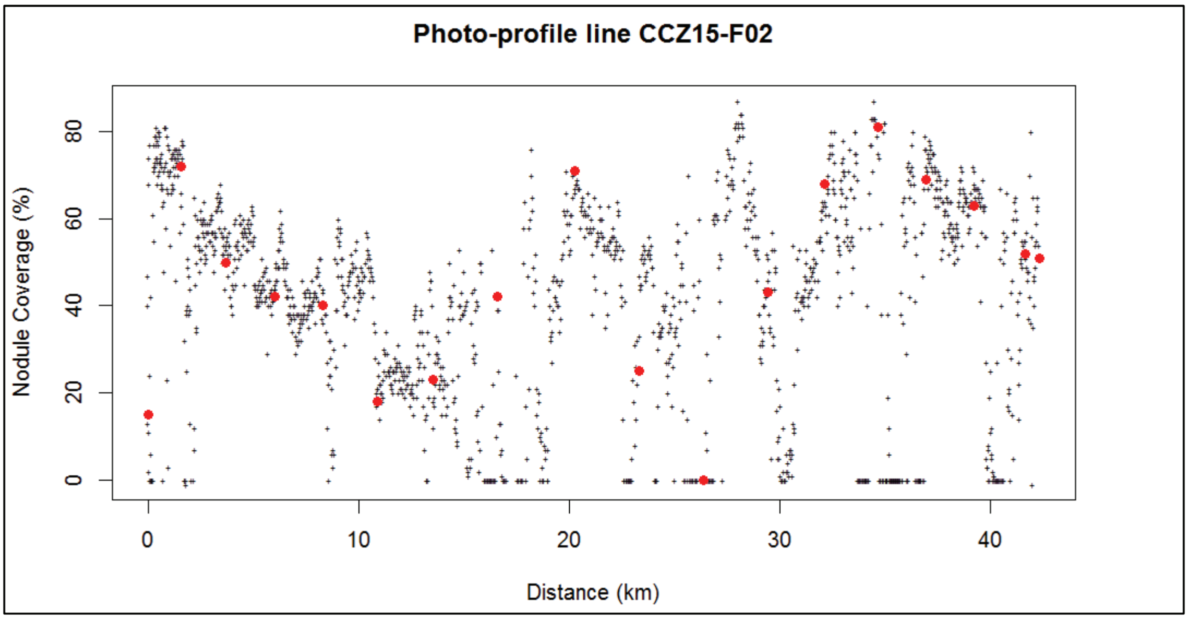
These plots show the presence of nodules between box-core locations. Note that the average distance between each photo is approximately 25 m and ranges from 5 m to 79 m.

Figure 14.18 Photo-profile line CCZ15-F01 that crosses Area B1 Mineral Resource



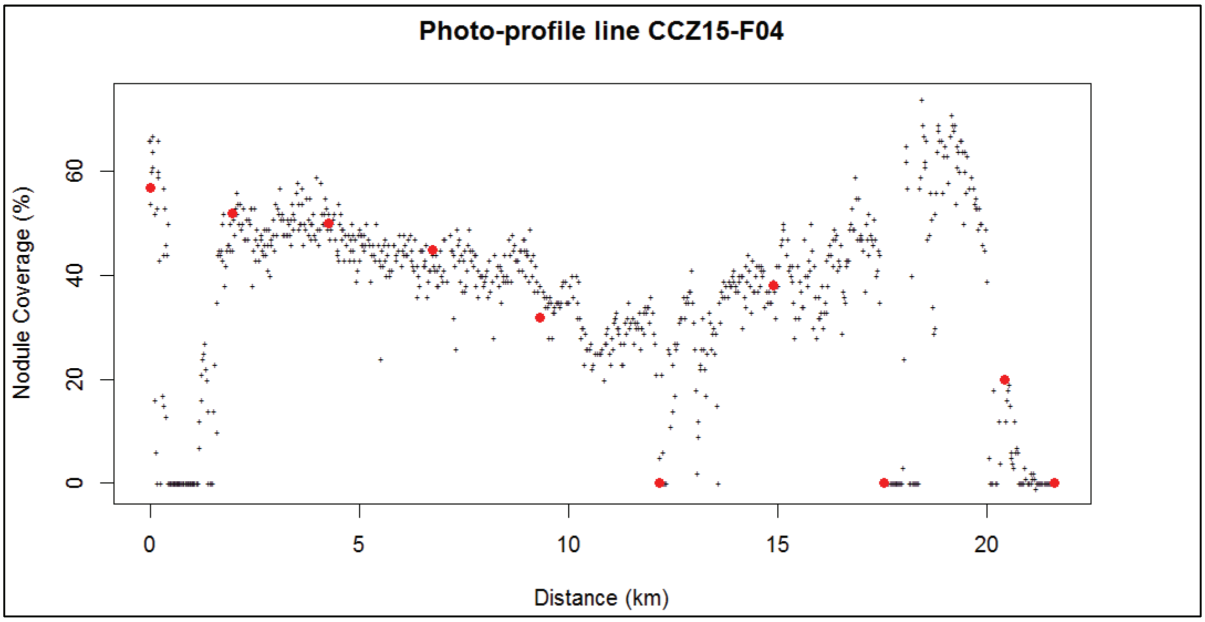
Red dots – nodule coverage for seafloor photos which were used in the manual estimate of abundance using the long-axis estimation method and used in the Mineral Resource estimate. Black dots – nodule abundance for all other seafloor photos.

Figure 14.19 Photo-profile line CCZ15-F02 that crosses Area B1 Mineral Resource



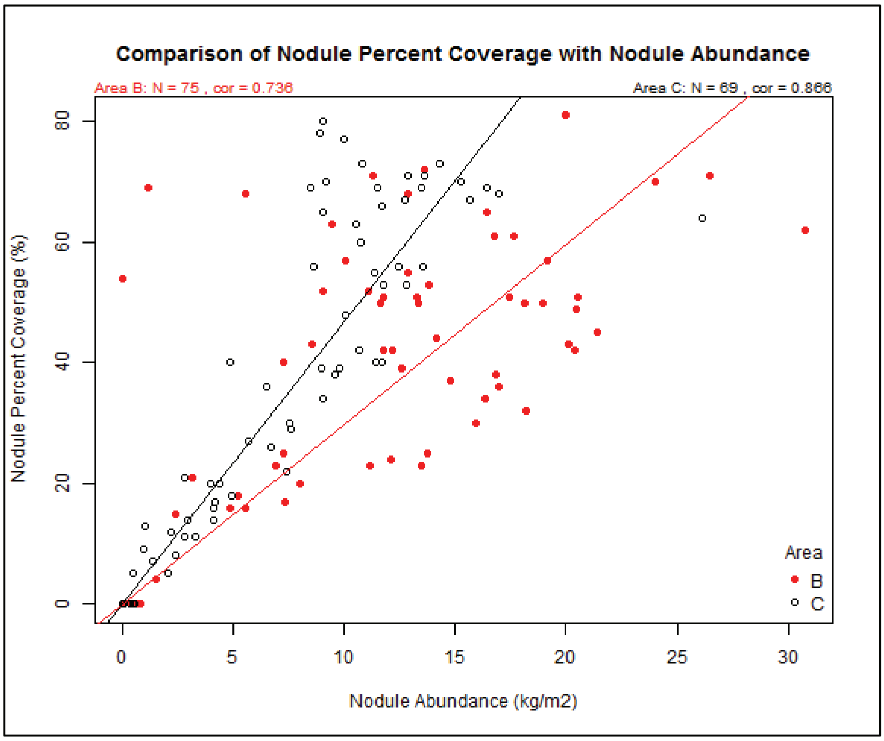
Red dots – nodule coverage for seafloor photos which were used in the manual estimate of abundance using the long-axis estimation method and used in the Mineral Resource estimate. Black dots – nodule abundance for all other seafloor photos.

Figure 14.20 Photo-profile line CCZ15-F04 that crosses Area B1 Mineral Resource



Red dots – nodule coverage for seafloor photos which were used in the manual estimate of abundance using the long-axis estimation method and used in the Mineral Resource estimate. Black dots – nodule abundance for all other seafloor photos.

Figure 14.21 Comparison of nodule percent coverage against nodule abundance



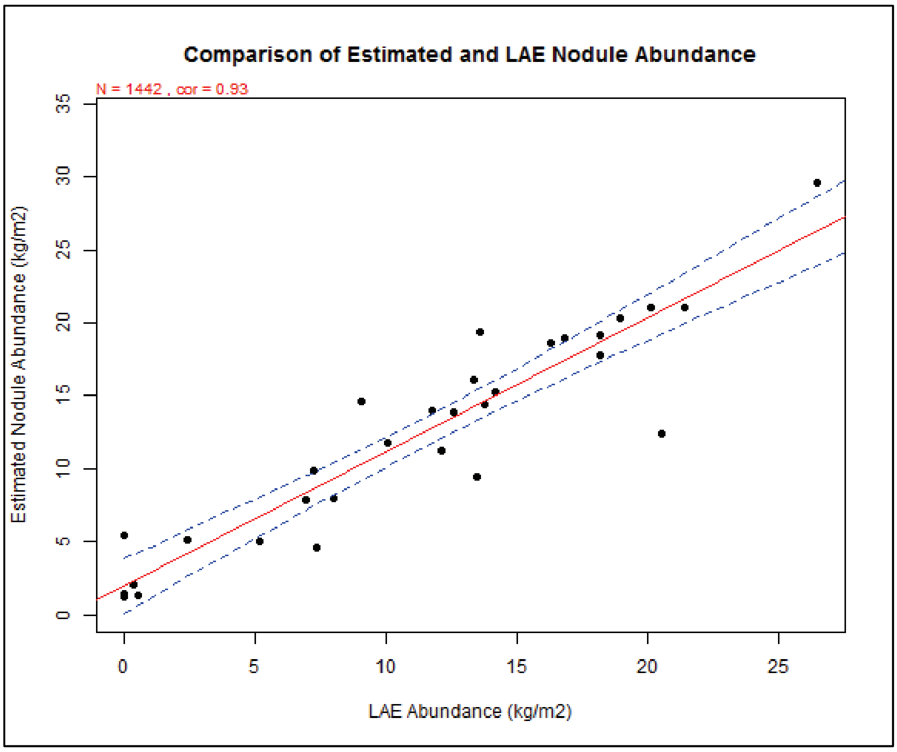
Gideon Steyl from GeoSquare Consulting analysed 2754 seafloor photos from the photo profile lines CCZ15-F01, CCZ15-F02 and CCZ15-F04, using an image analysis program to estimate the long axis dimensions of nodules in the photos. These photo-profile lines cover the Measured Mineral Resource area within TOML sub-area B1. The long axis estimates were then used to estimate the nodule abundance for each photo. This data was not required or used in estimation of the Mineral Resource, but they do support it.

There is very good agreement between the nodule abundance estimated from automated analysis of the seafloor photos and the nodule abundance estimated from manual measurement of the nodule long-axis

(Figure 14.22). Refinement of the automated method is likely to result in even better correlation with the manual method. The benefit of the automated method is reduced time in processing each image which enables more images to be processed. This will enable almost complete mapping of nodule abundance within selected areas prior to nodule harvesting and can be used in a grade control system.

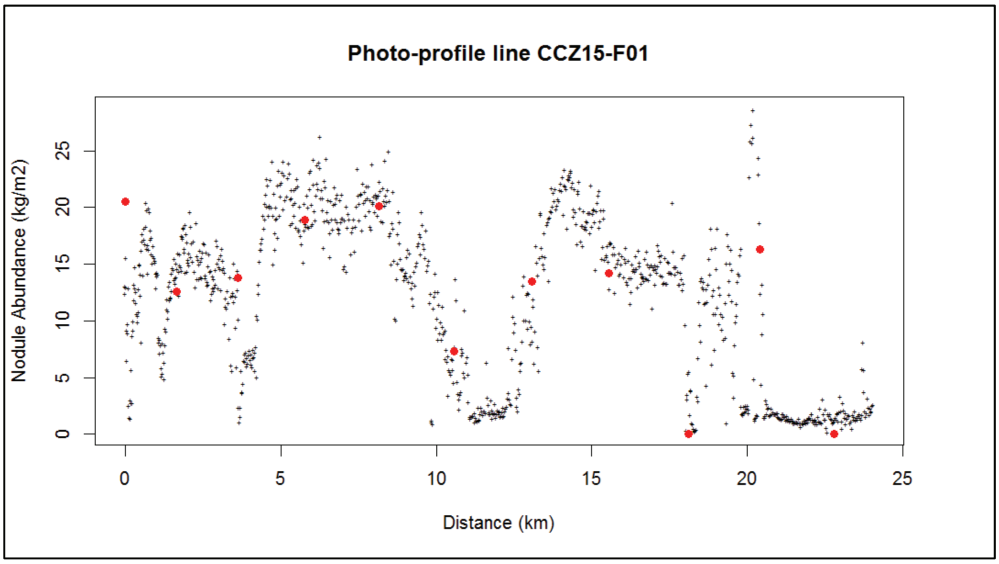
Figure 14.23 to Figure 14.25 show plots of the nodule abundance estimated from the seafloor photos. Note that the distance between each photo is approximately 30 m.

Figure 14.22 Comparison of nodule abundance estimated from photos against nodule abundance estimated manually using the long-axis estimation method



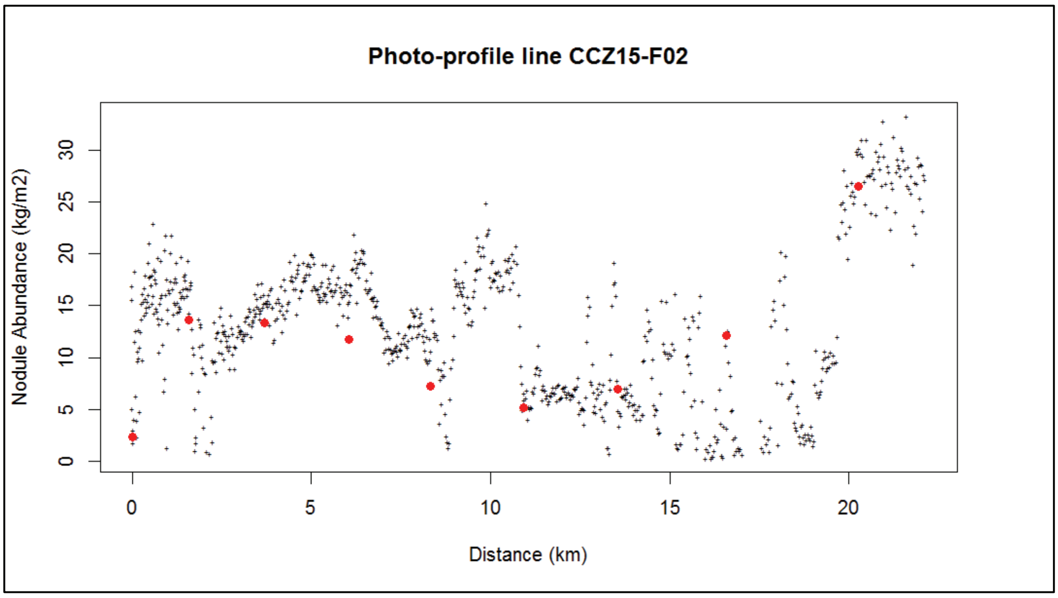
The red line is the fitted linear regression. The blue dashed lines are the 95% confidence intervals for the linear regression model.

Figure 14.23 Nodule abundance photo-profile line CCZ15-F01 that crosses sub-area B1 Measured Mineral Resource



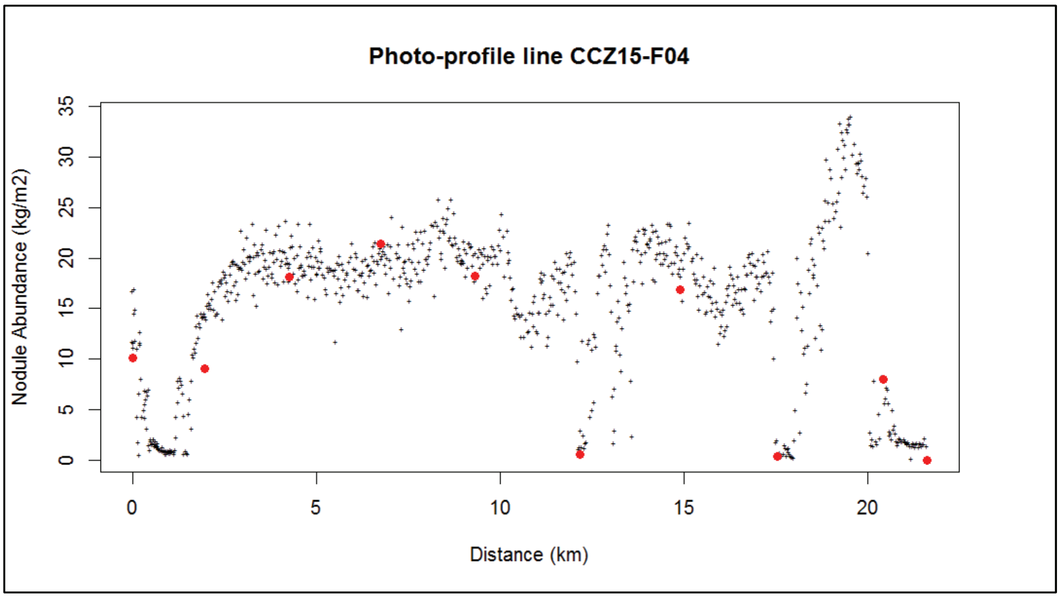
Red dots – nodule coverage for seafloor photos which were used in the manual estimate of abundance using the long-axis estimation method and used in the Mineral Resource estimate. Black dots – nodule abundance for all other seafloor photos.

Figure 14.24 Nodule abundance photo-profile line CCZ15-F02 that crosses sub-area B1 Measured Mineral Resource



Red dots – nodule coverage for seafloor photos which were used in the manual estimate of abundance using the long-axis estimation method and used in the Mineral Resource estimate. Black dots – nodule abundance for all other seafloor photos.

Figure 14.25 Nodule abundance photo-profile line CCZ15-F04 that crosses sub-area B1 Measured Mineral Resource



Red dots – nodule coverage for seafloor photos which were used in the manual estimate of abundance using the long-axis estimation method and used in the Mineral Resource estimate.

Black dots – nodule abundance for all other seafloor photos.

Polymetallic nodule grades (Table 14.3) within the CCZ have very low coefficients of variation (CV) which indicate a low risk in estimating grades and that ordinary kriging is an appropriate technique to use for estimation. The dredge sampling programme (Item 12) conducted by TOML on polymetallic nodules during their 2013 cruise, included analysis of multiple individual nodules taken from each dredge sample. It confirmed the very low variance in the nodule grades at the local scale.

Variograms of the polymetallic nodule grades of Mn, Ni, Cu and Co within the TOML Exploration Area show reasonable spatial continuity with ranges greater than the average sample spacing. The long variogram ranges for the nodule grades reflect the very large scale diffuse distribution of metals within the ocean water column and that the manganese acts like a sponge absorbing the metals. The variogram for abundance, on the other hand, has significantly shorter ranges. This reflects the mechanism of nodule formation and the less continuous distribution of nodules.

The Qualified Person, Matthew Nimmo, considers that the box-core and free fall grab sample spacing within the TOML Exploration Areas A to F are sufficient to demonstrate continuity of Mn, Ni, Cu and Co. The addition of photo profiling enables confidence in the continuity of nodule abundance and can be reasonably assumed on the basis of the scale of the deposit and the mechanisms of nodule formation.

14.4 Geostatistics

14.4.1 Nodule sample variography

All manganese nodule samples (historical box-core and free fall-grabs, TOML box-core and photos) within the TOML Exploration Area were combined and used for analysis of spatial continuity (autocorrelation). The experimental semi-variograms were scaled to the population variance. Variogram maps (Figure 14.31) were calculated for the purpose of determining the direction of greatest continuity.

Spherical semi-variogram models were fitted to the experimental variograms using two structures (Table 14.8). Where possible, consistent parameters were used between the fitted variogram models for each direction and each of the variables. This was done to ensure element relationships or correlations evident between samples are respected implicitly during estimation and reflected in the resource estimate. Also, the same type of variogram model was fitted to the experimental semi-variograms.

The directions of greatest continuity deduced from the variogram maps appears to be approximately 150º and 060º. Abundance and Cu show no anisotropy in the variogram ranges while Mn and Ni appear to show greater continuity in the 150º and Co shows greater continuity in the 060º direction. The 060º direction is roughly parallel to the broad regional trend of the CCZ and the 150º direction is parallel to the abyssal hills. Smaller scale local trends oriented parallel with bathymetry ridges are not visible in the wide spaced data.

The variogram models listed in Table 14.8 were used in estimating the values for nodule abundance, Mn, Ni, Cu and Co.

Table 14.8 Variogram models

Variable	Nugget	Spherical Structure 1			Spherical Structure 2			Anisotropy Ratio
	C0	C1	Range H1		C1	Range H2		
			060° (km)	150° (km)		060° (km)	150° (km)	
Abundance	0.40	0.60	5	5	–	–	–	1.0
Mn	0.21	0.37	5	10	0.42	15	30	0.5
Ni	0.21	0.37	5	10	0.42	15	30	0.5
Cu	0.21	0.37	22	22	0.42	70	70	1.0
Co	0.21	0.37	22	16	0.42	70	50	0.714

Figure 14.26 Abundance omni-directional, 060° and 150° directional variograms

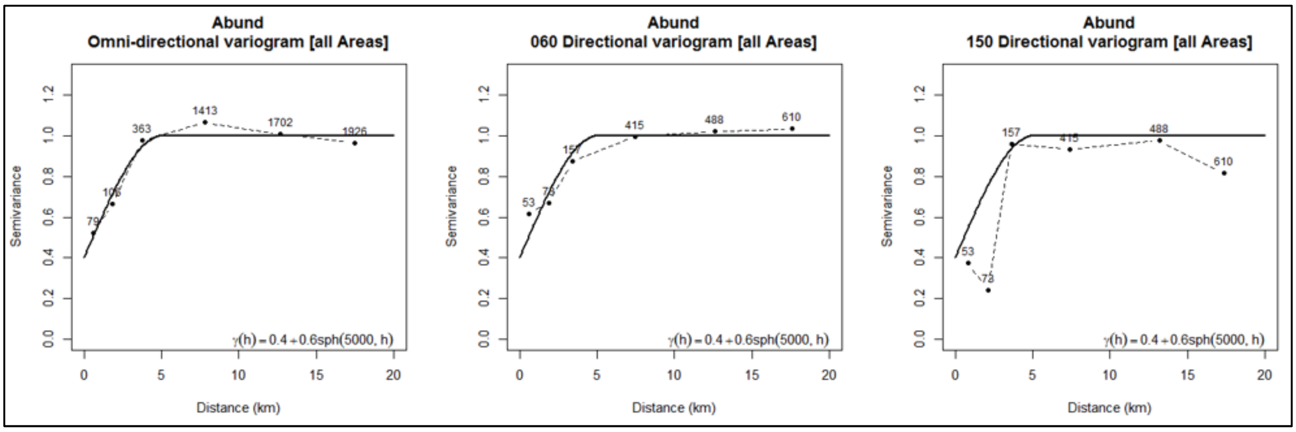


Figure 14.27 Mn omni-directional, 060° and 150° directional variograms

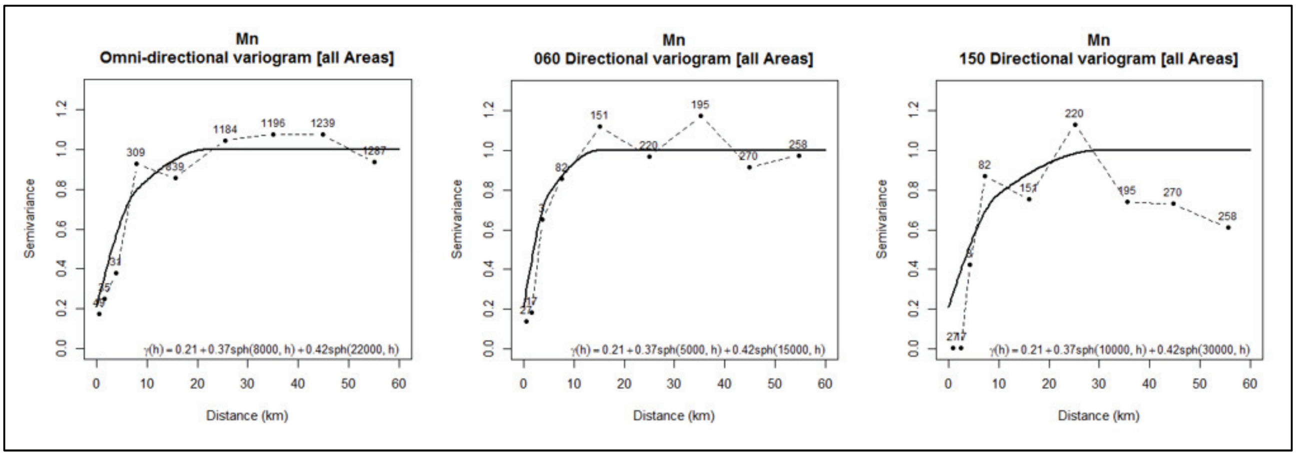


Figure 14.28 Ni omni-directional, 060° and 150° directional variograms

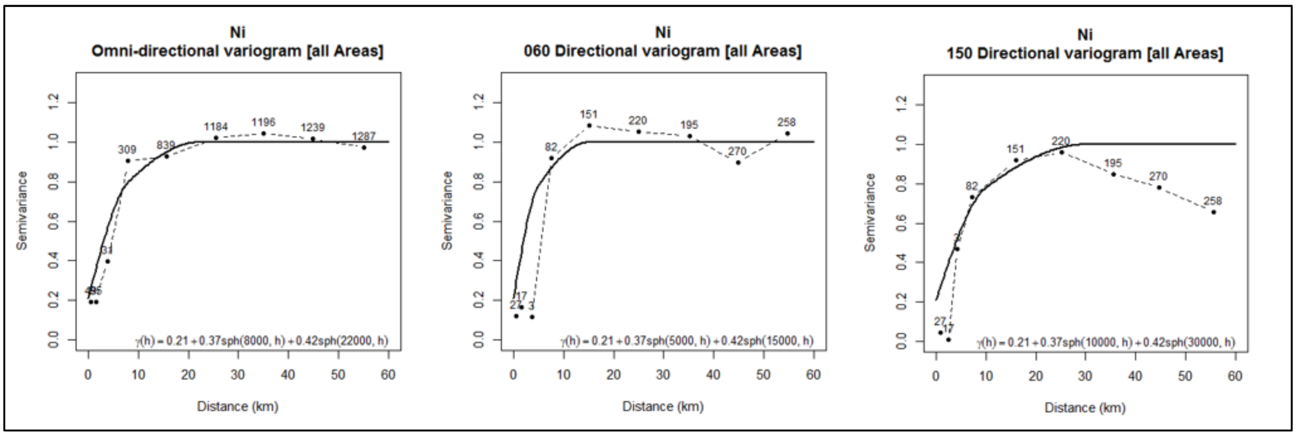


Figure 14.29 Cu omni-directional, 060° and 150° directional variograms

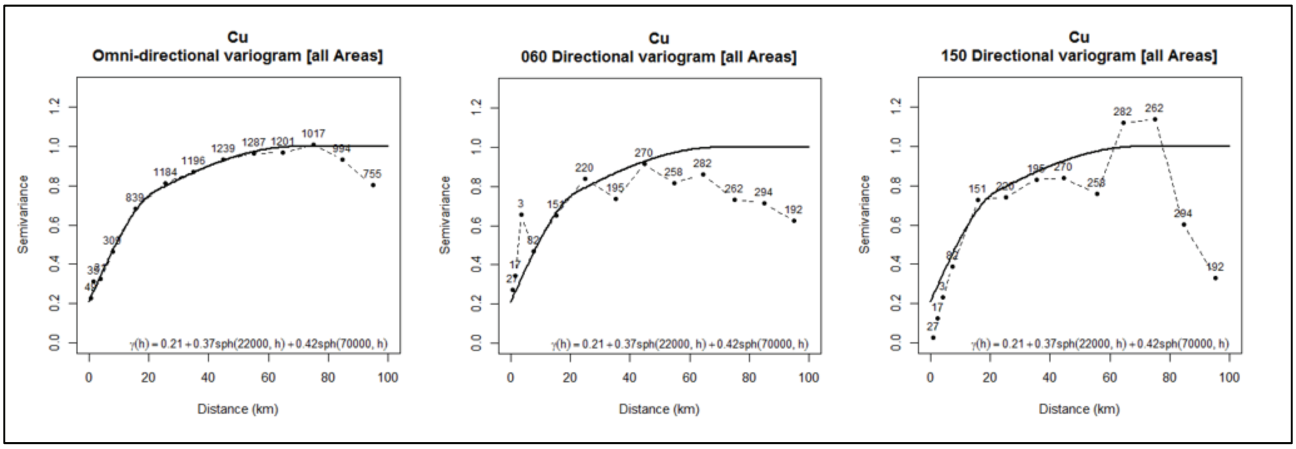


Figure 14.30 Co omni-directional, 060° and 150° directional variograms

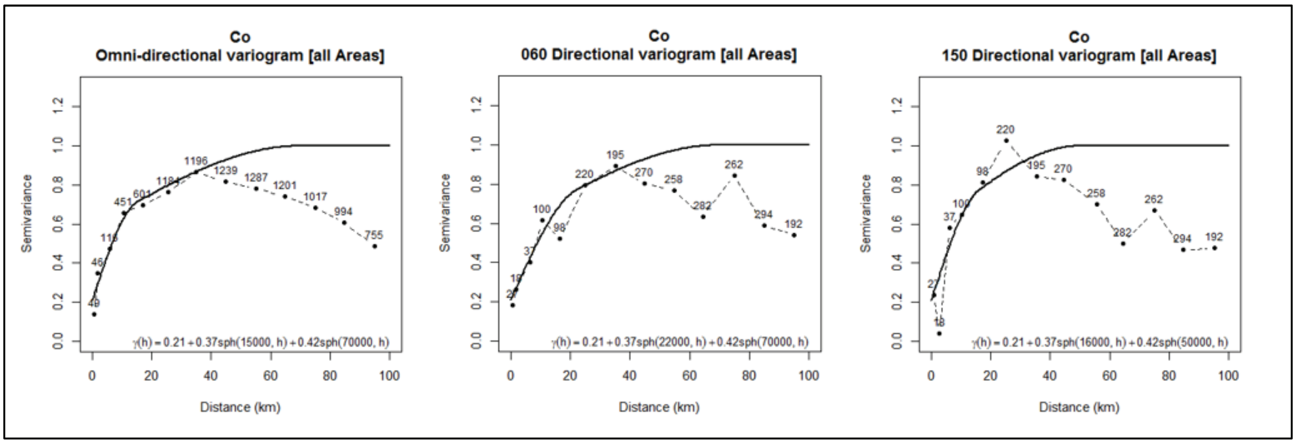
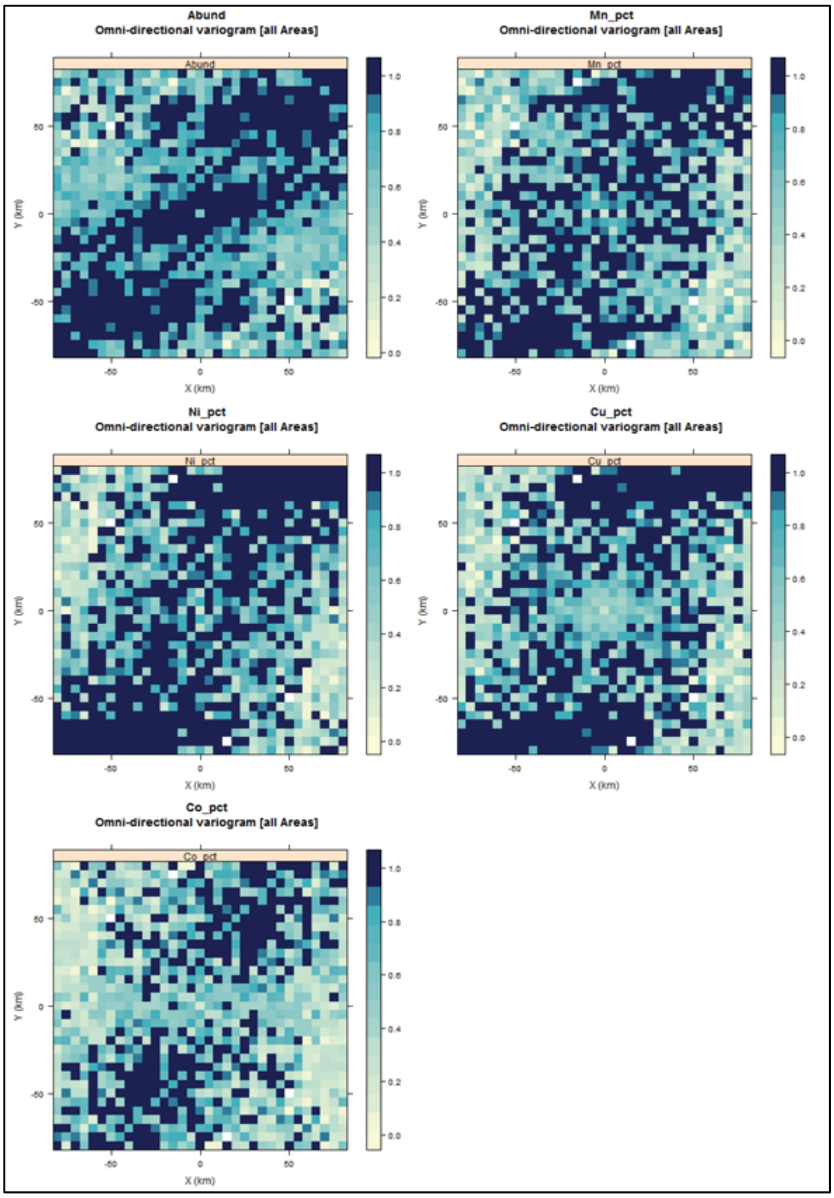


Figure 14.31 Semi-variogram maps for Abundance, Mn, Ni, Cu and Co



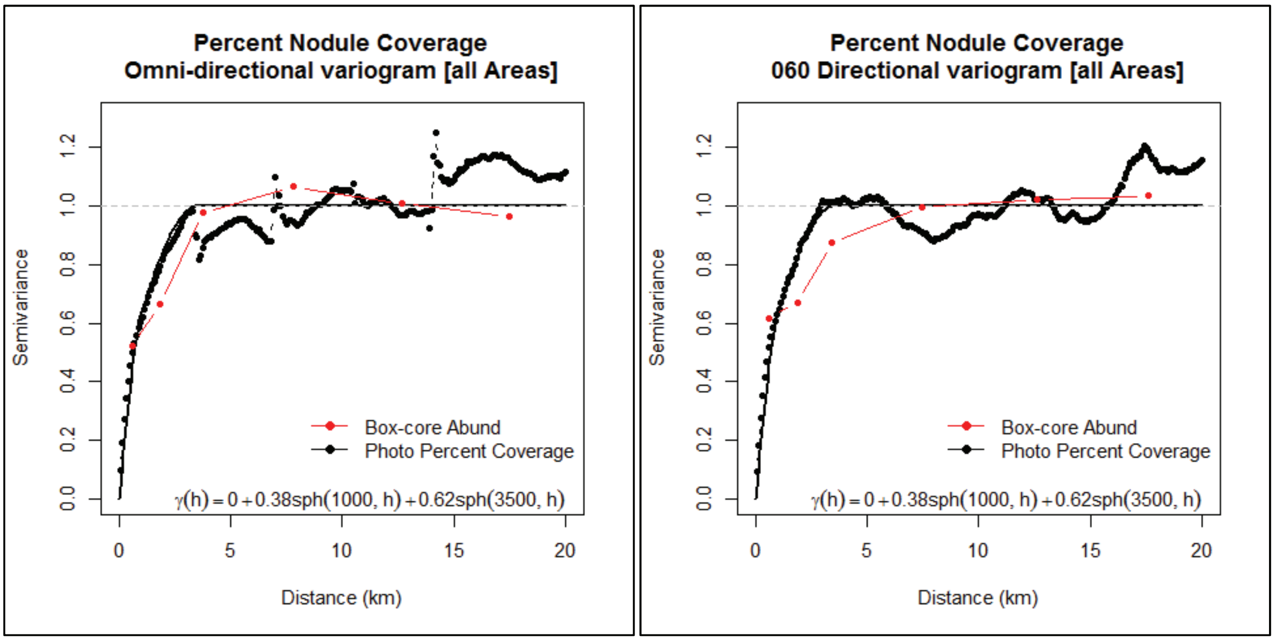
14.4.2 Variography of nodule percent coverage estimated from the photo profile lines

The continuity of nodule abundance as measured by the abundance variograms was checked by using the photo profile data.

The omni-directional and 060° directional variograms (Figure 14.32) for the percent nodule coverage estimated from the sea floor photos are similar to the box-core variograms. The range of percent nodule coverage is slightly shorter than the box-core samples. The large number of close spaced photos allows for a better estimate of the very short range spatial variability and nugget. The percent nodule coverage semivariance starts at 0 (nugget) and quickly rises to the same semivariance value (between 0.5 and 0.6) as the first point on the box-core nodule abundance variogram. This suggests that the nugget for nodule abundance is close to 0 and that the first variogram structure has a sill of approximately 0.38 at a range of 1,000 m.

Also interesting is the periodic effect (hole effect) evident in the sill at ranges of approximately 7.5 km and 15 km which may be related to the spacing between the abyssal hills.

Figure 14.32 Omni-directional and 060° directional variograms for percent nodule coverage estimated from sea floor photos

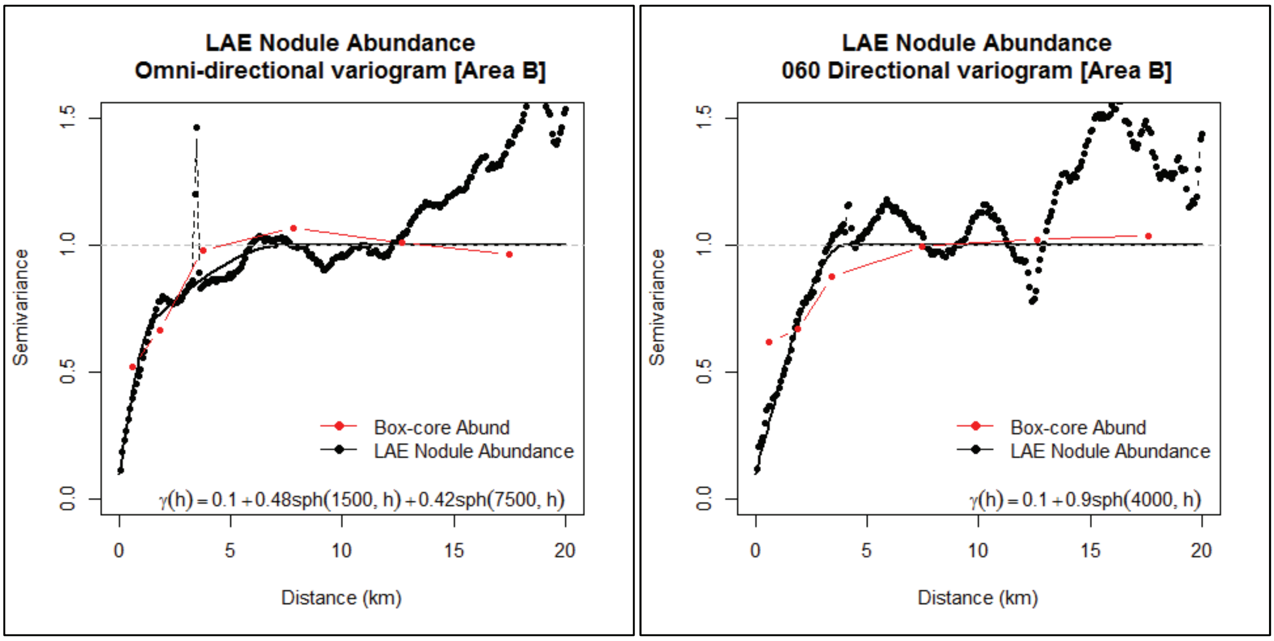


14.4.3 Variography of the estimated nodule abundance from the photo profile lines

The nodule abundance data automatically estimated from the seafloor photos using the LAE method were used to check the continuity of nodule abundance and compared with the variograms from the exploration sample data.

Compared with the nodule percent coverage variograms (Figure 14.32), the LAE nodule abundance omni-directional variograms show a slightly longer range of 7500 m. The same periodic effect (hole effect) evident in the percent nodule coverage variograms is also present in the 060° directional variogram while the omni-directional variogram hints at the presence of a long-range trend in the data. The omni-directional variogram is very similar to the nodule sample variogram but again shows a very low nugget variance.

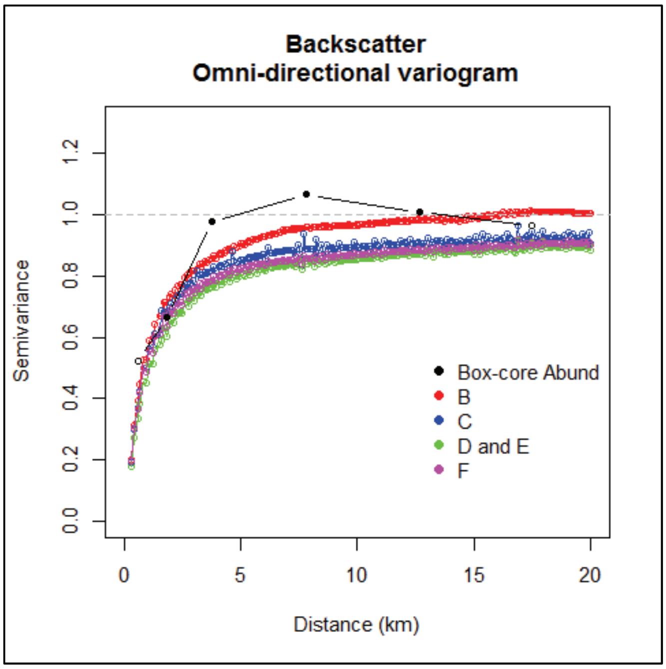
Figure 14.33 Omni-directional and 060° directional variograms for nodule abundance estimated using the LAE method from sea floor photos



14.4.4 Variography of the backscatter data

The backscatter data shows limited correlation with abundance but, in a broad sense, can be used to delineate zones of nodules from zones with very low to no nodules (the no nodule (NON) domain). Omni-directional variography (Figure 14.34) of the backscatter values indicate spatial variability that is consistent with the nodule sample data. The omni-directional variogram of the nodule sample data has a shorter range than the backscatter variograms but with similar very short range spatial variability. Interestingly Area B has the shortest range of the backscatter variograms and Area D and E have the longest.

Figure 14.34 Omni-directional variograms for backscatter values



14.5 Geological block model

Six block models were constructed, one for each TOML Exploration Area (A through to F). Each model was blocked according to the data spacing. Blocks of 1.75 km by 1.75 km were used to fill the areas tested by box core and photo profiles on a 3.5 km by 3.0 km grid (Measured Mineral Resource). Blocks of 3.5 km by 3.5 km were used to fill areas tested by box core sampling on a nominal spacing of approximately 7 km by 7 km (Indicated Mineral Resources), while the remainder were filled with blocks of 7.0 km by 7.0 km (Inferred Mineral Resources). Sub-cells with dimensions of 0.875 km by 0.875 km were used to accurately represent the boundaries of the TOML Exploration Areas, the areas interpreted to contain no nodules and the boundaries between Measured and Indicated.

The total area of the block model is 74 683 km^2 which is 99.96% of the actual total area of the TOML Licence Areas of 74 713 km^2 (Table 14.9). This indicates that the sub-blocks were adequate for approximating the licence boundaries.

Table 14.9 Comparison of model areas and actual licence areas

Area	Actual Area (m^2)	Model Area (m^2)	Percent Difference
A	10 280.560	10 309.141	0.278
B	9 966.266	9 950.062	–0.163
C	15 763.385	15 785.656	0.141
D and E	22 882.804	22 843.953	– 0.170
F	15 819.900	15 794.078	– 0.163
All	74 712.915	74 682.891	– 0.04

14.6 Mineral Resource estimation

Ordinary Kriging (OK) was used to estimate Abundance, Mn, Ni, Cu and Co into the block model. Grades were estimated on a parent block basis using block discretisation of 5 by 5 by 1. Grades were also estimated using Nearest Neighbour (NN) and Inverse Distance (IDW) to the power of 2 for validation of the OK estimates. Blocks and sub-blocks within the NON domain were set to zero.

Three separate estimation passes were run, one for each parent cell size (Mineral Resource classification). The estimates for Measured and Indicated Mineral Resource used a search range of 30km while for Indicated and Inferred a search range of 70km was used. A minimum of 1 and a maximum of 3 samples were allowed per octant search with a maximum of 8 samples per estimate.

The global Mineral Resource estimate is listed in Table 14.10 and the grade tonnage curves are shown in Figure 14.35. At abundance cut-offs of 7 kg/m^2 or less the tonnage and grade are relatively insensitive. Above 7 kg/m^2, global tonnage declines rapidly.

Figure 14.36 through to Figure 14.40 show sample locations on estimated block grades for Ni, Cu, Co, Mn and Abundance within the TOML Exploration Areas A to F. The figures indicate that for Ni, Cu, Co, Mn and Abundance there is continuity at ranges (40 to 80 km) several times greater than the average sample spacing. The patterns in distribution appear consistent between Ni, Cu, Co, and Mn reflecting the homogenous nature of the nodule chemistry across the TOML Exploration Area.

14.7 Mineral Resource classification

Classification of the Mineral Resource into Measured, Indicated and Inferred categories, in accordance with Canadian Institute of Mining, Metallurgy and Petroleum (CIM) definitions, considered: the nodule sample quality, uncertainty in the nodule sample abundance and grades, continuity of nodule abundance and grade and scale of the deposit.

- Inferred Mineral Resource classification was based on sampling by Pioneer Contractors on a nominal spacing of 20 km, the variation and uncertainty in the sample quality, and the likely presence of short range variation to nodule abundance.
- Indicated Mineral Resource classification was based on box core sampling by TOML on a nominal spacing of approximately 7 km by 7 km (including photo profiling in some cases at 7 km by 3 km), supplemented by sampling by Pioneer Contractors.
- Measured Mineral Resource was based on box core sampling by TOML on a nominal spacing of approximately 7 km by 7 km plus photo-profiling on a nominal spacing of 3.5 km by 3.0 km, supplemented by sampling by Pioneer Contractors.

Table 14.10 2016 Mineral Resource Estimate for the TOML Exploration Area within the CCZ at a series of nodule abundance cut-offs

Abundance Cut-off (wet kg/m^2)	Mineral Resource Classification	Abundance (wet kg/m^2)	Mn (%)	Ni (%)	Cu (%)	Co (%)	Polymetallic Nodules (x10^6 wet t)*
4	Measured	11.81	27.57	1.33	1.05	0.23	2.6
	Indicated	11.84	30.30	1.35	1.18	0.21	69.6
	Inferred	11.31	29.02	1.29	1.14	0.20	695.9
5	Measured	11.81	27.57	1.33	1.05	0.23	2.6
	Indicated	11.99	30.31	1.35	1.18	0.21	69.1
	Inferred	11.39	29.03	1.29	1.14	0.20	692.7
6	Measured	11.81	27.57	1.33	1.05	0.23	2.6
	Indicated	12.19	30.32	1.35	1.18	0.21	68.1
	Inferred	11.52	29.05	1.29	1.14	0.20	685.3
7	Measured	12.29	27.61	1.33	1.05	0.23	2.5
	Indicated	12.59	30.34	1.35	1.18	0.21	65.7
	Inferred	11.74	29.07	1.29	1.14	0.20	668.0
8	Measured	12.61	27.63	1.33	1.05	0.23	2.4
	Indicated	13.12	30.35	1.35	1.18	0.21	62.0
	Inferred	12.26	29.16	1.29	1.14	0.19	620.4

*Variations in Totals are due to rounding of individual values

Mn, Ni, Cu and Co assays on samples dried at 105°C

Moisture content of nodules is estimated at 28% (free water removed after drying at 105°C)

Figure 14.35 Nodule Abundance – Tonnage Curve

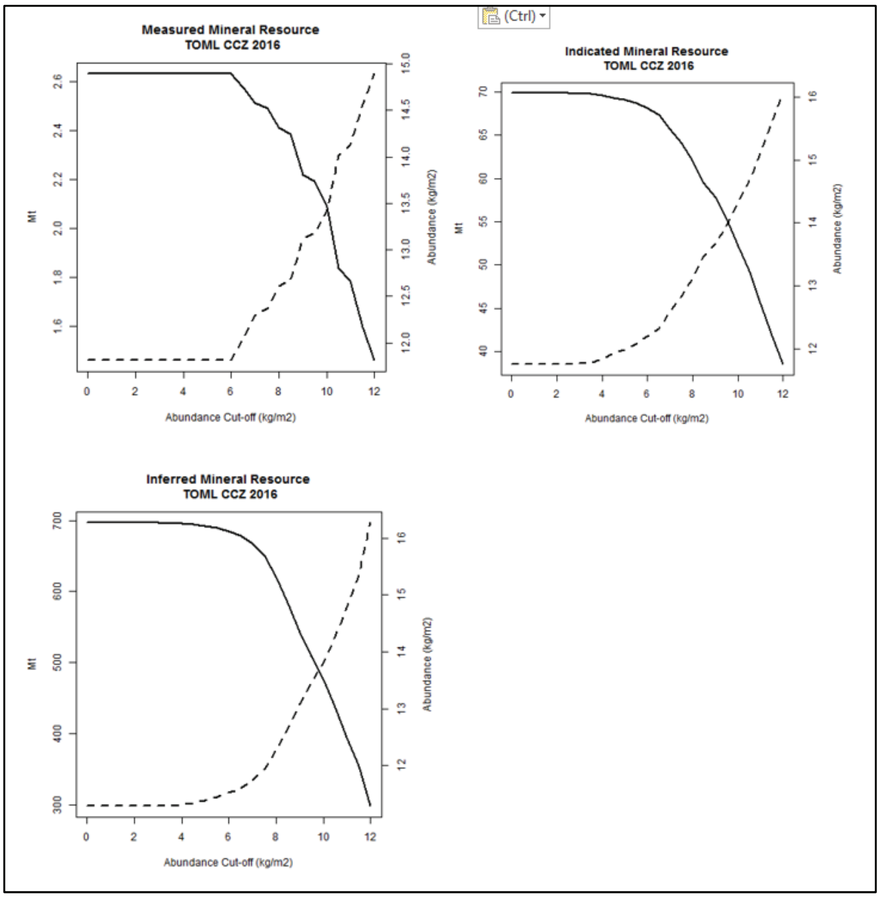


Figure 14.36 Map showing block model and sample distribution for Abundance Mn, Ni, Cu and Co in TOML Area A

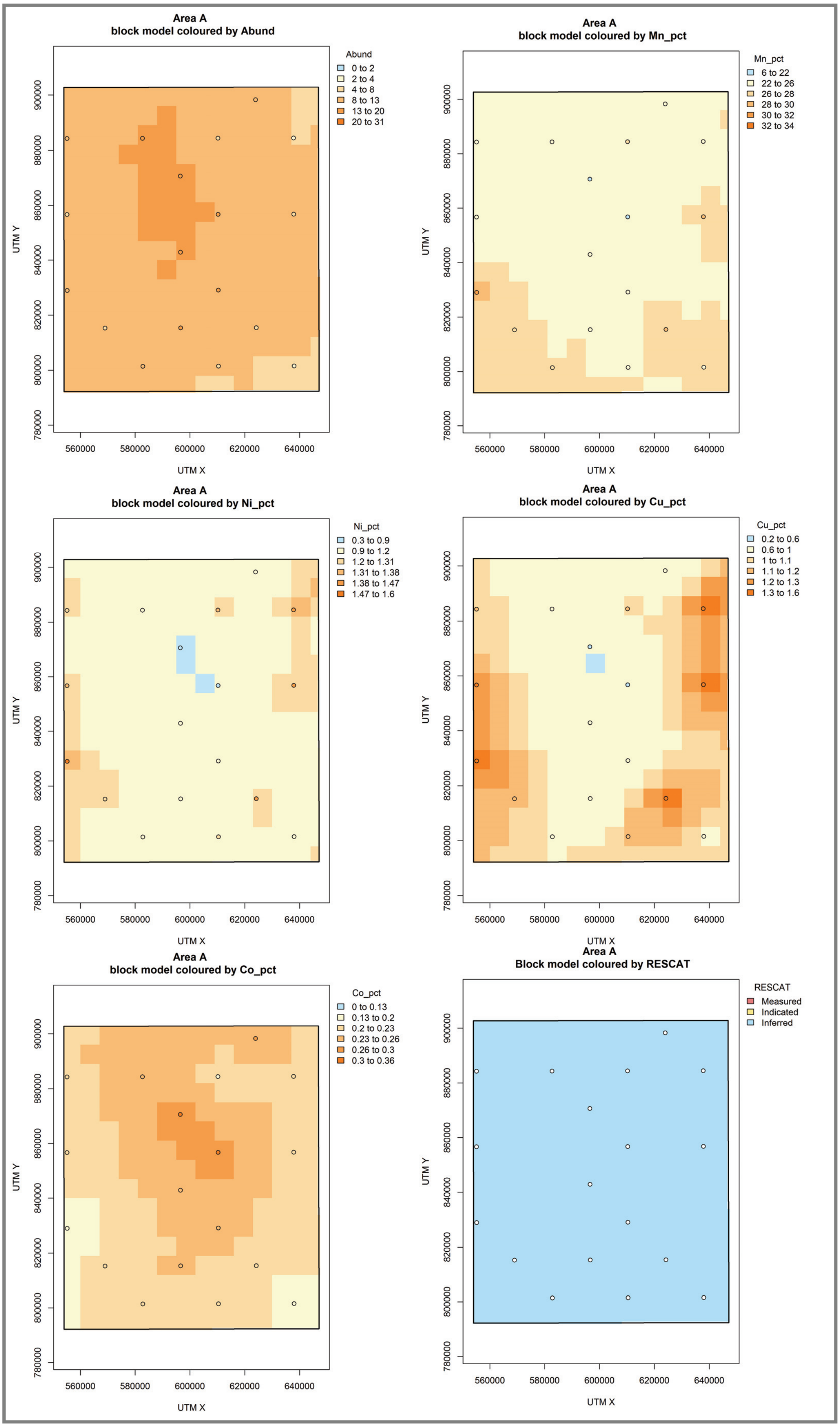
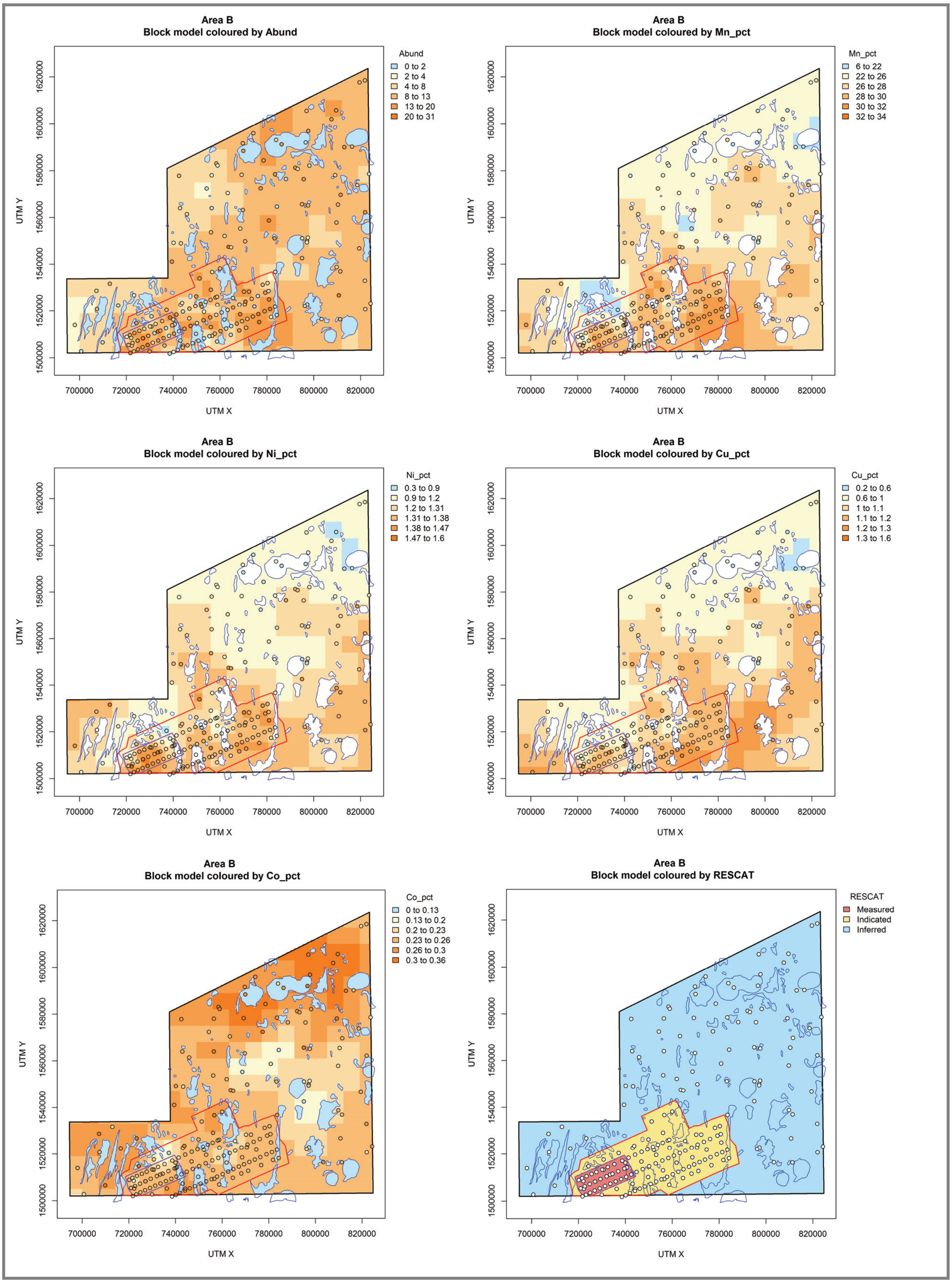


Figure 14.37 Map showing block model and sample distribution for Abundance Mn, Ni, Cu and Co in TOML Area B



Area B
Block model coloured by Abund

Area B
Block model coloured by Mn_pct

Area B
Block model coloured by Ni_pct

Area B
Block model coloured by Cu_pct

Area B
Block model coloured by Co_pct

Area B
Block model coloured by RESCAT

Figure 14.38 Map showing block model and sample distribution for Abundance Mn, Ni, Cu and Co in TOML Area C

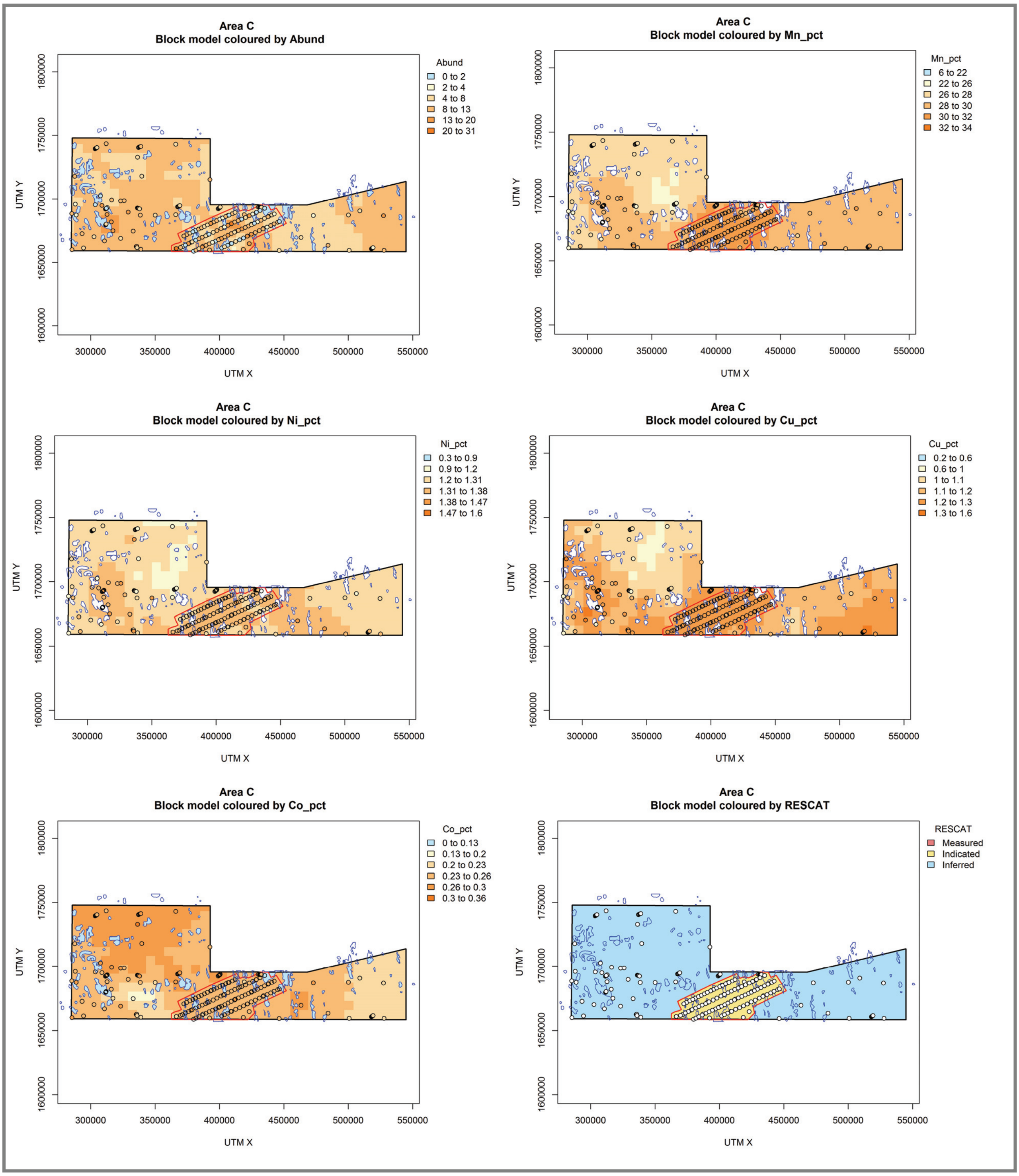


Figure 14.39 Map showing block model and sample distribution for Abundance Mn, Ni, Cu and Co in TOML Area D and Area E

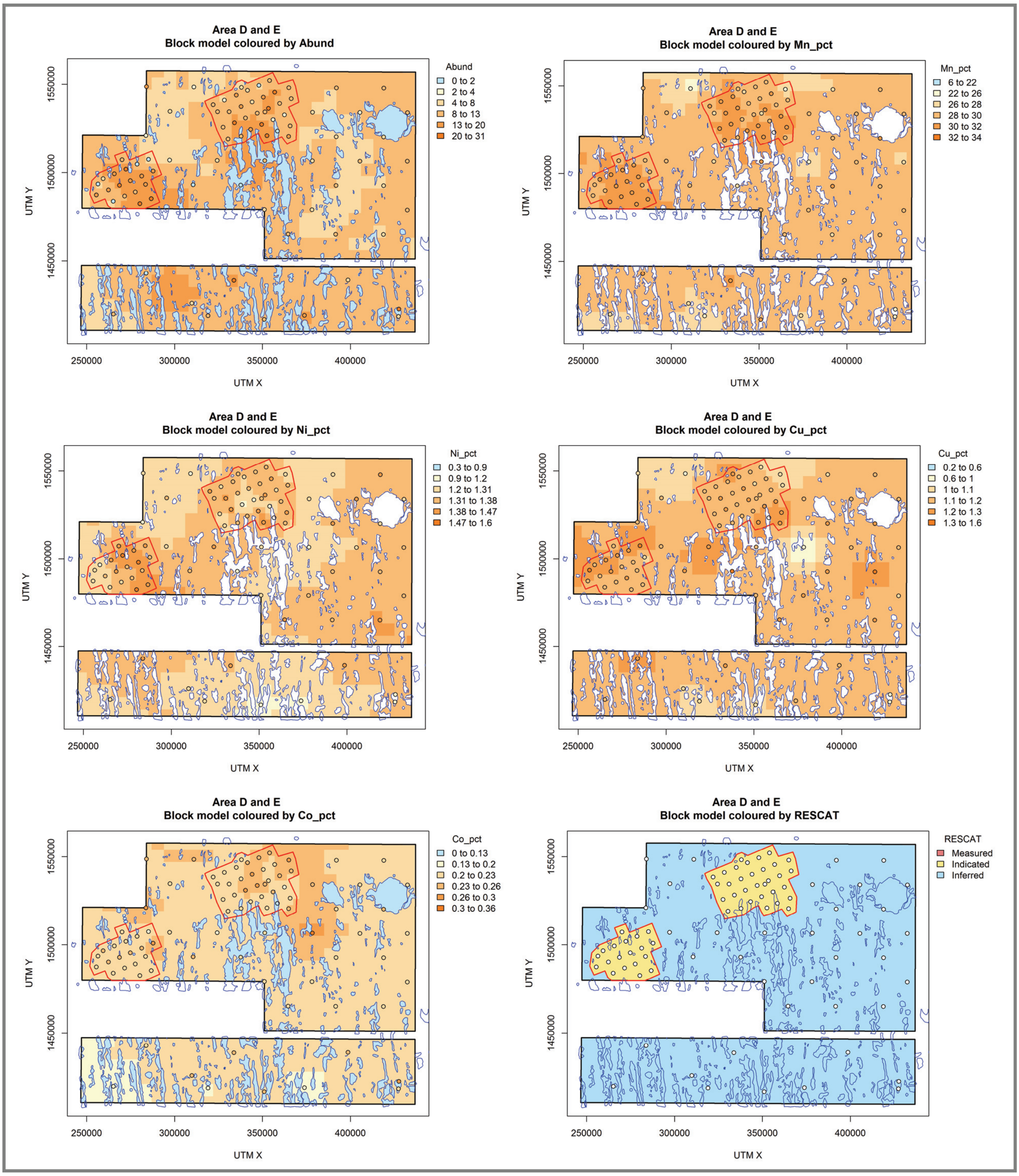
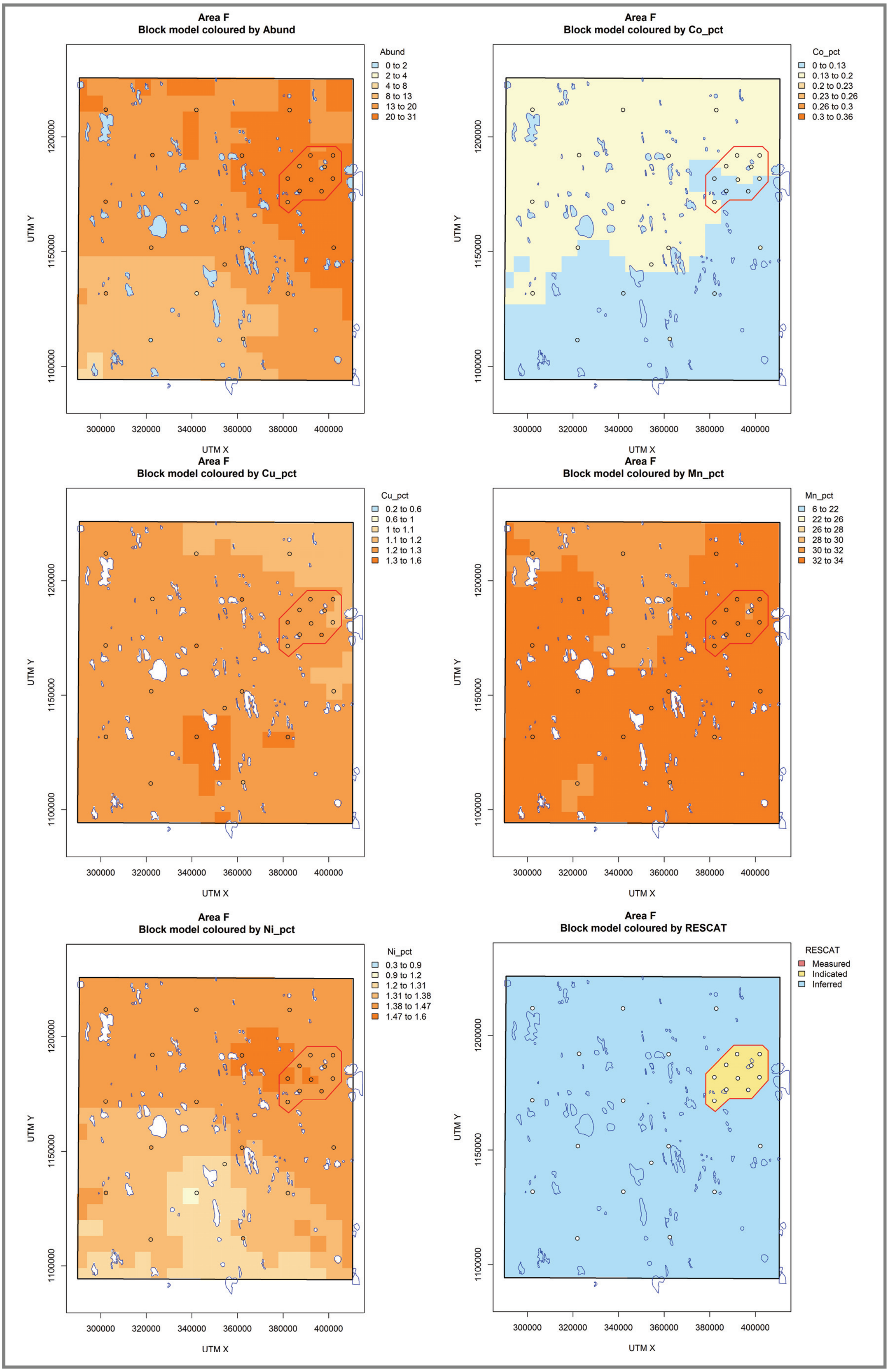


Figure 14.40 Map showing block model and sample distribution for Abundance Mn, Ni, Cu and Co in TOML Area F



The Mineral Resource model was validated by comparing the global mean and variance of the model against alternative nearest neighbour and inverse distance weighting estimates and the declustered samples, The comparative data for Abundance, Mn, Ni, Cu and Co are presented in Table 14.11. The mean grades compare favourably and the expected variance reduction is observed, indicating that the estimate is satisfactory.

Table 14.11 Global mean and variance comparison (excluding NON domain, model cells weighted by volume)

		Declustered Samples (N=476 Abund) (N=315 Metals)	Model (N=14939)		
			NN	IDW	OK
Abundance (wet kg/m^2)	Mean	10.39	10.78	10.98	11.33
	Variance	38.19	36.29	26.86	16.56
Mn (%)	Mean	28.19	28.57	28.60	28.65
	Variance	9.652	9.100	7.895	6.887
Ni (%)	Mean	1.27	1.28	1.28	1.28
	Variance	0.028	0.024	0.018	0.018
Cu (%)	Mean	1.12	1.13	1.13	1.13
	Variance	0.043	0.037	0.028	0.020
Co (%)	Mean	0.220	0.210	0.210	0.210
	Variance	0.003	0.003	0.003	0.002

14.8 Comparison with previous Mineral Resource estimate

The initial global Inferred Mineral Resource for the TOML Exploration Areas was reported (Table 14.12) on 20 March 2013 by Matthew Nimmo of Golder Associates (Golder Associates, 2013). The estimate was tabulated at various nodule abundance cut-offs. The nodule abundance cut-off of 6 wet kg/m^2 was the selected base case scenario considering a non-selective bulk mining operation. The effective date for the 2013 estimate is 22 June 2012 (the date when the last of the data used for the resource estimate was received by Golder).

The changes in the 2016 Mineral Resource estimate for the TOML CCZ Exploration Areas are due to:

1. Additional nodule abundance sample information (from box core and photo profile) collected during the 2015 Cruise (Table 14.13 and Table 14.14. Note that in Table 14.14 statistics of all nodules are close to the estimated abundance for the Indicated areas).
2. Inclusion of Areas E and F for the first time.
3. High Abundances and grades in Area F.
4. NON (no nodule) domain limiting extrapolation of low nodule abundance in areas covered by multibeam (TOML Areas B, C, D, E, F).
5. Use of ordinary kriging (rather than inverse distance) supported by short range variogram to estimate abundance.
6. Changes in block model parent cell size related to improved sample spacing.

Table 14.12 Previous 2013 Mineral Resource Estimate for the TOML Areas A-D

Abundance Cut-off (wet kg/m^2)	Mineral Resource Classification	Abundance (wet kg/m^2)	Ni (%)	Co (%)	Cu (%)	Mn (%)	Polymetallic Nodules (x10^6 wet t)*
4	Inferred	8.9	1.2	0.24	1.1	26.9	440
5	Inferred	9.1	1.2	0.24	1.1	26.9	420

Abundance Cut-off (wet kg/m^2)	Mineral Resource Classification	Abundance (wet kg/m^2)	Ni (%)	Co (%)	Cu (%)	Mn (%)	Polymetallic Nodules (x10^6 wet t)*
6	Inferred	9.4	1.2	0.24	1.1	26.9	410
7	Inferred	9.8	1.2	0.24	1.1	26.8	370
8	Inferred	10.4	1.2	0.24	1.0	26.7	310

*Variations in Totals are due to rounding of individual values

Table 14.13 Mean Abundance of historical and 2015 cruise nodule samples (including NON domain)

Sub-Area	Historical Abundance (wet kg/m^2)		2015 Abundance (wet kg/m^2)		All Abundance (wet kg/m^2)	
	N	Mean	N	Mean	N	Mean
B1	16	8.91	105	9.93	121	9.79
C1	11	11.26	102	7.41	113	7.78
D1	4	7.12	16	13.84	20	12.49
D2	6	9.42	26	11.59	32	11.19
F1	–	–	10	21.65	10	21.65

Table 14.14 Mean Abundance of historical and 2015 cruise nodule samples (excluding NON domain)

Sub-Area	Historical Abundance (wet kg/m^2)		2015 Abundance (wet kg/m^2)		All Abundance (wet kg/m^2)	
	N	Mean	N	Mean	N	Mean
B1	15	8.88	89	11.45	104	11.08
C1	11	11.26	92	8.08	103	8.42
D1	4	7.12	16	13.84	20	12.49
D2	5	9.21	25	12.05	30	11.58
F1	–	–	10	21.65	10	21.65

Table 14.15 Mean Ni grades of historical and 2015 cruise nodule samples (excluding NON domain).

Sub-Area	Historic % Ni		2015 % Ni		All % Ni	
	N	Mean	N	Mean	N	Mean
B1	14	1.31	23	1.32	37	1.31
C1	11	1.31	13	1.33	24	1.32
D1	3	1.31	14	1.36	17	1.35
D2	5	1.34	24	1.33	29	1.33
F1	–	–	10	1.46	14	1.38

Table 14.16 Mean Cu grades of historical and 2015 cruise nodule samples (excluding NON domain).

Sub-Area	Historic % Ni		2015 % Ni		All % Ni	
	N	Mean	N	Mean	N	Mean
B1	15	1.07	23	1.09	37	1.08
C1	11	1.23	13	1.24	24	1.24
D1	4	1.20	14	1.19	17	1.19
D2	5	1.15	24	1.17	29	1.17
F1	–	–	10	1.23	14	1.25

Table 14.17 Mean Co grades of historical and 2015 cruise nodule samples (excluding NON domain).

Sub-Area	Historic % Ni		2015 % Ni		All % Ni	
	N	Mean	N	Mean	N	Mean
B1	15	0.240	23	0.238	37	0.239
C1	11	0.248	13	0.243	24	0.245
D1	4	0.210	14	0.221	17	0.219
D2	5	0.232	24	0.224	29	0.226
F1	–	–	10	0.131	14	0.133

Table 14.18 Mean Mn grades of historical and 2015 cruise nodule samples (excluding NON domain).

Sub-Area	Historic % Ni		2015 % Ni		All % Ni	
	N	Mean	N	Mean	N	Mean
B1	15	28.0	23	28.6	37	28.4
C1	11	29.4	13	31.1	24	30.3
D1	4	29.3	14	30.5	17	30.3
D2	5	28.0	24	30.3	29	29.9
F1	–	–	10	32.5	14	32.1

Quantitative kriging neighbourhood analysis was also performed to check selected estimation parameters.

ITEM 15. Mineral Reserve Estimates

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study.

ITEM 16. Mining Methods

There are no Mineral Reserve estimates for the TOML Exploration Licence Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study.

16.1 Case for Reasonable Prospects of Economic Extraction

In assessing the project for reasonable prospects of economic extraction, the technical delivery and cost effectiveness of a potential mining project have been considered by Nautilus. Although the assessment considers more than just mining methods the explanation is included here because the mining method is perhaps the most critical part.

The possibility to collect nodules at the great depths in the CCZ project areas (approximately 5,000 m) is considered reasonable because samples of nodules have been collected in the CCZ by dredges since the 1800s and by trial mining in the late 1970s and early 1980s (Item 6). Technological development over the last three decades has progressed operating depths to up to: 2,000 m for rock placement on cables and pipes (Ship Technology, 2012); 2,500 m for oil and gas production (Shell Perdido Project, 2013); 3,000 m for drilling (Stephan, 2013); 5,000 m for cable laying and retrieving (History Magazine, 2013); and 11,000 m for sampling (National Geographic, 2013).

After years of research and development and sea trials of various designs, the mechanism by which nodules could be effectively gathered from the sea floor has been demonstrated by the commercial consortia summarised in Item 6. The effectiveness of these and any new tools would be improved by recent developments in hydraulics, subsea navigation and communication as shown in the current generation of deep ROVs and AUVs (WHOI, Underwater Vehicles, 2013).

Similarly the mechanism by which nodules could be lifted from the seabed to a surface ship has been demonstrated in the CCZ to be possible in three ways, via:

- Cable as used in dredges and skips (Murray and Renard, 1891; InfoMine, 2013)
- Hydro-hoist slurry riser pipe with intermediate slurry pumps (Van Den Berg and Cooke, 2004)
- Slurry riser pipe powered by airlift (Saito et al. 1989)

Nautilus Minerals is building a fourth type of system for the Solwara 1 project (1,600 m water depth). This is a hydro-hoist slurry riser pipe with single positive displacement pressure exchange pump (Leach et al, 2012).

With regards to the main surface vessel, offshore floating production storage and offloading vessels (FPSO’s) are routinely used in the offshore oil industry to act as the floating production platform for subsea operations (Oil & Gas Financial Journal, 2012).

Transport of the ore to market for nodules should be straightforward as nodules are oxides like manganese ore or nickel laterite. They are softer than many terrestrial based manganese ore, but unlike clayey laterite they are “lump” in form and not as prone to liquefaction (Fabi, 2010). Thus conventional bulk carrier ships, in sizes ranging from 25kt to 90kt, are well suited to performing this role.

Possible metallurgical processing routes for nodules (on-shore) are summarised in Item 13. Three of these processing routes are operating in various plants around the world using terrestrial ore sources.

With strong forecast growth in the developing world (Montgomery, 2008), the prospect for the future market for the key economic metals in nodules is encouraging (assumed as a minimum to be Ni, Cu and Co).

The cost effectiveness of a potential mining project is considered reasonable as on the revenue side:

- Grades of nickel are 20% higher than recently commissioned Ni-laterite projects (Daigle et al, 2011; Highlands Pacific, 2009).
- There is more tentative upside in terms of other metals not covered by the Mineral Resource such as Mo and REE (Item 7).

On the cost side:

- The challenges of working over large areas at depth will at least in part be compensated by the lack of any overburden or even digging in the sense normally needed in mines (the nodules can be in effect scooped or harvested from the seafloor mud).
- The vertical transport distance of approximately 5,000 m will at least in part be compensated by the lack of haul roads or need for horizontal pipelines that can reach 220 km in length on some terrestrial projects (Sherritt International 2008).
- Transport distances to markets are comparable with current trade routes in bulk commodities to Asia and Europe (Bockmann, 2010; Ashby, 2012).
- Processing costs may be lower than some laterites due to lower Fe grades (Dalvi et al, 2004; Daigle et al, 2011) and more homogenous chemistry/mineralogy.

Separate to the evaluation above, indirect corroboration of reasonable prospects for economic extraction come from interest in CCZ nodules from other commercially oriented groups. Both UK Seabed Resources and GSR (Item 23) represent large commercial groups making a significant investment in developing parts of the CCZ deposit. There are also recent and publically available financial evaluations on nodule extraction (Kotlinski et al, 2008; Yamazaki, 2008a; Agarwal et al, 2012).

Nautilus is working on engineering concepts with a view to produce a preliminary economic assessment.

ITEM 17. Recovery Methods

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study

ITEM 18. Project Infrastructure

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study.

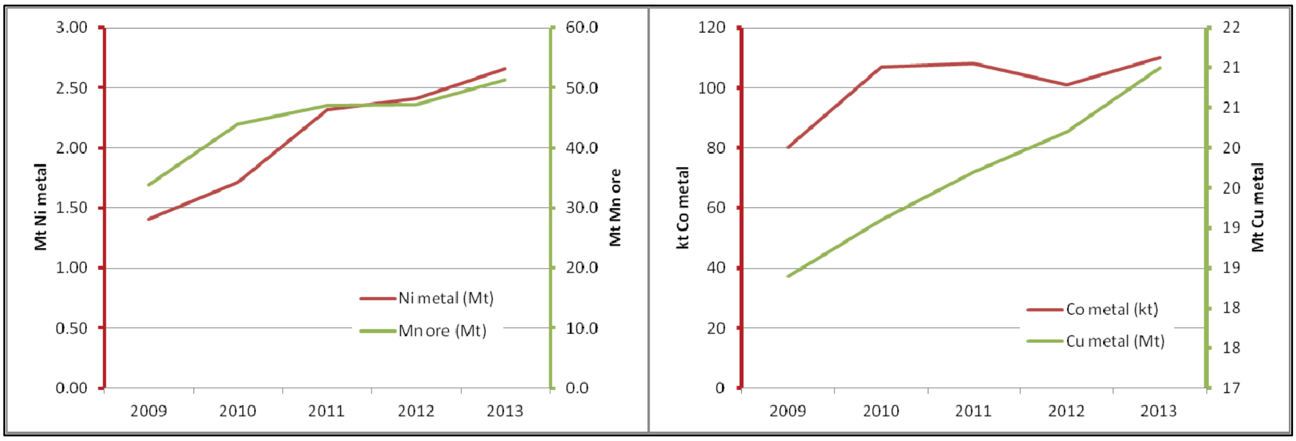
ITEM 19. Market Studies and Contracts

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study.

In terms of metal markets it is worth noting however that:

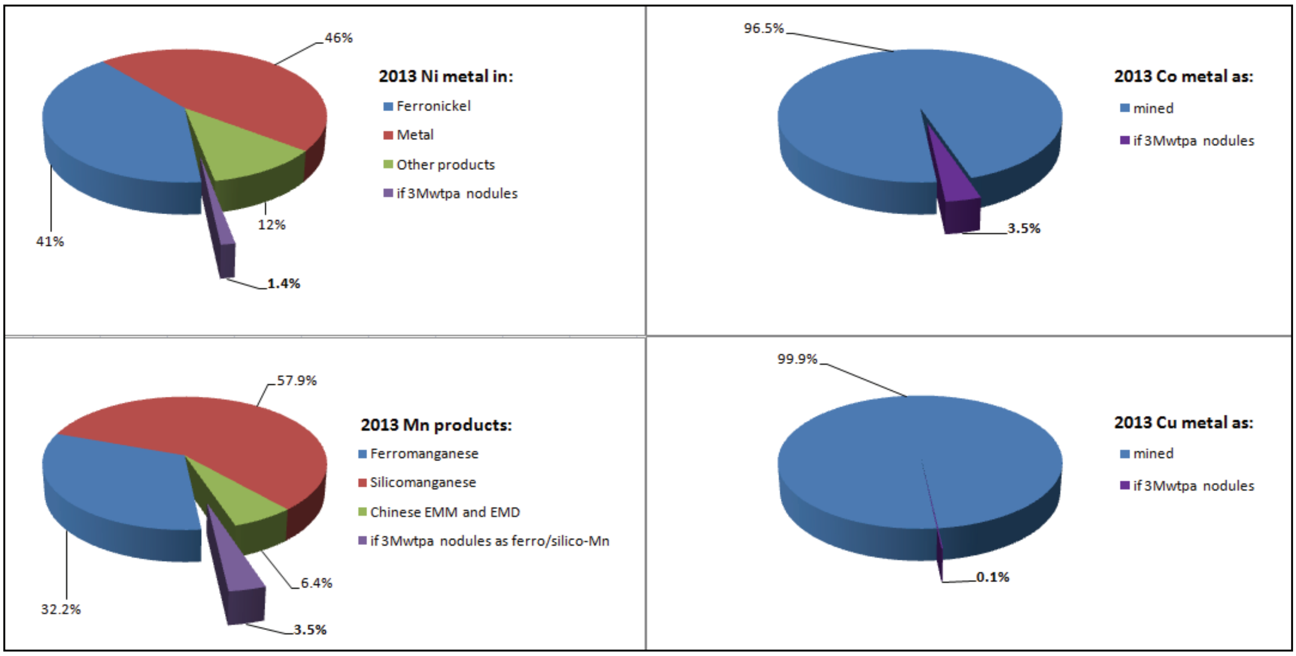
- Markets for the metals estimated in the Mineral Resource have grown over the last few years for which statistics are publically available (2009 to 2013; USGS, 2016)
- Marketable product ultimately is linked to metallurgical process circuit and then to the size of established intermediate and final product markets;
- Production of nodules at a nominal rate of three million wet tonnes per annum would not seriously disturb the land based supply industries.

Figure 19.1 Manganese, nickel cobalt and copper production



Source: USGS (2016)

Figure 19.2 Manganese, nickel cobalt and copper markets relative to conceptual contribution from nodule mining



Source: USGS (2016) and International Manganese Institute

ITEM 20. Environmental Studies, Permitting, and Social or Community Impact

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study including environmental and social or community studies or impact studies.

ITEM 21. Capital and Operating Cost

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study

ITEM 22. Economic Analysis

There are no Mineral Reserve estimates for the TOML Exploration Area of the CCZ and the potential viability of the Mineral Resources has not yet been supported by a preliminary economic assessment, a pre-feasibility study or a feasibility study.

ITEM 23. Adjacent Properties

Currently fifteen contractors have rights in the CCZ under the ISA (Item 4):

- Yuzhmorgeologiya (state owned company of the Russian Federation). Pioneer contract for exploration registered December 1987, executed March 2001, currently under application for five year extension. Currently they hold about approximately 75,000 km^2.
- Deep Ocean Resources Development Company (DORD; Japan). Pioneer contract for exploration registered December 1987, executed June 2001, currently under application for five year extension. Currently they hold approximately 75,000 km^2.
- Association Française d'Etude et de Recherche des NODules océaniques (AFERNOD; France). Managed by Ifremer (French Research Institute for Exploitation of the Sea). Pioneer contract for exploration registered December 1987, executed June 2001, currently under application for five year extension. Currently they hold approximately 75,000 km^2.
- China Ocean Minerals Research and Development Association (COMRA; China). Pioneer contract for exploration registered March 1991, executed May 2001, currently under application for five year extension. Currently they hold approximately 75,000 km^2, the reduced area being approved in November 2011.
- Interoceanmetal Joint Organization (consortium comprising Bulgaria, Cuba, Slovakia, Czech Republic, Poland and the Russian Federation). Pioneer contract for exploration registered August 1991, executed March 2001, currently under application for five year extension. Currently they hold approximately 75,000 km^2.
- Korean Association of Deep-Ocean Mineral Development (KADOM; Korea). Pioneer contract for exploration registered August 1994, executed April 2001, currently under application for five year extension. Currently they hold approximately 75,000 km^2.
- The Federal Institute for Geosciences and Natural Resources (BGR or FIGNR; Germany). Contract of approximately 75,000 km^2 being approved in November 2005. The application was based on contributions by the German consortium AMR through the historical consortium OMI (refer Item 8).
- Nauru Ocean Resources Inc. (NORI), wholly owned by the Nauru Education and Training Foundation and the Nauru Health and Environment Foundation (ISA, 2011). Sponsored by the Government of Nauru. Contract from the reserved areas of approximately 75,000 km^2 granted in November 2011.
- Nautilus Minerals’ Tongan registered and supported subsidiary, Tonga Offshore Mining Ltd (TOML). Sponsored by the Kingdom of Tonga. Contract from the reserved areas of approximately 75,000 km^2 granted in January 2012.
- UK Seabed Resources Ltd., a Lockheed Martin company sponsored by the Government of the United Kingdom. Converted an old Kennecott licence issued originally by the UK into ISA. Contract of approximately 58,000 km^2 granted February 2013. Converted a relinquished OMI licence issued originally by the USA into ISA. Second contract of approximately 75,000 km2 granted March 2016.
- Global Sea Mineral Resources (GSR; formerly G-Tec Sea Minerals Resources), a Belgian company sponsored by the Government of Belgium, converted an old OMA licence issued originally by the USA into ISA. Contract of approximately 75,000 km^2 granted January 2013.
- Marawa Research and Exploration Ltd., a state enterprise of the Republic of Kiribati. Contract from the reserved areas of approximately 75,000 km^2 granted in January 2015.
- Ocean Mineral Singapore (OMS) sponsored by the Government of Singapore. Contract from the reserved areas of approximately 58,000 km^2 granted in January 2015.
- Cook Islands Investment Corporation (CIIC) a state enterprise of the Cook Islands. Contract from the reserved areas of approximately 75,000 km^2 approved in July 2014.
- Minmetals a commercial company sponsored by China. Contract from the reserved areas of approximately 75,000 km^2 approved in July 2015.

Some background on these contractors is included in Item 6. Note that India holds a similar contract for the polymetallic nodules in part of the Indian Ocean.

Contractor licences are granted for 15 years. Work programmes and progress are reviewed annually by the Legal and Technical Committee of the ISA during its annual meeting. To date, no commercial production has taken place by these adjacent contractors.

Some of the contractors were explorers in the 1970s who moved to the ISA licensing system. However, Lockheed Martin Systems Co (LMS) or Ocean Minerals Company (OMCO; GPO, 2011, Spickermann, 2012) is recognised to have two US licenses granted by NOAA (Item 6).

ITEM 24. Other Relevant Data and Information

24.1 Areas of Particular Environmental Interest

As part of the eighteenth session of the ISA in July 2012, (ISA 2012b). Nine APEIs within the CCZ were designated by the Council of the ISA as part of an environmental management plan. None of the nine areas (Item 4) impact the TOML Exploration Area.

The APEIs are an important part of the ISA's EMP for the CCZ (ISA, 2012b; Smith et al, 2010) they aim to:

- Protect large enough areas to maximise both conservation benefits and exploitation benefits (at present they are more extensive than areas granted by the ISA to contractors for development;
- Be arranged to provide representative cover of different subregions as defined by productivity gradients and faunal turnover and as many seamounts as possible;
- Each APEI is large enough to ensure a core area is remote from even pessimistic estimates of impact from deep-sea mining;
- Complement ecosystem based management strategies for the area.

The APEIs were reviewed as required by policy in 2014 for the purposes of forthcoming review of the ISA's EMP and the decision (or not) to extend their location and validity. Independent consultants Seascape (Seascape Consultants, 2014) found no reason to change the APEI.

ITEM 25. Interpretation and Conclusions

TOML holds tenement over a significant part (74 713 km^2) of the CCZ polymetallic nodule deposit in 6 areas (Areas A through to F). These licences are under a contract for exploration of polymetallic nodules signed with the International Seabed Authority which has its remit from the United Nations Convention on the Law of the Sea.

Historical work over the last four decades has shown the deposit to be widespread and of very consistent grades. Exploration and development have progressed over this period, including scientific discovery and characterisation, successful efforts at trial mining, bench top scale metallurgical processing and development of an internationally accepted system of administration of the Mineral Resource.

Environmental study and management of the CCZ is continuing to develop, with a solid historical effort to understand fundamental science and mining related impact being improved with ongoing research and state of the art of techniques. The ISA, working with independent specialists has an EMP in place, including protected areas and environmental regulations for exploration and monitoring.

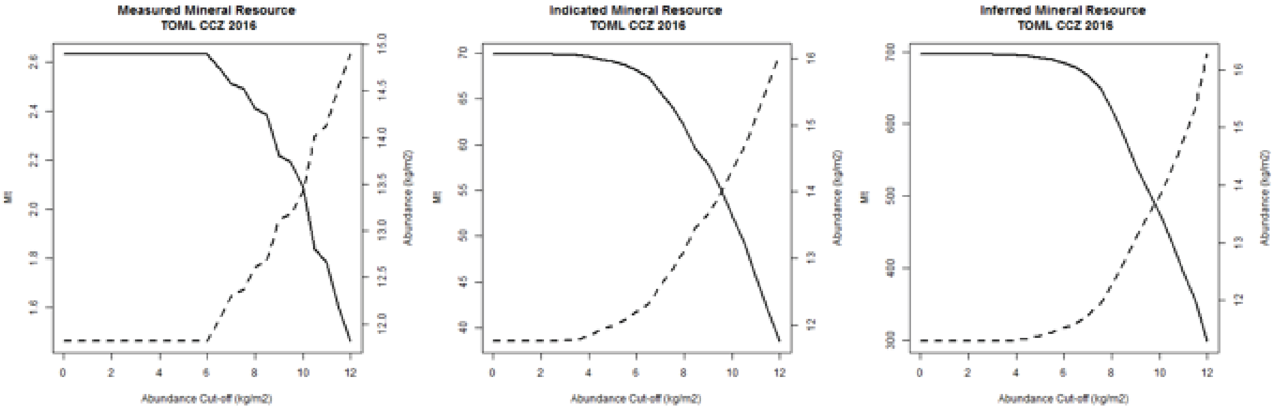
The formation and distribution of the nodules is a result of a interplay of factors, key being: a) net export of metal bearing biogenic detritus from the sea surface; b) release of metals below the lysocline through dissolution of the detritus; c) suitably oxidising conditions and d) stable nodule bearing geochemically active layer. Abundances of nodules at or near the seafloor vary more than grades.

Work by Nautilus subsidiary TOML confirms the historical data available for Mineral Resource estimation and furthermore provides significant additional detail and evidence for continuity such that Mineral Resource estimates of higher confidence can be determined. TOML also completed sampling of environmental and geotechnical data that is still being analysed. To date results complement, but have not revealed anything fundamentally different from, available historical work.

TOML Exploration Areas A to F have sufficient samples of adequate quality to define a Mineral Resource for Mn, Ni, Cu and Co. Other metals of potential value (e.g. Mo, REE) have not been estimated, but could provide significant upside. The estimate of abundance and hence tonnage for the Inferred Mineral Resource for the TOML Exploration Areas A to F may be biased low due to reliance on free fall grab samples in places.

The global Measured, Indicated and Inferred Mineral Resource estimate at various nodule abundance cut-offs for the TOML Exploration Areas within the CCZ polymetallic nodule deposit is presented as grade-tonnage curves in Figure 25.1. The selected base case scenario is an abundance cut-off of 6 wet kg/m^2 which is appropriate, given that a non-selective bulk mining operation is envisaged (Item 16). The effective date for the estimate is 30 March 2016.

Figure 25.1 Nodule abundance – tonnage curves.



ITEM 26. Recommendations

It is recommended that future work on the TOML Exploration Area focus on determining the viability of mining systems through trial nodule mining and appropriate methods for predicting, monitoring and controlling production rates during mining. Additionally, key modifying factors need to be constrained to a point where a Mineral Reserve could potentially be estimated for the TOML Exploration Areas.

It is recommended that future work include the following (in no order of priority):

Exploration

- Undertaking a conditional simulation study to quantify the uncertainty and risk in nodule abundance. This will likely help provide production bounds for the operating system(s).
- Similarly, investigate automated processing of nodule photographs to estimate nodule abundance using the long-axis method. This will allow very detailed short range determination of abundance along photo-profile lines informing a simulation study regarding variability during mining.
- If determined to be required in terms of production certainty, undertake additional photo profiling in areas categorized as Indicated Mineral Resource to increase the Measured Mineral Resource well ahead of commercial extraction of the existing Measured Mineral Resource.

Environment

- Complete analysis of data collected during the TOML CCZ13 and CCZ15 cruises, including analysis of oceanographic information, taxonomy of collected samples, habitat mapping from photo profiles, collection of moorings to enable:
    - Integration with CCZ-wide published data to support an Environmental Impact Statement for trial mining.
    - Environmental baseline conditions to be documented for the sub-areas (Priority Mining Areas).
- Feedback from the Engineering Concept study to support the Environmental Impact Statement (EIS) for trial mining.
- Development of a monitoring programme to accompany future work, including trial mining.

Engineering and Commercial Concept

- Complete analysis of geotechnical data collected during the TOML CCZ15 cruise.
- Complete system concept design and options and risking exercises.
- Prepare economic and commercial studies to provide scoping estimates for CAPEX and OPEX for mining, transportation and processing options.
- Complete metallurgical research with order of magnitude cost estimates for processing options.
- Complete scale testing of key mining equipment,

Trial Mining

- Conduct a trial mining operation within the TOML Exploration Area, which will inform a commercial mining feasibility study. This including:
    - Fabrication of pilot scale equipment;
    - Appropriate permitting;
    - Selection of a candidate site(s) amongst the five areas raised to the level of an Indicated Mineral Resource or better.
- Include an environmental monitoring programme, which will inform a commercial mining EIS

Possible budgets required for this work over the next two to three years may total $US30-50 million.

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Date

The effective date of this Technical Report is 30 March 2016

Signature

AMC Consultants Pty Ltd

I. T. Lipton

Date: 4 July 2016

Ian Lipton

Corporate Consulting Manager / Principal Geologist

Certificates of Qualified Persons and Authors

CERTIFICATE OF QUALIFIED PERSON

Regarding the “NI 43-101 Technical Report, TOML Clarion-Clipperton Zone Project, Pacific Ocean” (Technical Report) dated effective 30 March 2016, prepared for Nautilus Minerals Inc. (Issuer).

I, Ian Thomas Lipton, of Brisbane, Australia, do hereby certify that:

1. I have been Principal Geologist with AMC Consultants Pty Ltd. since 4 January 2015. I hold office at Level 21, 179 Turbot Street, Brisbane, Queensland, 4000 Australia.
2. I graduated with a degree in BSc (Hons) in geological sciences from the University of Birmingham in 1981.
3. I am a Fellow in good standing of the Australasian Institute of Mining and Metallurgy (#107663).
4. I have practiced my profession continuously since graduation.
5. I have read the definition of “qualified person” set out in National Instrument 43-101 (NI 43-101) and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfil the requirements to be a “qualified person for the purpose of NI 43-101.
6. My relevant experience with respect to the CCZ Deposit includes: involvement with the TOML CCZ project since 2012; 35 years in geology and Mineral Resource estimation that includes diverse nickel, copper, manganese and other multi-element deposits; 9 years’ experience in subsea minerals.
7. I am independent of the Issuer as described in Section 1.5 of NI 43-101.
8. I have not been involved with the property that is the subject of the Technical Report, prior to TOML acquiring the property.
9. I have read NI 43-101 and Form 43-101F1 and have prepared those Items of the Technical Report for which I am responsible in compliance with that instrument and form.
10. I am responsible for Items 1, 2, 3, 5, 10, 13, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 26 and 27 of the Technical Report.
11. As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the sections of the Technical Report for which I am responsible contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

12. I consent to the filing of the Technical Report with the relevant securities commission, any stock exchange and other regulatory authorities as may be determined, including general publication in hardcopy and electronic formats in company files or websites to shareholders and to the public.

Dated this Day of 4 July 2016 at Brisbane, Australia

I T. Lipton

Ian Thomas Lipton

Principal Geologist – AMC Consultants Pty Ltd.

CERTIFICATE OF QUALIFIED PERSON

Regarding the “NI 43-101 Technical Report, TOML Clarion-Clipperton Zone Project, Pacific Ocean” (Technical Report) dated effective 30 March 2016, prepared for Nautilus Minerals Inc. (Issuer).

I, Matthew John Nimmo, of Brisbane, Australia, do hereby certify that:

1. I am a self-employed Independent Geologist at 15 Crowcombe Place, Carseldine, Queensland, 4034, Australia.
2. I graduated with a degree in BSc (Hons) in geology from the University of Queensland in 1992.
3. I am a Member in good standing of the Australian Institute of Geoscientists (AIG #3606).
4. I have practiced my profession continuously since graduation.
5. I have read the definition of “qualified person” set out in National Instrument 43-101 (NI 43-101) and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfil the requirements to be a “qualified person for the purpose of NI 43-101.
6. My relevant experience with respect to the CCZ Deposit includes: involvement with the TOML CCZ project since 2012 including Mineral Resource estimation; 20 years in geology and Mineral Resource estimation that includes diverse nickel and copper deposits.
7. I am independent of the Issuer as described in Section 1.5 of NI 43-101.
8. I have not been involved with the property that is the subject of the Technical Report, prior to TOML acquiring the property.
9. I have read NI 43-101 and Form 43-101F1 and have prepared those Items of the Technical Report for which I am responsible in compliance with that instrument and form.
10. I am responsible for Items 11, 12, and 14 of the Technical Report.
11. As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the sections of the Technical Report for which I am responsible contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.
12. I consent to the filing of the Technical Report with the relevant securities commission, any stock exchange and other regulatory authorities as may be determined, including general publication in hardcopy and electronic formats in company files or websites to shareholders and to the public.

Dated this Day of 4 July 2016 at Brisbane, Australia

Matthew John Nimmo

Independent Geologist

CERTIFICATE OF QUALIFIED PERSON

Regarding the “NI 43-101 Technical Report, TOML Clarion-Clipperton Zone Project, Pacific Ocean” (Technical Report) dated effective 30 March 2016, prepared for Nautilus Minerals Inc. (Issuer).

I, John Michael Parianos, of Brisbane, Australia, do hereby certify that:

1. I have been Chief Geologist with the Issuer since 2 April 2012. I hold office at 33 Park Road, Milton, Queensland 4064, Australia.
2. I graduated with a degree in MSc in geology from the University of Queensland in 1993.
3. I am a Member in good standing of the Australian Institute of Geoscientists (AIG #5185).
4. I have practiced my profession continuously since graduation.
5. I have read the definition of “qualified person” set out in National Instrument 43-101 (NI 43-101) and certify that, by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfil the requirements to be a “qualified person” for the purpose of NI 43-101.
6. My relevant experience with respect to the CCZ deposit includes: involvement with the TOML CCZ project since 2012 including acting as Chief Scientist for two expeditions to the CCZ. Also over 23 years in geological evaluation, exploration and Mineral Resource estimation that includes nickel, copper, cobalt and manganese deposits.
7. I visited the property twice from September to 7 October 2013 on board the R/V Mt Mitchell and from 4 August to 10 October 2015 on board the R/V Yuzhmorgeologiya. I spent a total of approximately three months within the CCZ surveying and sampling the TOML Exploration Areas.
8. I am an employee of the Issuer and therefore I am not independent of the Issuer as described in Section 1.5 of NI 43-101.
9. I have not been involved with the property that is the subject of the Technical Report, prior to TOML acquiring the property.
10. I have read NI 43-101 and Form 43-101F1 and have prepared those Items of the Technical Report for which I am responsible in compliance with that instrument and form.
11. I am responsible for Items 4, 6, 7, 8, 9 and 19 of the Technical Report.
12. As of the effective date of the Technical Report, to the best of my knowledge, information and belief, the sections of the Technical Report for which I am responsible contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.
13. I consent to the filing of the Technical Report with the relevant securities commission, any stock exchange and other regulatory authorities as may be determined, including general publication in hardcopy and electronic formats in company files or websites to shareholders and to the public.

Dated this Day of 4 July 2016 at Brisbane, Australia

John Michael Parianos

Chief Geologist – Nautilus Minerals

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OUR VISION

ADVISER OF CHOICE TO THE WORLD'S MINERALS INDUSTRY

OUR PURPOSE

To optimize the value of the world's mineral resources

OUR VALUES

We regard safety as fundamental
We are client-focused
We act with integrity
We are always professional
We collaborate
We share our knowledge & expertise